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IN THIS ISSUE

PINEMAP is working to integrate key research, education, and outreach networks to create and disseminate the knowledge that enables landowners to:

- ***harness planted pine forest productivity to mitigate atmospheric CO_2;***
- ***more efficiently use nitrogen and other fertilizer inputs; and***
- ***adapt forest management approaches to increase resilience in the face of climate variability and climate change.***

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Mapping the future of southern pine management in a changing world.

Project Director's Message

Timothy A. Martin

Greetings from PINEMAP! This marks the first issue of the *PINEMAP Press*, a quarterly newsletter from the Pine Integrated Network: Education, Mitigation, and Adaptation Project. The purpose of this newsletter is to inform and educate on important research results and programs coming out of the PINEMAP project.

Loblolly pine (*Pinus taeda*).
Photo by John Seiler.

The southern pine ecosystem is one of the most widespread, economically and ecologically important forest ecosystems in North America. The PINEMAP project is working to integrate key research, education, and outreach networks to create and disseminate the knowledge that enables landowners to: harness planted pine forest productivity to mitigate atmospheric CO_2; more efficiently use nitrogen and other fertilizer inputs; and adapt forest management approaches to increase resilience in the face of climate variability and climate change.

We are currently more than halfway through the second year of the project and have made significant progress on deliverables and outputs which lay the foundation for successful completion of our mission.

Our work in PINEMAP is organized around six discipline-based "Aim Groups": Silviculture and Ecophysiology, Modeling, Genetics and Breeding, Economics and Policy, Education, and Extension. Most of the research reported in the *PINEMAP Press* originates in one or more of these Aim Groups. The work of the Aim Groups is coordinated by Integration Leaders for Mitigation, Adaptation, and Education/Extension who are tasked with making sure that the work of the disciplinary groups contributes to the overall PINEMAP objectives.

All of these efforts will come together through the assembly of a comprehensive Decision Support System (DSS) designed to support the sustainable management of southern pine. The development of this system will involve iterative cooperation among PINEMAP researchers and extension professionals and stakeholders. The process of planning and building the DSS will strengthen the integration of the team and linkages to our clientele, while the final product will provide powerful tools for decision-making in a changing and uncertain world. The PINEMAP research described in this and future newsletters will provide the underpinning for the tools and models which will form the DSS. A future article in the *PINEMAP Press* will describe the DSS development process in more detail.

I hope you enjoy the first issue of the *PINEMAP Press*. Please visit our web site (http://www.pinemap.org) for ongoing project updates.

~Tim Martin

PINEMAP Monitoring Network

One of the primary requirements of the NIFA grant which funded PINEMAP was to establish a monitoring network to develop carbon, water, and nutrient storage and flux baselines and responses to climate and management. 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) 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 2) contains 125 existing silvicultural trials that cover the full range of climate and soils in the region on which detailed C and nutrient balance will be measured. Finally, the Tier III "Throughfall Exclusion x Fertilization" network (Figure 3) was established on four sites situated at the edges of the range in which nutrients and water are manipulated.

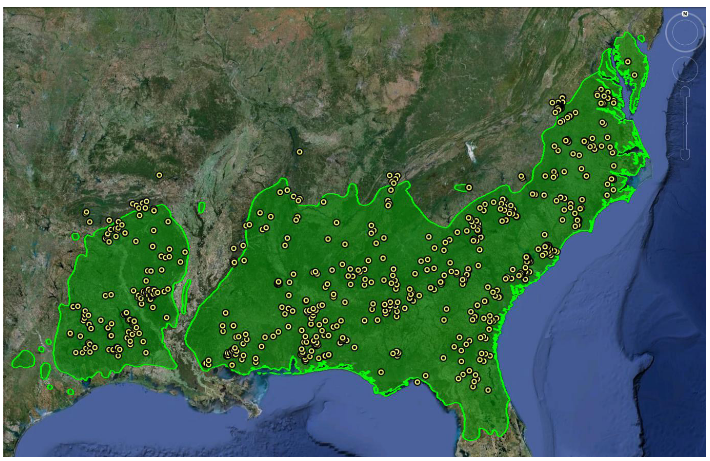

Figure 1. Tier I "Legacy" network.

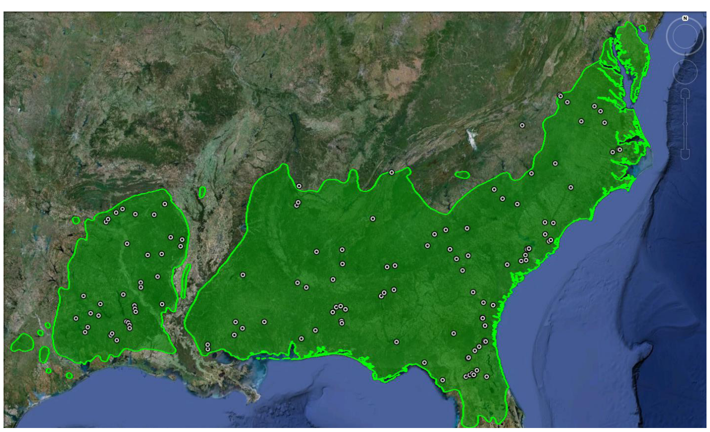

Figure 2. Tier II "Active Experiments" network.

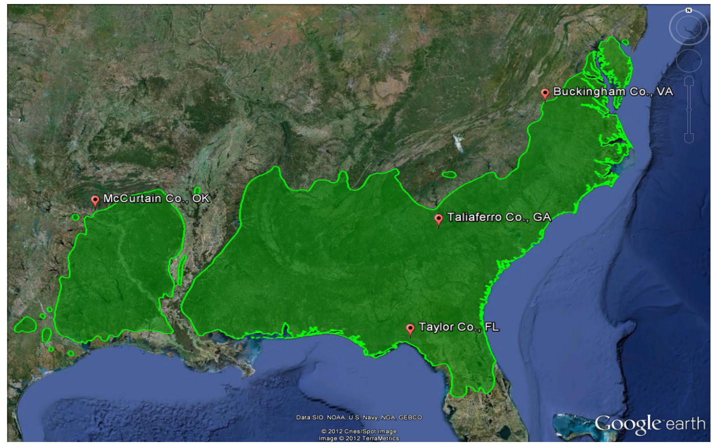

Figure 3. Tier III "Throughfall Exclusion x Fertilization" network.

Data being collected in the three-tiered monitoring network includes:

- Vegetation and soil sampling, including leaf area, standing live and dead trees, understory vegetation, coarse and fine woody detritus, forest floor and soil organic matter, roots, and chemical and physical soil properties collected at various depths.
- Growth response data combined with carbon and nitrogen pool data to determine nitrogen use efficiency.
- Various ecophysiological measurements, including sap flow measurements, transpiration and whole-tree water use, wood density measurements, and soil respiration.

Figure 4. Throughfall exclusion structures at Tier III site in Taylor County, Florida. Photo by Geoffrey Lokuta.

At the Tier III sites, four replications of a 2x2 factorial experiment are being installed with the following treatments:

- Control: no treatment
- Fertilizer: fertilizer additions to achieve "optimum" nutrition
- Throughfall exclusion: panels installed in understory to divert 30% of throughfall off of the plot (Figure 4)
- Fertilizer + throughfall exclusion: combined fertilizer and throughfall exclusion treatment.

The PINEMAP monitoring network will provide a wealth of data for model development and validation for better understanding and predicting the response of southern pine productivity to climate and soils both now and in the future.

The Canopy Underground: Convergence of the Effect of Root Hydraulic Functioning and Root Hydraulic Redistribution on Ecosystem Carbon Balance Across Divergent Loblolly Pine Forests

Jean-Christophe Domec[1,2], Jérôme Ogée[3], Asko Noormets[2], Julien Jouangy[3], Michael Gavazzi[4], Emrys Treasure[4], Ge Sun[4], Steve McNulty[4], and John S. King[1]

Under future climate scenarios predicted for parts of the loblolly pine range, tree stress resulting from drought is expected to become more pronounced. Root water uptake is governed by the rate of tree transpiration, the resistance to water flow through xylem, and the spatial distribution of absorbing roots in soil with heterogeneous areas of moisture availability. When trees are rooted through soil horizons with differing amounts of moisture, passive movement of water from moist soil horizons to drier soil horizons may occur via roots; this process is called hydraulic redistribution (HR). Deep root water uptake and HR play a major role in forest ecosystems during drought, such as prolonging survival of fine roots in dry soil. Even so, little is known about the impact of climate change, nitrogen fertilization, and soil characteristics on HR and the resulting impacts on transpiration rates, carbon partitioning, and whole ecosystem productivity.

Using data from three loblolly pine plantations with contrasting soil types in North Carolina (a piedmont site with shallow clay-loam soil, a coastal site with deep organic soil, and a site with sandy soil) and simulations with the process-based model MuSICA, this study found that HR can mitigate the effects of soil drying and has important implications for net ecosystem exchange of carbon and carbon uptake potential under current and future climate conditions, especially when nitrogen fertilization is considered. Specifically, at the coastal loblolly pine site characterized by deep organic soil, HR increased dry season tree transpiration by up to 40%, which in turn affected net carbon fluxes through major changes in gross carbon uptake or total photosynthesis. At the Piedmont site characterized by a shallow clay-loam soil, HR was low but not negligible, representing up to 10% of growing season water use. Deep-rooted trees did not necessarily translate into a large volume of HR unless soil texture allowed significant differences in water availability among horizons to develop, as was the case at the sandy site.

Under future climate conditions, characterized by an increase in air temperature, vapor pressure deficit (air dryness or evaporative power), and atmospheric CO_2, it is predicted that HR will be reduced by up to 25%, limiting the resilience of trees to drought. Our results highlight the interactive effects of nutrients and elevated CO_2 and show that the effect of nitrogen fertilization would be greater under future climate conditions. Our simulations also show that there would be a greater negative effect of drier nights on HR under future climate conditions. We concluded that the predicted reductions in HR under drier and hotter climatic conditions are expected to play an important regulatory role in land-atmosphere interactions by affecting whole ecosystem carbon and water balance. The same analysis can be used to demonstrate that models operating without including deep roots and HR will project overly sensitive responses of vegetation to drought, which may explain why many models fail to capture observed vegetation responses under droughts. We therefore suggest that root distribution should be treated dynamically in response to climate change and that HR and its interactions with rooting depth and soil texture should be implemented in soil–vegetation–atmosphere transfer models. Incorporating the effects of deep root function and HR in models will empower the refinement of models that can capture the effects of climate change in the future and will improve the application of new forest management approaches aimed at increasing forest resilience and sustainability under variable climates.

For additional information on this research, contact J.C. Domec (jdomec@ncsu.edu) or access the complete manuscript:

Domec, J.C., J. Ogée, A. Noormets, J. Jouangy, M. Gavazzi, E. Treasure, G. Sun, S.G. McNulty, and J.S. King. 2012. Interactive effects of nocturnal transpiration and climate change on the root hydraulic redistribution and carbon and water budgets of southern United States pine plantations. *Tree Physiology* 32: 707-723. doi: http://dx.doi.org/10.1093/treephys/tps018.

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Understanding Southeastern Science Teachers' Interest in Climate Change Education

Martha C. Monroe, Annie Oxarart, and Richard Plate
School of Forest Resources and Conservation, University of Florida

To achieve PINEMAP's youth and educator outcomes, a curriculum and teacher training program on climate change impacts on southern forest ecosystems is being developed in partnership with Project Learning Tree, a national environmental education program of the American Forest Foundation. Given the controversial nature of climate change and that most climate education occurs in earth science courses, we conducted an audience assessment of secondary science teachers in the Southeast to guide the development curriculum objectives, activities, and resources. In particular, we were interested in learning about the needs and preferences of life science educators, since they are most likely to use materials on climate change and southern forest ecosystems.

An online survey with 28 questions was developed, pilot tested, and distributed through 13 email lists of science coordinators and teachers in southern states. Because we did not have access to the email lists, it is impossible to know the population size or to assess non-response bias. Thus, these findings only report these respondents' opinions, likely over-report educators' interest in climate change, and cannot be generalized to secondary science educators in the Southeast.

A total of 746 surveys were received, with most respondents teaching 11th and 12th grades (61% each), 10th grade (57%), and 9th grade (48%). More than 75% of the respondents came from four states: Florida, North Carolina, Oklahoma, and Virginia. While most respondents (77%) already cover climate change, they do so in different ways depending on which courses they teach (Table 1).

Table 1. Methods for covering climate change in secondary courses.

Method for covering climate change	Courses
Informal discussions	Agriculture, Chemistry, and physical science
Planned lessons <1 week	Biology (regular and AP), earth science, integrated science, marine science
Planned lessons >1 week	Environmental science (regular and AP), ecology, environmental issues

A large majority (82%) of the respondents are interested in continuing to cover climate change in future courses. To meet their needs, our lessons should incorporate the following educational goals:

- Connect science to students' everyday lives (98%)
- Emphasize critical thinking (98%)
- Develop data analysis skills (94%)
- Emphasize choices that affect sustainability (92%)
- Emphasize systems thinking (92%)

Continued on page 5.

Photo by Annie Oxarart

Understanding Southeastern Science Teachers' Interest in Climate Change Education *continued from page 4*

Most respondents believe they have a moderate understanding (46%) or detailed understanding (24%) of climate change, with self-reported knowledge levels being significantly lower for agricultural educators than for biology and environmental science educators (Figure 1, $p<0.01$).

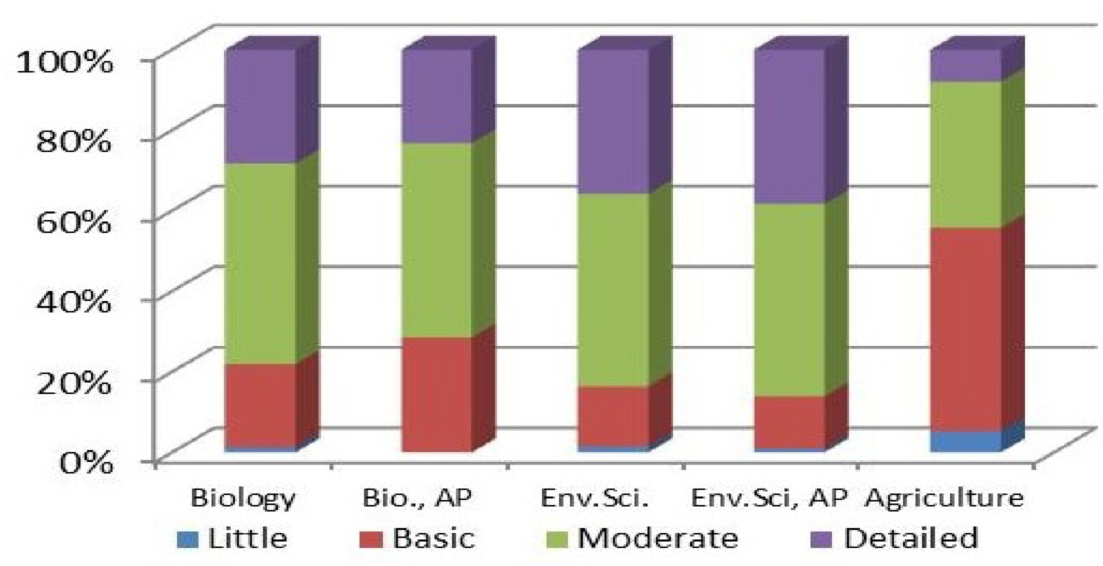
Most respondents are very comfortable (37%) or somewhat comfortable (35%) teaching about this controversial issue. Similar to knowledge levels, agriculture educators are significantly less comfortable teaching about climate change, with 80% of the biology and environmental science teachers being somewhat to very comfortable and 54% of agriculture educators making the same claim ($p<0.01$).

Regarding teaching strategies, over 85% of the respondents believe it is appropriate or very appropriate to: explain scientific uncertainty, present the rationale for how people interpret climate change differently, discuss advantages and disadvantages of climate related policies, and discuss the history of climate change science. Respondents disagreed on one teaching strategy—presenting all perspectives as valid—with 36% viewing this strategy as very inappropriate or inappropriate and 41% as appropriate or very appropriate. Many open-ended comments focused on addressing multiple perspectives about climate change through the lens of science.

These results suggest that life science and environmental science educators are interested in teaching about climate change and southern forests, especially if the lessons connect science to students' lives with critical thinking and data analysis skills. Interested agriculture educators may need additional support, which could be provided through supplemental materials and during trainings. Recognizing that climate change is a controversial issue, many of these educators see this topic as an opportunity to explore the nature of science with their students.

For additional information on this research, contact Martha Monroe (mcmonroe@ufl.edu) or view the PINEMAP Research Summary available at http://www.pinemap.org/publications/research-summaries/education/.

Figure 1. Respondents' level of knowledge about climate change.



Comparing Genotyping Technologies for Efficiency and Cost-effectiveness

Ross Whetten, Department of Forestry and Environmental Resources, North Carolina State University
Konstantin Krutovsky, Department of Ecosystem Science and Management, Texas A&M University
Jason Holliday, Department of Forest Resources and Environmental Conservation, Virginia Tech

One of the objectives of the Genetics team in the initial phase of the PINEMAP project is to compare and contrast different methods of obtaining dense datasets of molecular marker genotypes for hundreds to thousands of individual trees. These datasets will then be analyzed, together with phenotypic data and breeding records from the cooperative breeding programs, to test the hypothesis that genetic variation for resilience to climate variation exists in southern pine breeding programs. Previous results suggest that many trees in the breeding program show good adaptability across a range of site conditions, but confirming and extending those results will be important to allow pine breeding programs in the southeastern U.S. to structure their efforts to mitigate the risk that climate change will have dramatic impacts on pine plantation productivity.

Two general methods for detecting genetic variation are being compared, and some alternative strategies are being explored for one of the methods. One method, hybrid-capture sequencing, uses synthetic "bait" sequences to capture fragments of genomic DNA that correspond to genes of interest for sequencing. This approach requires a significant investment to synthesize the bait molecules, and therefore has a higher cost per individual sample analyzed, but is expected to yield more information about genetic variation in expressed genes. The other method, restriction-enzyme-based, utilizes the tendency of expressed genes to have lower levels of DNA methylation than repetitive elements or non-expressed DNA sequences. This tendency can be used to enrich for sequences in or near expressed genes, without requiring custom synthesis of gene-specific sequences. This method has a much lower cost per individual at present, but may yield information that is less narrowly focused on the coding sequences of expressed genes. Pilot experiments have been conducted for both methods; hybrid-capture at Texas A&M University (under the supervision of Kostya Krutovsky) and restriction-enzyme-based methods at North Carolina State University (Ross Whetten) and Virginia Tech (Jason Holliday).

One key question for application of these genotyping technologies will be whether a single technology is suited for all the experiments envisioned as part of the PINEMAP genetics component, or if different technologies will be better for different experiments. The cost difference between the hybrid-capture and the restriction-enzyme-based methods is significant at this point, although further optimization of the methods used may reduce that difference in the next year. A second key question is how best to utilize the reference genome sequence for loblolly pine in future analyses. Preliminary experiments have tested the utility of comparing the restriction-enzyme-based sequences to the draft (version 0.6) assembly with some success, and as more refined versions of the reference genome sequence are released, additional value will be gained from those comparisons.

In summary, preliminary results comparing genotyping technologies show that cost-effective high-throughput genotyping of pine breeding populations is feasible at a cost of about $30 per individual tree for the restriction-enzyme-based methods. Hybrid-capture sequencing may provide more information about coding sequences of expressed genes, which could be an important asset for detecting genetic variation that underlies phenotypic variation in adaptive traits in loblolly pine. The PINEMAP project includes several different genetics experiments based on different populations, and both the restriction-enzyme-based and hybrid-capture sequencing methods are likely to find application in achieving the project objectives.

For additional information on PINEMAP genotyping research, contact Ross Whetten (ross_whetten@ncsu.edu).

Photo by Gregory Powell

Predicting Species Richness in Forest Inventories: Implications for Assessing Ecosystem Service Trade-offs

Nilesh Timilsina, Wendell Cropper, Jr., Francisco Escobedo, and Joanna Tucker
School of Forest Resources and Conservation, University of Florida

When land managers assess and implement forest management for uses in addition to timber production, it is important to analyze potential trade-offs and/or synergies among different uses, including timber production, carbon sequestration, and biodiversity. It is also important to understand the role of land management in determining ecosystem structure and the resulting impacts on these functions and services.

Comprehensive biodiversity conservation is an important objective of multiple use forest management and requires an understanding of the makeup of the entire forest plant community, including understory shrubs and herbaceous vegetation. Most national forest inventory data are rich in tree-level data, but the quality and quantity of data on understory shrub and herbaceous components are limited. To fill this gap, we selected data from the literature and developed a model that combines stand history, number and type of past disturbances, and applied forest management to predict herbaceous richness. We used regression trees, models that predict the value of a target variable based on several input variables, to develop our model with an emphasis on USDA Forest Inventory and Analysis (FIA) data for coastal plain pine flatwoods of the southeastern United States. This approach could be generalized for other inventory data as well.

Our model explained 57% of the variation in herbaceous richness. Validation of the model with an independent dataset showed that the stand-level model predicted 1 species more than what was observed. Results indicated that stand age, forest type, time since fire, and time since herbicide and fertilizer application—all important management activities—influenced herbaceous richness in coastal plain pine flatwoods. Results also showed that separate processes acted on older and younger stands to influence herbaceous richness. Specifically, in younger stands, forest type and time since herbicide and fertilizer application influenced richness to a degree, however, in older stands, forest type and time since fire played a more significant role in influencing herbaceous richness.

This model provides a cost effective method for analyzing trade-offs/synergies between different ecosystem services by predicting herbaceous richness using USDA FIA data. This research will contribute to the PINEMAP goal of sustainable forest management under changing climate by providing information for the analyses of trade-offs/synergies between carbon sequestration and other ecosystems services due to change in forest management.

For more information on this research, contact Nilesh Timilsina (nilesht@ufl.edu).

Complete results will be presented in the following manuscript:

Timilsina N., W. Cropper, Jr., F. Escobedo, and J. Tucker. 2012. Predicting understory species richness and available forest inventories using regression trees. *Journal of Forestry*, in review.

Photo by Larry Korhnak

PINEMAP Education Updates

PLT Secondary Module

Project Learning Tree® (PLT) partnered with PINEMAP to develop a new secondary module on climate change impacts on southern forest ecosystems, forest impacts on climate, and ways people can affect these relationships. The module will include approximately 12 engaging activities, with each activity including concepts or research related to PINEMAP.

The module is being developed for use in life science, environmental science, and agriculture courses in grades 9-12, with potential use in middle school or community college courses. The module is currently in development and an Education Advisory Committee is providing critical feedback and guidance to ensure creation of high-quality materials that are both relevant and useful. We expect to begin regional pilot testing of the module in fall 2013.

For questions or more information, go to http://www.pinemap.org/education/secondary or contact Martha Monroe, mcmonroe@ufl.edu.

Photo by Annie Oxarart

Undergraduate Internship Program

The PINEMAP Internship Program is currently in the last phase of its first year. In November we will open up applications for the second year to recruit 12 undergraduate research fellows. These students, potentially from any post-secondary institution, will work for 12 weeks during summer 2013 with paired graduate students and staff at PINEMAP universities. After completing the summer research internship, undergraduates will return to their own school and continue the fellowship by enrolling in a distance education course on effectively communicating research. This course is part of the education/outreach mission of PINEMAP, and it will have undergraduate fellows present their work to local secondary schools near their home.

Look for announcements and the application this November on our web pages at: http://www.pinemap.org/education/undergraduate.

Photo by Jessica Ireland

Distance Graduate Course

A climate and forests distance graduate course was developed and launched in the spring of 2012, with 22 students from 8 universities across the Southeast participating. A second offering of the course will take place in spring 2013.

The course goals are to: engage graduate students in exploring climate change mitigation and adaptation issues in southern pine forests and build capacity for integration among research disciplines and between research and education/Extension.

For more information on the course, go to http://www.pinemap.org/education/graduate.

Webinar Series: Natural Resources Opportunities for Landowners

Leslie Boby and Bill Hubbard
Southern Regional Extension Forestry

PINEMAP's goals include maintaining and increasing southeastern forest carbon storage by increasing the resilience of planted loblolly pine. At their most basic level, these goals can be translated into: 1. keeping the current amount of planted pine in the southeast, 2. planting more pine plantations, and 3. promoting sound forest management practices to help planted forests survive and thrive under changing climatic conditions.

Because private landowners own more than 70% of southeastern forestlands, it is critical to provide these landowners with the knowledge and resources needed to sustainably manage forests in the face of changing climate. Private landowners' holdings vary from ten acres to thousands of acres and their relationships to the land vary just as much. Some landowners have inherited family land and may have some personal knowledge of the area and memories of their parents or grandparents and what they did with the land. Conversely, other landowners might have bought land as an investment or for recreation and hunting and they may be completely new to land ownership. Others may have 'woodlots' but may not know that they could be managing them more effectively, both for better timber returns and to meet non-timber goals.

A regional team of Extension Foresters including PINEMAP Extension team members, Dr. Ben Jackson (University of Georgia), and Drs. Greg Yarrow and Tamara Cushing (Clemson University), partnered to design the Natural Resources Opportunities for Landowners course, a 5-week online course. This course is a primer on natural resources and land management options with a goal of providing non-industrial private forest landowners an awareness of options available for managing their lands. The first session provides basics of natural resource conservation and management, including definitions and examples, so that participants gain a "working vocabulary."

The second session, "Natural Resource Enterprise Considerations," will give an overview of ways to make money off land in addition to timber production. Subsequent seminars address the basics of tree farming and wildlife management. The final seminar focuses on ways to increase recreational opportunities and land stewardship. Within these sessions, we will also include information about how climate change will affect land management and the latest information on how to adapt management strategies to mitigate climate change effects. This course is also a lead-in to three separate courses that will be taught in the spring of 2013: "Master Tree Farmer," "Master Wildlifer," and "Natural Resource Enterprises."

The course began October 11, 2012 and runs every Thursday through November 8, 2012. Course sessions will be recorded for future viewing, and an additional offering of the course will be available in spring 2013.

For more information, please go to: http://www.clemson.edu/extension/natural_resources/continuing_education/nrol/.

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

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