PINEMAP

Pine Integrated Network: Education, Mitigation, and Adaptation Project

Year 4 Annual Report | March 2014—February 2015

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 4 (March 2014–February 2015). We acknowledge the dedication and hard work of the entire PINEMAP team throughout the year.

We especially would like to thank the 70 authors who contributed to this report (see chapters for details).

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PINEMAP

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

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PINEMAP YEAR 4 ANNUAL REPORT | March 2014-February 2015

PHOTO BY JOHN HOGAN

Introduction

Welcome to the fourth annual Pine Integrated Network: Education, Mitigation, and Adaptation Project (PINEMAP) 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 work synergistically and creatively in integrative work 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 are working 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 Theme Icons

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

- 59 principal investigators
- 27 research/technical staff
- 10 postdoctoral research associates
- 64 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 successful existing networks, including:

- **The Southeast Climate Consortium** uses advances in climate sciences to provide scientifically sound information and decision support tools for forests and other ecosystems in the southeastern United States.

- **Southern Regional Extension Forestry** is working with the PINEMAP Extension team to disseminate knowledge, practices, and decision support tools to enable corporate and noncorporate landowners to increase forest carbon sequestration and forest resilience.

- **Project Learning Tree**®, a national environmental education program, is partnering with PINEMAP to implement a new module on climate change and forests for high school science teachers.

- **University-Corporate-Governmental Forestry Research Cooperatives** share research data with PINEMAP to establish regional carbon, nutrient, and water baselines. These partnerships enable PINEMAP to translate research results into practical applications for industrial land managers.
  - Cooperative Forest Genetics Research Program
  - Forest Biology Research Cooperative
  - Forest Modeling Research Cooperative
  - Forest Productivity Cooperative
  - North Carolina State University Cooperative Tree Improvement Program
  - Plantation Management Research Cooperative
  - Southern Forest Resource Assessment Consortium
  - Western Gulf Forest Tree Improvement Program

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 was 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 125 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 and improving understanding of how southern pine productivity responds to climate and soils now and in the future.

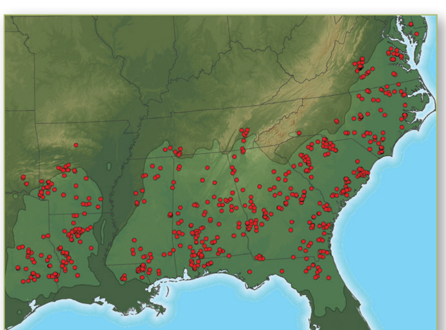

Figure 1.1. Tier I legacy network.

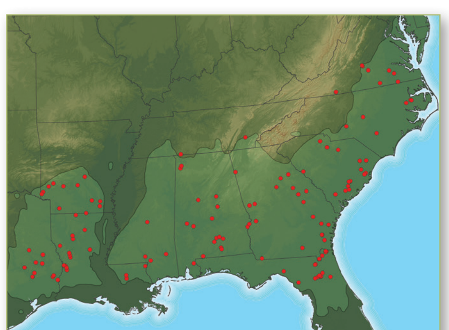

Figure 1.2. Tier II active experiments network.

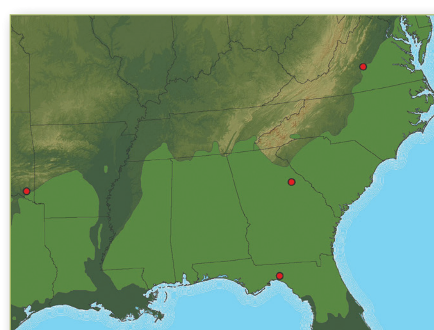

Figure 1.3. Tier III throughfall reduction x fertilization network.

Tier III throughfall reduction in Taylor County, Florida. Photo by Jessica Ireland.

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 PINEMAP monitoring network.

2. The Tier II Network: Estimating the Response of Regional Loblolly Pine Carbon Dynamics to Management

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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 can enhance connections between researchers and corporate forest landowners.

The Tier II network of sites was drawn from established research installations maintained by the industry-university research cooperatives participating in PINEMAP. The network of 125 sites and 458 measurement plots encompasses a wide range of environmental conditions (Figure 2.1) and silvicultural treatments. The purpose of the Tier II network is to evaluate how ecosystem carbon (C) accumulation is affected by silvicultural decisions, soils, and climate, and, thus, contributes to increased C sequestration, one of PINEMAP's outcome themes.

When pine ecosystems are managed to maximize wood production, managers also maximize the rate of C sequestration into plant biomass. This C uptake into pine biomass is the goal of the forest industry, and as a result it is a well-measured and well-modeled component of ecosystem C dynamics. Also important to ecosystem C accumulation or loss are the other C pools, such as the forest floor, soil, coarse woody debris, and understory, which when combined are larger than the pine tree C pool. For these nontree pools, it is not clear whether they will increase, decrease, or remain unchanged with an increase in pine productivity or biomass.

Forest manager decision making is less about maximizing ecosystem productivity than it is about whether a forest management decision is profitable. Often a means to increase profitability is to maintain the forest at a tree density below the maximum possible tree density by either reduced initial stocking or by thinning. This management approach increases average tree diameter growth, which more quickly moves tree size from less (e.g., pulp) to more profitable (e.g., lumber instead of pulp) timber products. At near optimal stocking densities, the larger proportion of thinned forest harvests that is converted into long-lived lumber products increases whole cycle C sequestration. However, if tree stocking is reduced below optimal levels, a net ecosystem C loss on an area basis is more likely.

Fertilization and competition (or weed) control increase pine growth, and therefore increase the amount of C stored in pine biomass. For other ecosystem C pools, increased pine biomass may or may not translate to increased C storage because these pools are heavily affected by how microorganisms responsible for organic matter decomposition respond to treatment. Fertilization with nitrogen (N) has been shown to suppress the activity of specific decomposer microorganisms; however, the effects of other fertilizer nutrients on microorganism activity are less well studied. In planted pine forests across the region both N and phosphorus are consistently added to relatively young forests. Weed control can change aggregate litter chemistry and microclimate, but it is unclear if these effects will result in significant changes in decomposer microorganism activity.

An exciting aspect of the Tier II network is that the breadth of treatments in the experimental sites encapsulates most management approaches used, and the network spans the range of climactic factors present on the landscape. The most common treatment category in the network is fertilization (fert) + chemical (chem) weed control (Figure 2.2), which is a common management approach used

The exposed profile of a Spodosol (Pomona series) at a Tier II location in Alachua County, Florida. Photo by Allan Bacon.

An exciting aspect of the Tier II network is that the breadth of treatments in the experimental sites encapsulates most management approaches used, and the network spans the range of climactic factors present on the landscape.

in the industrial forests of the southeastern United States. The next largest category is where thinning (thin), fert, and chem are included in an "all" treatment. Each category of treatment has within it at least 32 individual research plots, and the plots are present across the range of loblolly pine (Figure 2.1), allowing a robust assessment of treatment effects across the full range of climate and soils across the region.

The final estimates of ecosystem C accumulation in the Tier II network will enable us to quantify the combined effects of management, soils, and climate on planted pine carbon dynamics. In addition, data from the Tier II network will be compared to ongoing modeling efforts by other PINEMAP groups. Model parameters describing tree growth and allocation among plant parts, litter production, and heterotrophic respiration can be examined within the context of the measurements in the Tier II network. These measurements are expected to improve estimates of forest productivity and ecosystem C accumulation at the regional level under future climate scenarios and ultimately, inform decision makers about the management strategies that will enhance carbon storage.

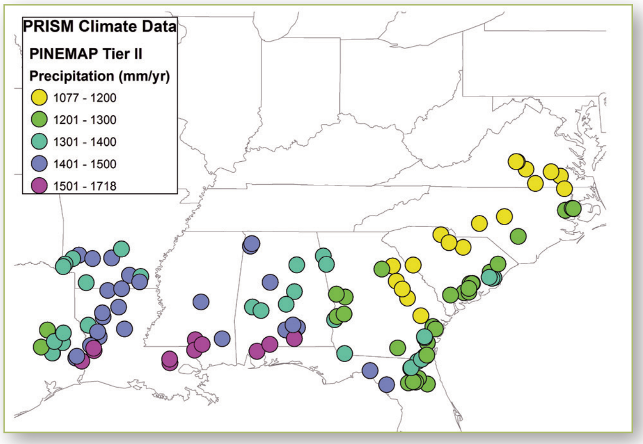

Figure 2.1. Precipitation estimated from PRISM historic climate data (1991–2010) for each Tier II research installation. Each dot represents a research installation where multiple treatments are being examined.

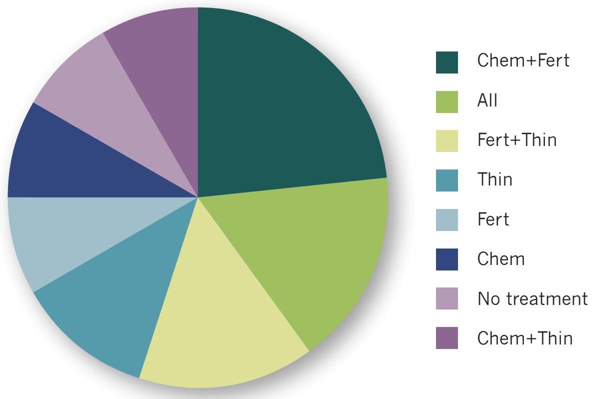

Figure 2.2. Distribution of plots in the Tier II network having different combinations of experimental treatments including fertilization (fert), chemical weed control (chem), thinning (thin), all treatments, and no treatment.

3. Tier III Sap Flux Network: New Efforts to Facilitate Region-wide Integration

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The analysis of Tier III sap flux data provides mechanistic explanations for variability observed in tree growth and tree carbon sequestration across regions, management and climate scenarios. Synthesizing results across all sites is a key output in translating field research to models, which can be used to help forest managers and policy makers understand how planted pine may respond to future management and climate conditions.

Since mid-2012, the PINEMAP sap flux monitoring network has collected more than 18 million data points on water use and environmental conditions across the four Tier III sites in Georgia, Florida, Virginia, and Oklahoma. As PINEMAP enters its final year, the challenge will be to assimilate these data, along with the 600,000-point monthly data stream, into a cross-site analysis that accounts for variability and uncertainties of scaling from individual tree measurements to the larger scale necessary for assessing climate change impacts on regional productivity. PINEMAP members have already begun several additional lines of data collection and analysis that will contribute to making this integration effort a success (see articles 4 and 5 in this report). Here we discuss three efforts to improve scaling precision: remote sensing of seasonal changes in leaf area, radial profiles of sap flux, and investigations of root area and function.

Remote Sensing of Leaf Area Index

Knowing the amount of leaf area per unit ground area (leaf area index or LAI) in a forest is critical for accurately modeling carbon uptake, water loss, and productivity. PINEMAP researchers periodically measure LAI in experimental plots, but pine LAI is highly variable within a year, so it can be challenging to interpolate LAI values between measurement periods. In addition, because the Tier III sites are distributed across the entire southeastern U.S., the timing of leaf area expansion and loss is expected to differ considerably between sites. To provide consistent estimates of seasonal LAI variation across sites, PINEMAP members have begun analyzing remotely sensed data from the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) satellite that are available for the 2003–2012 period from the Web-Enabled Landsat Data Project (https://landsat.usgs.gov/WELD.php). Using the approach of Flores et al. (2006), minimum and maximum LAI dates were determined from these data and used to inform the interpolation between ground-based measurements in each plot. Because these stands are relatively young and had pre-experimental understory vegetation control, this is an ideal situation for a remote sensing approach. Intra-annual curves fitted by harmonic regression (Brooks et al., 2012) may also be used to estimate seasonal LAI variation.

Radial Profiles of Sap Flux

The original experimental design of the Tier III monitoring network included five sap flux sensors per plot installed at 0-2 cm sapwood depths. Because tree trunks grow from cambium cells sandwiched between the bark and sapwood, these measurements represent flow rates in the youngest and usually most conductive wood. Xylem function declines with sapwood depth, so deeper, older sapwood has slower sap flux rates. Since outer sapwood in trees at Tier III sites was grown under the treatments imposed in 2012, but deeper sapwood was not, the radial pattern may differ between treatments. Additional sensors were installed at 2-4 cm and 4-6 cm sapwood depths in 2014 at all four Tier III sites to quantify these radial patterns and account for them when scaling the sap flux measurements up to total stand water use. As expected, sap flux declined with sapwood depth at the Florida site (Figure 3.1).

Sap flow sensors at the PINEMAP Tier III throughfall reduction x fertilization site in Taylor County, Florida. Photo by Jessica Ireland.

As PINEMAP enters its final year, the challenge will be to assimilate data into a cross-site analysis that accounts for variability and uncertainties of scaling from individual tree measurements to the larger scale necessary for assessing climate change impacts on regional productivity.

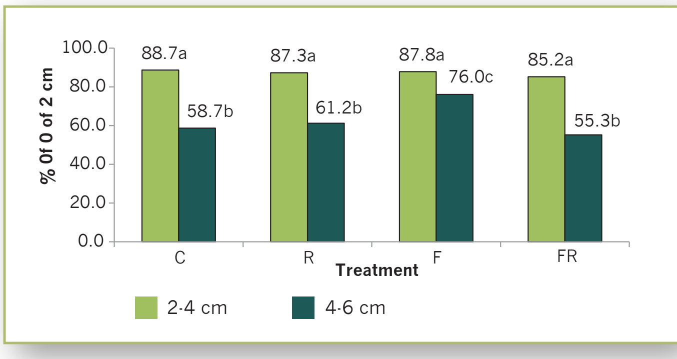

Figure 3.1. Sap flow rates at 2-4 cm and 4-6 cm depths at Florida Tier III site expressed as a percentage of sap flow at 0-2 cm depth for control (C), throughfall reduction (R), fertilization (F), and throughfall reduction and fertilization (FR) treatments. Percentage values shown above each bar; values followed by the same letter are not significantly different (p = 0.05).

Root Area and Function

Data from the Virginia site (Ward et al., in review) show greater declines in stomatal conductance under the combined treatment of fertilization and throughfall reduction than either treatment alone (Figure 3.2). This decline in stomatal conductance without significant difference in LAI suggests that resistance to water flow has increased in some other component of the hydraulic pathway to the leaves, most plausibly the roots. This may occur through changes in root area, root spatial distribution and/or resistance to water flow in root xylem. Accordingly, PINEMAP investigators at this site will be examining all three of these components of root function during the 2015 growing season to identify mechanisms underlying the observed patterns of water use. Knowing which mechanisms affect water use can help to improve regional models and may inform forest management recommendations in a variable climate.

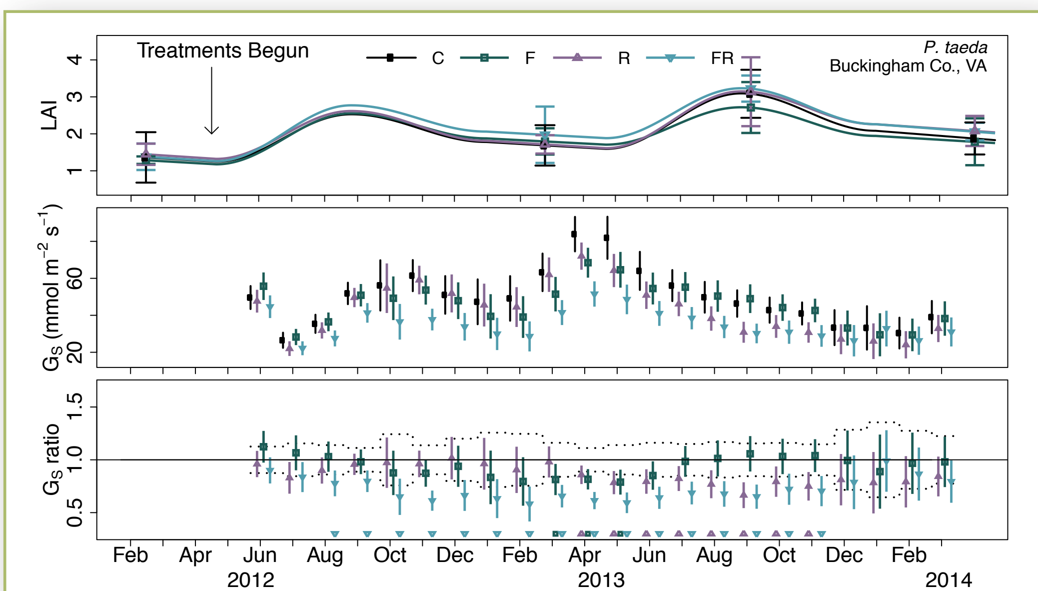

Figure 3.2. Estimated monthly daytime canopy-averaged stomatal conductance (GS, mmol m-2 leaf area s-1) for control (C), throughfall reduction (R), fertilization (F), and throughfall reduction and fertilization (FR) treatments at Virginia Tier III site (top) and the ratio of the GS in each treatment to the control value (bottom), where a 95% credible interval of the control is indicated by the dotted line and by error bars for treatment values. Small symbols at the bottom of the panel represent treatments where monthly value was different from the control with 95% confidence using a normal parametric bootstrap of model posterior values.

4. Regional Soil Respiration: Measurement, Validation, and Modeling

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Increasing carbon sequestration in forests requires an improved understanding of the factors that affect soil carbon inputs and outputs. Clarifying the regional patterns of total, plant-based, and microbial soil respiration versus climate and soil factors will guide the development of management scenarios aimed at optimizing both forest productivity and carbon sequestration.

Managing forests for both timber production and carbon sequestration requires an improved understanding of the factors that affect carbon sequestration in soil. While there are robust models predicting aboveground loblolly pine productivity across climate and soil gradients in the southeastern United States, our understanding of the mechanisms governing belowground carbon sequestration is much more limited. Carbon sequestration in soil depends on the balance between soil carbon inputs and losses. Inputs of aboveground and belowground litter can be measured or estimated allometrically. Measuring the carbon losses from respiration of decomposer microorganisms (heterotrophic respiration, R_H) is more resource intensive and must be inferred from total soil CO_2 efflux (soil respiration, R_S) observations. After gross primary productivity (GPP, an ecosystem-level measure of photosynthesis), R_S is the largest carbon flux in forests (Figure 4.1). Partitioning R_S into its plant-derived (autotrophic, R_A) and decomposer derived (heterotrophic) components remains an area of active PINEMAP research, especially the search to understand how these fluxes vary with soil type, climate, and seasonality. The primary goals of the PINEMAP regional soil respiration group are to provide a region-wide model for R_S, partition R_S into heterotrophic and autotrophic components, understand how partitioning varies over space and time, and incorporate this information into ecosystem-level models to better quantify the carbon sequestration capacity of loblolly pine forests under variable climate and management scenarios.

One of the great strengths of the PINEMAP research approach is its ability to integrate and leverage existing data sets to address PINEMAP-specific questions or challenges. Development of a region-wide model for R_S is a prime example. Even at the large scope and scale of PINEMAP, developing this information anew would be inefficient and time consuming. PINEMAP scientists have combined years of historic research from more than 150 study plots in 11 states spanning the natural range of loblolly pine in order to derive a region-wide model of R_S (Figure 4.2; Templeton et al. 2015). Five different environmental variables (soil temperature, soil bulk density, soil nitrogen concentration, latitude, and soil moisture) accounted for 56% of the variability in R_S. A single-variable model based on soil temperature alone (which accounted for 45% of R_S variability) was also developed to ease the computational burden of integration into regional ecosystem carbon flux modeling efforts.

A challenge in developing a region-wide model of R_S is describing both how this carbon flux changes across different forest stands (space) and how it changes throughout the year at any particular place (time). For example, the model shown in Figure 4.2 has a high degree of spatial coverage but potentially low predictive power at finer time intervals. Incorporating additional data sets and research sites (i.e., Duke FACE and two regional AmeriFlux sites) has enabled PINEMAP scientists to evaluate the robustness of this region-wide model across daily, seasonal, and annual time scales. Efforts to date have shown that the existing region-wide model accounts for about

Photo by John Seiler.

One of the great strengths of the PINEMAP research approach is its ability to integrate and leverage existing data sets to address PINEMAP-specific questions or challenges.

60% of the variability in instantaneous flux measurements, an improvement over the original range-wide model. Further model refinement is underway using both the existing range-wide data set and the new data collected by PINEMAP scientists. This new model will improve our predictive power, better capture interannual variability in R_S, and provide a more accurate annual estimate of this important ecosystem carbon flux.

Improved prediction of R_S is an important step toward estimating forest carbon sequestration. Many existing models (e.g., 3-PG) require both accuracy in predicting R_S and accurate partitioning of R_S into R_H and R_A. Previous PINEMAP work has reported near uniform partitioning of R_S ($R_H/R_S = 0.84$) across the Tier III manipulative experiments, irrespective of drought, fertilization, or time of year. Further exploration is underway across the Tier II sampling network and is already providing a more nuanced view of the dynamic components of R_S. Preliminary results suggest that the degree of site occupancy by both trees and understory vegetation changes the relative size of autotrophic and heterotrophic soil respiration components. So, forest management, and the degree of control of competing vegetation in particular, is expected to be an important driver of the net carbon balance of forest ecosystems.

PINEMAP scientists are working to parameterize process-based models of belowground carbon and nitrogen fluxes to extend the empirical observations being made at the Tier II and Tier III sites. DayCent (a daily time-step version of the CENTURY biogeochemical model) is being parameterized using observations from the Florida and Georgia Tier III sites, incorporating loblolly pine-specific phenology and leveraging existing weather and soils data. Ultimately, DayCent will be calibrated and validated across all four Tier III sites and scaled up across the region. This approach will help improve seasonal estimates of productivity and will provide the added advantage of facilitating the modeling of other important soil-atmosphere gas fluxes, like nitrous oxide, to more fully understand the role of forest management in mitigating climate change.

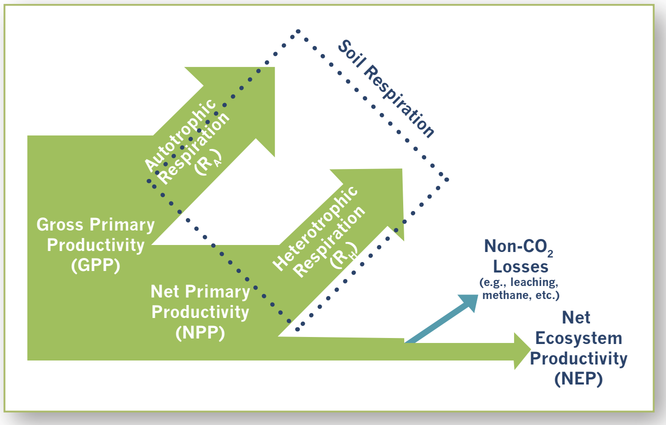

Figure 4.1. Carbon flow in forest ecosystems leading to net ecosystem productivity (NEP), or carbon sequestration.

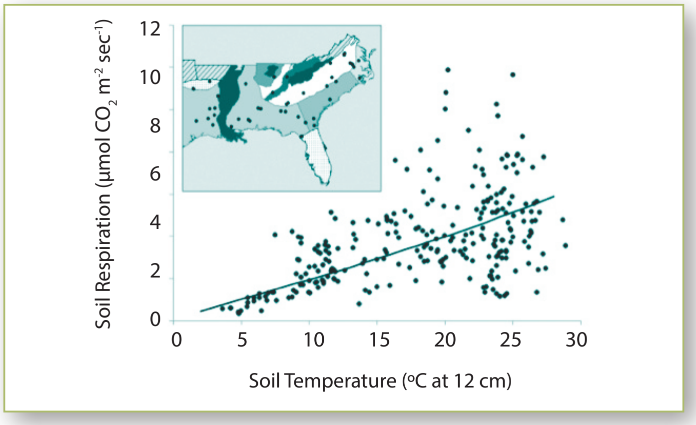

Figure 4.2. Region-wide model of soil respiration as a function of a single environmental variable, soil temperature derived from the sites depicted in the inset.

5. PINEMAP's Integrated Modeling Program

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The PINEMAP modeling group uses a suite of complementary models to better estimate the uncertainty in carbon sequestration predictions across the region.

The PINEMAP integrated modeling program is working to provide predictions of how managed pine systems may respond over the next century in response to environmental change. Each model used in the project has specific, often complementary, strengths and weakness, and the most useful end-user products are predictions that include both the anticipated changes in ecosystem processes and the uncertainties associated with those changes. These form the underlying rationale for creating this integrated modeling program.

The PINEMAP modeling program uses multiple independent and equally valid approaches for simplifying and simulating forest dynamics. Using a set of independent models allows us to better quantify uncertainty because each set of predictions is associated with a unique set of model assumptions (in contrast to the more frequent case where the full potential range of uncertainty cannot be explained because models share subcomponents). To address the need for independent models with different strengths and weakness, we use five forest models: an empirical Growth and Yield model, Water Supply Stress Index model (WaSSI), Physiological Principles in Predicting Loblolly Growth (3-PG), the Community Land Model (CLM), and the Daily CENTURY model (Daycent). The complementary nature of these models can be summarized using two categories: the mechanism of parameterization and the focal processes.

The first dimension of Figure 5.1 shows whether the model is based on empirical (statistical) relationships from field observations or based on physiological processes (i.e.,

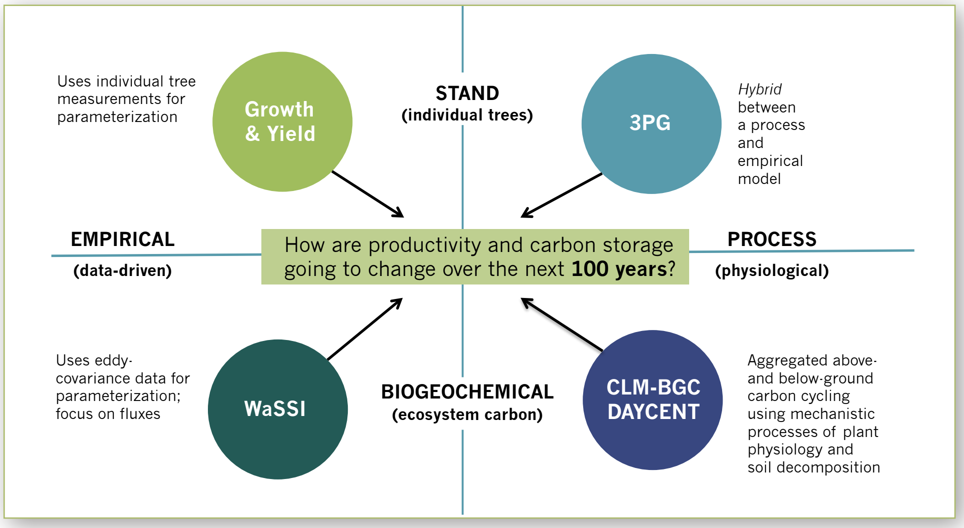

Figure 5.1. A characterization of the models used for prediction in the PINEMAP project. Each model is independent of one another and has a unique set of strengths and weaknesses.


Photo by John Seiler.

Each model used in the project has specific, often complementary, strengths and weakness, and the most useful end-user products are predictions that include both the anticipated changes in ecosystem processes and the uncertainties associated with those changes.

an explicit representation of photosynthesis and growth process). The empirical relationships used in the PINEMAP project are based on either plot-level forest management experiments (Growth and Yield model) or eddy-covariance data of gross primary productivity and evapotranspiration (WaSSI model). In contrast, the 3-PG, CLM, and Daycent use physiological principles rather than statistical relationships to simulate forest dynamics. For example, the CLM scales cellular-level physiological processes up to the coarse canopy scale, while 3-PG focuses on whole canopy-level parameterizations of physiology. Both approaches have strengths and weaknesses. Models that use empirical parameterizations likely are better suited for predictions in environments similar to the range of conditions used for parameterization. The more generalized and mechanistic descriptions in physiologically based models are more likely transferable to novel conditions (e.g., projections into a future with climates that have not previously been observed in the region).

The second dimension of Figure 5.1 shows if the model can predict individual tree and stand dynamics (Growth and Yield and 3-PG) or if it focuses on predicting ecosystem forest carbon dynamics (WaSSI, CLM, and Daycent). Growth and Yield and 3-PG are able to simulate individual tree dynamics and report changes in basal area and yield production, which are variables directly useful for forest managers. In contrast, WaSSI, CLM, and Daycent models focus on ecosystem scale carbon cycling and, in the case of CLM and Daycent, can simulate both aboveground and belowground carbon dynamics.

PINEMAP's integrated modeling program is also exploring uncertainty associated with future climate by examining the differences in outputs of differently parameterized climate models, climate model structure, and future emission scenarios. These emission scenarios are partly based on human behavior, which is challenging to predict. We are using a wide range of alternative climate models (20) and scenarios (2) that encompass alternate pathways of human behavior and global development. Since these scenarios and models are used as inputs into the five forest dynamics models, the outputs reflect the uncertainty about future climate, human behavior, and uncertainty inherent in the assumptions of the forest dynamics models.

The integrated modeling effort is central to almost all aspects of the PINEMAP program, but has particular relevance to the following project outcomes: (1) increased deployment of adaptive strategies to ensure the sustainability of planted southern pines within the context of projected climate variability and change, and (2) clearer understanding of adaptive forest management strategies and their potential roles in climate change mitigation.

6. Full-Scale Regionalization of Physiological Principles in Predicting Growth (3-PG)

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[1] Postdoctoral Associate • [2] Applied Climatologist • [3] State Climatologist • [4] Associate Professor • [5] 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.

Physiological Principles Predicting Growth (Landsberg and Waring 1997) is one of a suite of models used by PINEMAP's integrated modeling group to provide robust and complementary estimates of changes in loblolly pine (*Pinus taeda*) productivity over the remainder of the 21st century. The other models in the program include Growth and Yield, the Water Supply Stress Index (WaSSI), and the Community Land Model (CLM). As a process-based model, Physiological Principles Predicting Growth (3-PG) focuses on the physiological components of growth and provides forest growth and health-related outputs (volume, basal area, leaf area index) and carbon storage-related outputs (biomass accrual, net primary productivity, and gross primary productivity).

In order to provide opportunities for model intercomparisons, 3-PG was adapted to run at the same USGS 12-digit hydrologic unit (HUC-12) spatial scale as WaSSI. This scaling also makes a regional run of 3-PG computationally feasible, with approximately 10,000 HUC-12 units in the generally recognized range of loblolly pine.

Both 3-PG and its loblolly-specific variation (Bryars et al. 2013) are originally stand-based, relying on point measurements of soil and weather conditions in order to function. Accordingly, one of the greatest challenges to implementing 3-PG has been acquiring sufficient reliable input data to calibrate the model across the PINEMAP region.

Soil data were obtained for all states in the PINEMAP region from the USDA's Natural Resource Conservation Service's Soil Survey Geographic Database (SSURGO). Since the SSURGO spatial resolution is finer than the HUC-12 scale, we spatially aggregated soil data to the HUC-12 unit scale using area-weighted averaging, which was then used either directly or converted into soil classes for use in 3-PG. In cases where the gridded SSURGO data included a representative site index value for loblolly pine, those estimates were extracted and spatially aggregated to the HUC-12 units. Enough site index estimates were present across the range of loblolly pine to generate a regional map of site index at HUC-12 resolution (Figure 6.1). We were then able to translate these site index estimates into the "fertility rating," a key input into 3-PG.

We obtained climate data and derived variables via Multivariate Adaptive Constructed Analog (MACA) downscaling of the 1-degree Idaho climate data, commonly used in global climate modeling efforts and in PINEMAP's CLM. The MACA data used for 3-PG cover a baseline historical period of 1950–2005 and a series of future predictions for 2006–2095 according to two radiative forcing scenarios: greenhouse gases are emitted in the future at the same rate as today, which equals the business-as-usual scenario, and at a reduced emissions scenario. In all, 20 different global climate models (GCMs) were downscaled, converted to 3-PG input variables, and aggregated to the HUC-12 level by area-weighted averaging. The high number of GCMs used allows us to estimate variability due to the uncertainty in climate predictions.

Photo by Steve McKeand.

Initial runs of 3-PG have been completed using a single GCM under a portion of the business-as-usual emissions scenario.

Initial runs of 3-PG have been completed using a single GCM under a portion of the business-as-usual emissions scenario. Results for two of the 3-PG outputs are shown in Figure 6.2. The results of these runs will be compared to the Tier I dataset of historical forest stand growth, as well as to outputs from the other regional productivity models. This will allow us to fine-tune the parameter sets and the input calibration for 3-PG in order to optimize the model for the region. 3-PG will be run across the entire timeframe for each of the 20 GCMs under the two radiative forcing scenarios, yielding region-wide estimates of productivity and carbon accumulation, as well as estimates of variability in those outputs. These results will be used as key inputs in economic models in PINEMAP and beyond. 3-PG model outputs will be integrated into PINEMAP's Decision Support System (DSS) so that Extension agents and landowners may access the most up-to-date estimates and uncertainty for both regional-scale and local-scale loblolly production in the 21st century.

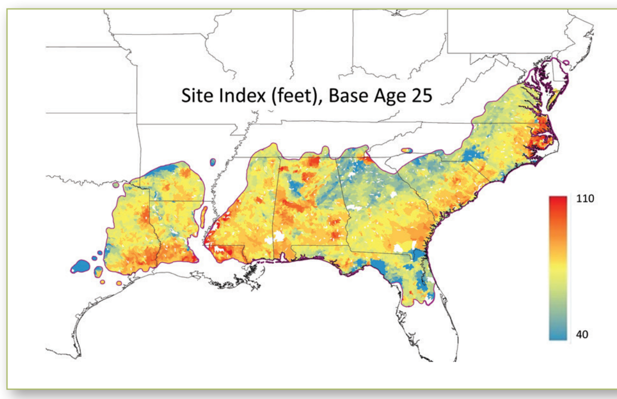

Figure 6.1. SSURGO-derived site index for the PINEMAP region. The natural range of loblolly pine is outlined in purple.

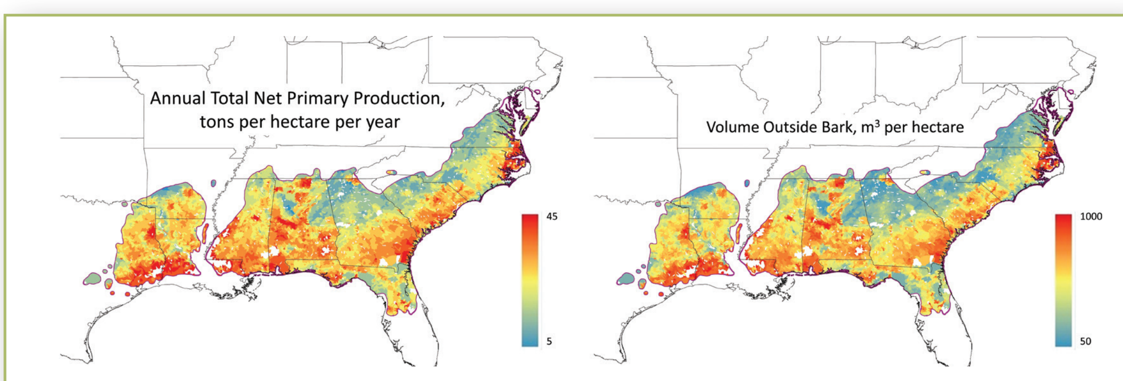

Figure 6.2. Example outputs from 3-PG. The natural range of loblolly pine is outlined in purple.

7. WaSSI Model Examines Drought Impacts on National Forests

Ge Sun[1, 3] • Steve McNulty[2, 3]

[1] Research Hydrologist • [2] Team Leader, Ecologist • [3] USDA Forest Service Southern Research Station Eastern Environmental Threat Assessment Center

The WaSSI model has been expanded to the regional scale to predict future interactions between tree growth, water availability, and drought. WaSSI allows us to better assess the potential risks of drought to forest growth and carbon sequestration under future climate scenarios.

The 781,000 km^2 (193 million acre) United States National Forests and Grasslands system (NFs) provides important ecosystem services including clean water, timber, wildlife habitat, and recreation opportunities for the American public. Quantifying the historic impact of climate change and drought on ecosystem function at a national scale is essential to developing sound forest management and watershed restoration plans for the future.

PINEMAP has expanded the Water Supply Stress Index (WaSSI) hydrologic model to the regional scale in order to understand the broad consequences of pine forest management and climate change. We have incorporated new discoveries about the interactions of climate, atmospheric carbon dioxide (CO_2), and fertilization impacts on forest ecosystem services into WaSSI. A detailed description of WaSSI is available in the WaSSI Ecosystem Services Model User Guide (http://www.forestthreats.org/research/tools/WaSSI). The earlier version of the WaSSI model has been tested and successfully applied to geographical regions across the United States, and in Asia and Africa. WaSSI now covers more than 88,000 HUC-12 watersheds over the conterminous U.S. (CONUS). WaSSI predictions of historic water yield (Q) have been validated for 72 USGS gauged watersheds. In addition, WaSSI predicted evapotranspiration (ET) and gross primary productivity (GPP) have been compared to ET and GPP estimates derived by satellite data for 170 national forests and grasslands across the CONUS. Overall, the latest WaSSI model had the capability to reconstruct long-term water and carbon fluxes on a broad scale (Figure 7.1). More detailed model evaluation results will be published soon (Sun et al. 2015a, in press).

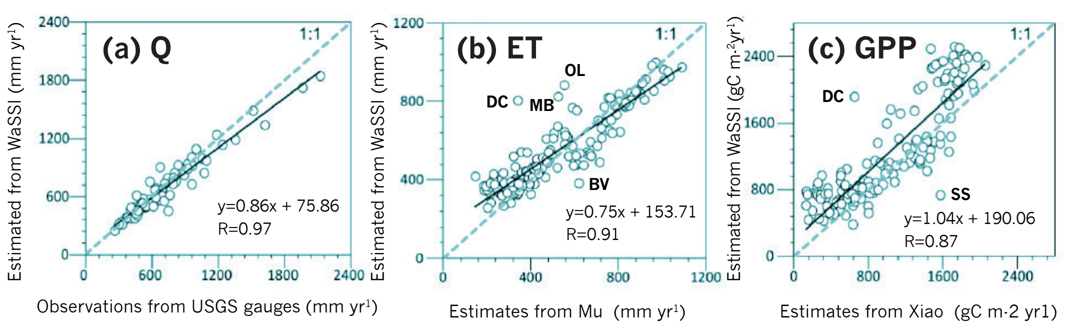

Figure 7.1. Comparisons of simulated multiyear mean annual Q, ET, and GPP by WaSSI against observed Q at USGS gauges. ET was estimated by Mu et al. (2010) and GPP estimated from Xiao et al. (2014), respectively. Note: Validation of Q was conducted at the corresponding watersheds monitored by USGS gauging stations (72 samples), while ET and GPP were scaled to the NF scale (170 samples). Dots with italic characters represent large discrepancies between ET or GPP modeled by WaSSI and other estimation methods. *OL=Olympic National Forest*; *MB=Mt. Baker National Forest*; *DC=Deschutes National Forest*; *SS=Siuslaw National Forest*; *SK=Siskiyou National Forest*; and *BV=Butte Valley National Grassland*.

Photo by Josh Cucinella.

We applied the previously validated WaSSI model to 170 National Forests and Grasslands in the conterminous US to examine how historic droughts have impacted forest water yield (Q) and gross primary productivity (GPP).

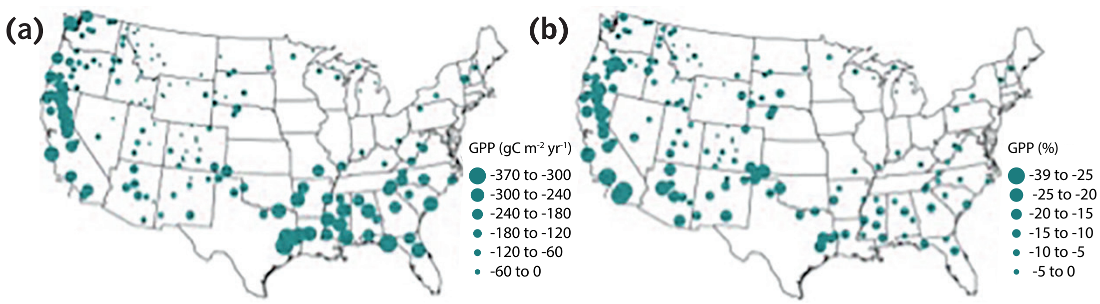

Figure 7.2. Deviations of (a) absolute values and (b) relative values of GPP for the top five drought years from the long-term (1962–2012) means in 170 National Forests and Grasslands.

We applied the previously validated WaSSI model to 170 National Forests and Grasslands in the conterminous US to examine how historic droughts have impacted forest water yield (Q) and gross primary productivity (GPP). For each NF, we identified the top five extreme drought years from 1962 through 2012, defined as the years with the smallest annual three-month Standardized Precipitation Index (SPI3). We found that both the extent of extreme droughts (the number of NFs affected) and total area affected by droughts have increased over the last decade. At the national level, the most extreme drought during the past decade occurred in 2002, resulting in a mean reduction of water yield by 32% and GPP by 20%. The top five droughts for the 170 individual NFs represented an average reduction in precipitation of 145 mm yr^{-1} (or 22%), causing reductions in ET by 29 mm yr^{-1} (or 8%), Q by 110 mm yr^{-1} (or 37%), and GPP by 65 gC m^{-2} yr^{-1} (or 9%). The responses of the forest hydrology and productivity to droughts varied spatially due to different land-surface characteristics (e.g., baseline climate and vegetation) and drought severity at each NF. Figure 7.2 illustrates the magnitude of drought impacts on GPP in national forests. The detailed model evaluation results will be published in Sun et al. (2015b, in press).

This study provides a comprehensive benchmark assessment of likely drought impacts on the hydrology and productivity in national forests using consistent methods and datasets across the conterminous U.S. The study results will allow foresters to develop appropriate strategies to restore and protect ecosystem services under potential future increases in drought. We will use PINEMAP's Tier II and Tier III field experiment results to specifically validate WaSSI's ET and GPP model output predictions for loblolly pine stands, allowing us to examine impacts of climate change on forest productivity and water yield across the southeastern region for multiple global circulation models (GCMs) and emissions scenarios. As PINEMAP moves into the final year of funding, we will work with the PINEMAP Decision Support System team to incorporate WaSSI model results into the SouthEast Regional Climate Hub (SERCH) with an ongoing mission to maintain and increase working land (i.e., forest, rangeland, and grassland) productivity in the southeastern U.S. (http://globalchange.ncsu.edu/serch/).

8. Regional Carbon Cycle Predictions Using the Community Land Model

***R. Quinn Thomas*[1, 3] • *Benjamin Ahlswede*[2, 3]**

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Our regional Community Land Model predictions of carbon cycling contribute to the understanding of how a changing climate and rising (carbon dioxide) CO_2 may alter the production of wood from pine ecosystems. Our results increase the knowledge base available to be shared among scientists, Extension and education professionals, and forest landowners.

Future predictions of managed pine systems over the next century require mathematical models that simplify reality yet accurately describe forest ecosystem dynamics. Since no model perfectly predicts all aspects of managed pine ecosystems, the PINEMAP modeling approach integrates predictions from multiple independent and equally valid models to provide a more complete description of the potential future and uncertainty surrounding these predictions.

We have integrated the Community Land Model (CLM) into the set of PINEMAP models to address the need for a process-based, biogeochemical model. The Community Land Model simulates terrestrial carbon and nitrogen cycling, hydrology, and energy balance at regional to global scales. It is a component of the Community Earth System Model, a widely used model for predicting global climate. The CLM's strength for PINEMAP is its capacity to simulate both plant growth and soil respiration using mechanistic model representations of ecosystem processes. Weaknesses of the CLM include the coarse spatial resolution of the model, the relatively large number of parameters required, and the requirement for fine temporal scale (sub-daily) weather data.

As part of PINEMAP, we have adapted the CLM to simulate managed loblolly pine ecosystems. We modified the CLM to simulate a 25-year rotation cycle and reduced tree mortality rate from the default 2% per year to 1% per year in order to more accurately reflect the lower mortality in managed stands. Furthermore, we modified the default plant parameterization to better match a loblolly pine by adjusting tissue allocation and leaf-lifespan parameters. Most importantly, we used PINEMAP's Tier I field data-observed relationship between aboveground net primary productivity (ANPP) and the ratio of stem (wood biomass plus coarse root biomass) to leaf allocation to parameterize the same relationship in the CLM (Figure 8.1). Prior to this study, the stem to leaf allocation relationship in the

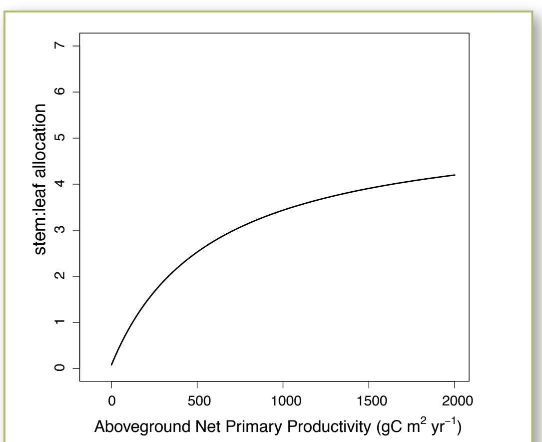

Figure 8.1. The observed Tier I relationship between aboveground net primary productivity and the ratio of stem to leaf allocation. The best fit line (black) was used to parameterize the allocation routine in the Community Land Model (CLM).

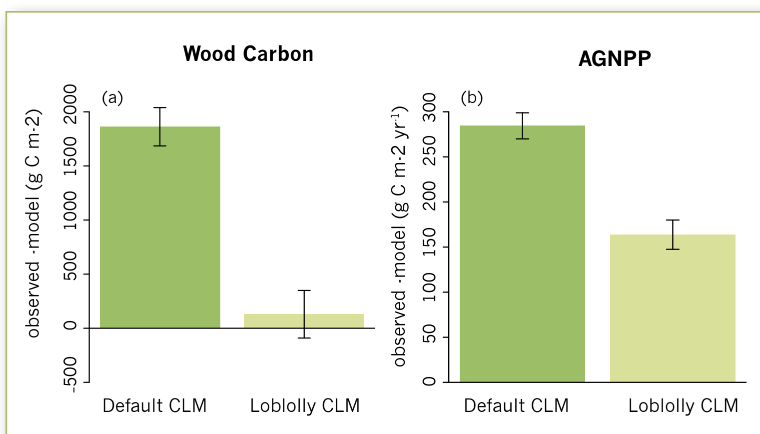

Figure 8.2. Creating a loblolly plant functional type reduced CLM model bias. The mean difference (± 1 SE) between the Tier I observations and CLM modeled wood carbon (a) and aboveground net primary productivity (b). The default CLM used the standard parameterization of a temperate needle-leaf evergreen tree and the loblolly CLM used the loblolly specific plant functional type.

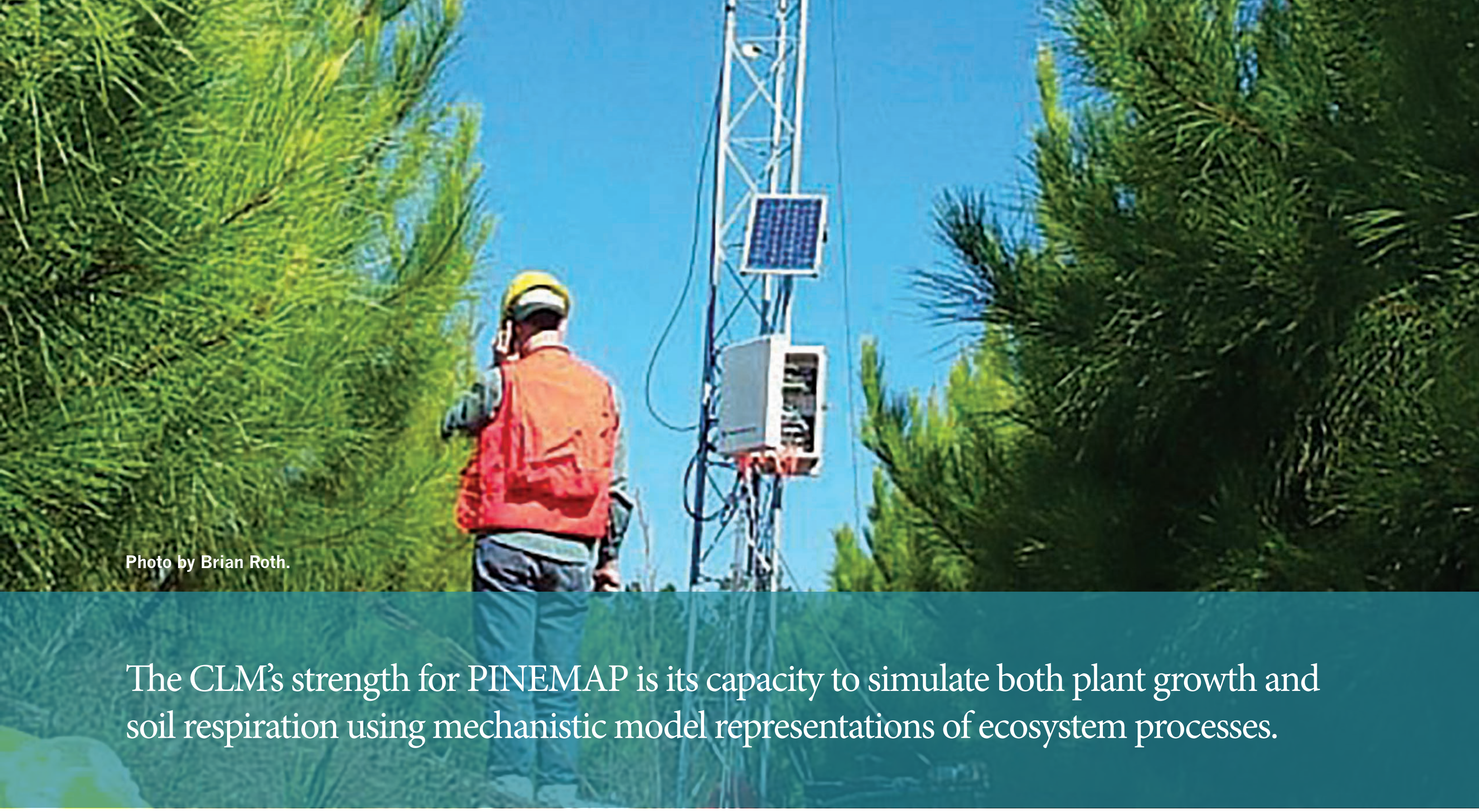

Photo by Brian Roth.

> The CLM's strength for PINEMAP is its capacity to simulate both plant growth and soil respiration using mechanistic model representations of ecosystem processes.

CLM was unconstrained by observations. The Tier I data were critical for building region-wide parameterizations into the CLM.

We evaluated the CLM outputs by comparing them to Tier I observations of wood biomass, leaf-area index, and aboveground net primary productivity. The CLM simulated a 25-year rotation cycle beginning in 1970 for each 1 x 1 degree spatial resolution grid cell. For each Tier I plot location, we extracted the CLM predictions and compared the model predictions to plot-level observations. We focused our evaluation on region-wide trends because of the substantial spatial scale mismatch between the ~10,000 km^2 area CLM grid cell and the 4 x 10^{-4} km^2 area of field plots and the considerable uncertainty that is expected between measurements at a single plot and the model prediction. At the regional scale, our modifications to the CLM improved the representation of loblolly pine ecosystems by reducing the bias between the modeled woody biomass and observed woody biomass in the Tier I data (Figure 8.2), though key areas do remain for reducing model uncertainty.

Using the loblolly specific version of the CLM, we ran models under two future emissions scenarios: RCP 4.5 (reduced future greenhouse gas emissions) and RCP 8.5 (business-as-usual; i.e., future emissions similar to now) for comparison to simulations from the other PINEMAP models. We focused on the change in wood carbon, average ANPP, and the average net ecosystem production (NEP) between 25-year rotation cycles in periods 1970–1995 and 2070–2095. Preliminary model simulations predict average wood carbon at year 25 across the PINEMAP region could increase by 3844±372 g C m^{-2} (±1 SD), ANPP could increase by 171±16 g C m^{-2} (±1 SD) and NEP could increase by 124±14 g C m^{-2} (±1 SD) under the RCP 8.5 (CCSM 4) scenario (Figure 8.3). Additional model simulations will isolate the influence of rising atmospheric carbon dioxide (CO_2) on the predicted changes. Model estimates are still preliminary.

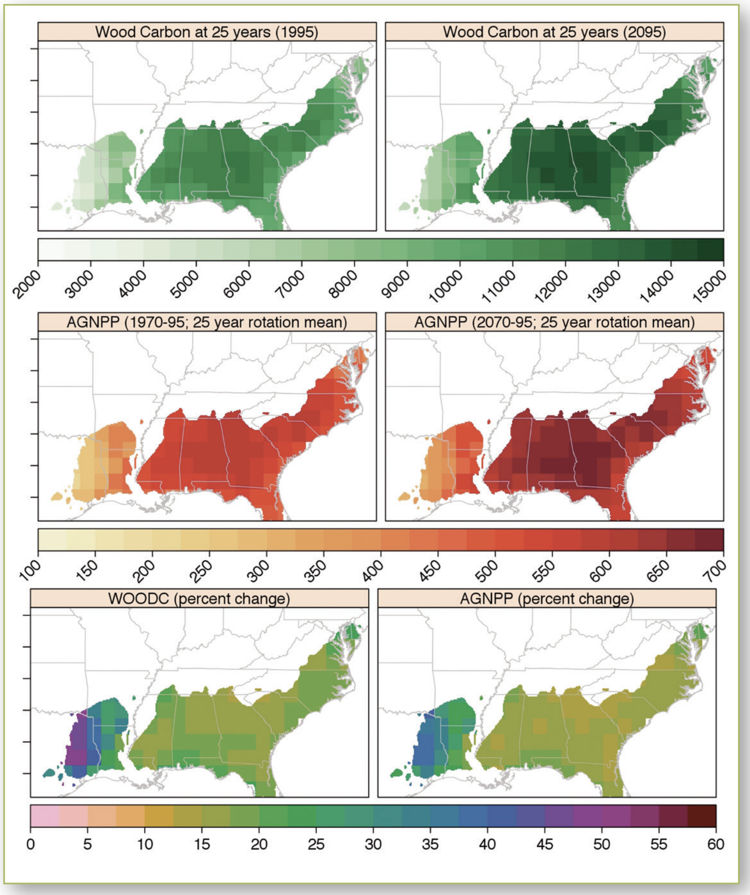

Figure 8.3. Wood carbon stocks (a,b) at year 25 of rotation (g C m^{-2}) and aboveground net primary productivity (ANPP) (c,d) averaged over a 25-year rotation (g C m^{-2} yr^{-1}). The value for a 25-year rotation that ends in 1995 (a,c) and in 2095 (b,d) is shown in addition to the relative difference (e,f). Simulations used the Community Climate System Model 4 RCP 8.5 scenario.

9. Assisted Migration: Matching Genetics to Sites

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Gary Peter[5,8] • *Ross Whetten*[5,7] • *Jianxing Zhang*[2,8]

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Understanding how weather interacts with genetics will allow the creation of more resilient forests with higher capacities to store carbon. To do this effectively, the PINEMAP team is integrating knowledge of climate, genetics, physiology, and silviculture for creating tools to optimize seedling deployment decisions.

Early seed source studies of loblolly pine showed differences between eastern and western populations and revealed finer scale variations within these broad groupings (Wells and Wakeley 1966, Dorman 1976). Furthermore, some of this variation clearly mirrored climate patterns, indicating local adaptation. Locally sourced specimens, however, were not always the fastest growing. Schmidtling (1994) showed that better growth could be achieved if loblolly seedlings were planted north of their source of origin, optimally in zones with minimum winter temperatures no more than 5°F cooler. He concluded that this effect was likely the result of climate change following the most recent glaciation. Schmidtling postulated that as the climate warmed, the optimal environmental zone would shift northward at a faster pace than can be matched by natural seed source movement (expressed by maximum growth rate). This lag will be further exacerbated if climate change accelerates. By better understanding how weather variables impact deployment decisions, the PINEMAP team hopes to provide guidelines for optimal seedling deployment, a form of assisted migration, which will result in healthier and more vigorous forests.

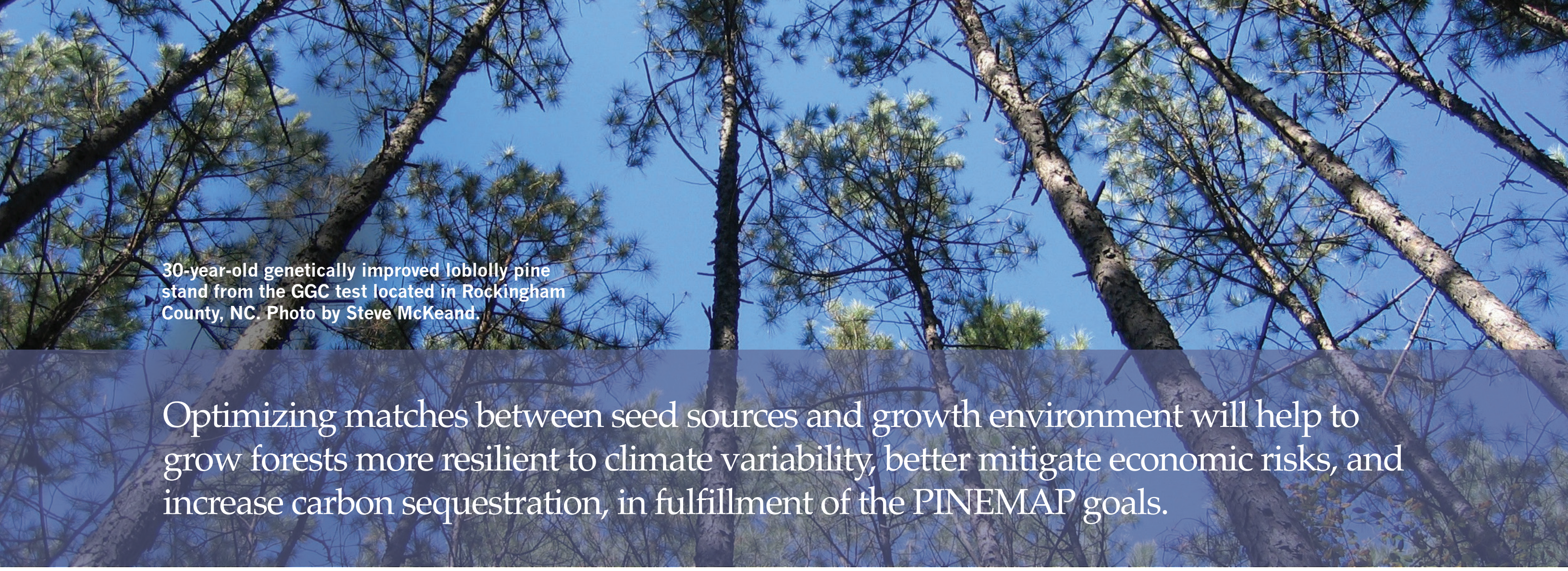
Schmidtling (1994) identified minimum winter temperature as a critical factor for optimizing loblolly pine seed source deployment. Water availability is another important factor impacting plant growth that is known to vary across the landscape. While climate change may affect average precipitation and temperature, it may also impact both seasonal and interannual patterns of variation; therefore, variation itself should be considered as a possible limit to growth. For that reason, we modeled the influences of temperature and water availability and their variability in order to predict optimal loblolly pine seed movement.

PINEMAP used five loblolly pine seed source studies established by the three southern tree improvement cooperatives to refine seed movement guidelines within their respective breeding programs. Each study involved multiple families from a number of seed procurement zones planted across wide geographic areas. Despite the fact that these studies had little to no overlap in families, making a joint regional analysis impossible, our separate independent analyses largely confirmed Schmidtling's findings on the importance of minimum winter temperatures. Some measure of water availability (or aridity) was also identified as an important additional factor in crafting seed movement guidelines (Table 9.1).

Table 9.1. Significant variables predicting seed source performance in the independent analyses performed by the three teams at the University of Florida (UF), North Carolina State University (NCSU), and Texas A&M University (TAMU).

Variable	UF	NCSU	TAMU
Minimum Temperature	×	×[2]	×[3]
Maximum Temperature	×	×[2]	
Precipitation		×[2]	×[5]
Annual Heat-Moisture index	×		
Humidity	×		
Longitude (Provenance)	×		
SD (Minimum Temperature)			×
CV (Precipitation)			×
Interactions	×	×	×

[1] Coldest 3 days mean, [2] annual mean, [3] monthly mean (coldest month), [4] warmest 3 days mean, [5] summer (June–August).



30-year-old genetically improved loblolly pine stand from the GGC test located in Rockingham County, NC. Photo by Steve McKeand.

Optimizing matches between seed sources and growth environment will help to grow forests more resilient to climate variability, better mitigate economic risks, and increase carbon sequestration, in fulfillment of the PINEMAP goals.

Each of the PINEMAP analyses added specific insights into the population and the region investigated. For example, while the effects of minimum winter temperature were observed across the entire region, summer maximum temperatures were only found to have a significant impact on optimal seed source assignment in the eastern populations. Similarly, the impact of rainfall on growth, while important in all studies, was more evident at the western edge of the species distribution (east Texas and Oklahoma) where growing-season rainfall is the scarcest and yearly variation is most pronounced. The analysis of eastern plantings showed that the differences in average height between local and introduced material was generally greatest in southern plantings and narrowed in the northeastern sites, near the northern edge of the species distribution, where winter weather conditions are generally harsher (Figure 9.1). While it was possible to model individual family performance, the predictive power of these individual models generally dropped for families tested on fewer sites and/or sites with more homogeneous climates. An alternative analytical method predicts the probability that a given seed source would fall into a range of productivity classes, allowing us to incorporate an estimate of risk into deployment decisions (Figure 9.2).

These studies on seed movement indicate that temperature and rainfall, along with their variability, likely contribute significantly to the current boundaries of the loblolly pine range. Given favorable soil conditions, these factors are likely to also determine the species' future distribution. Along with the average weather conditions, the probability of extreme events, such as sudden cold snaps, and their impacts on growth may be poorly understood and require more attention in both climate models and physiological studies. Currently, provenance-level performance is easier to accurately model than family-level performance; although the latter is possible provided large numbers of testing locations are established and measured. Improved growth potential lies in water management through appropriate silvicultural practices. Finally, projecting growth rates in terms of risk allows for further practical evaluation of outcomes by foresters based on local knowledge, a format well fitted to a decision support tool framework. Optimizing matches between seed sources and growth environment will help to grow forests more resilient to climate variability, better mitigate economic risks, and increase carbon sequestration, in fulfillment of the PINEMAP goals.

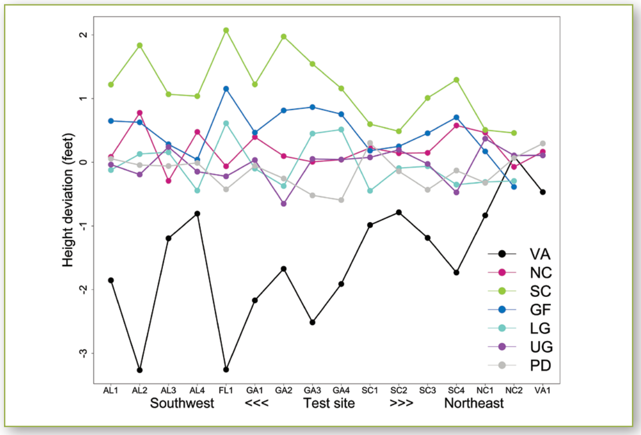


Figure 9.1. Mean height deviation of seven seed sources (average of families) from site mean. Each curve represents the relative performance of families from a geographic region (seed source) across test sites from southwest to northeast (from Farjat et al. 2015).

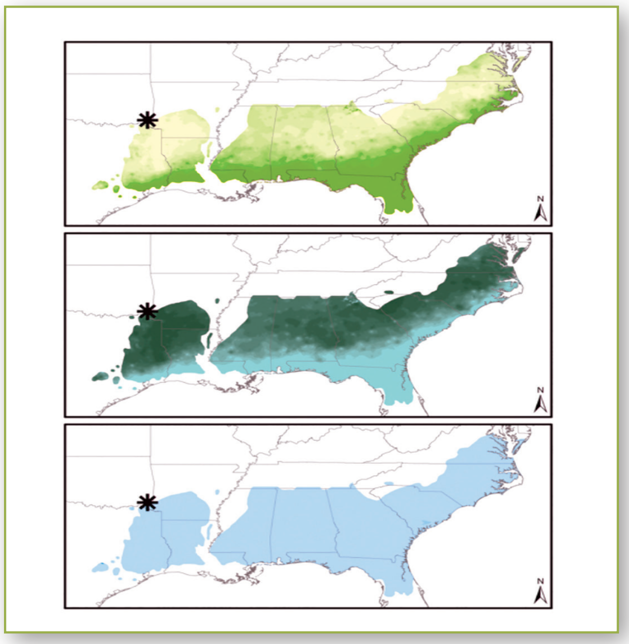


Figure 9.2. Shading indicates increased probability that a hypothetical source from Oklahoma (star) would perform in each of three performance categories created by dividing the standardized perfomance distribution into three partitions: poor (top map), fair (middle map), and good (bottom map). Similar model output maps can be produced for seed sourced from any area with historical weather records.

10. What are Genes Good for? Molecular Genetics in Applied Forest Tree Breeding Programs

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PINEMAP will improve our understanding of genetic variation within and among groups of trees, allowing for the development of new tools for current and future tree breeding. Genetic enhancement of productivity, efficiency of fertilizer use, and resilience to climate variation will contribute to the goals of increased carbon sequestration and a more robust and resilient forest-based economy, both in the near future and in decades to come.

Federal funding over the past several decades has enabled the development of new technologies that have dramatically changed the study of genetic variation (differences in DNA sequences among individuals in a population). Most notably, the cost of determining DNA sequences has dropped dramatically over the past eight years (Figure 10.1). These tools are now being applied to address long-standing questions in forest genetics, including how to breed trees for increased growth as well as increased resilience to changes in environmental conditions, pest attack, and disease.

The particular combination of different versions of genes present in any individual tree is its genotype, and the process of describing it is called genotyping. There are several methods for genotyping, and the context of tree breeding necessitates careful choices among the available technologies. The following list (although not comprehensive) describes some of possible applications of genotyping in tree breeding, ranked from simplest to most complex.

1. The simplest use of DNA sequence variation is the identity verification of specific individuals, or “DNA fingerprinting”. Testing all trees in seed orchards and eliminating trees that are incorrectly identified would assure seedling purchasers that the planting stock has the expected characteristics.
2. A related application is the analysis of relationships among individuals. This can be as simple as confirming the identity of parents of individual offspring in seeds derived from a controlled cross, or as complex as identifying the degree of relatedness among distant relatives that share one or a few common ancestors. The ability to determine the success of controlled crosses is important for breeding programs, as is an accurate assessment of the degree of

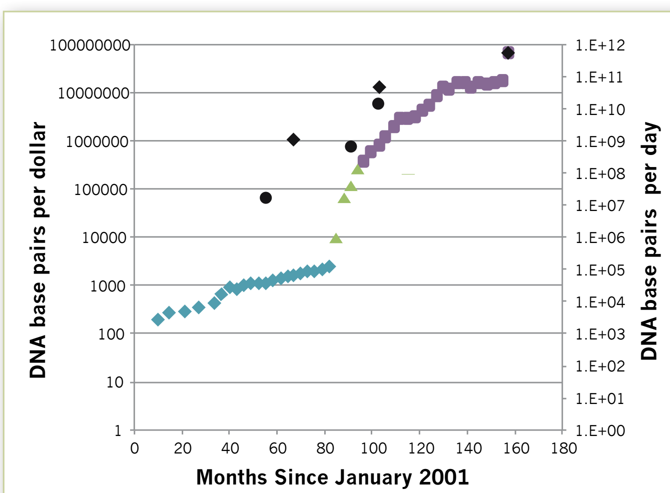

Figure 10.1. A figure from http://www.genome.gov/sequencingcosts/, showing the decrease in the cost of DNA sequencing since 2001. The dramatic decrease since 2007 is the result of technological breakthroughs that decreased the cost per million base pairs of DNA sequence by more than 11,000-fold from July 2006 to July 2014. The straight line shows a rate of technical advance resulting in doubling every two years, which is referred to as “Moore’s Law” in the context of advances in computer technology.

Loblolly pine seeds ready for sowing.
Photo by Steve McKeand.

The value of this work to landowners and land managers will come by the application of these genotyping technologies by university tree-breeding cooperatives.

relatedness among trees within breeding populations. Resemblance of related individuals tends to increase as the degree of relationship increases, but maintaining genetic diversity is also important, particularly for crops such as trees that are exposed to pests, diseases, and environmental change over decades. Current methods rely on pedigree information from decades of tree breeding (Figure 10.2) to describe relatedness, but genotyping could identify relationships that pre-date recorded breeding history.

3. A long-term goal is to use knowledge of DNA sequence variants to predict characteristics of interest in mature trees. This is an area of active research because not only is the proportion of DNA sequence variants that actually affect tree growth and development unknown, but also the majority of sequence variation observed may be neutral, without any effect on individuals' characteristics. This creates a signal to noise problem. Furthermore, only a subset of observed DNA sequence variants are likely to be important in controlling functional traits of interest to land managers or tree breeders, and those may only be important under certain environmental conditions. Sophisticated statistical approaches are helping overcome the low signal-to-noise ratio, as are complementary analytical approaches to use all available information without concern for signal or noise.

The value of this work to landowners and land managers will come by the application of these genotyping technologies by university tree-breeding cooperatives (e.g., the North Carolina State University Cooperative Tree Improvement Program) and private companies to more rapidly develop pine seedlings that are both adapted to particular environments and more resilient to variation in environmental conditions.

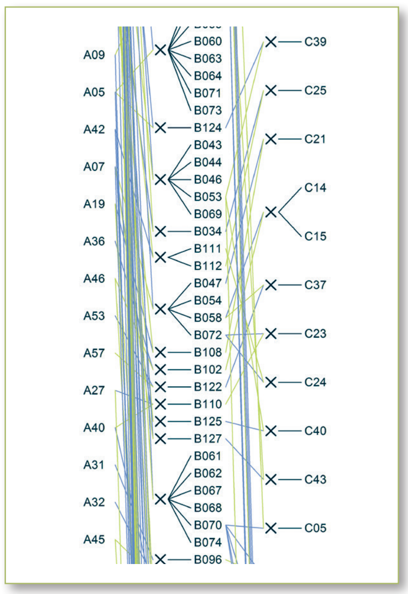

Figure 10.2. A small example segment of a pedigree diagram; the full diagram shows relationships among 234 individuals. Even that diagram is small relative to the size of current breeding populations, which can include up to 400 or more individual trees. This pedigree diagram is based only on recorded ancestry; more complex diagrams can also show similarities among individuals based on similarities of genetic fingerprints. This diagram was produced with Pedimap (Voorrips, 2012), available from https://www.wageningenur.nl/en/show/Pedimap.htm

11. Trends in Deployment of Advanced Loblolly Pine Germplasm

***Steve McKeand*[1, 3] • *Gary Peter*[1, 4] • *Tom Byram*[2, 5]**

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

In the southeastern United States, planting genetically improved loblolly pine seedlings has increased carbon sequestration over the past 40 years by about 13%. With the increased productivity from improved genetic stock and silvicultural practices, carbon sequestration in loblolly pine plantations will be an even more important component of mitigation strategies in the future.

Investment in forest management has large, positive impacts on stand productivity, land owner returns, and carbon budgets (Albaugh et al. 2012, Gonzalez-Benecke et al. 2011, Miner et al. 2014). In the southeastern United States, Aspinwall et al. (2012) estimated that relative to no genetic improvement, planting genetically improved loblolly pine over the past 40 years has resulted in an additional 3.7 billion m^3 (17% increase) in volume of wood and 1,100 Tg C (13%) in carbon sequestration.

Loblolly pine is the most widely planted forest tree species in the world. In the southern U.S., about 80% of the more than 30 million planted acres are loblolly pine, and virtually all of those were established with genetically improved seedlings. Advanced tree breeding and seedling deployment programs now provide landowners with options to plant specific families that are 40% to 60% more productive than unimproved loblolly pine. A wide range of planting stock is available to landowners with different costs, benefits, and levels of genetic diversity.

To determine the genetics of loblolly pines currently being planted, we surveyed seedling vendors who are members of the three pine tree improvement cooperatives in the South (see box below). We wanted to quantify how many seedlings of various types are being planted as well as determine evidence of risks associated with planting genetically more homogeneous seedlots, such as specific full sibling families or clonal varieties.

In the 2011, 2012, and 2013 planting seasons, 31 cooperative members planted an average of 843.5 million tree seedlings per year. This is 37% fewer than the 1.35 billion seedlings grown yearly during the previous survey period (McKeand et al. 2003). Reduced seedling production was expected given the reduction in annual acres of plantation established during last 10 years. Of these 843.5 million seedlings, 87.1% (734.6 million) were loblolly pine, 6.1% (51.1 million) slash pine, 5.7% (48.5 million) longleaf, and 1.1% other conifers and hardwoods.

For loblolly pine, the most dramatic change from the previous survey period is that 95% of plantations are now being established as genetically more homogeneous stands to capture greater gains in yield from improved genetics. In the previous survey, 59% of loblolly stands were planted with open-pollinated (OP) families and the rest with mixtures of seedlings from different mother trees. Today, the vast majority of stands are planted with OP families (84%), where seedlings share the same mother but have many different pollen fathers (Figure 11.1). About 8% of stands are planted with specific crosses or full-sib families, where both the mother and father are known (see photo on opposing page), and about 2% are planted with clonal varieties where every tree is

- The **Cooperative Forest Genetics Research Program at the University of Florida** (http://www.sfrc.ufl.edu/cfgrp/), **North Carolina State University Cooperative Tree Improvement Program** (http://treeimprovement.org/), and **Western Gulf Forest Tree Improvement Program at Texas A&M University** (http://www.ars-grin.gov/misc/wgftip/), collectively represent over 90% of pine seedlings planted in the South.

- For a comprehensive survey of southern forest nurseries, see the annual survey of the **Southern Forest Nursery Management Cooperative at Auburn University** (https://www.nurserycoop.auburn.edu/).

Photos courtesy of Steve McKeand (L) and Don Chastain, TIR (R).

Mass production of specific crosses is becoming routine and accounts for almost 10% of loblolly pine plantations. Female strobili ("flowers") are isolated from pollen in the air, and pollen from a specific parent tree is used to pollinate them.

genetically identical. Landowners can now choose families that best match their management goals. They can also select families that may be better suited to future climate scenarios.

Although most individual plantations are relatively genetically homogeneous, there is substantial genetic diversity across the landscape. Within a planting zone, up to 354 OP families and 86 full-sib families were planted, although some of these families were undoubtedly the same for different companies and agencies. On average, there were 24 different parent trees grafted in seed orchards (Figure 11.1), with a minimum of 14 and a maximum of 36.

To determine risks associated with establishing plantations with relatively homogeneous germplasm, we asked respondents if they were aware of any unexpected environmental or pest problems (e.g., diseases, insects, cold, or storm damage) encountered in single family plantings. One of the 33 respondents experienced freeze damage with one southern coastal family planted in northern environments that were colder than recommended by Schmidtling (2001), and one tree family consistently showed about 10% lower survival compared to other families. No respondents reported outright plantation failures due to the use of family blocks.

Planting genetically improved families of loblolly pine in family blocks has become standard in southern U.S. plantations. As older plantations are replaced with newer, faster growing families planted in blocks and managed with good silvicultural practices, increased yields have the potential to increase carbon sequestration by up to an additional 10% relative to the stands they are replacing, becoming an important carbon mitigation strategy in the region.

Figure 11.1. Seeds collected from open-pollinated seed orchards are used in 84% of loblolly pine plantations. On average, these orchards have 24 different parent trees grafted to produce a diverse range of progeny. Photo courtesy of Steve McKeand.

12. The PINEMAP Decision Support System Seedling Deployment Tool

***Heather Dinon Aldridge*[1, 4] • *Gary Peter*[2, 5] • *Corey Davis*[1, 4] • *Ryan Boyles*[3, 4]**

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[5] School of Forest Resources and Conservation, University of Florida

The seedling deployment tool will equip our target audience with the capacity to make better informed, practical decisions related to climate, forest ecosystems, and forest management. It will also enhance connections among forestry professionals, climate researchers, and education and outreach professionals as we present the tool at workshops and trainings.

Current southern pine seedling deployment guidelines available from the U.S. Forest Service (http://www.srs.fs.usda.gov/pubs/gtr/gtr_srs044.pdf) are based on research conducted several decades ago that identified winter minimum temperature as the climate variable best correlated with pine tree growth and survival of genetic sources moved northward (Schmidtling 2001). Schmidtling also showed that when southern sources were planted farther north, they often grew faster than the local northern source (see article 9). The PINEMAP genetics team has used newer provenance trials and analytical tools to reassess and confirm winter minimum temperature as a significant climate variable affecting loblolly pine growth across the region. This suggests that the expected increase in minimum temperatures associated with climate change may provide opportunities for optimizing pine productivity by planting more southern seed sources even farther north than currently advisable. Some risk from increased freeze damage can occur if seedlings are moved too far from sources. Therefore, foresters and forest landowners need tools to assess risks while maximizing growth potential. To help landowners with important seedling deployment decisions, PINEMAP investigators are developing a seedling deployment tool (Figure 12.1) for the PINEMAP Decision Support System (DSS) that enables foresters and landowners to visualize potential future changes in mean winter minimum temperatures.

The seedling deployment tool is an interactive map-based system that covers the Southeast U.S. The tool features a map with 5°F isotherms (lines of equal temperature) of historical

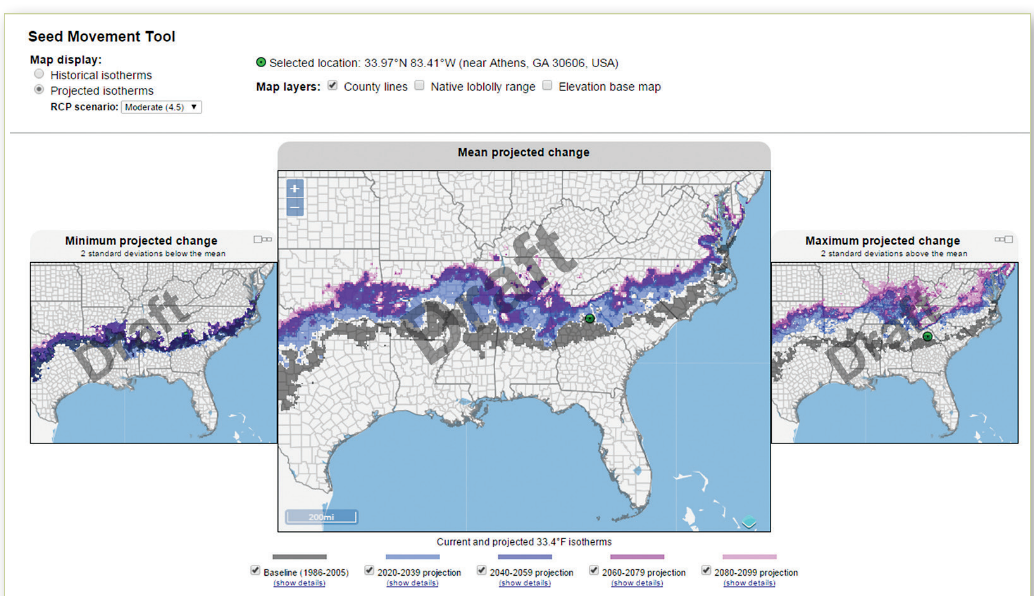

Figure 12.1. Seedling deployment map depicting possible future migration of the 33°F isotherm (associated with Athens, Georgia) of historical average winter minimum temperature (1986–2005)

Photo by Larry Kohrnak.

The PINEMAP seedling deployment tool builds on the research of Schmidtling by mapping predicted future average January minimum temperature isotherms, which allows users to select a temperature range around the historical isotherm based on individual freezing risk tolerance.

average January minimum temperatures (1986–2005), which closely mimic the current seed transfer guidelines of Schmidtling 2001. When a user clicks on a location of interest on the map, the minimum average January temperature line currently associated with that location (e.g., the 33°F isotherm for Athens, Georgia, is shown in Figure 12.1) is highlighted along with the possible migration of that isotherm for selected future periods (e.g. 2020–2039, 2040–2059, 2060–2079, and 2080–2099), resulting from state-of-the-art climate projections. The tool also allows users to select a temperature range around the historical isotherm (e.g. +/-1°F, +1 to -3°F, and +1 to -5°F) to explore the projected risk associated with a source zone for each planting location (ranging from low to high) as shown in Figure 12.2.

The PINEMAP seedling deployment tool builds on the research of Schmidtling by mapping predicted future average January minimum temperature isotherms, which allows users to select a temperature range around the historical isotherm based on individual freezing risk tolerance. Thus, the tool enables foresters and forest landowners to better match seed sources with future climates to increase optimize productivity.

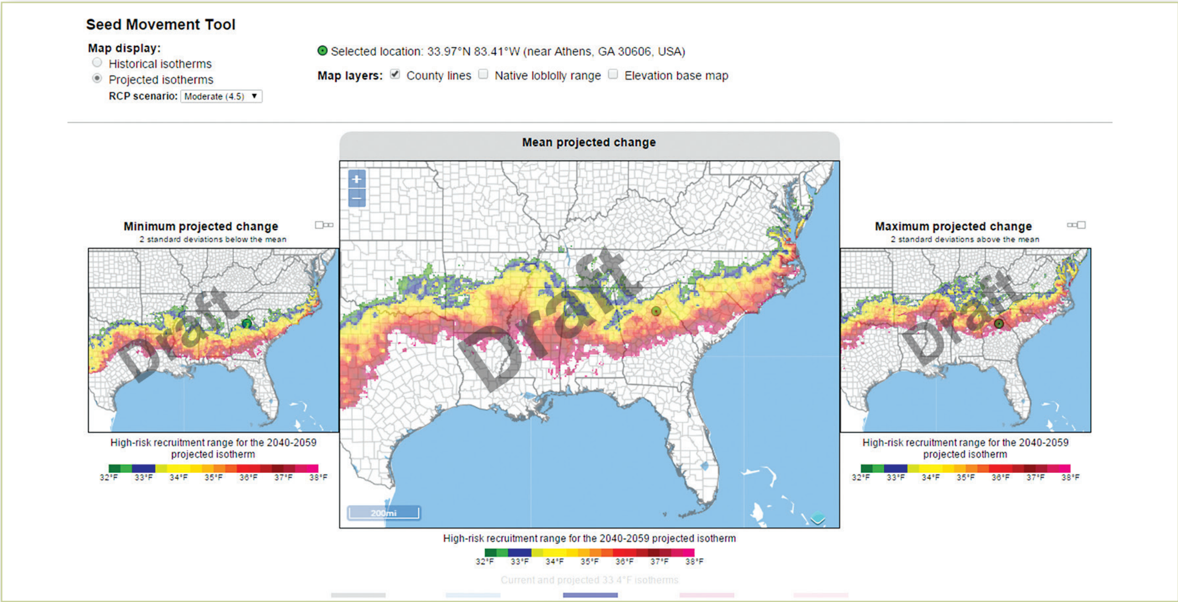

Figure 12.2. Seedling deployment map that allows users to explore different risk levels by selecting different ranges around the historical isotherm (e.g. +/-1°F, +1 to -3°F, and +1 to -5°F)

13. Impact of Climate Change on the Efficiency of Ecosystem Services Provision in Loblolly Pine Forests

Andres Susaeta[1, 4] • Damian Adams[2, 4] • Douglas Carter[3, 4] • Puneet Dwivedi[2, 5]

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

Results from this economic analysis will help policymakers formulate instruments and incentives to encourage the sustainable management of planted pines and foster the forest based economy in the Southeast U.S. under changing climatic conditions.

Forests provide many important ecosystem services including timber, biodiversity, wildlife habitat, and water quality (Kreye et al. 2014). Forests of the Southeast provide nearly 62% of timber harvested in the U.S. (Smith et al. 2009), have the potential to sequester 23% of the region's emissions of greenhouse gases (Han et al. 2007), and help protect water quality that is critical to the functioning of fragile ecosystems (Kreye et al. 2014). Changing climatic conditions are expected to affect the structure and function of forests, and thus, forest derived ecosystem services (Susaeta et al. 2014).

This study used forest plot data to assess the efficiency in the production of ecosystem services from southern loblolly pine (*Pinus taeda* L.) plantation forests under climate change. We employed data envelopment analysis (DEA), a nonparametric approach in which each forest plot is assumed to need the same inputs to generate the same outputs (Charnes et al. 1978). Inputs and outputs are classified as fixed (F) and discretionary (D) (i.e., they can be controlled or not, respectively, by forest landowners and managers); inputs and outputs are presented in Table 13.1. The ecosystem services provision inefficiency measure becomes larger as efficiency decreases.

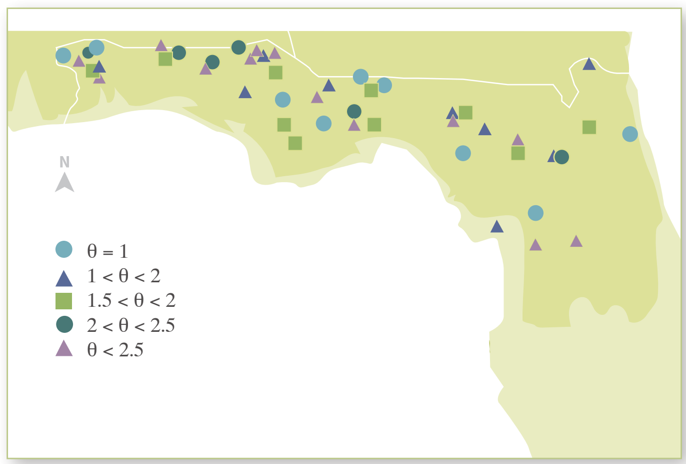

Figure 13.1. Spatial distribution of forest plots with efficiency measures for all scenarios in Florida.

We used Florida data from the Forest Inventory and Analysis (FIA) research program (U.S. Department of Agriculture Forest Service 2014) between 2002 and 2011 to determine silvicultural inputs and outputs for each loblolly pine plantation forest plot. To capture climatic inputs, we used observed total annual precipitation and average minimum and maximum temperatures for each forest plot (at the time of FIA observation) from the National Oceanic and Atmosphere Administration's National Climatic Data Center (NOAA 2014). We modeled the effects of climate change scenarios that encompassed changes in temperature, precipitation, site index, timber production, carbon sequestered, and species richness for 2014–2030 under two representative concentration pathways (RCPs) for greenhouse gas emissions: RCP4.5 (reduced emissions scenario) and RCP8.5 (business-as-usual emissions scenario) (Table 13.2). Forecasts of precipitation and temperatures for both RCPs were obtained using the Canadian Earth system model CanESM2 (University of Idaho 2013).

Photo by John Seiler.

Our results suggest that altered future temperatures and precipitation have a small negative impact on average plot efficiency in the provision of ecosystem services. However, thinning and lower planting density significantly improve timber production, carbon sequestration, and species richness."

In the southern U.S., site index at base age 25 years is expected to increase by 3 to 6 m on average by 2030, with a further 9 m increase by 2100 (Teskey 2014, Bob Teskey, March 26, 2014). Changes in site index will have a direct impact on both timber production and carbon sequestration. For example, Jokela et al. (2010) estimated that a 35% increase in the current site index for loblolly pine stands would double total stand volume; and when applying the growth, yield, and carbon balance model for loblolly pine (Carbon Resource Science Center 2014), we find an 8% increase in total loblolly pine volume for each 1 m increase in site index (increasing site index from 20 to 25 m with 1500 trees ha^{-1}). Average carbon sequestration in high quality sites can be increased by 38% over average quality sites (Gonzalez-Benecke et al. 2011). Slight increase in tree species richness, up to 10% in the southern U.S., is expected under changing climatic conditions (Currie 2001).

Figure 13.1 shows the spatial distribution of the forest plots and their efficiency measures for all scenarios. Our results indicate that the average efficiency across plots ranges between 2.9 and 2.95 and between 1.8 and 1.84 when species richness is considered as a fixed and discretionary input, respectively (Table 13.3). So when species richness can be modified by management (Scenario B), then the provision of timber, carbon sequestered, and species richness can be improved by 83%. Our results also suggest that altered future temperatures and precipitation have a small negative impact on average plot efficiency in the provision of ecosystem services. However, silvicultural practices that reduce the number of trees (e.g., thinnings and lower planting density) significantly improve timber production, carbon sequestration, and species richness.

Inputs	Type
Site index (m)	F
Forest stand age (years)	F
Number of trees	D
Average annual maximum temperature (°C)	F
Average annual minimum temperature (°C)	F
Total annual precipitation (mm)	F
Outputs	
Timber production (m^3)	D
Carbon sequestered (Mg)	D
Species richness	F, D

Table 13.1. Inputs and outputs per loblolly pine forest plot (F=fixed, D=discretionary).

Changes in ecosystem	2002-2009 (historical)	2014-2030	
	Scenario A (baseline)	**Scenario B** (RCP 4.5)	**Scenario C** (RCP 8.5)
Site index	No change	+3 m	+6 m
Timber production	No change	+25%	50%
Carbon sequestration	No change	+25%	50%
Tree species richness	No change	+2.5%	5%

Table 13.2. Provisions of ecosystem services under time frame 2014–2030 and representative concentration pathways RCP4.5 and RCP8.5.

Species richness	Scenario A	Scenario B	Scenario C
Fixed	2.90	2.94	2.95
Discretionary	1.80	1.83	1.84

Table 13.3. Average efficiency measure for forest plots for each scenario with fixed and discretionary species richness.

14. Insurance as an Adaptation to Wildfire Risk under Climate Change: Evidence from Southeastern Family Forestland Owners

***Jianbang Gan*[1, 4] •*Adam Jarrett*[2, 5] • *Cassandra Johnson Gaither*[3, 6]**

[1] Professor • [2] Regional Director • [3] Research Social Scientist • [4] Department of Ecosystem Science and Management, Texas A&M University

[5] Texas Department of Wildlife and Parks Service • [6] USDA Forest Service

Reducing economic loss from wildfire on family forestlands through adequate insurance coverage can contribute to the establishment of a more robust and resilient forest-based economy in the Southeast U.S. Additionally, understanding the factors attributable to landowners' purchase of wildfire insurance will aid in developing public policy that supports sustainable management of planted pines under future climate change scenarios. Insurance can support forest restoration and incentivize fire protection and prevention as an integrated part of sustainable forest management.

Wildfire has emerged as an increasing threat to properties, ecosystems, and human life (USDA and USDI 2000). Climate change is likely to further alter future wildfire regimes (Gan 2005a, Pechony and Shindell 2010), creating a greater challenge for wildfire management and necessitating more effective response strategies. In the southeastern U.S., the effectiveness of wildfire mitigation measures, such as fuel reduction, depends on broad and coherent collaboration among diverse neighboring landowners, which is challenging (Ostrom 1990). An appropriate alternative for the southeastern U.S. region, where the majority of forestlands are owned by households, is wildfire insurance, which compensates a landowner for economic losses sustained by wildfires (Smith et al. 2009).

Although wildfire insurance was proposed many decades ago (Shepard 1935), there are currently few such insurance programs, and studies that examine the participation of forestland owners in wildfire insurance markets are even rarer. We identified factors that influenced landowners' purchase of wildfire insurance and assessed the potential of insurance as an adaption to wildfire risk under climate change for family forestland owners in the southeastern U.S.

We surveyed 2,500 family forestland owners who owned at least 10 acres of forestland in five states: Alabama, Florida, Georgia, Mississippi, and South Carolina. The survey yielded a 24.7% response rate. Using the survey data and logistic regression, we identified the factors that influence landowners' decision to purchase wildfire insurance. Hurricanes are attributable to wildfire as blowdown trees and branches are a fire hazard. Combining the logistic regression model with the projected future wildfire (Gan 2005b) and category 4 and 5 hurricane activity (Knutson et al. 2013, Pielke et al. 2008), we assessed the impact of climate change on the adoption of wildfire insurance by family forestland owners as an adaptation to wildfire risk under future climate change (Gan et al. 2014). These projections reflected the greenhouse emission scenario of A1B, which represents approximately the average of all emission scenarios considered by the Intergovernmental Panel on Climate Change (IPCC 2000).

Only 9.4% of survey respondents had wildfire insurance even though approximately 96% of them believed that their lands could be damaged by wildfire. The low participation rate of these landowners in the wildfire insurance market might be partly due to the limited choices of such insurance programs and a perception that low-probability wildfire events would not happen to them and that governments would help them out if a disaster were to occur (Kunreuther 1996).

Several factors showed statistically significant correlations with wildfire insurance purchase. Female landowners were much more likely than males to buy wildfire insurance. Landowners who were well educated or whose land had been hit by a hurricane were also more willing to buy wildfire insurance. However, the owners of forestlands that were heirs' properties or forestlands that had been burned by wildfire previously were less interested in wildfire insurance (Table 14.1). The ownership of an heirs' property is often less clear or more complex and thus easier to lose (Graber 1978), which can discourage the landowner from investing funds in protecting it.

Photo courtesy of Leda Kobziar.

The reluctance of family forestland owners to purchase wildfire insurance calls for private-public partnerships in wildfire insurance markets. Such partnerships could make wildfire insurance more affordable, thus incentivizing landowners to buy insurance and reducing the wildfire disaster relief burden for taxpayers.

On average, climate change is predicted to increase wildfire occurrence by 15% (Gan 2005b) and category 4 and 5 hurricane activity by 63% (Knutson et al. 2013), respectively. With these assumptions, landowners' propensity to purchase wildfire insurance would increase by a moderate level of 14% (with a range of 1% to 30%) (Figure 14.1).

Our findings have several implications for insurance as a tool for mitigating economic losses for family forestland owners in the southeastern U.S. due to wildfire. First, because only a small portion of landowners have bought wildfire insurance, great potential exists to expand the current wildfire insurance market in the region. However, challenges coexist with this potential because landowners' belief in wildfire threat does not necessarily translate into their purchase of wildfire insurance. Second, the owners of recently burned forestlands are less likely to buy insurance because they assume a reduced risk of fire. Conversely, the owners of forestlands recently hit by a hurricane are more willing to purchase wildfire insurance in the context of an elevated fire risk. This could lead to adverse selection, where only the landowners with high wildfire risk buy insurance, potentially causing the insurance market to collapse. Finally, the reluctance of family forestland owners to purchase wildfire insurance calls for private-public partnerships in wildfire insurance markets. Such partnerships could make wildfire insurance more affordable, thus incentivizing landowners to buy insurance and reducing the wildfire disaster relief burden for taxpayers.

In conclusion, less than10% of family forestland owners in the southeastern U.S. have wildfire insurance, and climate change may only moderately increase their propensity to purchase wildfire insurance. The wildfire insurance market niche and barriers reveal both opportunities and challenges to expand insurance as an adaptation to the risk of economic loss due to wildfire.

Factor	Impact on landowners' purchase of wildfire insurance
Wildfire occurrence in the past 10 years	↓
Hurricane hit	↑
Heirs' property	↓
Female landowner	↑
Educational level of the landowner	↑

Table 14.1. Influences on landowners' purchase of wildfire insurance.

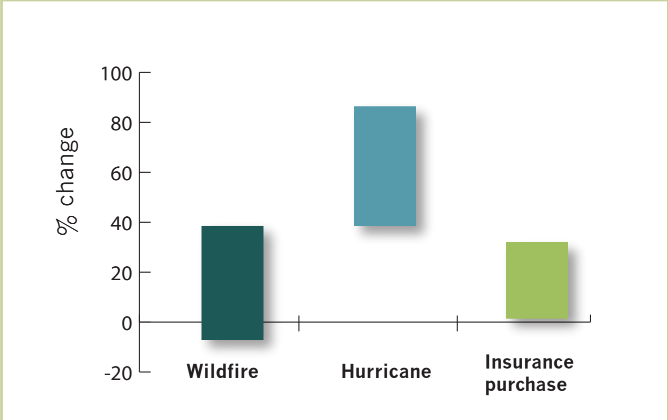

Figure 14.1. Impacts of climate change on wildfire, hurricanes (categories 4 and 5), and wildfire insurance purchase by family forestland owners.

15. Who Lives Near the Carbon? Socio-Ecological Considerations in Forest Carbon Sequestration

***Jose R. Soto*[1, 4] • *Francisco J. Escobedo*[2, 4] • *Damian C. Adams*[3, 4]**

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

We analyzed U.S. census data to characterize the demographics of people and communities near high carbon storage forests in Florida. Results of this study can help policy makers consider the broader social implications of compliance strategies that include forest carbon offset payments. Similarly, these communities can influence forest management through support for elected officials as well as key environmental and land use policies and regulations.

The United States Environmental Protection Agency (EPA) recently announced its goal to reduce net carbon dioxide (CO_2) emissions from U.S. power plants by 30% of 2005 baseline levels by 2030 (EPA 2014a, EPA 2014b, EPA 2014c). The proposed rules would require states to develop portfolios for emissions compliance that could include CO_2 offsets from other industries such as forestry. Several regional and national studies have found that using forests to capture greenhouse gas emissions merits strong consideration from both policy makers and landowners (e.g., Lubowski et al. 2005, Stainback and Alavalapati 2002). Storing carbon in forests as well as incentivizing landowners to participate in carbon markets, which are encouraged under the proposed EPA rules (EPA 2014a), are cost-effective means for reducing net CO_2 emissions (Stavins 1999), thus providing attractive avenues for states to meet the EPA's emissions reduction goals.

As lawmakers develop programs to achieve these CO_2 emissions reductions, it is important to consider the broad social context of increasing forest carbon (C) sequestration. Changes in forest management could potentially impact the communities where these forests grow (e.g., Buschbacher 1990) through changes in land use, economic activity, or employment. One approach to understanding how management and policy changes may affect communities is to quantify community demographics in relation to forest carbon characteristics. To better understand the characteristics of communities located near where forest C sequestration policies are likely to be implemented, we used Florida as an example to examine the relationship between socio-ecological factors (stand size, tenure, pine-dominated stands, population age, income, education) and the size of existing forest C stocks. Florida is one of the fastest growing states in the U.S., with a highly urbanized population of 19.9 million residents (Smith et al. 2009). As shown in Figure 15.1, more than half the counties in Florida are over 50% forested (Brown and Nowak, 2012), so changes to forest structure and function are likely to have a large impact on state-level C sequestration totals.

We used available U.S. Department of Agriculture (USDA) Forest Service Forest Inventory and Analysis (FIA) data and recent U.S. census data in a coupled geospatial and econometric framework to analyze what demographic and ecological factors are correlated with forest carbon stocks in Florida. The data included 902 forest plots (adjusted for geo-referencing) and census observations from 2009 to 2011 of representative forested areas across the entire state (see Figure 15.2). Ecological variables included stand age (years); stand type (pine or other); basal area; ownership type (private or other); land improvements (e.g., site preparation; and whether or not fertilizers and herbicides were used); natural disasters (e.g., whether or not ground fire damage, drought, flooding occurred between 2000 and 2010); and forest site productivity classes based on volume production. Socioeconomic variables included ethnicity (Hispanic or African-American), education, land tenure (whether or not the owner lived on property), urban indicator (urban or rural), age, and income.

As expected, the ecological factors of *site quality*, *basal area*, *stand age, forest production quality,* and *stand size* were associated with higher C stocks. Forests with larger C stocks were associated with census areas containing higher percentages of graduate degrees or a higher percentage of the population aged 22-39. Smaller forest C stocks were found in areas with predominantly minority residents, with higher portions of the population aged 65, or with annual household incomes above $50,000.

Forests with larger C stocks were associated with census areas containing higher percentages of graduate degrees or a higher percentage of the population aged 22-39. Smaller forest C stocks were found in areas with predominantly minority residents, with higher portions of the population aged 65, or with annual household incomes above $50,000.

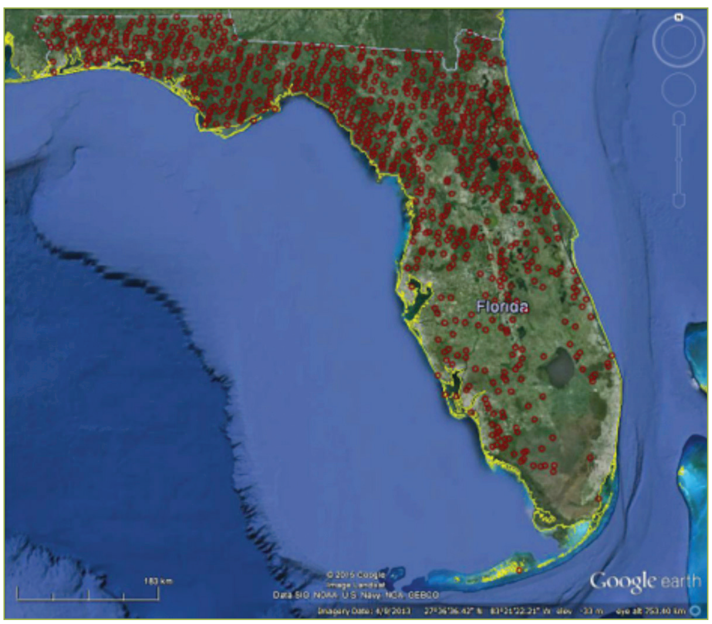

Figure 15.1. Satellite map of Florida and the 902 USDA Forest Service Forest Inventory Analysis (FIA) plots for a particular area in the state. Each point on the map represents an FIA plot.

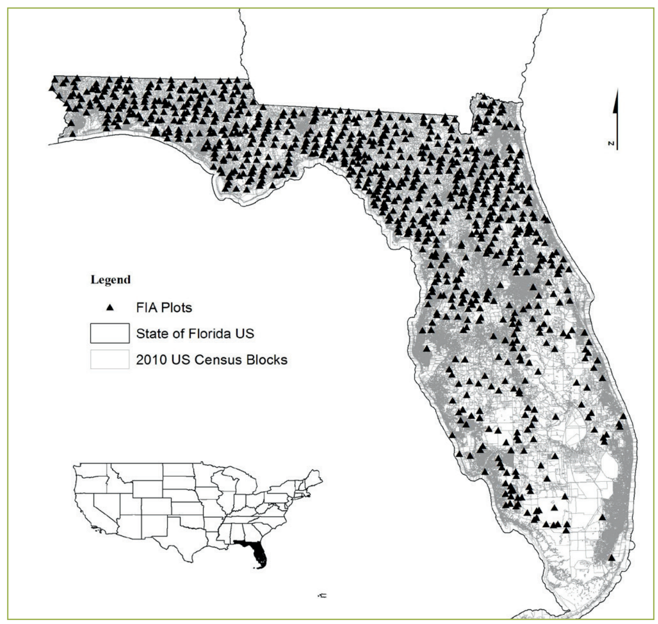

Figure 15.2. Map of Florida's 902 USDA Forest Service Forest Inventory Analysis (FIA) plots and 2010 U.S. Census Blocks. Each point represents an FIA plot; light-gray regions are U.S. Census Blocks.

Given the cost-effectiveness of forest-based carbon sequestration (Stavins 1999) and the high percentage of forest land that is privately held in the southern U.S. (e.g., 70% in Florida) (FFS 2010), we are likely to see states meet the EPA emissions goals in part by creating landowner payment programs that incentivize more forest C sequestration. If these policies have economic effects on nearby communities, our model results point out that these effects in turn can disproportionately influence certain demographics more than others, as income, education, and ethnicity varied with forest C stock levels. Other studies have pointed out the importance of understanding landowner characteristics for designing effective conservation initiatives. In the context of this literature, our work directs attention to the potential for such programs to impact communities in differing ways. Though not prescriptive, our findings suggest a role for understanding this broader social context when designing C sequestration programs, considering not only impacts that landowners might have on the state's capacity to sequester C via urban forestry or forest management projects, but also quality of life considerations, economic impact of these policies on local communities, and policy preferences of a variety of stakeholders.

16. PINEMAP's Outreach Efforts Producing On-the-Ground Results

***Eric Taylor*[1, 3] • *Leslie Boby*[2, 4]**

[1] Silviculturist III • [2] Extension Associate • [3] Texas A&M Forest Service • [4] Southern Regional Extension Forestry

One of PINEMAP's primary target audiences, the professional land manager (e.g., forester, silviculturist) working with large-acreage landowners, and to a lesser extent small-acreage landowners, significantly impacts land management prescriptions in southern pine forests. For this reason, PINEMAP directed outreach efforts primarily towards this group in 2014. As a result of this effort, a significant number of acres across the South should receive improved silvicultural practices within the next five years that will result in lower risk of catastrophic tree loss, improved resilience to climate-related environmental stressors, and increased potential to sequester carbon among other benefits.

Foresters, working as private consultants or with large land-owning industrial and investment organizations, provide management guidance for millions of acres in the southern region of the United States. This is a key group for fostering management changes in southern forests. The PINEMAP Extension team made considerable progress reaching this audience through multiple workshops in 2014, both stand-alone PINEMAP activities and those developed in collaboration with organization meetings and in-service training events within the forestry community.

The PINEMAP outreach team is tasked with extending knowledge gained through PINEMAP efforts to people and groups who can create changes that contribute to PINEMAP outcome goals. The PINEMAP research community is rapidly developing standardized protocols that will allow us to measure gains in silvicultural knowledge and to measure the predicted scale of impact on forest management from these workshops. Meanwhile, our outreach and Extension efforts are building a strong foundation in order to share the next, critical wave of silvicultural information from PINEMAP by focusing on

- the ecophysiology of pine forests and their response to extreme environmental stressors resulting directly or indirectly from climate variability;
- how silvicultural practices affect change; and
- key management questions addressed by PINEMAP efforts that should promote forest production, health, and resilience.

PINEMAP's efforts toward increasing forest resilience and carbon sequestration rest on successfully developing and providing appropriate management information to foresters and landowners. Foresters can be considered the "gatekeepers" for meeting these goals, as they are often responsible for managing the land and developing the management plans. PINEMAP outreach activities in 2014 were directed toward producing in-the-woods results and focused on expanding pine acres and promoting production, health, resilience, and carbon sequestration of existing southern pine forests. While climate change is considered by some to be a controversial issue, managing forests well, reducing costs, and protecting forests from environmental stressors are smart management decisions under any circumstances.

Training events conducted in 2014 reached more than 175 practicing foresters influential in managing an estimated 16.4 million nonfamily forestland acres in the region. Although our evaluation efforts tried to discern duplicate acres of those training event participants working within the same company, some duplication may exist. Of the pine acres currently owned or managed, 29% over the next five years and 45% over the next ten years are anticipated to show an increase in production, health, resiliency, and ability to sequester carbon from changes in management based on knowledge gained from PINEMAP's outreach activities.

Our outreach efforts also were directed to agency and consulting foresters who primarily influence forest management practices on small-acreage owners (family forests) in the region. PINEMAP's outreach efforts are expected to indirectly disseminate information through agency and consulting foresters to more than 9,600 family forest landowners and influence their management practices on

Training events conducted in 2014 reached more than 175 practicing foresters influential in managing an estimated 16.4 million nonfamily forestland acres in the region.

16.2 million acres. As a result, nearly 690,000 family forestland acres currently in pine in the western Gulf region of the southern U.S. are likely to have management changes implemented that will increase health and resilience in the face of climate-driven environmental stressors in the next five to ten years.

Response to PINEMAP's outreach focus has been good. Notable events from 2014 include the following:

- Nearly 100 forestry practitioners attended the Western Gulf Silvicultural Technology Exchange (http://wgste.org) annual meeting. More than half (53%) felt their knowledge of all subjects taught had increased, and more than half (57%) plan to adopt (or already have adopted) at least one new forest management practice learned about at the meeting. This group of foresters collectively own and/or manage about 6 million acres. Over the next 10 years, 45% (on average) of the pine acres currently owned or managed will be positively affected by information from this regional meeting.
- A workshop session organized as part of a Tree Improvement Cooperative meeting increased attendees' knowledge of climate as a risk to consider in forest management. The session also provided information on choices and selection criteria of trees with specific genetic characteristics. The 60 attendees said that they planned to adopt some of the practices that were mentioned. Since these respondents work mostly for corporate forest landowners, their management choices may affect up to 2.5 million acres.
- An Advanced Silvicultural Concepts training focused on provided tools and information for natural resource professionals who work with small-acreage landowners and included Extension agents from land grant universities, foresters with the Texas A&M Forest Service, and consulting foresters. This group influences nearly 23,000 landowners and 1.05 million acres through their services and programs. Training attendees estimated that 63% of pine forests are likely to have a significant increase in health and resilience over the next 10 years through management changes that they are recommending.

Participants at a multistate Society of American Foresters meeting in a session on drought and climate impact management tools being developed by PINEMAP.

Information from these workshops has fostered awareness of the challenges that climate variability brings for forest management and has motivated participants to implement changes to counteract those risks. In the final year of PINEMAP, we are refining our management tools and messages and are excited to share new PINEMAP results with foresters, providing them with the resources to make improvements to forest health, growth, and resiliency.

17. Training the Trainer: Southern Region Extension Climate Academy

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Bill Hubbard[5, 8] • Shelby Krantz[6, 11] • Mark Megalos[7, 12]

[1] Extension Associate • [2] Professor and Extension Specialist • [3] Assistant Research Scientist • [4] M.S. Student • [5] Regional Forester • [6] Coordinator • [7] Extension Forestry Specialist
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Offering professional development on climate change and related natural resource management issues are critical for Extension agents and enhances the capacity for interdisciplinary collaboration. Extension agents are an effective educational link between landowners and researchers. Our evaluations suggest that learning about climate and interacting in the climate academy increased participants' willingness to work together on these issues.

A critical component of PINEMAP's mission is to engage forest landowners with information that enables them to adjust forest management in relation to potential changes in climate. Extension agents and specialists within the university land-grant system are a primary link to those landowners, and training them to better understand climate change (CC), adaptation possibilities, and how to communicate with landowners is the first step to improving land management. PINEMAP Extension faculty joined colleagues from two USDA National Institute of Food and Agriculture funded projects focused on crops and livestock to engage more than 100 Extension agents and specialists from across the South in the Southern Region Extension Climate Academy (SRECA).

One of the key features of the Extension system is that agents are typically similar to their clients (Rogers 2003), thus agents are able to relate to clients easily about common concerns and topics. The issue of climate change, however, challenges some agents. The need for SRECA emerged from a PINEMAP researcher's presentation to university Extension leaders regarding a PINEMAP survey of southern Extension professionals' attitudes toward climate change. Results indicate that Extension agents' views on climate change mirror those of the general public, ranging from very concerned to very skeptical (Wojcik et al. 2014). Furthermore, perceptions of climate change appear to alter the perceptions agents have about the need to address climate change topics during their in-service training (Monroe et al. 2014). Since these agents and specialists may benefit from regionally specific content, Extension directors agreed to support an in-service training program for their faculty.

Extension directors in each district selected participants that best fit their needs for trained faculty, and the program was launched with a three-day academy held September 3–5, 2014, in Athens, Georgia (Figure 17.1). SRECA was designed to be a starting point for

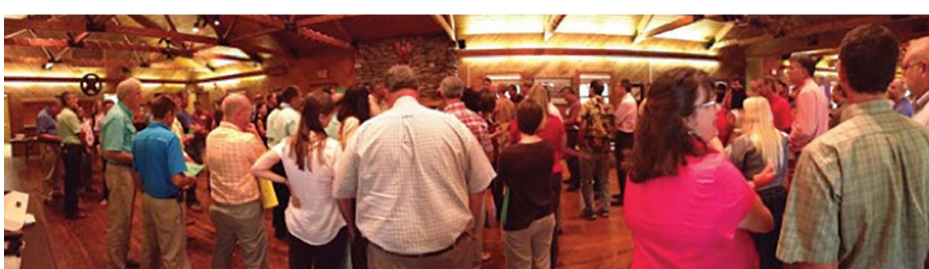

Figure 17.1. Southern Extension agents gather for an icebreaker exercise on the first day of the SRECA academy. Photo by Shelby Krantz

Bill Hubbard (Aim 6 co-leader) reports on the Forestry group perspectives to a plenary of SRECA participants. Photo by Martha Monroe.

SRECA attendees were pleased with the workshop. One participant said, "I was not excited about the subject matter prior to the workshop… it was better than expected. I am now more open to discussing climate change."

Extension professionals to network with their colleagues as they begin to incorporate climate change information into their programming.

Specifically, the program aimed to do the following:

- Support Extension professionals in the application of climate science and stakeholder engagement methods in order to provide localized adaptation and mitigation strategies that promote more resilient forest, crop, livestock, and coastal systems in the Southeastern U.S.
- Build an alumni network of innovative leaders in Extension who are knowledgeable on key climate science basics, are skilled in stakeholder engagement strategies, are capable of serving as state or local resources, and can share ideas with others regionally through exchanging innovative program ideas and outreach materials.
- Fifteen states were represented by 122 participants.

In addition to plenary session lectures and discussions, participants interacted in smaller breakout groups. Results of the pre- and post-event surveys of perceptions about climate change showed a decrease in the number of respondents who answered that "climate change is occurring but we don't know its cause" and "there is insufficient evidence to know with certainty whether climate change is occurring" (Bartels et al. 2014).

Overall, SRECA attendees were pleased with the workshop. One participant said, "I was not excited about the subject matter prior to the workshop… it was better than expected. I am now more open to discussing climate change."

The positive impact of SRECA is just beginning. Participants developed ideas for Extension resources and ways to communicate effectively with their clients. A series of webinars is planned to continue our interaction with participants, to engage them in ongoing discussions about their programs, and to support their efforts. Additionally, SRECA participants are being connected to the new resources and opportunities now available through the USDA Climate Hubs. Many resources have already been collected and posted on the program's website (www.srecablog.wordpress.com), including a short video about the event. As agents use this information in their programming, they will develop resources to be shared among the SRECA cohort.

SRECA was created by PINEMAP's Extension team in collaboration with faculty from two other USDA-NIFA funded projects: Animal Agriculture in a Changing Climate, led by the University of Nebraska-Lincoln, and the Southeast Climate Extension Project led by Clyde Fraisse, University of Florida.

18. Extending PINEMAP Benefits into a Post-PINEMAP Future

***Timothy Martin*[1, 3] • *Steve McNulty*[2, 4]**

[1] Professor, PINEMAP Project Director • [2] Ecologist, Team Leader • [3] School of Forest Resources and Conservation, University of Florida

[4] USDA Forest Service Southern Research Station Eastern Forest Environmental Threat Assessment Center

Because PINEMAP is a five-year project with outcome-focused goals for increased carbon sequestration and forest resilience projecting 30 years into the future, we need a plan that enables our stakeholders to continue to benefit from our work after the project is completed.

The PINEMAP project's mission is to enable southeastern U.S. landowners to increase carbon sequestration and resilience in planted pine forests over the next 30 years. In order for the five-year project to achieve these long-term goals, PINEMAP's data, tools, and networks established during the funded phase of PINEMAP must remain available to our stakeholders after the project expiration in February 2016. A key resource for extending PINEMAP's outreach will be the U.S. Department of Agriculture, Southeast Regional Climate Hub (SERCH), directed by PINEMAP co-principal investigator and modeling team co-leader Steven McNulty.

SERCH was established in 2014 to deliver science-based knowledge and practical information on climate variability and change to farmers, ranchers, and forest land managers. SERCH's mission is to connect public, academic, and private sector organizations, researchers, and outreach specialists to deliver technical support and provide tools and strategies to help producers cope with challenges associated with drought, heat stress, excessive moisture, changing growing seasons, and changes in pest pressures. SERCH's outreach mission meshes with the goals of the PINEMAP project, and nicely leverages USDA's investments in both SERCH and PINEMAP for the long-term benefit of forestland owners and managers in the southeastern United States.

The details of the PINEMAP-SERCH partnership are still under development, but we plan to include the following elements:

Data, Analyses, and Tools

The PINEMAP project is producing a large quantity of data, analyses, and tools, including ecosystem measurements on hundreds of experimental forest plots; gridded soils and historical and projected climate data for the entire region; model simulations; and a host of tools and resources on the PINEMAP Decision Support System (DSS) for assessing risk and capitalizing on opportunities associated with climate change. Data resources will be hosted on the Terra-C terrestrial carbon data management system. SERCH could play an important role both in bringing these resources to stakeholders' attention and in facilitating the use of Terra-C and the PINEMAP DSS. SERCH's focus on the direct application of information and tools for adaptive land management will allow these databases to be maintained for future researchers and provide an interface to extend the utility of these data.

Measuring clonal demonstration at age four. Photo by Steve McKeand.

SERCH's outreach mission meshes with the goals of the PINEMAP project, and nicely leverages USDA's investments in both SERCH and PINEMAP for the long-term benefit of forestland owners and managers in the southeastern United States.

Outreach Products

PINEMAP's outreach products, which are targeted to both corporate and noncorporate pine forest landowners, include fact sheets, videos, archived webinars, and the tools and resources on the PINEMAP DSS. SERCH will capitalize on these resources by hosting this material on the federal and cooperator SERCH websites, providing resources through presentations and distributing resources at meetings, workshops, and seminars. SERCH may also assist Project Learning Tree with updates to the PINEMAP module for secondary science teachers.

Enhanced Coordination Among Regional and National Networks

One of the most important PINEMAP outcomes is enhanced coordination among regional and national networks of researchers, educators, and outreach professionals. For example, PINEMAP helped to coordinate collaboration on forestry and climate research among many of the major forestry research cooperatives in the region, including three tree-improvement cooperatives, two silviculture-biology cooperatives, two modeling cooperatives, and an economics and policy cooperative. Continuing these coordinated efforts will be essential for maximizing PINEMAP's benefits for corporate forestland in the region. Additionally, the linkage of these organizations cooperatives to SERCH as a high priority federal program could significantly increase the potential for successfully competing for future competitive grant funding. SERCH will provide an important framework for organizing this collaboration.

The long-term outlook and regional scope of SERCH will allow PINEMAP's data, decision support tools, outreach and educational resources, and network coordination benefits to remain accessible to the region's forest land owners and managers, helping to ensure positive outcomes for this critical resource in a changing world.

19. Three Years and Three Tiers: Education and Outreach in the PINEMAP Undergraduate Fellowship Program

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 graduate students, undergraduate students, public secondary school teachers, and public secondary school students. This integration offers the potential for each participant to be exposed to a variety of research interests, skill sets, and learning experiences. Undergraduates from across the southeastern United States and Puerto Rico are hired as wage employees of Virginia Tech, earning up to $7,000 for work in the summer and fall terms. These undergraduate fellows are paired with graduate student researchers at PINEMAP's collaborating universities (Figure 19.1). The program includes an intensive, distributed (students hosted at different sites) summer research internship followed by a distance-delivered education course in the fall. In this course, undergraduate fellows learn science communication skills, develop lessons on natural resources and climate change issues, and present those lessons to public secondary school students. In the summer and fall terms of 2012, 2013, and 2014, a total of 26 fellows delivered 233 presentations to 5,043 secondary school students (Table 19.1).

Will Kennerley, a 2012 undergraduate fellow, prepares root samples for incubation during his PINEMAP fellowship. Photo courtesy of John Seiler.

Three undergraduate cohorts have completed the fellowship since the program's initial offering in 2012. Thirty fellows have been part of the program, and twenty-six have successfully completed it to date. The majority of fellows were recruited as sophomores or juniors, and eighteen fellows are still pursuing their undergraduate degrees. Many of these students have since also participated in other research internships. Of the eight fellows who graduated, five are presently working and three are now graduate students pursuing master degrees.

The fellowship's two components offer complementary gains to students. Alumni regard the research internship as a critical learning experience that teaches content and procedural knowledge applicable to subsequent coursework and provides a foundation for obtaining and performing professional work in natural resources disciplines. Interacting with experienced researchers, professionals, and graduate students also offers undergraduates a positive, confidence-building experience. For instance, Rudy Rutemiller, a 2013 alumnus, remarked, "The summer of research itself taught me how to interact with true professionals, and to not be afraid to ask questions and really learn."

The fellowship also gives undergraduate students a deeper understanding of the personal investments in and the broader impacts of professional research. The fall distance learning course provides undergraduates with useful communication tools, including instruction in how to develop and present

Will Kennerley studying goose breeding phenology during a United States Geological Survey summer internship in Alaska in 2013. Photo courtesy of David Ward.

> "My experience in the classroom during this program boosted my confidence in my public speaking abilities, specifically in reaching out to younger students to discuss environmental issues."
>
> —KRISTEN GLOVER, 2013 ALUMNUS

educational lessons targeted toward public audiences, as well as the preparation of scientific research abstracts and posters. Additionally, undergraduate students develop confidence and experience in public speaking, as Kristen Glover, a 2013 alumnus, noted, "My experience in the classroom during this program boosted my confidence in my public speaking abilities, specifically in reaching out to younger students to discuss environmental issues."

Public school teachers also value the program and commented on its positive and engaging experiences for their classes: "Thank you so much for providing this opportunity! This has got to be as great for your students as it is for mine. I cannot imagine giving a presentation like this when I was a sophomore in college!" wrote an environmental science teacher at Twin Springs High School, Nickelsville, Virginia. Teachers see the program as providing valuable lessons for students that "fit perfectly" within the curricular units, thanks to the training the fellows received on state science standards. This observation also extends to the program's broader relevance, as a teacher at Robious Middle School in Midlothian, Virginia, wrote, "Connection to current research & global issues = more please!" This work in the public schools also had unexpected positive outcomes: one of the host teachers asked an undergraduate fellow to consider collaborating in the development of an environmental club at the school that would involve other interested local university students (e.g., undergraduates and graduate students) in giving presentations.

The fellowship program concludes in 2015 after offering the same opportunities to a fourth and final participant cohort. From graduate student mentors to undergraduate fellows to secondary school teachers and students, the PINEMAP fellowship has made impacts in the areas of research and education. This program is an important outreach component of the overall project as it continues to convey the relevance and value of southeastern forest resources and climate. The program's positive influence has been visible and has a high likelihood of persisting for years to come.

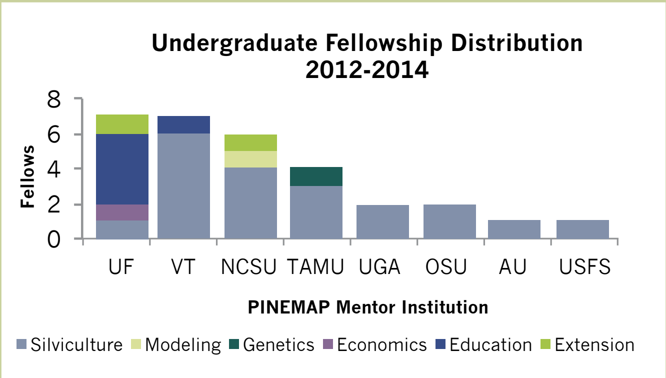

Figure 19.1. Distribution of undergraduate fellows among PINEMAP's collaborating institutions and disciplines from 2012–2014.

Outreach metric	2012	2013	2014	TOTAL
Fellowships completed	5	12	9	26
Presentations delivered	54	107	72	233
Schools visited	14	25	23	62
Teachers visited	29	40	28	97
Students reached	1060	2629	1354	5043

Table 19.1. Individuals reached through the PINEMAP Undergraduate Fellowship Program as of February 2015.

20. New Secondary Module Increases Knowledge, Builds Skills, and Nurtures Hope

Martha Monroe[1, 5] • *Annie Oxarart*[2, 5] • *Christine Jie Li*[3, 5] • *Kristen Kunkle*[4, 5] • *Tracey Ritchie*[3, 5]

[1] *Professor and Extension Specialist* • [2] *Coordinator, Environmental Education Programs* • [3] *Ph.D. Student* • [4] *M.S. Student* • [5] *School of Forest Resources and Conservation, University of Florida*

The development and implementation of a new instructional module is directly tied to PINEMAP's 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 training educators to use the module activities in classrooms, both teachers and students are learning concepts being investigated in PINEMAP.

The *Southeastern Forests and Climate Change* secondary module is designed for middle school and high school science educators and is framed around PINEMAP's research activities (Figure 20.1). This collection of 14 activities helps biology, agriculture, and environmental science teachers focus on the interactions between climate and forests and the ways we can manage forests to adapt to and mitigate future change.

Developed in partnership with Project Learning Tree® (PLT), the printed module is an interdisciplinary approach to climate change containing experiential activities, background information, step-by-step instructions, science-based perspectives, systems thinking connections, suggested modifications and enrichment adaptations, and correlations to national science standards. The online module website (http://sfrc.ufl.edu/extension/ee/climate) not only offers a downloadable version of the module but also a wealth of supplementary resources including interactive activity descriptions, slide presentations, specialized systems thinking exercises, answer keys, videos of researchers explaining their work, and quotes from pilot-test teachers that provide encouraging words of wisdom for each activity. The module website also includes tests of knowledge and web links for additional information to build teacher knowledge and skills.

Student Learning

As part of the formative evaluation to pilot test the module activities, 24 teachers from six states in the Southeast collected student data before and after completing four module activities to measure changes in student knowledge, skills, and attitudes. Dependent t-tests were used to compare student scores. We grouped the activities into four themed packages in order to explore different learning outcomes. Data suggest a significant increase in knowledge of forest management, carbon cycle, life cycle assessment and externalities, and the role of forests in mitigating climate change. Students' feelings of hopefulness about climate change significantly improved among all packages. Decision-making skills about consumption and systems thinking skills significantly increased among students who received the packages that featured these skills (Table 20.1).

Training Educators and Facilitators

Using PLT's network of state coordinators, facilitators, and educators in the Southeast U.S., a total of 94 people were trained at three regional workshops held in North Carolina, Arkansas, and Florida. These "train-the-trainer" workshops introduced the module to facilitator teams from 12 states and an additional 36 educators. Since being finalized in September 2014, more than 2,000 printed books have been shipped to PLT state coordinators, facilitators, educators, and other stakeholders, and more than 125 people have registered on the website to access the module materials. Mini-grants have been distributed to 11 states through the national PLT organization to assist with upcoming educator workshops.

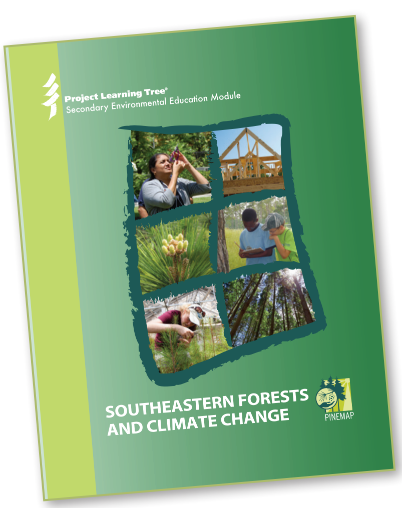

Figure 20.1. The secondary module contains 14 activities framed around the research activities associated with PINEMAP.

Workshop participants walking along a "timeline" of events related to climate science and policy in Activity 1: Stepping through Climate Science. Photo by Martha Monroe.

"It was very well done—excellent choice on activities presented, sharing of knowledge, and excellent presentation skills. Thanks for all of the helpful info and especially the take home stuff!"

—PARTICIPANT FROM NC WORKSHOP

At each workshop, pre and post surveys were distributed to participants (n=85). Paired t-tests suggested that all three workshops significantly increased participants' self-efficacy in teaching about climate change. In addition, participants indicated that it is very likely that they will use this educational resource in their future work, recommend this educational resource to their colleagues, and expand the coverage on climate change in their work. Several participants provided open-ended comments that indicated their satisfaction with the materials and the workshop.

Summary

These educational materials support several current education initiatives—STEM education (Science, Technology, Engineering, and Mathematics) and Education for Sustainability. *The Southeastern Forests and Climate Change* activities engage learners in science, math, technology, economics, and environmental justice. Module activities build student skills in critical and systems thinking, as well as enhance group communication and collaboration. It is good education! A summative evaluation with 45 high school teachers from throughout the Southeast is currently underway to assess the degree to which the module is meeting the intended outcomes for both students and educators.

The authors would like to thank additional members of our incredible team who assisted with finalizing the module and conducting workshops in Year 4: Alison Bowers, Kristy Bruja, Morgan Cheek, Kristen Glover, Shelby Krantz, Lindsey McConnell, Richard Plate, and Ahnaia White—as well as team members from previous years: Paul Decker, Stephanie Hall, Tiara Holmes, and Molly McGovern.

Figure 20.2. Teams of PLT coordinators and facilitator discuss their plans for rolling out the module to formal and informal educators in their state. Photo by Martha Monroe.

Learning Outcome	Pre-test Mean (N)	Post-test Mean (N)	T
Knowledge of forest management, carbon cycle, and the role of forests in mitigating climate change	4.61 (238)	6.33 (238)	9.05***
Knowledge of LCA and externalities	2.83 (114)	4.25 (114)	5.97***
Systems thinking skills	2.21(194)	2.40 (194)	2.15*
Hope concerning climate change	58.48 (873)	60.31 (873)	5.93***
Decision making skills	29.24 (174)	30.24 (174)	2.16*

Table 20.1. Dependent t-tests results from students' pre- and post-tests

21. Building Hope Among High School Students About Climate Change

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Hope is an important element of engaging people in problem solving. Results of this study provide insights on how to engage the public with hope and the capacity to make informed and practical decisions related to climate, forest ecosystems, and forest management. The data suggests that classroom instruction with four activities from Southeastern Forests and Climate Change significantly increased students' sense of hopefulness.

Hope is an important element of engaging people in problem solving. Effectively addressing climate change entails nurturing hope as well as increasing understanding. However, hope is a relatively new construct in the literature, and little is known about measuring and enhancing it. Using the Reasonable Person Model (RPM) (Kaplan and Kaplan 2009) (Figure 21.1), we hypothesized that students are more likely to be hopeful and work toward solutions if they (1) are able to make sense of information (*mental models*); (2) perceive there are actions they can take to make a difference (*meaningful actions*); and (3) believe that they have skills to undertake these actions (*being effective*). We chose RPM over other theories because of the vital roles that RPM plays in predicting reasonableness, hopefulness, and civil behavior.

High school students (n=872) from 18 schools in the southeastern United States completed a survey before and after participating in a set of four activities from *Southeastern Forests and Climate Change* (SFCC) between September 2013 and January 2014. Students were equally divided by gender; 65% were 11th and 12th graders and 35% were 9th and 10th graders. The survey measured

- student knowledge about climate change (*mental models*),
- beliefs regarding necessary skills for taking action (*being effective)*,
- perceptions about actions they can take (*meaningful actions)*,
- worry about climate change,
- hope about climate changes solutions, and
- demographic characteristics.

The hope items were adapted from Snyder's hope scale (1994) and a Swedish study about hope and climate change (Ojala 2012). The survey was pilot tested with 89 high school students and revised to incorporate teacher and student feedback.

We used dependent t-tests to determine if feelings of hopefulness changed after exposure to the SFCC activities. We used a path analysis and a correlation analysis among latent

variables to test the ability of RPM to predict hope. The model fit indices of the path analysis indicate that the final model explained the data well ($\chi^2_{146} = 342.99$, $p < .05$; CFI = .97, TFI = .95) (Figure 21.2).

Preliminary results suggest that engaging in the activities significantly increased students' hopefulness (t = 5.93, df = 872, $p < .001$) regarding climate change. The path analysis partially supported the RPM framework: *being effective* was part of a significant direct path and mediator in the model [.75 ($p < .001$)] but *mental models* and *meaningful actions* were not found to be significant paths to hope. The correlation analysis among latent variables suggests that both *being effective* [.76 ($p < .001$)], *meaningful actions* [.53 ($p < .001$)], and *mental models* [.44 ($p < .001$)] were significantly correlated with hope. These results indicate that students' belief that they have skills to undertake actions is correlated with hope. The perception that there are actions students can take and

Students participated in the SFCC activities to learn how consumer choices can play a role in reducing carbon emissions. Photo by Annie Oxarart.

Hope was significantly increased after exposure to activities that focus on climate and forests, which indicated that environmental education programs can nurture hope by providing opportunities to students to practice skills and broadening thinking in potential ways and solutions to solve problems.

understanding that human activities cause climate change were also correlated with hope (Table 21.1), but did not cause hope (Figure 21.2).

Based on the path analysis, worry about climate change has a moderate effect on hope. The total effect is .50 ($p < .001$). Gender, grade level, opportunities to practice forest management, and knowing people who are managing forests have small total effects on hope, which indicated that female gender, students experience level, and networks led to greater hopefulness [-.11 ($p < .05$), .09 ($p < .05$), .09 ($p < .05$), .09 ($p < .05$), respectively].

Conclusion

This study provides useful insights from the RPM for how to design effective environmental education programs to engage the public and foster hope regarding climate change. Programs can increase students' hopefulness by providing imagery of what others are doing and enable youth to practice skills they can use to address climate change. When educators lead lessons on climate change, they may wish to include more than the details of climate science. These results suggest that it may be equally important to explore a variety of potential solutions using real examples. Discussions about connections between the decisions we make today and future impacts should help foster students' hope agency thinking. A role-play about how consumers can select products with smaller environmental footprints, for example, can broaden student ideas about what is possible.

	MM	BE	MA	Hope	Worry
MM	1.00				
BE	.65	1.00			
MA	.28	.59	1.00		
Hope	.44	.76	.53	1.00	
Worry	.34	.36	.30	.53	1.00

Table 21.1. Correlations matrix among latent variables

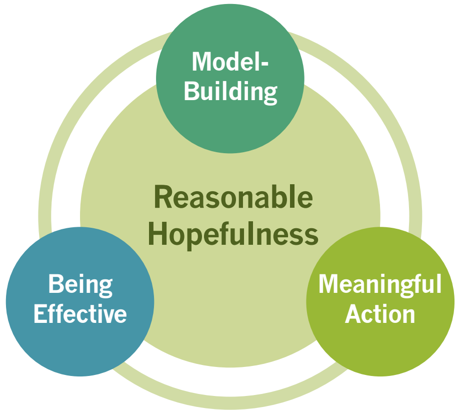


Figure 21.1. Three interrelated components of the Reasonable Person Model (adapted from Kaplan and Kaplan 2009)

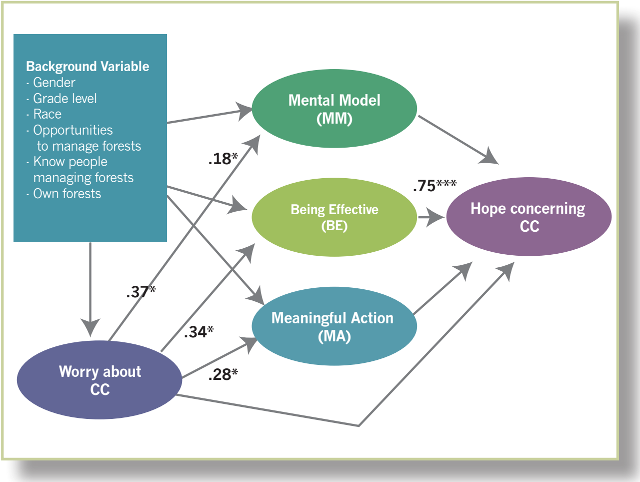


Figure 21.2. The model for path analysis of how the Reasonable Person Model predicts Hope: structural model with latent variables. Numbers indicate path coefficients and represent the effects of each exogenous variable on endogenous variables; for example, .75 from being effective to hope indicates that being effective is a significant direct path and it has .75 effect on hope.

22. Engaging Educators in Climate Change Curriculum

Kristen Kunkle[1, 3] • Martha Monroe[2, 3]

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

A big step toward building an engaged and literate public may be the widespread integration of climate change education in schools and informal education settings. We explored effective communication strategies for increasing educators' interest in and intentions to support climate change education. The theories and strategies tested in this study also assist scientists and outreach professionals communicate climate change information to forest landowners, other scientists, and policy makers.

Effective communication is an important step toward increasing the impact and practical applications of PINEMAP research. People often evaluate information about the issue based on criteria that match their worldview (Slovic 2000, Jenkins-Smith 2001), and so successful climate change communication must acknowledge diverse perspectives and informational needs among audiences. This research focuses specifically on how to reach an important group of science communicators—education professionals.

Theoretical Framework

Many theories suggest that engaging people in conversations about climate change is difficult and confirm there are diverse opinions of climate science among the public (CRED 2009, Roser-Renouf et al. 2014, McCright and Dunlap 2011). The theory of cultural cognition suggests that climate change is one of several science-based but socially controversial issues that divide the public because each side of the debate identifies with a different set of values that define their worldview. Based on this concept, people disagree about climate change because they have opposing opinions about the societal conditions that most effectively contribute to the success of the nation (Nisbet 2009). For instance, individuals with "hierarchical-individualist" values prioritize commerce and industry. Individuals holding these values tend to more easily accept evidence that warming is due to natural not anthropogenic processes, minimize the available evidence of anthropogenic climate change, and believe actions to reduce emissions would harm free enterprise. In contrast, those with "egalitarian-communitarian" values honor equality and social opportunity and may be concerned about climate change because they are concerned about the risks to vulnerable populations (Figure 22.1). According to cultural cognition theory, individuals will subconsciously credit or discredit evidence of climate change in ways that reflect their attachments to certain worldviews. As a result, information that only provides facts about climate change will not effectively increase concern or acceptance. Using communication strategies that engage cultural values offers one potential solution to this problem.

In this study, we explored how worldview values might influence educators' intentions to support climate change in the classroom and whether activating professional values could overcome these cultural biases. An online survey with quantitative and qualitative items was used to collect opinions from formal and nonformal educators in Florida, North Carolina, Pennsylvania, Arkansas, and Virginia. We assessed the influence of worldview values on educators' intentions to support climate change education and determined if educators with opposing personal beliefs shared professional opinions about the value of climate change as a component of science education. The survey included items used extensively in previous studies to measure climate change beliefs (Roser-Renouf et al. 2014), cultural worldview values (Kahan 2009), and behavioral intentions (Ajzen 1991). Items used to measure personal beliefs and professional opinions about climate change education were pilot tested with three groups of educators prior to implementation.

The study generated 251 completed responses. The majority of respondents were formal science educators (55%) who teach in public schools (51%). Respondents generally had positive attitudes about climate change education (mean = 20.83/25) and relatively high intentions to support it (mean = 29.37/35). However, these attitudes and intentions were significantly influenced by cultural worldview values ($p < .001$) (Figure 22.2). Hierarchical-individualist values were associated with more negative attitudes and lower intentions ($\beta = -.746$, $p < .001$), while egalitarian-communitarian values were associated with more positive attitudes and higher intentions ($\beta = .538$, $p < .001$).

Understanding if and how personal beliefs and values affect educators' attitudes about climate change education or intentions to support it in the classroom can be applied to improve instructional resources and professional development programs that focus on the subject.

Values and personal beliefs also influenced respondents' perceptions about the perceived value and desired content of climate change education ($p < .01$). Hierarchical-individualist educators demonstrated a greater desire to communicate that evidence of anthropogenic climate change is inconclusive and that observed changes are due to natural processes. Contrarily, those with egalitarian-communitarian values expressed greater intent to emphasize human impacts on the climate system and discuss the influence of consumer behavior on mitigating climate change.

Notwithstanding their different opinions, both groups of educators indicated a strong intent to teach only scientific facts free of influence from their personal opinions about the matter (mean = 3.86/5). However, the same cognitive processes that lead them to selectively credit or discredit empirical evidence may hinder that effort in practice. Despite disagreement over what constitutes a climate fact, educators of both value sets expressed the shared belief that climate change education offers valuable opportunities for empowering students to engage in real world issues and problem solving (mean = 12.01/15).

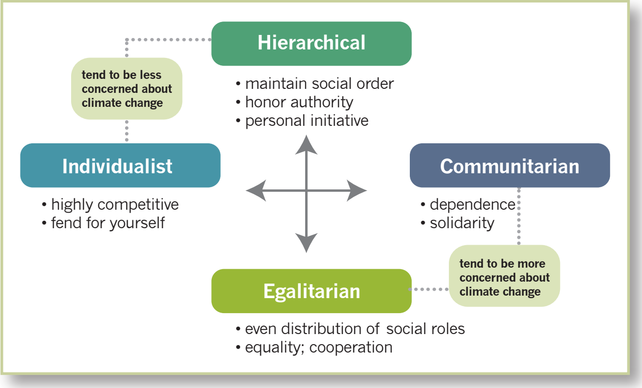


Figure 22.1. According to cultural cognition theory, the American public tends to fall into two primary worldview groups (hierarchical-individualist and egalitarian-communitarian), which tend to have different perceptions of risks associated with climate change.

Because of the potentially contentious and complex nature of teaching about climate change, building trust among educators, researchers, and curriculum developers may be a necessary first step for creating widely accepted and well-balanced resources. Though scientists may find the strategies of communicating climate change to diverse perspectives frustrating, the results of this study suggest it is important to consider the audience's cultural views as much as the facts. Reminding educators of commonly held professional values, such as the importance of providing students with opportunities to connect their learning to real world issues, should help science communicators neutralize dismissive cultural associations and allow them to capitalize on the profound confidence that the public has historically had in scientists. While this study suggests that educators, similar to the public, subconsciously rely on their cultural worldview to assess new information about climate change, experimental studies among representative educator samples are needed to confirm the plausibility of activating professional values (such the desire to teach unbiased empirical evidence) that may override worldview identity commitments.

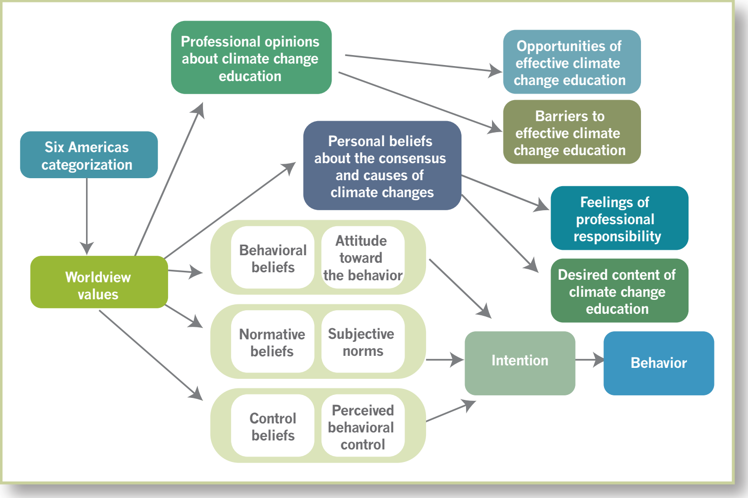


Figure 22.2. This model demonstrates the effect of cultural worldview on educators' personal beliefs and professional opinions about climate change education. It builds on the Theory of Planned Behavior model (Ajzen 2006) and illustrates the factors that influence science educators' decision to support climate change education.

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

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

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

While the Decision Support System supports almost every outcome theme, the primary goal for development of this tool is to help our target audience make informed, practical decisions related to climate, forest ecosystems, and forest management. We also aim to enhance connections among forestry professionals, climate researchers, and education/outreach professionals as we roll out the DSS at workshops and trainings.

The PINEMAP Decision Support System (DSS) is a project-wide integration vehicle designed to provide regional information on the range and likelihood of future climate conditions and their impact on forest productivity. The DSS is a collection of web-based tools and educational materials to assist foresters with land management practice decision making, including tools to assess potential changes in risk factors such as pests, disease, and climate. These web-based tools transform output data from PINEMAP research into a framework to allow professionals and clients to make informed land management decisions.

This effort has been computationally intensive and impressive: in order to create these map-based DSS products, nearly 10 terabytes of historical and projected future climate data were stored and aggregated. For example, the subset of files that we generated during the calculation of monthly frost-day maps amounts was about 900 gigabytes. This process has allowed us to refine best practices on how to evaluate software and to store, efficiently manipulate, and provide access to the data.

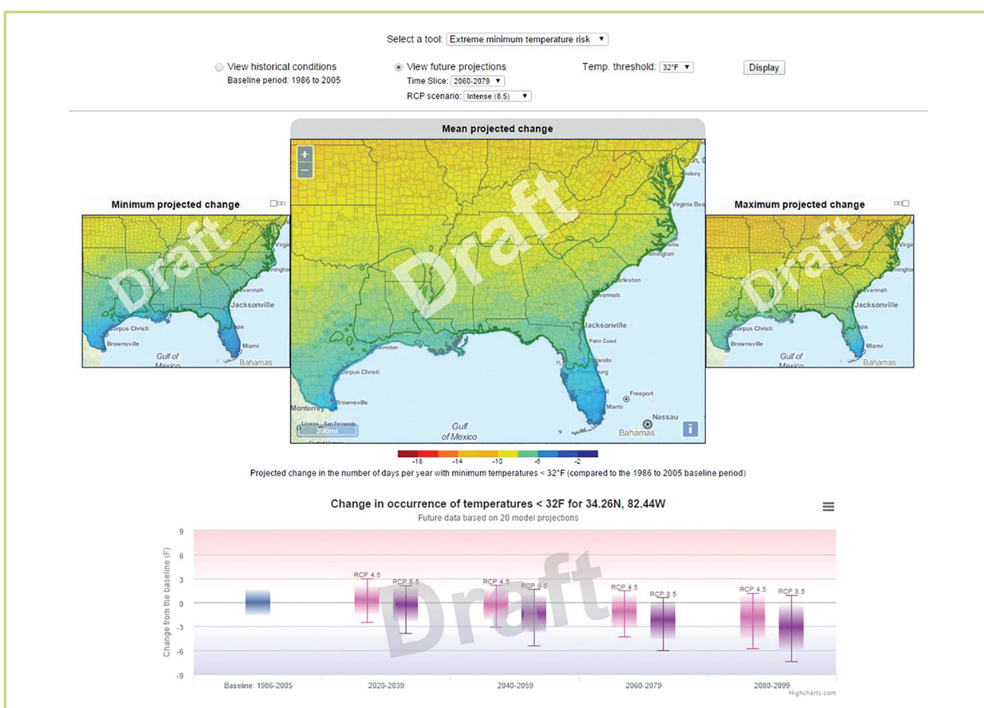


Figure 23.1. Draft version of the extreme minimum temperature risk tool, highlighting the mean (center) as well as minimum and maximum (left and right, respectively) projected change (across 20 climate models) in the number of days with minimum temperatures below 32°F. The map represents a change expected for the future period of 2060–2079 assuming that our pathway continues in the same trajectory in terms of factors such as population growth, economic development, and greenhouse gas emissions.

Photo by Larry Kohrnak.

The DSS is a collection of web-based tools and educational materials to assist foresters with land management practice decision making, including tools to assess potential changes in risk factors such as pests, disease, and climate.

Our first completed products are climate risk and opportunity tools: predictions of extreme minimum and maximum temperature risk, growing season length, and frost days; and a seedling deployment tool (featured in article 12).The final version of PINEMAP's DSS will contain decision-making tools and educational information organized by stand life stage: environment, establishment, management, and production. The environment category will contain climate-related tools, such as the extreme minimum temperature risk tool (Figure 23.1), which depicts the mean (center) as well as the minimum and maximum (left and right, respectively) projected change in number of days with minimum temperatures below 32°F. A user can change the future time period as well as the future emissions scenario to view the range of possible futures. The establishment category will contain the seedling deployment tool as well as other tools related to planting and site preparation. Tools under the management category will include guidance on thinning, pests, diseases, and nutrients. The production category will feature maps of green weight and carbon sequestration as well as market information.

To ensure that foresters can easily use and interpret these tools, DSS developers have identified a small team of beta testers who either represent our target audience or are very familiar with the needs of our core users. During the fifth year of the PINEMAP project, more DSS features will be developed and refined using an iterative process of interaction between scientists and stakeholders through beta testing, workshops, and meetings (Figure 23.2).

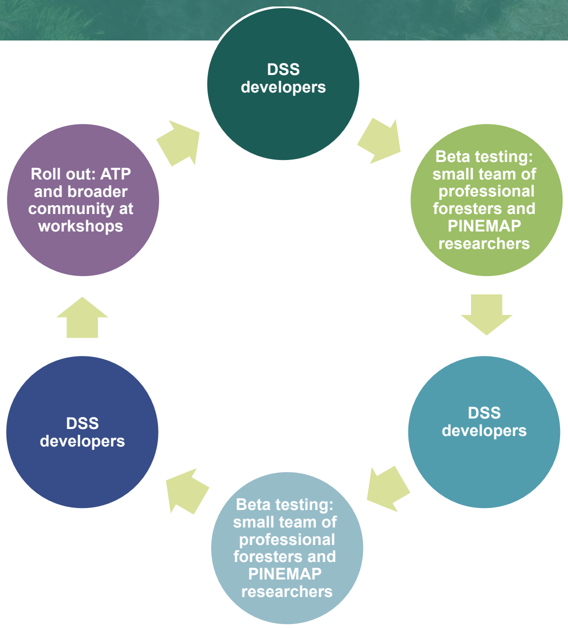


Figure 23.2. Schematic diagram depicting the iterative process of DSS development between scientists and stakeholders.

Rachel in a field site in Alaska

Shelby in her new role as a science communicator

Cody with a bear

24. Training the Next Generation of Scientists: Student Alumni Spotlight

K. Grace Crummer[1,3] • *John Kidd*[2,4]

[1] *PINEMAP Project Coordinator* • [2] *Coordinator, PINEMAP Undergraduate Fellowship Program* • [3] *School of Forest Resources and Conservation, University of Florida* • [4] *Department of Forest Resources and Environmental Conservation, Virginia Tech*

GRADUATE STUDENT ALUMNI

Rachel (Burnett) Greene graduated with a M.S. from NCSU and worked with Mark Megalos, Martha Monroe, and Damian Adams to publish data on North Carolina Extension professionals' attitudes toward climate change. As part of PINEMAP, Rachel gained insight into conveying scientific research to non-science audiences and learned the importance of program evaluation. Rachel has continued collaborating with PINEMAP to publish a spatial analysis of southern foresters' observations of climate change and a commentary paper on survey results. Rachel is now working at Mississippi State University as a wildlife research associate.

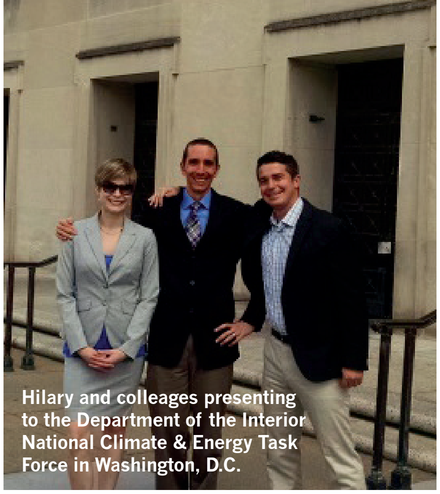
Shelby Krantz worked with Martha Monroe to explore the efficacy of video to communicate climate change science to forest landowners in North Florida. Working as a graduate student in PINEMAP gave Shelby a unique perspective on large, interdisciplinary project management, communication, and leadership. She also gained invaluable experience in communicating effectively with diverse and nontechnical audiences. Understanding the nature of interdisciplinary research and professional communication more deeply from these experiences has fostered new opportunities since PINEMAP. Shelby graduated from the University of Florida with a M.S. degree in 2014. She continues to engage researchers, Extension agents, farmers, and the public to seek solutions to climate-associated problems in her new role as the coordinator for the Southeast Climate

UNDERGRADUATE FELLOWSHIP ALUMNI

Will Kennerley
Following his freshman year at Virginia Tech, Will worked with M.S. student Brett Heim on soil carbon dynamics as an undergraduate fellow during summer 2012. The fellowship was Will's first real research experience and opened his eyes to the planning, data collection, and adaptive management required for research. Will participated in other summer internships since becoming a PINEMAP alumnus, including a summer in Alaska's North Slope working with the USGS on a goose breeding phenology project. He hopes to return to Alaska for employment after graduating with his B.S. in Wildlife Conservation from Virginia Tech in May 2015.

Scott McConaghy
Scott was an undergraduate fellow during summer 2013 working with Yang Zhang, a doctoral student from Texas A&M. Scott graduated from Kansas State in May 2014 and is now a graduate teaching assistant in the Department of Geography at Texas A&M studying south-central U.S. grassland species diversity. He credits the PINEMAP fellowship program with his choice of graduate school and for providing a foundation for teaching.

Amanda Diamond
Amanda was an upcoming sophomore at Virginia Tech during her fellowship in 2013 at the University of Georgia working with research technician Madison Akers. She will graduate from VT in May 2016 with a B.S. in Environmental Resource Management. During summer of 2014, she was accepted into a three-week immersion program as one of two American students studying forestry, environmental issues, and global leadership at Kangwon National University in South Korea.



Hilary and colleages presenting to the Department of the Interior National Climate & Energy Task Force in Washington, D.C.

Maxwell at the Florida Tier III field site

Elizabeth in the lab

Consortium (www.seclimate.org), based at the University of Florida.

■ **Cody Luedtke** started with PINEMAP in 2011 and received her M.S. degree from the University of Georgia where she worked with Bob Teskey. Cody measured soil respiration and its autotrophic and heterotrophic components at the Georgia Tier III site. As part of PINEMAP, Cody gained skills in forest ecology and ecophysiology field research and learned how to communicate and cooperate effectively with other researchers. Cody is now a part-time faculty member at the University of Georgia's Perimeter College Dunwoody Campus, teaching environmental science. She also works part-time at Tree Atlanta on an urban forestry crew and is a naturalist at the Chattahoochee Nature Center.

■ **Hilary (Cole) Morris** researched southern foresters' attitudes toward climate change and how those attitudes influenced their willingness to implement climate-smart adaptive management strategies. PINEMAP helped her develop invaluable skills in survey design and data analysis and for delivering effective presentations. She also learned the importance of understanding an audience's perceptions for a successful outreach strategy and how much people's preconceptions and experiences shape their outlook on the world. Hilary now works for the U.S. Fish and Wildlife Service as the Blueprint User Support & Communications Specialist for the South Atlantic Landscape Conservation Cooperative (LCC), a partnership dedicated to conserving priority natural and cultural resources across the Southeast in the face of future change.

■ **Maxwell Wightman** explored the relationship of water and loblolly pine in response to fertilization and throughfall reduction at the Florida Tier III site. He graduated with an M.S. from the University of Florida in 2014, where he worked with Tim Martin. In addition to the experience he gained at UF with forest productivity and ecophysiology research, Maxwell also advised a PINEMAP undergraduate fellow and participated in several activities associated with the development of the PINEMAP Project Learning Tree module. Maxwell is currently a research assistant at North Carolina State University, where he continues his work on forest carbon and water cycle responses to management practices.

■ **Elizabeth Wilson** studied the ecophysiological responses of loblolly pine to drought as part of her M.S. thesis at Texas A&M under Jason West, Jason Vogel, and J.-C. Domec. She measured leaf conductance of clones in a greenhouse experiment to improve interpretation of leaf carbon isotope ratios. Elizabeth also collaborated with Rod Will's group in assessing ecophysiological responses of trees at the Oklahoma Tier III site. Elizabeth is currently working for the city of Mannheim, Germany, in landscaping and hopes to continue to use her passion for plants in her career.

■ **Kristen Glover**

Kristen was a fellow in 2013 and worked on the Project Learning Tree module with doctoral student Christine Li at the University of Florida. Kristen graduated from UF in May 2014 and completed a M.S. in Forest Resources and Conservation with a specialization in environmental education under Martha Monroe in April 2015. Her work as a PINEMAP fellow reinforced her career trajectory in environmental education and boosted her confidence in public speaking abilities, particularly when discussing environmental issues with younger students.

■ **Paul Decker**

Paul Decker, a 2012 fellow, graduated from Virginia Tech with dual B.S. degree in Natural Resources Conservation and Environmental Resources Management in May 2014. He is now a graduate student at the University of Florida in the School of Forest Resources and Conservation, working under Matt Cohen. As a PINEMAP fellow, Paul worked at UF with M.S. student Stephanie Hall on the Project Learning Tree module. Paul's decision to pursue graduate school instead of a teaching certificate resulted at least in part from his participation in the fellowship program as he realized how much he enjoyed working in the forestry field.

■ **Brittany Baggett**

Brittany was a rising junior and PINEMAP fellow when she worked with Oklahoma State University doctoral student Adam Maggard during summer 2013. Brittany said that PINEMAP influenced her path in school, as she found out how much she enjoyed research and wanted to incorporate it into her undergraduate degree program. This experience significantly contributed to her ability to conduct field research, and she is currently participating in an invited directed study on environmental toxicology. She graduates from the University of West Florida in May 2015 with a B.S. in environmental science with a focus on policy and management. She is considering pursuing graduate school to study hydrology.

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

PINEMAP GRADUATE STUDENTS

Name	Institution	Advisor(s)	Degree	Thesis / Dissertation Title / Topic
Benjamin Ahlswede	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
Mukhtar Ahmed	University of Florida	Francisco Escobedo	M.S.	Remote Sensing and Ecosystem Service Tradeoffs
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 Souza	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	M.S.	Fertilization Effects on Water Use of 8-year-old Loblolly Pine *(Pinus taeda* L.*)* Vary with Throughfall Treatment
Rajesh Bawa	Virginia Tech	Jason Holliday	Ph.D.	Association and Evolutionary Genetics of Loblolly Pine
Robert Brown	University of Georgia	Daniel Markewitz	M.S.	Seasonal Proportions of Heterotropic Soil Respiration in Southern Loblolly Pine Plantations
Rachel Burnett	North Carolina State University	Mark Megalos	M.S.	Climate Predictors of Wildfire Size in North Carolina, 1979-2006: A Quantile Regression Approach
Zach 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
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
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
Carla Gann	University of Georgia	Daniel Markewitz	M.S.	Surface Efflux of N_20 and CH_4 within *Pinus taeda* L. Plantations in the Piedmont and Lower Coastal Plain of the Southeast United States
Ranjith Gopalakrishnan	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 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
John Hastings	North Carolina State University	Mark Megalos	M.S.	Beta Testing DSS, Climate Term Glossary, GIS Model to Identify Genetically Significant Populations.
Brett Heim	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.	Ecophysiological Responses of Loblolly Pine to Water Deficits
Omkar Joshi	Mississippi State University	Donald Grebner	Ph.D.	Woody Biomass and Bioenergy Opportunities in Mississippi
Puskar Khanal	MSU	Donald Grebner	Ph.D.	Nonindustrial Private Forest Landowners Willingness to Sequester Forest Carbon in the Southern United States
John Kidd	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
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 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' Hope and 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 (Miranda) 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.*)*

Name	Institution	Advisor(s)	Degree	Thesis / Dissertation Title / Topic
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 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
Marco Minor	Texas A&M University	Jason Vogel	M.S.	Relationship Between Decomposition and Soil CO_2 Efflux under Different Management Regimes
Percy Montecinos	Virginia Tech	Tom Fox	M.F.	Impact of Fertilization and Weed Control on Growth of Loblolly, Shortleaf, White and Virginia Pine
Hilary Morris (Cole)	North Carolina State University	Mark Megalos	M.S.	2013 Climate Change Attitudes of Southeast Forestry Professionals: Implications for Outreach
Lara Nichols	Virginia Tech	Tom Fox and Brian Strahm	M.S.	Relationships among Soil Properties and Soil CO_2 Efflux in a Loblolly Pine-Switchgrass Intercropped System
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 Tech	Thomas Fox	Ph.D.	Use of N^{15} 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.
Ed Russell	Virginia Tech	John Seiler	Ph.D.	Fertilizer and Throughfall Reduction on Water Relations and Drought Tolerance of Loblolly Pine
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 Tech	Thomas Fox	Ph.D.	Fertility Rating Assessment in the 3-PG Model
Praveen Subedi	University of Florida	Eric Jokela	Ph.D.	Inter-rotational Effects of Fertilization and Weed Control Treatments on the Productivity and Soil Nutrient Availability in Juvenile Loblolly Pine Plantations
Ram Thapa	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	University 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
Amy Werner	Virginia Tech	Tom Fox	M.S.	Nitrogen Release, Tree Uptake and Ecosystem Retention in a Mid-Rotation Loblolly Pine Plantation Following Fertilization with ^{15}N Enriched Enhanced Efficiency Fertilizers
Jared Westbrook	University of Florida	John Davis	Ph.D.	Discovering Genes and Predicting Phenotype for Improved Bark Beetle Resistance in Loblolly Pine
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
Marco Yanez	Virginia Tech	Tom Fox and John Seiler	Ph.D.	Management Intensity Effects on Growth and Physiological Responses of Loblolly Pine Varieties and Families Growing in the Virginia Piedmont and North Carolina Coastal Plain of the United States
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.	Finding Ideotypes by Examining Interactions among Silvicultural Intensity, Genotype, and Environment for Full-Sib Loblolly 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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Southeast Climate Consortium

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