



PINEMAP

Pine Integrated Network: Education, Mitigation, and Adaptation Project

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

Year 1 Annual Report

February 29, 2012



United States
Department of
Agriculture

National Institute
of Food and
Agriculture

Cover photos courtesy of John Seiler, Tim Martin, Tom Fox, and Lindsey McConnell; remote sensing map from Google Earth; range map from USDA Forest Service.



PINEMAP

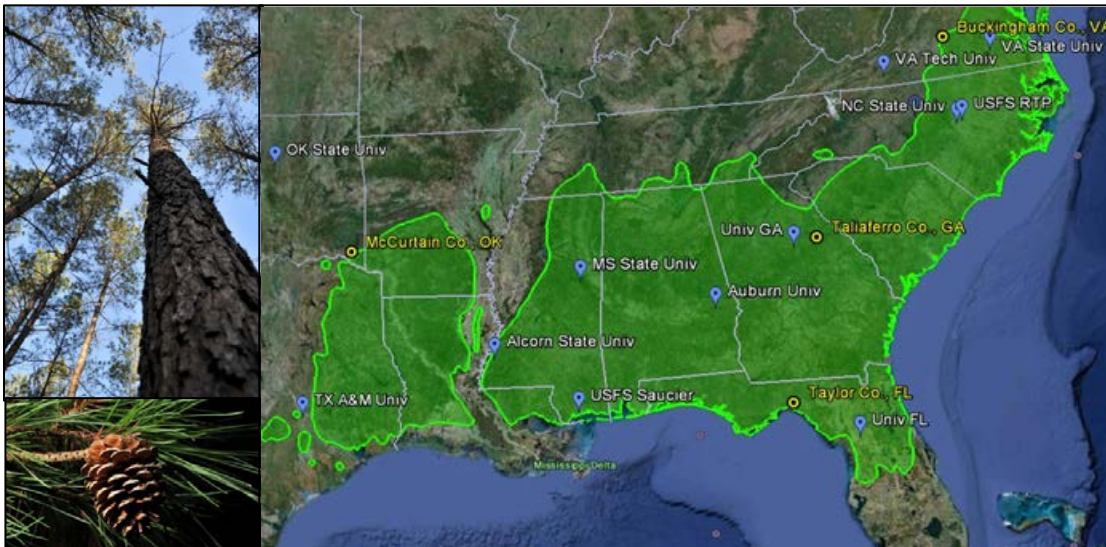
Mapping the future of southern pine management in a changing world

Year 1 Annual Report Executive Summary

Pine Integrated Network: Education, Mitigation, and Adaptation Project (PINEMAP) is one of three Coordinated Agricultural Projects awarded in 2011 by the USDA National Institute of Food and Agriculture. PINEMAP focuses on the 20 million 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 U.S. citizens. Southeastern forests contain 1/3 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 of the region.

PINEMAP's overall goal is to create, synthesize, and disseminate knowledge that enables southern pine landowners to

- manage forests to increase carbon sequestration by 15% by 2030;
- increase the efficiency of nitrogen and other fertilizer inputs by 10% by 2030;
- adapt forest management approaches and plant improved tree varieties to increase forest resilience and sustainability under variable climates.



Loblolly pine (*Pinus taeda*)
Photos courtesy of John Seiler

The shaded area depicts the native range of loblolly pine; tags show collaborating institutions and circles show locations of manipulative field experiments to examine the interaction of soil nutrient and water availability. Remote sensing image from Google Earth; range map from USDA Forest Service.

An unprecedented team of over 50 scientists, educators, and Extension professionals from eleven southeastern land grant universities and the USDA Forest Service work together in six disciplinary groups to achieve these outcomes by integrating research, extension, and education activities.

- The ecosystem ecology / silviculture team is implementing a regionwide monitoring network to evaluate the effects of climate, soils, and management approaches on carbon sequestration rates of planted pine. The team installed four large manipulative field experiments along the edges of the native range of loblolly pine to subject the species to environmental conditions that may occur in the future. The team also selected sites from existing research trials to provide regional baseline data on carbon, water, and nutrient storage rates as well as responses to climate and management. The TerraC terrestrial carbon information system was developed to archive and serve spatially-explicit PINEMAP datasets.

- The modeling team is applying a multi-scaled modeling program incorporating monitoring network data with spatially-explicit historical and predicted future climate data to assess alternative forest management approaches and the impacts on carbon sequestration and resilience to disturbance. The team established a standardized set of models and climate datasets and conducted initial regional-scale assessments to guide future analyses.
- The genetics team is developing guidelines to help growers understand where to plant specific southern pine seed sources given future climate scenarios and identify genes controlling traits such as growth, nitrogen responsiveness, cold hardiness, water usage, and resistance to southern pine beetle and fungal diseases. Analyses of weather and climate response of over 500 loblolly pine families in studies across the region are underway. The team has initiated a comprehensive assessment of current genotyping techniques.
- The economics and policy team is analyzing life-cycle carbon balance of regional forest management systems and conducting multi-scale analyses of market and non-market forest benefits and services under future management and climatic conditions. In year 1, the team completed key regional analyses of pine productivity responses to future climate scenarios and assessed optimal harvesting regimes for varying hurricane risk.
- The education team is creating resources and programs to educate high school students and teachers as well as university students about the relevance of forests, forest management, and climate impacts. The PINEMAP education program also engages university students in collaborative, interdisciplinary research aimed at solving complex societal problems. In year 1, the team launched a regionwide undergraduate internship program; coordinated a distance graduate education course to prepare students to address climate change mitigation and adaptation issues in southern pine forests; and partnered with the national Project Learning Tree education network to develop a module for high school students on southern pine forests and climate change.
- The extension team is disseminating emerging knowledge, practices, and PINEMAP decision support tools to enable corporate and non-corporate landowners to increase forest carbon sequestration, nitrogen fertilizer efficiency, and forest resilience under changing climate. The team has implemented a comprehensive audience assessment program, including a survey assessing climate change perceptions of over 4,000 Extension professionals across the region. Integrating efforts with state climatologists and Extension foresters has been a key focus.

PINEMAP is coordinated by the University of Florida; project collaborators include the following:

- eight regional university-corporate-governmental research cooperatives whose members manage 55% of the privately owned planted southern pine forestland and produce 95% of the pine seedlings planted each year;
- over 50 scientists at 11 land grant universities, including three 1890s institutions;
- the USDA Forest Service;
- the Southern Regional Extension Forester and associated Extension professionals;
- secondary school educators and the national Project Learning Tree network;
- state climate offices and the multi-state Southeast Climate Consortium.

TABLE OF CONTENTS

Introduction.....	1
Aim 1 (Ecosystem Ecology / Silviculture)	
Executive Summary.....	5
Outcomes/Impacts	6
Outputs.....	6
Milestones and Deliverables.....	9
Broad Impacts.....	14
Training.....	14
Collaborations and “Integrated” Knowledge Developed.....	15
Plan-of-Work for Year 2.....	16
Aim 2 (Modeling)	
Executive Summary.....	21
Outcomes/Impacts	22
Outputs.....	22
Milestones and Deliverables.....	24
Broad Impacts.....	29
Training.....	29
Collaborations and “Integrated” Knowledge Developed.....	30
Plan-of-Work for Year 2.....	30
Aim 3 (Genetics and Breeding)	
Executive Summary.....	33
Outcomes/Impacts	34
Outputs.....	34
Milestones and Deliverables.....	35
Broad Impacts.....	38
Training.....	38
Collaborations and “Integrated” Knowledge Developed.....	39
Plan-of-Work for Year 2.....	39
Aim 4 (Economics and Policy)	
Executive Summary.....	43
Outcomes/Impacts	44

Outputs.....	44
Milestones and Deliverables.....	47
Broad Impacts.....	48
Training.....	49
Collaborations and “Integrated” Knowledge Developed.....	50
Plan-of-Work for Year 2.....	50
Aim 5 (Education)	
Executive Summary.....	53
Outcomes/Impacts.....	54
Outputs.....	54
Milestones and Deliverables.....	55
Broad Impacts.....	63
Training.....	63
Collaborations and “Integrated” Knowledge Developed.....	65
Plan-of-Work for Year 2.....	65
Aim 6 (Extension)	
Executive Summary.....	69
Outcomes/Impacts.....	70
Outputs.....	70
Milestones and Deliverables.....	73
Broad Impacts.....	78
Training.....	79
Collaborations and “Integrated” Knowledge Developed.....	80
Plan-of-Work for Year 2.....	81
Administrative Report.....	87
Concluding Statement.....	101
References.....	103
Appendices	
1: PINEMAP Distance Graduate Course Syllabus	
2: PLT/PINEMAP Secondary Module Logic Model	
3: Draft PLT/PINEMAP Secondary Module Scope and Sequence	
4: PLT/PINEMAP Secondary Module Education Advisory Committee Members	
5: PINEMAP Operating Principles and Guidelines	



Year 1 Annual Report Introduction

The overall goal of the Pine Integrated Network: Education, Mitigation, and Adaptation Project (PINEMAP) is to create, synthesize, and disseminate knowledge that enables southern pine landowners to manage forests to increase carbon sequestration by 15% by 2030; increase the efficiency of nitrogen and other fertilizer inputs by 10% by 2030; and adapt forest management approaches and plant improved tree varieties to increase forest resilience and sustainability in response to variable climates. PINEMAP focuses on the 20 million acres of planted pine forests managed by private landowners in the Atlantic and Gulf coastal states from Virginia to Texas, plus Arkansas and Oklahoma. Our primary concentration is the dominant commercial species in the region, loblolly pine (*Pinus taeda*) (Schultz 1997). Our team integrates disciplinary expertise from all eight major regional university-corporate-governmental research cooperatives, as well as more than 50 years of accumulated data, germplasm, and infrastructure, with Extension and education specialists from major southeastern research universities and minority-serving institutions, the USDA Forest Service, secondary school teachers using forest curriculum, and climate scientists associated with the multi-state Southeast Climate Consortium and state climate offices. Integrating these existing networks builds interdisciplinary research, education, and outreach capacity focused on mitigating climate change impacts on southern pine forests through an understanding of adaptation and management potential in the region. This report summarizes activities and accomplishments related to the milestones and deliverables from the first year of the PINEMAP project (March 1, 2011-February 29, 2012).

Forests occupy 60% of the land area in the southeastern U.S., with a large fraction dominated by pine forests. Because of their large area and high productivity, southern forests are a significant portion of the U.S. carbon budget, containing 36% of the sequestered forest carbon (C) in the conterminous United States (Turner *et al.* 1995). Forests in the region annually sequester C equivalent to 13% of regional greenhouse gas emissions and have the potential to sequester even more through reforestation, afforestation, and improved forest management (Johnsen *et al.* 2001, Han *et al.* 2007). Southern pine forests are also central to the economic vitality of the nation: the forest products industry is responsible for 5.5% of the jobs and 7.5% of total industrial output in the region (Wear & Greis 2002). Nationally, this industry employs more people than the automotive, chemical, or plastics industries combined. In the southeastern U.S., approximately 85% of all forestlands are privately owned, and planted pine forests are projected to become increasingly important components of southern forests in the future.

Over the past 50 years, the productivity of planted pine has tripled (Fox *et al.* 2007, Jokela *et al.* 2010), enabling southern forests to produce about 16% of global industrial wood, more than any other country (Prestemon & Abt 2002). These productivity gains

are attributable to widespread implementation of improved genetics, seedling culture, and nutrient and competition management technology developed and deployed by university-corporate-governmental research cooperatives involving forest industry, federal and state forestry agencies, forest management consulting firms, and state Extension services (Stanturf *et al.* 2003, Fox *et al.* 2007) (Table Ia). The impact of cooperative research on forest management in the Southeast U.S. cannot be overstated, as corporate members of the research cooperatives alone manage more than 20 million acres of planted forests in the region (about 55% of the total privately owned planted pine forestland) and produce 95% of the pine seedlings planted in the region each year (McKeand *et al.* 2003). Because research cooperatives include scientists and land managers from member organizations, research innovations from the cooperatives are translated seamlessly and rapidly into practice on lands managed for industrial wood production, as well as to non-corporate private forest landowners, by forestry consulting companies and state forestry agency staff. Because these cooperatives are based at land-grant universities, the research findings can be readily conveyed to private forest landowners and Extension agents.

Climate change will likely have important impacts on southern planted pine systems. A 2009 summary from the U.S. Global Change Research Program (Karl *et al.* 2009) indicates that the Southeast U.S. will experience continued increases in the rate of warming through the end of the century with a rise in average temperature of 2.5 to 5° C within 80 years, a magnitude of temperature increase that is predicted to decrease loblolly pine productivity by at least 10% (Schmidtling 1994). Precipitation predictions for the region are less certain but generally indicate that summertime precipitation will decline by 10% to 30% (Christensen *et al.* 2007, Karl *et al.* 2009). Rising sea surface temperatures are predicted to increase hurricane intensity, leading to greater windstorm damage, which has great potential to impact regional C balance (Chambers *et al.* 2007). Finally, changing temperatures are likely to alter population dynamics of insects and may therefore change the risk of outbreaks of important pests such as the southern pine beetle (Ungerer *et al.* 1999, Ayres & Lombardero 2000). All of these changes represent potential risks to an ecologically and economically critical resource.

PINEMAP is designed to develop and evaluate mitigation and adaptation activities which will reduce potential risks associated with changes in climate variability and educate landowners to ensure the continued sustainability of southern pine management in a changing world. The project is also designed to promote scientist and citizen understanding of future risks to pine forests and opportunities to address them.

PINEMAP is focused on delivering real-world outcomes including:

- improved economic return and reduction of loss from catastrophic events;
- increased forest carbon sequestration and fertilizer efficiency;
- enhanced capacity for regional, multi-disciplinary collaboration among climate and forest scientists, Extension and education professionals, and graduate students;
- increased capacity for non-corporate forest landowner participation in C markets;

- increased deployment of adaptive strategies to ensure the sustainability of planted southern pines in advance of climatic changes;
- climate-smart audiences making informed decisions related to the southern planted pine system and consumption of forest products;
- diverse stakeholders, including landowners, secondary school teachers, and students, with a clearer understanding of adaptive forest management strategies and their role in climate change mitigation.

Because these expected outcomes are closely intertwined with regional economic, ecological, and cultural factors, the PINEMAP project has adopted multi-disciplinary approaches which integrate biophysical research with social science research to engage diverse stakeholders in understanding and influencing society's relationships with forests and forest management. Due to the complexity of issues relevant to forest management, it is also critical that we prepare the next generation of scientists, educators, and Extension professionals to plan and implement problem-solving, output-oriented programs which are seamlessly integrated across disciplines.

With this perspective, six integrated Aim groups were formed to conduct rigorous disciplinary work within the project's context of multi-disciplinary collaboration and engagement with a focus on achieving project outputs and outcomes.

Aim 1 (Ecosystem Ecology / Silviculture): Establish a regionwide, three-tiered monitoring network to evaluate the effects of climate, soils, and management approaches on planted pine carbon sequestration rates and develop standardized methods to quantify carbon, water, and nutrient storage and flux baselines, as well as responses to climate and management.

Aim 2 (Modeling): Apply a multi-scaled modeling program incorporating data from the monitoring network with spatially-explicit historical and predicted future climate data to assess alternative forest management systems and their impacts on carbon sequestration and resilience to disturbance.

Aim 3 (Genetics and Breeding): Analyze genetics of breeding and natural populations to discover alleles in genes controlling important adaptation and mitigation traits such as growth, nitrogen responsiveness, cold hardiness, water usage, and resistance to southern pine beetle and fungal diseases and deliver deployment guidelines for genotypes suited for varied climatic conditions to maximize resiliency and reduce adverse impacts of climate change on productivity.

Aim 4 (Economics and Policy): Conduct comprehensive life cycle analyses of regional forest management systems and multi-scale policy and economic analysis of market and non-market forest benefits and services to provide the framework necessary to guide land manager decision-making in future management and climatic conditions.

Aim 5 (Education): Create and evaluate resources and training programs to educate high school students and teachers and undergraduate and graduate students about the relevance of forests, forest management, and climate impacts. The education program also provides a process for engaging university students in collaborative, interdisciplinary research aimed at solving complex societal problems.

Aim 6 (Extension): Develop and disseminate emerging knowledge, practices, and decision support tools to enable corporate and non-corporate landowners to increase forest carbon sequestration, nitrogen fertilizer efficiency, and forest resilience to changing climate.

Table Ia. University-corporate-governmental research cooperatives collaborating with the PINEMAP project.

Research Cooperative	Host University (year founded)	# Members
Cooperative Forest Genetics Research Program http://www.sfrc.ufl.edu/CFGGRP/	University of Florida (1953)	8
Cooperative Tree Improvement Program http://www.treeimprovement.org/	North Carolina State University (1955)	25
Forest Biology Research Cooperative http://www.sfrc.ufl.edu/fbrc/	University of Florida (1996)	8
Forest Modeling Research Cooperative http://frec.vt.edu/forestmodelingresearchcooperative/	Virginia Tech (1979)	21
Forest Productivity Cooperative http://www.forestnutrition.org/	Virginia Tech/North Carolina State University/Universidad de Concepción (1969)	52
Plantation Management Research Cooperative http://warnell.forestry.uga.edu/pmrcpub/	University of Georgia (1975)	17
Southern Forest Resource Assessment Consortium http://cnr.ncsu.edu/fer/research/sofac/whoweare.html	North Carolina State University (1994)	22
Western Gulf Forest Tree Improvement Program http://www.ars-grin.gov/misc/wgftip/about.html	Texas A&M University/ Texas Forest Service (1969)	13



Year 1 Annual Report
Aim 1 (Ecosystem Ecology / Silviculture)

EXECUTIVE SUMMARY

The overall objective of the ecosystem ecology / silviculture group (Aim 1) is to establish a regionwide, three-tiered monitoring network to evaluate the effects of climate, soils, and management approaches on planted pine carbon sequestration rates and to develop standardized methods to quantify carbon, water, and nutrient storage and flux baselines, as well as responses to climate and management.

During year 1, Tier I, Tier II, and Tier III sites were established and monitoring began on these sites. Specific year 1 accomplishments include the following:

- Tier I study sites were identified and archival data for these sites was obtained from university-corporate-governmental research cooperatives.
- Tier II study sites were identified. Data from Tier II sites will be submitted to PINEMAP after Tier I data are assimilated.
- The first phase of the N fertilizer uptake study using ^{15}N labeled fertilizer was completed on a subset of the Tier II sites.
- A study was initiated evaluating N_2O emissions following N fertilization.
- Tier III study sites were established at four locations which together span the full temperature and precipitation range of loblolly pine in the southern United States. The rain throughfall exclusion structures were designed and tested and are currently under construction at each of the sites.
- Standardized methods for soils, carbon, and ecophysiology measurements were developed and are currently being reviewed to ensure that minimum data required by the other PINEMAP Aim groups will be collected.

In year 2, the monitoring network will be installed and baseline measurements will begin. Aim 1 will complete the transfer of research cooperative data from Tier II sites to PINEMAP; finalize standard methodology for carbon and ecophysiology measurements; complete installation of rain throughfall exclusion structures at Tier III sites; identify a subset of Tier II sites where additional ecophysiology measures on carbon efflux, leaf area, and water use will be measured; and begin baseline measurements at Tier III and Tier II sites.

OUTCOMES/IMPACTS

Aim 1 activities contribute to project-level outcomes and impacts primarily through the establishment and measurement of carbon and nutrient pools and fluxes on a three-tiered monitoring network. The data generated from this network will quantify the climatic, soils, and management impacts on carbon sequestration in planted pine ecosystems and provide data necessary for the Aim 2 team to build and verify stand- to regional-level models that simulate pine forest dynamics under varying climate. These data and simulations will form the core of the PINEMAP Decision Support System which will provide landowners and managers the tools necessary to make decisions about managing planted pine for increased carbon sequestration, enhanced fertilizer efficiency, and resilience to altered disturbance regimes.

OUTPUTS

During year 1, Aim 1 contributed a number of outputs that advanced the overall project goals and objectives.

- The first set of Tier I sites was selected as part of the regionwide monitoring network. Archival data from university-corporate-governmental research cooperatives was submitted to TerraC, the PINEMAP database.
- Potential sites for Tier II were identified among the active research sites currently managed by the university-corporate-governmental research cooperatives. Archived data are being organized and will be submitted to PINEMAP as soon as the Tier I data are assimilated. Additional data to quantify carbon sequestration will be collected at the Tier II sites.
- The first phase of the N fertilizer uptake study was completed utilizing a subset of the Tier II sites. At seven sites, N uptake following forest fertilization was measured using ¹⁵N labeled urea and three formulations of enhanced efficiency N fertilizers.
- The study of N₂O emissions following N fertilization was initiated. Sample collection systems were designed and installed in the field. Gas chromatography methodologies were developed to analyze N₂O in samples.
- The four Tier III sites were identified. The rain throughfall exclusion structures were designed and are under construction at each of the sites. Prescriptions for the fertilization treatment were identified.
- Standardized sampling protocols which will be used across the network were developed. Sampling protocols were established for: stand parameters; ecosystem C and N; ¹⁵N fertilizer uptake and fate; NH₃ volatilization and N₂O loss following N fertilization; soil chemical and physical properties; soil CO₂ efflux measurements including separation of heterotrophic and autotrophic components of soil respiration; leaf level gas exchange from photosynthesis, respiration, leaf area dynamic/leaf phenology, and transpiration rates based on sap flow; and water use efficiency based on C isotope analysis of wood samples.

- The following papers were published or are currently in review/in press:
 - Albaugh, T.J., E.D. Vance, C. Gaudreault, T.R. Fox, H.L. Allen, J.L. Stape, and R.A. Rubilar. Carbon emissions and sequestration from fertilization of pine in the southeastern United States. *Forest Science*, in press.
 - Blinn, C.E., T.J. Albaugh, T.R. Fox, R.H. Wynne, J.L. Stape, R.A. Rubilar, and H.L. Allen. 2012. A method for estimating deciduous competition in pine stands using Landsat. *Southern Journal of Applied Forestry*, in press.
 - Bracho, R., G. Starr, H.L. Gholz, T.A. Martin, W.P. Cropper, Jr., and H.W. Loeschner. 2012. Controls on carbon dynamics by ecosystem structure and climate for southeastern U.S. slash pine plantations. *Ecological Monographs*, in press.
 - Domec, J.-C. 2011. Let's not forget the critical role of surface tension in xylem water relations. *Tree Physiology* 31:359-360. doi: 10.1093/treephys/tpr039
 - Maier, C., K.H. Johnsen, P. Dougherty, D. McInnis, P. Anderson, and S. Patterson. 2012. Effect of harvest residue management on tree productivity and carbon pools during early stand development in a loblolly pine plantation. *Forest Science*, in review.
 - Miller, B.W. and T.R. Fox. 2011. Long-term fertilizer effects on oxalate desorbable phosphorus pools in a typical paleaquult. *Soil Science Society of America Journal* 75 (3):1110-1116. doi: 10.2136/sssaj2010.0037
 - Mortazavi, B., M.H. Conte, J.P. Chanton, T.A. Martin, T. Teklemariam, J.C. Weber, and W.P. Cropper, Jr. Carbon isotopic composition of assimilated and respired CO₂ in Southeastern U.S. pine forests. *Journal of Geophysical Research*, in review.
 - Peduzzi, A., R.H. Wynne, T.R. Fox, R.F. Nelson, and V.A. Thomas. 2012. Estimating leaf area index in intensively managed pine plantations using airborne laser scanner data. *Forest Ecology and Management* 270:54-65. doi: 10.1016/j.foreco.2011.12.048
 - Samuelson, L.J., T.A. Stokes, and K.H. Johnsen. 2012. Ecophysiological comparison of 50-year-old longleaf pine, slash pine and loblolly pine. *Forest Ecology and Management*, in press.
 - Stovall, J. P., C.A. Carlson, J.R. Seiler, T.R. Fox, and M.A. Yanez. 2011. Growth and stem quality responses to fertilizer applications by 21 loblolly pine clones in the Virginia Piedmont. *Forest Ecology and Management* 261(3): 362-372. doi: 10.1016/j.foreco.2010.10.018

- Stovall, J.P., J.R. Seiler, and T.R. Fox. Allometry varies among six-year-old *Pinus taeda* (L.) clones in the Virginia Piedmont. *Forest Science*, in press.
- Stovall, J.P., T.R. Fox, and J. R. Seiler. Short-term changes in biomass partitioning of two full-sib clones of *Pinus taeda* L. under differing fertilizer regimes over four months. *Trees: Structure and Function*, in press.
- Vogel, J.G., L. Suau, T.A. Martin, and E.J. Jokela. 2011. Long term effects of weed control and fertilization on the carbon and nitrogen pools of a slash and loblolly pine forest in north central Florida. *Canadian Journal of Forest Research* 41(3):552-567. doi: 10.1139/X10-234
- Xiao, J., Q. Zhuang, B.E. Law, D.D. Baldocchi, J. Chen, A.D. Richardson, J.M. Melillo, K.J. Davis, D.Y. Hollinger, S. Wharton, R. Oren, A. Noormets, M.L. Fischer, S.B. Verma, D.R. Cook, G. Sun, S.G. McNulty, S.C. Wofsy, P.V. Bolstad, S.P. Burns, P.S. Curtis, B.G. Drake, M. Falk, D.R. Foster, L. Gu, J.L. Hadley, G.G. Katul, M. Litvak, S. Ma, T.A. Martin, R. Matamala, T.P. Meyers, R.K. Monson, J.W. Munger, W.C. Oechel, K.T. Paw U, H.P. Schmid, R.L. Scott, G. Starr, A. Suyker, and M.S. Torn. 2011. Assessing net ecosystem carbon exchange of U.S. terrestrial ecosystems by integrating eddy covariance flux measurements and satellite observations. *Agricultural and Forest Meteorology* 151:60-69. doi: 10.1016/j.agrformet.2010.09.002
- Zerpa, J. L. and T.R. Fox. 2011. Controls of volatile ammonia losses from loblolly pine plantations fertilized with urea in the Southeast U.S. *Soil Science Society of America Journal* 75(1):257-266. doi:10.2136/sssaj2010.0101
- Zhang, F., J.M. Chen, J. Chen, C.M. Gough, D. Dragoni, and T.A. Martin. Evaluating spatial and temporal patterns of MODIS GPP over the conterminous U.S. against flux measurements and a process model. *Remote Sensing of Environment*, in review
- A PINEMAP overview presentation was given at the October 4, 2011 Forest Productivity Cooperative Advisory Committee meeting. A valuable discussion resulted regarding protocols related to the sharing of Forest Productivity Research Cooperative data with PINEMAP. Furthermore, this presentation resulted in a reaffirmation of support for PINEMAP from forest industry members. In addition, a PINEMAP presentation was given on January 26, 2012 at the Texas Center for Climate Studies.

MILESTONES AND DELIVERABLES

Existing regionwide research cooperative field trials serve as the backbone of the three-tiered monitoring network used to develop carbon, water, and nutrient storage and flux baselines, as well as responses to climate and management. During year 1, a first set of Tier I and Tier II sites were selected and Tier III sites were installed and monitoring has begun on these sites.

Selecting/Installing and Monitoring Tier I, II, and III Sites

Tier I uses an existing network of several thousand growth and yield cooperative (e.g., Shiver & Martin 2002, Russell *et al.* 2010) plots which blanket the region to provide extensive, spatially-explicit information on regional variability in productivity. A wide range of growth and yield trial series are available, some of which include management treatments such as planting density, thinning, fertilization, and weed control. Most of these plots have repeated tree inventory measurements (typically survival, trees/acre, and tree height and diameter) and thus provide excellent information on spatial and temporal variability in tree productivity across the soil and climate factors in the region. While these sites will not provide direct information on all carbon (C) and nitrogen (N) pools, tree biomass dynamics (which will be derived from the inventory data and allometric relationships) dominate C and N flux relationships in most forest systems, and therefore, Tier I will be very informative given the number and distribution of sites and will have great utility for the development of improved growth and yield models (the standard for prediction of tree productivity under varying management regimes) and for verification and validation of simulation output from the biological models. Tier I sites have been selected and the protocol for transferring the existing data to TerraC, the PINEMAP database, has been established.

Tier II sites will be chosen from existing research cooperative field studies and planted pine AmeriFlux installations which cover the full range of climate and soils in the region, and most of which include replicated silvicultural treatments. All of these trials have multiple historical tree inventory measurements, and some have additional C and N budget measurements. Tier II sites are being chosen based on the strength of existing data for each trial and to maximize variation in geography, soils, climate, stand age, and treatment (focusing on nutritional, competition control, and thinning or planting density treatments). New, more intensive measurements on Tier II sites will enable standardized quantification of C and N pools and fluxes including soil heterotrophic respiration, the key link between net primary production (NPP) and net ecosystem production (NEP).

Tier II is the heart of the PINEMAP monitoring network, representing a very ambitious, geographically diverse set of coordinated C and N pool and flux measurements. Carefully chosen ecophysiological parameters measured on a subset of the Tier II sites (e.g., maximum intercepted photosynthetically active radiation, estimates of fertility rating, and soil autotrophic and heterotrophic respiration) will enable us to parameterize

key model inputs and characterize regional variation in important biological functions related to C and N cycling. Archived university-corporate-governmental research cooperative data are being organized and will be submitted to PINEMAP as soon as the Tier I data are assimilated.

Data from the extensive Tier I and Tier II sites will provide substantial information on historic and current climatic influences on carbon sequestration and ecosystem productivity due to the wide geographic range and time span covered by the studies. However, climate change may produce combinations of conditions that have no analog in past climates. For this reason, we chose to situate the four *Tier III* sites across the full temperature and precipitation range of the species and then to reduce precipitation by approximately 30%, which is at the extreme end of predictions for precipitation and/or soil moisture variation associated with climate change for the region (refer to Box 1a). Because most planted pine forests are nutrient limited and nutrient management is widespread, it is important to examine the interaction of the rain throughfall exclusion treatment with an imposed nutritional gradient on Tier III. At sites in Virginia, Georgia, Florida, and Oklahoma, four replications of a 2 X 2 factorial experiment are being installed with the following treatments:

- Control: no treatment
- Fertilizer: fertilizer additions to achieve “optimum” nutrition
- Rain throughfall exclusion: panels installed in understory to divert 30% of throughfall off of the plot
- Fertilizer + rain throughfall exclusion: combined fertilizer and throughfall exclusion treatments

The experiments are being installed near canopy closure in loblolly pine stands with diverse genetic composition (seed orchard mixes). Using diverse genetics enables us to broaden the inferences that can be made from the experiments. Intensive measurements of nutrient and carbon pools and fluxes and ecophysiological parameters at Tier III sites will enable us to parameterize ecophysiological models for conditions likely outside the historical range of climatic variability encountered in the loblolly pine range and, therefore, broaden the inference space for the models parameterized from these measurements. Table 1a summarizes the characteristics of the three-tiered monitoring network.

Tier III sites incorporate treatments designed to help us understand how future, drier conditions may affect pine forest productivity and to what extent addition of fertilizer may alleviate these effects.

Table 1a. Overview of the PINEMAP three-tiered monitoring network.

Network Level	Number of Sites	Treatments	Measurements	Questions to be Addressed
Tier I	~ 500	Combinations of fertilization, competition control, planting density, thinning, and stand age	Existing height, stem diameter, trees/acre inventory data	How does tree productivity vary with climate, soil, stand development, and management? Verification and validation of growth and yield and carbon models.
Tier II	~ 140	Combinations of fertilization, competition control, planting density, thinning, and stand age	Existing inventory data, C & N pools, soil GHG fluxes, and key ecophysiological model parameters on subset	How do above- and below-ground C and N pools and fluxes, as well as key ecophysiological modeling parameters, vary with climate, soils, stand development, and management factors? Parameterization, verification, and validation of growth and yield and carbon models.
Tier III	4	Factorial combination of fertilization (control and “optimum”) and precipitation (rain fed and ~ 30% reduction)	Same as Tier II, plus intensive C, N, and H ₂ O, and various ecophysiology measurements	Same as Tier II, plus extension of parameter space to climatic conditions likely not experienced within the historic loblolly pine range and verification and validation of growth and yield, carbon, and water models.

Measurements that will be taken on the Tier II and III sites include the following:

- 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).

The university scientists involved in Aim 1 are divided into four geographic “teams” to carry out Tier II and Tier III measurements: (1) Texas A&M University and Oklahoma State University, (2) Auburn University and University of Georgia, (3) Virginia Tech and North Carolina State University, and (4) University of Florida. Dividing measurements geographically minimizes travel distance to individual network locations and builds regionwide research capacity by standardizing research protocols and approaches.

Protocols were developed for the following sampling methods: stand parameters; ecosystem C and N; ^{15}N fertilizer uptake and fate; NH_3 volatilization and N_2O loss following N fertilization; soil chemical and physical properties; soil CO_2 efflux measurements including separation of heterotrophic and autotrophic components of soil respiration; leaf level gas exchange from photosynthesis, respiration, leaf area dynamic/leaf phenology, and transpiration rates based on sap flow; and water use efficiency based on C isotope analysis of wood samples. A planning meeting to review the standardized sampling protocols developed by Aim 1 and coordinate the measurement activities on Tier II and Tier III sites will take place in Athens, Georgia in April 2012 with members of Aims 1, 2, 3, and 4.

Implementation of Additional Field Studies

Seven sites have been selected across the South for studies of N volatilization and uptake efficiency following forest fertilization. ^{15}N urea was purchased and converted into five different N fertilizer formulations that are being used in the following treatments: check, urea, NBPT treated urea, DAP coated urea, and polymer coated urea. Fertilizers were applied to one set of plots in the winter and a second set of plots in the summer at each site. Soil and foliage samples have been collected monthly. A companion study of N volatilization was conducted at each site. Virginia Tech has purchased an Isotope Ratio Mass Spectrophotometer and renovated a lab to facilitate analysis of ^{15}N in the samples.

A study of greenhouse gas (i.e., CO_2 , N_2O , and CH_4) soil fluxes following forest fertilization has been initiated to compare soil drainage class, fertilizer type, fertilizer rate, and season of fertilizer. Plots have been located and treatments established. Greenhouse gas (GHG) fluxes are being measured at 6 week intervals over the next year. To facilitate this work, Virginia Tech obtained a gas chromatograph (GC) equipped with electrochemical and flame ionization detectors, a methanizer, and an auto sampler. Sample collection systems were designed and installed in the field and GC methodologies were developed to analyze N_2O in samples.

During the summer of 2011, a study was installed and measured repeatedly to test the feasibility of deep coring to separate heterotrophic from autotrophic soil respiration. Eight replications were installed in pine plantations that are similar to the Tier III sites. Six weeks following core installation, efflux rates decreased 30% compared to adjacent uncored soil suggesting that autotrophic respiration in this stand of loblolly pine is 30% of the total CO_2 efflux.

Box 1a. PINEMAP Tier III Sites

We chose to situate the four Tier III sites across the full temperature and precipitation range of the species and then to reduce precipitation by approximately 30%, which is at the extreme end of predictions for precipitation and/or soil moisture variation associated with climate change for the region. Because most planted pine forests are nutrient limited and nutrient management is widespread, it is important to examine the interaction of the rain throughfall exclusion treatment (Figures 1b and 1c) with an imposed nutritional gradient on this tier. Tier III sites are located in Taylor County, Florida, Buckingham County, Virginia, Taliaferro County, Georgia, and McCurtain County, Oklahoma (Figure 1a).

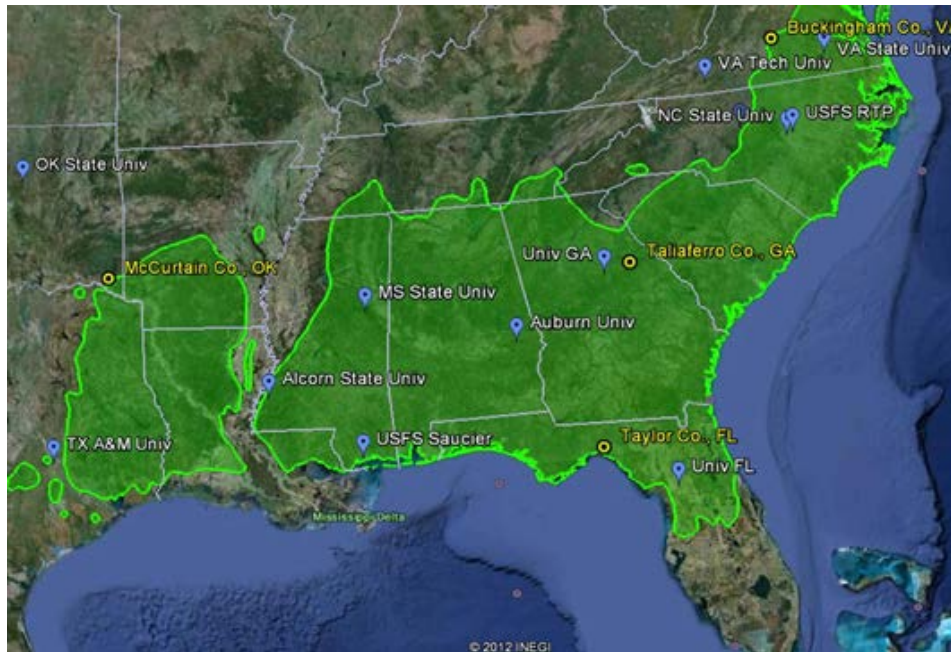


Figure 1a. Location of Tier III sites (circles) and collaborating institutions (point markers). The shaded area indicates the native range of loblolly pine. Remote sensing image from Google Earth; range map from USDA Forest Service



Figure 1b. Rain throughfall exclusion structures under construction at Tier III site in Buckingham County, Virginia.
Photo courtesy of Tom Fox.



Figure 1c. Completed prototype of rain throughfall exclusion structure at Tier III site in Buckingham County, Virginia.
Photo courtesy of Tom Fox.

BROAD IMPACTS

Several Aim 1 Co-PIs (including Tom Fox, Eric Jokela, Mike Kane, and Jose Stape) are also Co-PIs within the National Science Foundation Center for Advanced Forestry Systems (CAFS). The efforts of PINEMAP and CAFS are complimentary, and close collaboration will benefit both projects. For example, the ^{15}N fertilizer uptake study has received substantial funding from NSF that is leveraging the PINEMAP efforts.

PINEMAP faculty at North Carolina State University (Jose Stape) and Virginia Tech (Tom Fox) are working with forest products companies in Brazil to develop a series of field trials in eucalyptus plantations that are similar to the Tier III studies in PINEMAP. This will provide an opportunity to compare the impact of rain throughfall exclusion and nutrient additions in other regions.

TRAINING

The following list summarizes graduate students and technical staff involved in Aim 1 research. PINEMAP scientists are mentoring students through their graduate programs. Most of the students are also participating in the PINEMAP distance graduate course that is providing a comprehensive overview of climate change, southern forests, extension strategies, and the PINEMAP project.

- Madison Akers, Research Coordinator, University of Georgia. Madison is coordinating baseline measurements on Tier II sites and overseeing installation and data collection on the Georgia Tier III site.
- Tim Albaugh, Research Associate, North Carolina State University. Tim is evaluating impacts of weed control and fertilization on loblolly pine using the 3-PG model.
- Jose Alvarez, Postdoctoral Associate, North Carolina State University. Dr. Alvarez is evaluating changes in loblolly pine leaf area due to silvicultural treatments as a component of the 3-PG model.
- Joe Clark, M.S. student, Auburn University. Joe's research focus is assessing relationships among intercepted radiation, LAI, photosynthetic capacity, phenology, and productivity in loblolly pine.
- Sam Frye, Research Technician, Virginia Tech. Sam is assisting with soil CO_2 efflux and N_2O measurements and installation and data collection on Tier II and Tier III sites.
- Brett Heim, M.S. student, Virginia Tech. Brett's research focus is separating heterotrophic and autotrophic respiration components of soil CO_2 efflux.
- Andy Laviner, Research Coordinator, Ph.D. student, Virginia Tech. Andy is coordinating baseline measurements on Tier II sites and overseeing installation and data collection on the Virginia Tier III site; his research focus is water use efficiency in loblolly pine.

- Wen Lin, Ph.D. student, North Carolina State University. Wen's research focus is water use efficiency in loblolly pine using $^{12}\text{C}/^{13}\text{C}$ ratios in wood.
- Geoffrey Lokuta, Research Coordinator, University of Florida. Geoff is coordinating baseline measurements on Tier II sites and overseeing installation and data collection on the Florida Tier III site.
- Cody Luedtke, Ph.D. student, University of Georgia. Cody's research focus is soil CO_2 efflux.
- Adam Maggard, Ph.D. student, Oklahoma State University. Adam's research focus is ecophysiology on Tier II and Tier III sites.
- Casey Meek, Research Associate, Oklahoma State University. Casey is assisting with ecophysiological and process measurements on Tier III and Tier II sites.
- Jason Pike, Research Technician, Oklahoma State University. Jason is assisting with installation, maintenance, and data collection on Tier II sites.
- Jill Qi, Ph.D. student, University of Georgia. Jill's research focus is soil water and deep soil carbon responses under rain throughfall treatment at Tier III sites.
- Jay Raymond, Ph.D. student, Virginia Tech. Jay's research focus is N uptake efficiency of enhanced efficiency N fertilizers using ^{15}N stable isotopes.
- Santosh Subedi, Ph.D. student, Virginia Tech. Santosh's research focus is identifying an improved method to determine fertility rating for 3-PG.
- Elaine Stebler, Research Technician, Oklahoma State University. Elaine is coordinating baseline measurements on Tier II sites and overseeing installation and data collection on the Oklahoma Tier III site.
- Tom Stokes, Research Associate, Auburn University. Tom is assisting with installation and data collection on Tier II and Tier III sites.
- Maxwell Wightman, M.S. student, University of Florida. Max's research focus is ecophysiology of drought response on the Florida Tier III site.
- Lu Zhai, Ph.D. student, Texas A&M University. Lu's research focus is family and culture effects on ecosystem C and N dynamics.

COLLABORATIONS AND "INTEGRATED" KNOWLEDGE DEVELOPED

The PINEMAP project has been presented to members of the university-corporate-governmental research cooperatives. The research cooperatives collectively control two-thirds of the pine plantation land base in the South. These corporate members are concerned about the impacts of climate change on the long-term sustainability and economic viability of southern pine plantations and are anticipating recommendations resulting from PINEMAP research.

PLAN-OF-WORK FOR YEAR 2

The Aim 1 plan-of-work for year 2 (March 1, 2012 - February 28, 2013) (Table 1b) summarizes tasks and activities to be conducted/completed each quarter during year 2 to ensure delivery of overarching Aim 1 milestones and deliverables.

Table 1b. This work plan summarizes Aim 1 quarterly tasks and activities for year 2.

Develop standardized methodology for carbon, water, and nutrient pools and fluxes			
Quarter	Task/Activity	People Responsible	Additional Personnel Involved
Quarter 1-2 (3/1/12-8/31/12)	Develop standardized methods for baseline C inventory	Samuelson, Wilson, Strahm, Markewitz, Vogel, Fox	
	Develop standardized methods for baseline soil characterization	Markewitz, Strahm, Wilson, Jokela, Fox	
	Develop standardized methods for baseline ecophysiology measures	Samuelson, Seiler, Will, Teskey, Noormets, Vogel	King, Domec, Maier, Johnsen
	Develop standardized method for separating soil heterotrophic and autotrophic respiration	Seiler, Vogel, Noormets, Strahm	
Establish monitoring network and collect baseline data			
Quarter	Task/Activity	People Responsible	Additional Personnel Involved
Quarter 1 (3/1/12-5/31/12)	Compile list of research cooperative studies serving as Tier I study sites and send archival data to PINEMAP	Research cooperative Directors Fox – FPC Kane – PMRC Jokela – FBRC Whetten – NCTIP Byram-WGTIP Peter-CFGRP	Research cooperative Data Managers; PINEMAP Data Manager
	Install Tier III study treatments (rain throughfall exclusion system and fertilization)	Research Associates (Akers, Laviner, Lokuta, Stebler, Frye)	
Quarter 1-2 (3/1/12-8/31/12)	Collect soil baseline data on Tier III sites	Research Associates (Akers, Laviner, Lokuta, Stebler, Frye)	
Quarter 1-2 (3/1/12-8/31/12)	Install instruments at Tier III sites	Noormets	Research Associates (Akers, Laviner, Lokuta, Stebler, Frye)

Quarter	Task/Activity	People Responsible	Additional Personnel Involved
Quarter 1-2 (3/1/12-8/31/12)	Identify active research cooperative study sites suitable for Tier II installations	Research cooperative Directors Fox – FPC Kane – PMRC Jokela – FBRC Whetten – NCTIP Byram – WGTIP Peter – CFGRP	
Quarter 1-3 (3/1/12-11/30/12)	TerraC database training	Sub-region Leads (Fox, Kane, Jokela, Will)	PINEMAP Data Manager
Quarter 1-4 (3/1/12-2/28/13)	Install studies to measure N fertilizer uptake efficiency using ¹⁵ N labeled fertilizer at Tier II and Tier III sites	Fox, Strahm	Graduate students; FPC postdoc
	Install studies to measure N ₂ O and CH ₄ emissions following N fertilization	Strahm	Postdoc
	Develop improved method to evaluate fertility rating (FR) in 3-PG	Fox	Graduate students
	Develop improved method to evaluate stomatal response functions to update 3-PG	Samuelson, Teskey	Graduate students
	Ongoing measures of carbon, nutrient pools and fluxes, and water flux at Tier III sites (i.e. soil respiration, soil nutrient availability, leaf level PS and respiration, etc.)	Samuelson, Will, Wilson, Seiler, Teskey, Noormets, Vogel; Research Associates (Akers, Lavinier, Lokuta, Stebler, Frye)	King, Domec, Maier, Johnsen; graduate students
Quarter 2 (6/1/12-8/31/12)	Identify subset of Tier II sites for additional ecophysiology measures	Noormets, Will, Teskey, Martin, Samuelson, Seiler, Wilson; West	Sub-region Leads (Fox, Kane, Jokela, Will); Vogel
Quarter 2-3 (6/1/12-11/30/12)	Arrange to send archival data for Tier II sites to PINEMAP	Research cooperative Data Managers; PINEMAP Data Manager	
Quarter 2-4 (6/1/12-2/28/13)	Wood samples for O and C isotope analysis from Tier II sites	Sub-region Leads (Fox, Kane, Jokela, Will); Vogel, West	Graduate students (Zhai); Research Associates (Akers, Lavinier, Lokuta, Stebler, Frye)

Quarter	Task/Activity	People Responsible	Additional Personnel Involved
Quarter 3-4 (9/1/12-2/28/13)	Collect baseline data at Tier II sites to evaluate treatment effects on C and nutrient pools and fluxes	Sub-region Leads (Fox, Kane, Jokela, Will); Vogel, West	Graduate students (Zhai); Research Associates (Akers, Lavinier, Lokuta, Stebler, Frye)
	Collect additional data on water and carbon fluxes at subset of Tier II sites previously identified	Sub-region Leads (Fox, Kane, Jokela, Will); Vogel, West, Domec, King	Graduate students (Zhai); Research Associates (Akers, Lavinier, Lokuta, Stebler, Frye)

Aim 1 Members

Name	Institution	Role	E-mail address
Tom Fox	Virginia Tech	Co-PI; Aim 1 Leader; Mitigation Integration Leader	trfox@vt.edu
Mike Kane	University of Georgia	Co-PI; Aim 1 Leader	mkane@warnell.uga.edu
Madison Akers	University of Georgia	Research Coordinator; Aim 1 Member	akersm@warnell.uga.edu
Tim Albaugh	North Carolina State University	Research Associate; Aim 1 Member	Tim_albaugh@ncsu.edu
Jose Alvarez	NCSU	Aim 2	j Alvarez@ncsfnc.cfr.ncsu.edu
J.-C. Domec	North Carolina State University	Co-PI; Aim 1 Member	jdomec@ncsu.edu
Sam Frye	Virginia Tech	Research Technician; Aim 1 Member	samfrye@vt.edu
Sabine Grunwald	University of Florida	Co-PI; Aim 1 Member	sabgru@ufl.edu
Tom Hennessey	Oklahoma State University	Co-PI; Aim 1 Member	tomhenn@okstate.edu
Kurt Johnsen	U.S. Forest Service	Co-PI; Aim 1 Member	kjohnsen@fs.fed.us
Eric Jokela	University of Florida	Co-PI; Aim 1 Member	ejokela@ufl.edu
John King	North Carolina State University	Co-PI; Aim 1 Member	john_king@ncsu.edu
Andy Laviner	Virginia Tech	Research Coordinator; Aim 1 Member	alaviner@vt.edu
Geoff Lokuta	University of Florida	Research Coordinator; Aim 1 Member	bassman@ufl.edu
Chris Maier	U.S. Forest Service	Co-PI; Aim 1 Member	cmaier@fs.fed.us
Dan Markewitz	University of Georgia	Co-PI; Aim 1 Member	dmarke@warnell.uga.edu
Tim Martin	University of Florida	Project Director; Aim 1 Member	tamartin@ufl.edu
Casey Meek	Oklahoma State University	Research Associate; Aim 1 Member	
Asko Noormets	North Carolina State University	Co-PI; Aim 1 Member	anoormets@gmail.com
Jason Pike	Oklahoma State University	Research Technician; Aim 1 Member	jason.pike@okstate.edu
Lisa Samuelson	Auburn University	Co-PI; Aim 1 Member	samuelj@auburn.edu
John Seiler	Virginia Tech	Co-PI; Aim 1 Member	jseiler@vt.edu
Jose Stape	North Carolina State University	Co-PI; Aim 1 Member	jlstape@ncsu.edu
Brian Strahm	Virginia Tech	Co-PI; Aim 1 Member	brian.strahm@vt.edu
Elaine Stebler	Oklahoma State University	Research Technician; Aim 1 Member	elaine.stebler@okstate.edu
Tom Stokes	Auburn University	Research Associate; Aim 1 Member	stoketa@auburn.edu
Eric Taylor	Texas AgriLife Extension, Texas A&M University	Co-PI; Aim 1 Member	eltaylor@tamu.edu
Robert Teskey	University of Georgia	Co-PI; Aim 1 Member	rteskey@uga.edu
Jason Vogel	Texas A&M University	Co-PI; Aim 1 Member	jason_vogel@tamu.edu
Jason West	Texas A&M University	Co-PI; Aim 1 Member	jbwest@tamu.edu
Rodney Will	Oklahoma State University	Co-PI; Aim 1 Member	rodney.will@okstate.edu
Duncan Wilson	Oklahoma State University	Co-PI; Aim 1 Member	duncan.wilson@okstate.edu

EXECUTIVE SUMMARY

The overall objective of the modeling group (Aim 2) is to apply a multi-scaled modeling program incorporating data from the PINEMAP three-tiered, regionwide monitoring network with spatially-explicit historical and predicted future climate data to assess alternative forest management systems and their impacts on carbon sequestration and resilience to disturbance. The multi-scaled modeling program will facilitate stand- to regional-scale assessment of alternative forest management systems for sustainably increasing mitigation of greenhouse gases while adapting to changing climate and associated disturbances.

During year 1, Aim 2 completed multiple case studies and assessments to guide modeling efforts, including: management and climate effects on loblolly pine C and H₂O budgets over a rotation cycle; resolution of alternative methods for quantifying forest water use; predictions of C pool dynamics for alternative land use, management, and climate scenarios at the stand level; and management alternatives with Tier I data and existing models of carbon sequestration.

Important infrastructure development in the first year included implementation of model code in standardized platforms available to all PINEMAP participants and compilation of regional satellite, meteorological (including climate scenarios), and soils data needed for model runs, all made available for project-wide use. Two FORTRAN implementations of the Physiological Principles in Predicting Growth (3-PG) model were developed to enable computationally expensive geoprocessing, supercomputing, regionwide simulations, sensitivity analyses, and Monte-Carlo style analyses.

During year 2, major Aim 2 activities include the following:

- Evaluate initial growth and yield fitting using Tier I data.
- Conduct a preliminary assessment of potential effects of climate change on loblolly water and C balance.
- Complete initial modeling of Tier I sites using 3-PG, 3-PGS, and Carnegie-Ames-Stanford Approach biogeochemical model (CASA) (latter two using Landsat data).
- Incorporate climate variables into growth and yield components.
- Complete assessment of Tier I big leaf modeling and reparameterize models.
- Add climate scenarios to Ames System.
- Run regional baseline big leaf models using Landsat Leaf Area Index (LAI) (3-PGS and CASA).
- Improve 3-PG parameterization from network measurements.
- Complete a prototype of growth and yield components and begin scale-up to region.

OUTCOMES/IMPACTS

Aim 2 activities contribute to project-level outcomes and impacts by assessing and analyzing how changing management and climate will impact stand and regional carbon sequestration, productivity, and resilience to disturbance. Because climate and management effects on forests span such large spatial and temporal scales, modeling approaches remain the only method available to assess outcomes and impacts for the entire region.

OUTPUTS

During year 1, Aim 2 contributed a number of outputs that advanced the overall project goals and objectives.

- Multiple case studies and assessments were completed to guide future modeling, including the following: management and climate effects on loblolly pine C and H₂O budgets over a rotation cycle using the Physiological Principles in Predicting Growth (3-PG) (Landsberg & Waring 1997) model; comparison of alternative methods for quantifying forest water use; predictions of C pool dynamics for alternative land use, management, and climate scenarios at the stand level; and management alternatives with Tier I data and existing models of carbon sequestration.
- Important infrastructure development in the first year involved implementation of model code in standardized platforms available to all PINEMAP participants so that analyses by multiple groups from across the project can be executed using comparable, consistent model formulations.
- Regional satellite, meteorological (including climate scenarios), and soils data needed for model runs was compiled and made available for project-wide use.
- A sap-flow workshop with 15 PINEMAP collaborators resulted in a standardized sap flow technique (heat dissipation method) that will be used at all Tier III sites to measure tree water use and finalized methods for future data analysis.
- The following papers were published or are currently in review/in press:

Bryars *et al.* 2012a. A single physiological parameter set for the 3-PG model produced accurate estimates of loblolly pine growth in stands in the Coastal Plain and Piedmont Provinces of Georgia, USA. *Forest Ecology and Management*, in review.

Bryars *et al.* 2012b. Parameterization of the 3-PG model for use with two contrasting clonal loblolly pine genotypes and their simulated performance under altered climate regimes. *Southern Journal of Applied Forestry*, in review.

- Domec, J.C., J. Ogée, A. Noormets, J. Jouangy, M. Gavazzi, E. Treasure, G. Sun, S. McNulty, and J.S. King. 2012b. The impact of soil texture and water table depth on root hydraulic redistribution and consequences for the carbon and water budgets of southern U.S. pine plantations. *Tree Physiology* ID: TPS018, in press.
- Domec, J.C., G. Sun, A. Noormets, M. Gavazzi, E. Treasure, E. Cohen, J.J. Swenson, S. McNulty, and J. King. 2012a. A comparison of three methods to estimate evapotranspiration in two contrasting loblolly pine plantations: Age-related changes in water use and drought sensitivity of evapotranspiration components. *Forest Science*, in press.
- Garcia, O., H.E. Burkhart, and R.L. Amateis. 2011. A biologically-consistent stand growth model for loblolly pine in the Piedmont physiographic region, USA. *Forest Ecology and Management* 262(11):2035-2041. doi: 10.1016/j.foreco.2011.08.047
- Gonzalez-Benecke, C.A., E.J. Jokela, and T.A. Martin. 2012. Modeling the effects of stand development, site quality, and silviculture on leaf area index, litterfall, and forest floor accumulations in loblolly and slash pine plantations. *Forest Science*, in press.
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- Noormets *et al.* 2012. Forest rotation length impacts on ecosystem carbon balance. *Forest Ecology and Management*, in review.
- Sabatia, C.O. and H.E. Burkhart. 2012. Competition among loblolly pine trees: Does genetic variability of the trees in a stand matter? *Forest Ecology and Management* 263(1):122-130. doi: 10.1016/j.foreco.2011.09.009
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- Sun, G., P. Caldwell, A. Noormets, E. Cohen, S.G. McNulty, E. Treasure, J.-C. Domec, Q. Mu, J. Xiao, R. John, and J. Chen. 2011. Upscaling key ecosystem functions across the conterminous United States by a water-centric ecosystem model. *Journal of Geophysical Research*: 116, G00J05. doi:10.1029/2010JG001573.
- Sun, G., K. Alstad, J. Chen, S. Chen, C.R. Ford, G. Lin, C. Liu, N. Lu, S.G. McNulty, H. Miao, A. Noormets, J.M. Vose, B. Wilske, M. Zeppel, Y. Zhang, and Z. Zhang. 2011. A general predictive model for estimating monthly ecosystem evapotranspiration. *Ecohydrology* 4(2): 245–255. doi: 10.1002/eco.194.
- Timilsina, N., F. Escobedo, W. Cropper, Jr., T. Brandeis, S. Delphin, and S. Lambert. A framework for identifying carbon hotspots and forest management drivers. *Journal of Environmental Management*, in review.
- PINEMAP researchers presented at the Ecological Society of America 2011 Annual Meeting: *A framework for mapping carbon storage hotspots and determining optimal forest structure and management regime characteristics*. (poster), N. Timilsina, F. Escobedo, A. Abd-Elrahman, W. P. Cropper, Jr., S. Delphin, and S. Lambert, 96th ESA Annual Meeting, August 7-12, 2011, Austin, Texas.

MILESTONES AND DELIVERABLES

The existing inventory data from the Tier I network, as well as existing inventory and new C and nutrient dynamics data from the Tier II and III networks and experimental manipulations, will be used to parameterize and validate a coordinated series of open-source models ranging in complexity and scale from tree to regional-level. These models will be used to design and test novel forest management systems focused on greenhouse gas mitigation, enhanced resource use efficiency, and resilience to climate change. The larger-scale models, coupled with remote sensing, will provide the framework for regionwide bioeconomic assessment of the response of forests and forest management systems to climate change and policy scenarios. Models and model output will be used to help develop the PINEMAP open-source Decision Support System that will serve as a primary outreach tool and as a hub for interaction between the research Aim groups and the Extension Aim group.

Aim 2 deliverables and outcomes this year derived from five types of activities: (1) familiarization, (2) standardization, (3) parameterization, (4) model development, and (5) initial model deployment.

Familiarization

Although most of the investigators had some familiarity with each of the models being used, the depth of knowledge was not sufficient to begin substantive discussion of model integration. Therefore, investigators participated in a series of group discussions about current modeling capabilities to search for points of interchange among models. These discussions broaden mutual understanding of the models.

Standardization

As our familiarization with the models improved, two important issues became clear. First, while the models may provide similar types of output (e.g., measures of forest productivity), the specific form of output varies between models (e.g., gross ecosystem productivity, GEP; net primary productivity, NPP). Inter-model output must be standardized between scales. The second issue is input data. The PINEMAP models will rely on Aim 1 data for both parameterization and validation. In addition to the difficulties inherent to systematically converting different ecosystem variables, conditions, or processes, there are difficulties associated with measuring ecosystem attributes. For example, there are multiple methods for measuring leaf area index (LAI). Each method has advantages and disadvantages. Models are often developed using data from different methods and the systematic bias of one measurement method could produce unacceptable prediction error if coupled with input data that used a different measurement method (and its own systematic bias). Aim 2 developed a draft standard for LAI measurement that was further honed in collaboration with Aim 1. Some of the most important standardization issues have been addressed but others remain, particularly with respect to the measurements on Tier III sites. A meeting among Aims 1, 2, 3, and 4 at the Georgia Tier III site is being held in April 2012 to ensure both adequacy and uniformity of Tier III measurements in support of overall PINEMAP objectives.

Parameterization

As previously discussed, parameterization of the various models/scales is a complex task. During year 1, Aim 2 developed a matrix for examining input and output variables and their sources. The scale of data varied from very large (e.g., NASA Landsat LAI data) to the very small (e.g., Tier I data). During the coming year, Aim 2 will finish formatting the data tables and continue the parameterization of the models. Parameterization will continue as the experiments and field observations progress over the next few years. These data will be used to assess model performance and, where possible, improve prediction accuracy (e.g., 3-PG).

Development

In addition to the work involving model integration, development work on each of the individual models continued. The form of development varied with the specific model. Some well-established models (e.g., 3-PG) were further improved using PINEMAP data. Other less well-established models (e.g., the Water Supply Stress Index Model, WaSSI) were finalized for use in PINEMAP analyses (e.g., WaSSI upscaling of net ecosystem exchange, NEE, for the southeastern U.S.) (refer to Box 2a).

Initial Model Deployment

Both WaSSI (see Sun *et al.* publication) and 3-PG (see Bryars *et al.* publication) have been deployed in support of project objectives in Year 1.

Major Activities and Associated Deliverables

During year 1, Aim 2 completed multiple case studies and assessments to guide future modeling efforts including: management and climate effects on loblolly pine C and H₂O budgets over a rotation cycle; resolution of alternative methods for quantifying forest water use; predictions of C pool dynamics for alternative land use, management, and climate scenarios at the stand level; and management alternatives with Tier I data and existing models of carbon sequestration.

The assessment of management and climate effects on loblolly pine C and H₂O budgets over a rotation cycle was completed using the Physiological Principles in Predicting Growth (3-PG) (Landsberg & Waring 1997) model and is reported in Bryars *et al.* 2012a and 2012b. An assessment of alternative methods for quantifying forest water use has also been completed and a paper has been accepted with minor revisions (Domec *et al.* 2012a). Finally, to predict C pool dynamics for alternative land use, management, and climate scenarios at the stand level, we are exploring linking 3-PG and Century models to examine forest ecosystem carbon sequestration.

Using regionwide growth and yield plot installations with thinning treatments and unthinned control plots for initial analyses we have (a) compared alternative expressions for spatially explicit and non-spatially explicit measures of competition; (b) evaluated alternative parameter estimation methods in systems of equations for individual tree growth; (c) developed initial expressions for generalized response functions to reflect various silvicultural inputs; (d) initiated a search for published work that incorporates climatic influences in empirical growth and yield models; and (e) submitted plot records from the individual research cooperatives to the PINEMAP TerraC database.

Because multi-scaled modeling assessments and simulations are central to the work of multiple PINEMAP Aim groups, it is critical to develop modeling infrastructure that can support multiple users and provide consistency in modeling analyses. Important

infrastructure development in the first year includes implementation of model code in standardized platforms available to all PINEMAP participants so that analyses by multiple groups from across the project can be executed using comparable, consistent model formulations. In addition, Aim 2 compiled regional satellite, meteorological (including climate scenarios), and soils data needed for model runs and made these data available for project-wide use.

We ported two versions of 3-PG to FORTRAN 2003 and released them to both project investigators and the original model developers. One is based on Peter Sands' Excel spreadsheet-based program, '3-PG-pjs' and the other is based on Robert Teskey's Visual Basic graphical user interface (GUI) program, '3-PG+'. The FORTRAN versions of this model will be used in more computationally expensive geoprocessing, supercomputing, regionwide simulations, sensitivity analyses, and Monte-Carlo style analyses. In addition, because they are housed on a UNIX server, they can be accessed through a web-based interface and are accessible to remote users with no need for installation. Future changes to the algorithms will be made to the centrally located software, preventing versioning discrepancies between users. The GUI created for 3-PG+ will be adapted to make it easier for users to generate text files for input into the FORTRAN version.

For the non-WaSSI regional modeling, we have chosen four Landsat scenes on which to test a model ensemble approach in concert with Rama Nemani using the Terrestrial Observation and Prediction System (TOPS), with the models including BIOME-BioGeochemical Cycles (BIOME-BGC), Lund-Postdam-Jean Model (LPJ), Carnegie Ames Stanford Approach (CASA), and TOPS-BGC. We are also looking at ways to add 3-PGS to the model ensemble with some input from Nicholas Coops. We have taken delivery of raster Soil Survey Geographic (SSURGO) data for the region which will be made available through both the NEX program and the PINEMAP TerraC database. North American Regional Climate Change Assessment Program (NARCCAP) scenarios have been downloaded for key climate variables and reformatted/reprojected. These will also be available through NEX and the PINEMAP TerraC database. LAI for the ETM/ETM+ (extracted time model) period of record (1984 - present) is being developed for all available Landsat images within each of the four chosen WRS-2 (worldwide reference system) scenes using a variant of the Moderate Resolution Imaging Spectroradiometer (MODIS) radiative transfer Look Up Table (LUT) approach subsequent to Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) preprocessing. These results are being validated (for more recent data) with in situ LAI collected under the PINEMAP aegis. Initial model results are being checked with both Tier I data and USDA Forest Service Forest Inventory and Analysis (FIA) data in concert with the USDA Forest Service Southern Research Station.

Box 2a. Regional Water and Carbon Dynamics Modeling

A water-centric ecosystem model (WaSSI) was used to simulate effects of climate change on carbon sequestration and water yield under four cornerstone Intergovernmental Panel on Climate Change (IPCC) climate change scenarios (CSIROA1B, CSIROB2, HADB2, and MIROCA1B) across 674 watersheds in the southern U.S. (Figure 2a). Model output suggests that the response of forest Gross Ecosystem Productivity (GEP) may vary spatially depending on the background climate regime and magnitude of changes in both air temperature and precipitation. The western part of the region is more likely to see reductions in carbon sequestration than the eastern part of the region under all scenarios except for the dry and hot MIROCA1B climate change scenario which would likely cause regionwide reductions to forest carbon sequestration (Figure 2b).

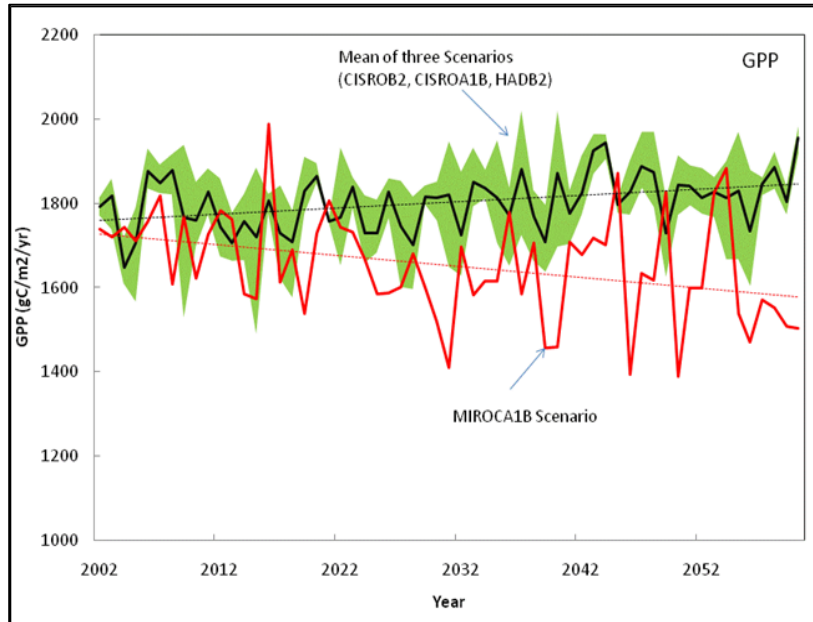


Figure 2a. Effects of climate change on carbon sequestration and water yield under 4 IPCC climate change scenarios.

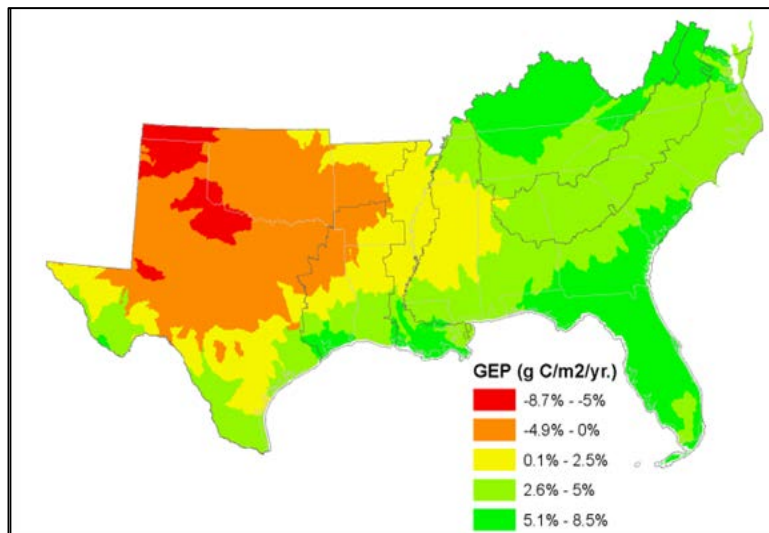


Figure 2b. Change in mean GEP under three climate scenarios in 2060.

BROAD IMPACTS

Strong connections have been made with the NASA Ames Research Center that will improve the quality of Aim 2 work. Regional modeling efforts can use the TOPS modeling framework, and the now available ANSI-code versions of 3-PG can be used in a high performance computing environment for stand-scale modeling. Our port of 3-PG from Excel to FORTRAN will be helpful to the entire forest ecosystem modeling community. Perhaps most important, linkages across Aim groups is helping us to better parameterize and, in some instances, improve forest ecosystem models used throughout the world.

TRAINING

The following list summarizes graduate students and Postdoctoral Associates involved in Aim 2 research.

- Ranjith Gopalakrishnan, Ph.D. student, Virginia Tech. Ranjith is downloading and reformatting the NARCCAP scenarios for key climate variables from six models (GCM/RCM combinations).
- Nabin Gyawali, Ph.D. student, Virginia Tech. Nabin is utilizing Tier I data to develop a growth and yield model flexible enough to allow modification in diameter, height, and mortality at tree- and stand-level for diverse genotypes and silvicultural practices under varying conditions.
- C. Wade Ross, Ph.D. student, University of Florida. Wade is investigating soil carbon dynamics along hydrology and fire regimes in southern pine ecosystems, as well as the effects of fire disturbance on the structure and function of soil carbon dynamics in pine and wetland ecosystems and developing a mechanistic model to upscale site specific findings to the regional scale.
- Maggie Wang, Ph.D. student, University of Georgia. Maggie is working on a research proposal to predict C pool dynamics for alternative land use, management, and climate scenarios at the stand level. The proposal is to link 3-PG and Century to examine forest ecosystem carbon sequestration.
- Nilesh Timilsina, Postdoctoral Associate, University of Florida. Dr. Timilsina is working on assessing the interactions between different ecosystem services in pine flatwoods and optimizing modeling to maximize a particular ecosystem service and assess the tradeoff of the others.

COLLABORATIONS AND “INTEGRATED” KNOWLEDGE DEVELOPED

A primary goal was to improve understanding and communication between the various modeling efforts. Therefore, the integration of knowledge was developed in the form of familiarization, standardization, and parameterization. Development of a solid foundation is critical to model integration. During 2012, Aim 2 will focus on bridging the individual model components.

PLAN-OF-WORK FOR YEAR 2

The Aim 2 plan-of-work for year 2 (March 1, 2012 - February 28, 2013) (Table 2a) summarizes tasks and activities to be conducted/completed each quarter during year 2 to ensure delivery of overarching Aim 2 milestones and deliverables.

Table 2a. This work plan summarizes Aim 2 quarterly tasks and activities for year 2.

Quarter	Task	People Responsible	People Helping	Resources Needed
Quarter 1 (3/1/12-5/31/12)	Start evaluation of initial growth and yield fitting using all Tier I data	Burkhart	Wynne, Amateis, Gopalakrishnan, postdoc	Tier I data
	Preliminary assessment of potential effects of climate change on loblolly water/C manuscript submitted	Domec	SGCP/EFETAC Team	Tier II data
	Evaluation of Ames RT LAI product complete	Wynne	Burkhart, Thomas, Nemani, Gopalakrishnan, Blinn, postdoc	Sufficient LAI validation sites
	Initial modeling of Tier I sites using 3-PG, 3-PGS, and CASA (latter two using Landsat data) complete	Wynne and Thomas	Burkhart, Amateis, Musy, Gopalakrishnan, Nemani, Coops, Teskey, postdoc	Tier I data
Quarter 2 (6/1/12-8/31/12)	Initial empirical LAI modeling complete	Burkhart and Wynne	Nemani, Gopalakrishnan, Thomas	Tier I data
	Incorporate climate variables in growth and yield components	Burkhart	Wynne, Amateis, Gopalakrishnan, postdoc	Ames Landsat LAI
	Assessment of Tier I big leaf modeling completed; models reparameterized	Wynne and Thomas	Burkhart, Amateis, Musy, Gopalakrishnan, Nemani, Coops, Teskey, postdoc	Tier I data

Quarter	Task	People Responsible	People Helping	Resources Needed
Quarter 3 (9/1/12-11/30/12)	Climate scenarios added to Ames System Regional baseline big leaf models runs using Landsat LAI (3-PGS and CASA)	Wynne	Nemani, Boyles, Thomas, Burkhart, Amateis, Musy, Gopalakrishnan, Coops, Teskey, Wang, Aim 1 ecophysiology group	
Quarter 3 (9/1/12-11/30/12)	Improved process model (3-PG) parameterization from network measurements	Wynne, Thomas, Teskey		Tier I data, personnel resources
Quarter 4 (12/1/12-2/28/13)	Completed prototype of growth and yield components; start of scale-up	Burkhart	Wynne, Amateis, Gopalakrishnan, postdoc	

Aim 2 Members

Name	Institution	Role	E-mail address
Randy Wynne	Virginia Tech	Co-PI; Aim 2 Leader	wynne@vt.edu
Steve McNulty	North Carolina State University/ USDA Forest Service	Co-PI; Aim 2 Leader	steve_mcnulty@ncsu.edu
Ryan Boyles	State Climate Office of North Carolina	Co-PI; Aim 2 Member	ryan_boyles@ncsu.edu
Harold Burkhart	Virginia Tech	Co-PI; Aim 2 Member	burkhart@vt.edu
Tom Byram	Texas A&M University	Co-PI; Aim 2 Member	t-byram@tamu.edu
Wendell Cropper	University of Florida	Co-PI; Aim 2 Member	wcropper@ufl.edu
J.-C. Domec	North Carolina State University	Co-PI; Aim 2 Member	jdomec@ncsu.edu
Francisco Escobedo	University of Florida	Co-PI; Aim 2 Member	fescobed@ufl.edu
Tom Fox	Virginia Tech	Co-PI; Aim 2 Member; Mitigation Integration Leader	trfox@vt.edu
Sabine Grunwald	University of Florida	Co-PI; Aim 2 Member	sabgru@ufl.edu
Mike Kane	University of Georgia	Co-PI; Aim 2 Member	mkane@warnell.uga.edu
Tim Martin	University of Florida	Project Director; Aim 2 Member	tamartin@ufl.edu
Steve McKeand	North Carolina State University	Co-PI; Aim 2 Member	steve_mckeand@ncsu.edu
Asko Noormets	North Carolina State University	Co-PI; Aim 2 Member	anoormets@gmail.com
John Nowak	U.S. Forest Service	Co-PI; Aim 2 Member	jnowak@ncsu.edu
Jose Stape	North Carolina State University	Co-PI; Aim 2 Member	jlstape@ncsu.edu
Ge Sun	North Carolina State University	Co-PI; Aim 2 Member	ge_sun@ncsu.edu
Robert Teskey	University of Georgia	Co-PI; Aim 2 Member	rteskey@uga.edu
Valerie Thomas	Virginia Tech	Co-PI; Aim 2 Member	thomasv@vt.edu
Nilesh Timilsina	University of Florida	Postdoc; Aim 2 Member	nilesht@ufl.edu

EXECUTIVE SUMMARY

The overall objective of the genetics and breeding group (Aim 3) is to help growers understand where to plant southern pine seed sources given future climate scenarios and identify genes controlling traits such as growth, nitrogen responsiveness, cold hardiness, water usage, and resistance to southern pine beetle and fungal diseases. Aim 3 research will enable future tree breeding strategies and deliver deployment guidelines for genotypes suited for varied climatic conditions to maximize resilience and reduce adverse impacts of climate change on loblolly pine productivity. Aim 3 is employing two general strategies to fulfill these objectives.

The first strategy is to refine deployment guidelines using a uniform response function (URF) approach which models growth performance corrected for weather at the progeny test site and at the source of origin for the select trees. The three pine breeding cooperatives involved in PINEMAP have each selected a set of progeny tests appropriate for this analysis and have developed databases with the locations for all progeny tests and select tree families. In total, these analyses include over 500 genetic families evaluated at over 50 locations across the loblolly pine range.

The second strategy is to genotype as many trees from relevant tests as possible to identify genes under selective pressure. To meet this objective, four alternative genotyping methods are being compared for efficiency and cost effectiveness: Agilent's Sure Select Target Enrichment System; RAD-seq libraries as described by Baird *et al.* (2008); the genotyping-by-sequencing procedure reported by Elshire *et al.* (2011); and DArT-seq libraries as described by Sansaloni *et al.* (2011). Plant material on which to conduct these comparisons has been distributed and DNA extraction and genotyping is currently in progress at Texas A&M University, North Carolina State University, University of Florida, and Virginia Tech.

Year 2 activities will continue development of both strategies. Weather variables will be selected and tested in mixed model analysis to define the URF. In addition, the group will work with Aim 6 researchers to develop a design for the web-based Decision Support System tool that will eventually be used to convey this information to the public and policy makers. Initial genotyping will be completed and the four alternatives will be evaluated for cost, recovery of single nucleotide polymorphisms (SNPs), the ability to distinguish paralogous variants from allelic variants, and suitability for high-throughput genotyping of field test populations. Appropriate populations for sequencing will be sampled and genotyping will begin in earnest. In addition, ongoing collection of phenotypic data for cold tolerance and bud phenology, insect and disease resistance, and response to fertilizer will continue.

OUTCOMES/IMPACTS

Aim 3 activities will contribute to project-level outcomes and impacts by providing a genetic deployment tool necessary for stakeholders to make sound genetic deployment decisions under changing climatic conditions and by discovering genes and markers associated with important mitigation and adaptation traits that can be incorporated into future breeding programs. Aim 3 will work closely with Aims 1 and 2 to provide input and benefit from insights gleaned from the stand-level studies and modeling to make tree improvement more efficient. Simultaneously, knowledge of traits varying at the gene level should contribute to the ecophysiology studies.

OUTPUTS

During year 1, Aim 3 contributed a number of outputs that advanced the overall project goals and objectives.

- To determine appropriate genome reduction methods for genotyping-by-sequencing, Aim 3 completed the following activities:
 1. Established a bioinformatics server dedicated to the genetic study and analysis of nucleotide data generated by the project; installed Agilent Genomics Workbench 6.5 for Agilent Sure Select Target Gene Enrichment System.
 2. Obtained 35,550 unigene sequences and partitioned for probe design.
 3. Designed and began synthesis of oligonucleotide hybridization probes.
 4. Conducted pilot scale experiment to test genotyping-by-sequencing (Elshire *et al.*, PLoS One 6(5): e19379, 2011).
 5. Obtained appropriate material for DNA extraction and exploring complementary novel method for genome reduction and genotyping-by-sequencing.
 6. Germinated seed, harvested megagametophytes, and extracted haploid DNA for tests of genotyping methods and captured megagametophytes for genomic DNA isolation.

- The following paper was submitted and is in review:

Aspinwall, M.J., S.E. McKeand, and J.S. King. 2012. Estimates of total volume production and carbon sequestration from 40 years of planting genetically improved loblolly pine across the Southeast United States. *Forest Science*, in review.

- Presentations regarding the PINEMAP project were given to groups representing tree improvement practitioners, industry foresters, and family forest owners.
 - A presentation was given by Tim Martin at the April 2011 Cooperative Forest Genetics Research Program annual meeting. Twenty people attended this meeting.
 - A presentation was given by Ross Whetten at the November 2011 Cooperative Tree Improvement Program meeting. Thirty people attended this meeting.
 - A presentation was given by Tom Byram at the “Drought Impacts to Forestlands and Where We Are Going?” symposium, February 8, 2012, in Diboll, Texas. One hundred and forty people attended this meeting.
 - A presentation was given by Tom Byram at the May 2011 Western Gulf Forest Tree Improvement Program Contact meeting. Thirty people attended this meeting.

MILESTONES AND DELIVERABLES

The first overarching Aim 3 goal is to develop new, dynamic genetic deployment guidelines that take into account future predicted climate. Seed deployment decisions are crucial for achieving high productivity and depend on matching genetic material to planting environments. Current deployment guidelines for southern pines (Schmidting 2001) are based primarily on survival and growth data from the Southwide Southern Pine Seed Source Study (SSPSSS) conducted from 1950 to the 1980s with wild seed under historical weather conditions. In these guidelines, minimum winter temperature is a key factor with both benefit and risk of moving southern or coastal material northward or inland to colder environments (Schmidting 1994, Schmidting 1997). Since the SSPSSS, the tree improvement cooperatives have conducted more extensive, large-scale provenance, family, and clone tests across the physiographic regions (e.g., Sierra-Lucero *et al.* 2002). Provenance trials have demonstrated that loblolly pine from the East grows faster than the interior western material, which is better adapted to a more continental climate with more extreme temperatures and precipitation. This knowledge has led to widespread planting of field-tested Atlantic Coastal Plain families on industry lands in Arkansas, Mississippi, and Oklahoma rather than locally adapted stock (Lambeth *et al.* 2005).

The best planting decisions are based on growth and survival data obtained from genetic tests that are 10-20 years old. Such information, however, is available for only a limited set of environments, and the impacts of changing climate during the rotation are rarely taken into account. Thus, our goal is to inform future deployment decisions with projected climate change scenarios taking into account uncertainty and risk introduced by performance instability. To accomplish this goal, available growth, survival, genetic, and environmental data from our participants’ and cooperators’ provenance, family, and clone trials is being used to parameterize uniform response functions (Wang *et al.* 2010). We

will integrate response functions with geospatially specific climatic predictions in a dynamic model to estimate the relative productivity and adaptation of genetic material to specific climatic conditions analogous to that developed for Douglas fir (Howe *et al.* 2010). This analysis will be conducted by all three tree improvement cooperatives and climatologists to provide guidance for seed deployment. Work is currently underway to develop the uniform response functions using provenance trial data. Aim 3 colleagues have determined latitude and longitude for the progeny tests and county centroids for the family origins and conducted preliminary development of mixed model analysis using ASReml software (refer to Box 3a).

The second overarching Aim 3 goal is to analyze genetics of breeding and natural populations to discover alleles in genes controlling important adaptation and mitigation traits that enable future tree breeding strategies. Seed sources of loblolly pine differ in growth rate, drought and cold tolerance, and insect and fungal resistance (Wells & Wakeley 1966, Wells 1983, Schmidting 1994, Schmidting 2007). Pine productivity and adaptive traits are controlled by many genes, but their number and identity are unknown (Gonzalez-Martinez *et al.* 2006, Neale & Ingvarsson 2008). We will investigate the genetic basis of these traits in loblolly pine by conducting linkage and association mapping (Myles *et al.* 2009, Myles *et al.* 2010) to identify alleles that can be screened in breeding populations, therefore helping to accelerate improvement of productivity and adaptive traits. We expect to identify alleles in genes controlling growth, nitrogen responsiveness, cold hardiness, water usage, and resistance to southern pine beetle and fungal diseases. Of particular interest are alleles that influence adaptive traits because these will enable screens of fast-growing material in breeding programs for adaptability to changing pest, disease, and climate conditions.

Progress has been made in determining appropriate genome reduction methods for genotyping-by-sequencing. Specifically, during year 1, Aim 3 completed the following activities:

1. Established a bioinformatics server dedicated to the genetic study and analysis of nucleotide data generated by the project; installed Agilent Genomics Workbench 6.5 for Agilent Sure Select Target Gene Enrichment System.
2. Obtained 35,550 unigene sequences and partitioned for probe design.
3. Designed and began synthesis of oligonucleotide hybridization probes.
4. Conducted pilot scale experiment to test genotyping-by-sequencing (Elshire *et al.*, PLoS One 6(5): e19379, 2011).
5. Obtained appropriate material for DNA extraction and exploring complementary novel method for genome reduction and genotyping-by-sequencing.
6. Germinated seed, harvested megagametophytes, and extracted haploid DNA for tests of genotyping methods and captured megagametophytes for genomic DNA isolation.

Box 3a. Analyzing responses of diverse loblolly pine genotypes to weather and climate

To understand how different genotypes respond to climate, Aim 3 is using a uniform response function (URF) approach which models performance corrected for the weather at the progeny test site and climate at the source of origin for the select trees. The three tree improvement cooperatives involved in PINEMAP have each selected a set of progeny tests appropriate for this analysis and have developed databases with the locations for all progeny tests and select tree families. For the western portion of the region, the Western Gulf Forest Tree Improvement Program will analyze data from two series of tests (tags labeled “3” in Figure 3a). Each series evaluated 20-25 select tree families both within and outside their region of origin. For the central part of the region, the North Carolina State University Cooperative Tree Improvement Program will analyze data from a series of tests planted across the region (tags labeled “1” in Figure 3a) involving 20 families from each of seven regions (140 families total) planted at each of the sites. The Cooperative Forest Genetics Research Program at the University of Florida will analyze data from tests of 341 families from four different coastal provenances planted in the coastal region (tags labeled “2” in Figure 3a).

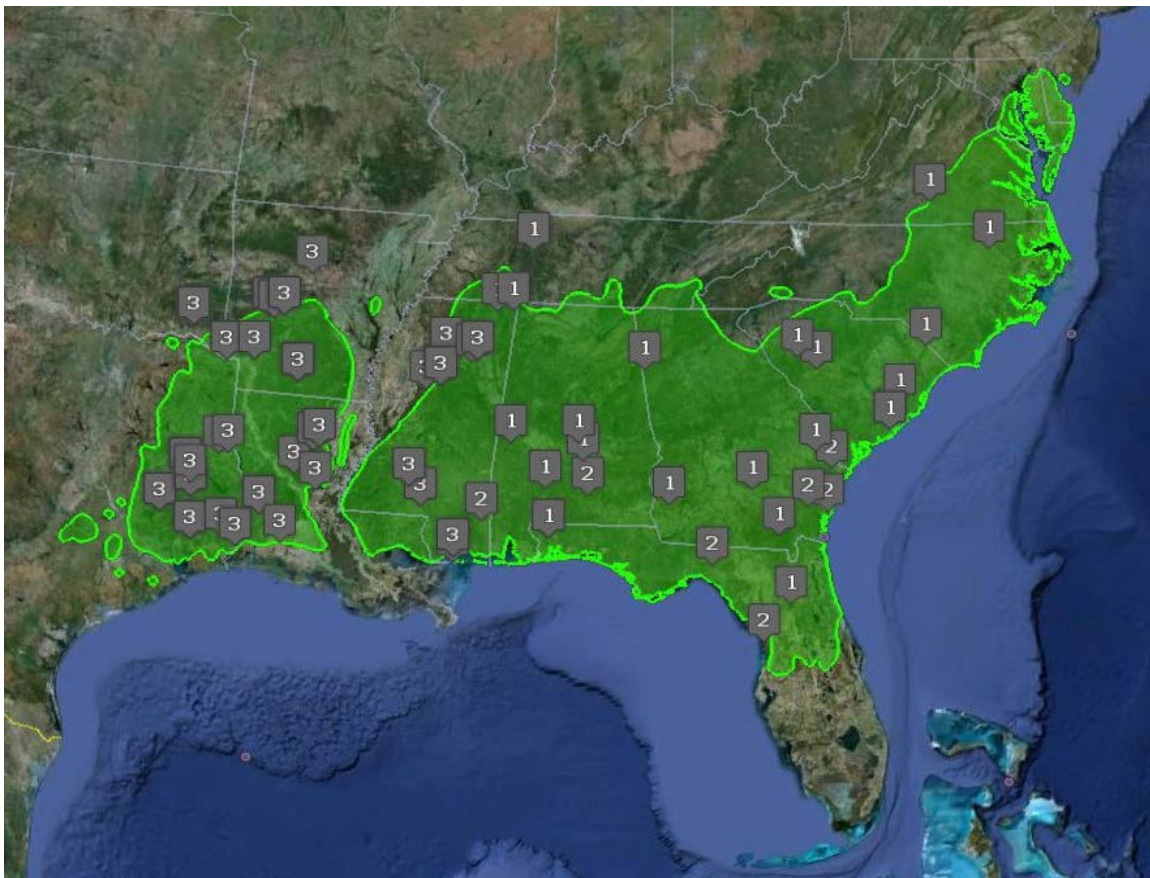


Figure 3a. Tags labeled “1” denote locations of North Carolina State University Cooperative Tree Improvement Program provenance tests; tags labeled “2” denote locations of Cooperative Forest Genetics Research Program provenance tests; and tags labeled “3” denote locations of Western Gulf Forest Tree Improvement Program provenance tests.

Remote sensing image from Google Earth; range map from USDA Forest Service.

BROAD IMPACTS

The future productivity and resiliency of southern pine forests depends on optimal deployment of seedlings to sites. To do this we need both a perspective on how trees perform in different environments and the genetic variation that is tempering that performance. The development of the URF meets the overall Aim 3 objective of quantifying how different individuals perform in different environments. The genotyping that will occur under the second strategy will aid in the discovery alleles in genes controlling important adaptation and mitigation traits that enable future tree breeding strategies.

TRAINING

The following list summarizes graduate/undergraduate students and Postdoctoral Associates involved in Aim 3 research.

- Rajesh Bawa, Ph.D. student, Virginia Tech. Rajesh is conducting Phenotyping of adaptive traits (i.e., cold hardiness and bud phenology) in the loblolly pine progeny trials and working with universities across region to conduct genome-wide association mapping between these traits and the re-sequencing data.
- Alfredo Farjat, Ph.D. student, North Carolina State University. Alfredo is carrying out joint analysis of progeny test data and climate data for the Cooperative Tree Improvement Program.
- Tomasz Koralewski, Postdoctoral Associate, Texas A&M University. Dr. Koralewski is building a location database for the progeny tests and the parents represented in those progeny tests that can be linked to climatic data. This database will form the backbone of the URF analysis to optimize seedling deployment.
- Mengmeng Lu, Ph.D. student, Texas A&M University. Mengmeng is evaluating efficiency of Agilent SureSelect target gene enrichment system for Illumina GAI and HiSeq high-probe design using the Agilent eArray tool and the most recent and comprehensive unigene set consisting of 42077 sequences representing individual genes expressed in loblolly pine.
- Benjamin Rusche, undergraduate student, North Carolina State University. Benjamin is working on the pilot scale experiment to test genotyping-by-sequencing as a cost-effective means of genotyping the experimental populations.
- Jianxing Zhang, Ph.D. student, University of Florida. Jianxing is conducting analyses linking progeny test performance with climatic data and developing a database for the URF analysis to optimize seedling deployment.

COLLABORATIONS AND “INTEGRATED” KNOWLEDGE DEVELOPED

A more precise understanding of how tree growth and vigor are impacted by site and weather interaction from available progeny tests will help inform the ecophysiology and modeling groups as to important genetic traits. Tree improvement will in turn be made more efficient and effective through insights from the ecophysiology and modeling groups.

In addition, contacts to seek opportunities for synergy have been made with two other NIFA CAP projects: the Southeast Partnership for Integrated Biomass Supply Systems (IBSS) led by Tim Rials at University of Tennessee-Knoxville which includes southern pines as a biomass resource and the Triticeae CAP (T-CAP) wheat and barley climate change project that includes genotyping-by-sequencing as a research and breeding tool.

PLAN-OF-WORK FOR YEAR 2

The Aim 3 plan-of-work for year 2 (March 1, 2012 - February 28, 2013) (Table 3a) summarizes tasks and activities to be conducted/completed each quarter during year 2 to ensure delivery of overarching Aim 3 milestones and deliverables.

Table 3a. This work plan summarizes Aim 3 quarterly tasks and activities for year 2.

Parameterize Uniform Response Function (URF)		
Quarter	Task/Activity	People Responsible
Quarter 1 (3/1/12- 5/31/12)	Obtain appropriate weather data for each of the entries in the progeny test database	Tree Improvement Cooperatives with help of USDA Forest Service Climate Specialists and State Climatologists
	Agree to standardized traits for analysis and a methodology for stratifying locations	Tree Improvement Cooperatives
Quarter 3 (9/1/12- 11/30/12)	Develop mixed model analysis for URF	Tree Improvement Cooperatives
Quarter 4 (12/1/12- 2/28/13)	Develop outline for design of the PINEMAP Decision Support System (DSS) Deployment Tool	Tree Improvement Cooperatives
Compare and contrast three methods of Next Generation Sequencing		
Quarter 1 (3/1/12- 5/31/12)	Continue Phenotyping for: <ol style="list-style-type: none"> 1. Cold tolerance and bud phenology 2. Insect and disease resistance 3. Response to fertilizer 	

Quarter	Task/Activity	People Responsible
Quarter 2 (6/1/12- 8/31/12)	Continue Phenotyping for insect and disease resistance	
	Reduction of Genome Complexity for generating molecular markers. <ol style="list-style-type: none"> 1. Test of genotyping-by-sequencing protocol and data analysis pipeline reported by Elshire <i>et al.</i>, PLOS One 6(5): e19379, 2011 2. SureSelect 3. DaRT libraries 4. RAD-seq libraries 	R. Whetten K. Krutovsky G. Peter/J. Davis J. Holliday
Quarter 3-4 (9/1/12- 2/28/13)	Compare methods for: <ol style="list-style-type: none"> 1. Cost per sample 2. Recovery of polymorphic SNPs 3. Ability to distinguish paralogous variants from allelic variants 4. Suitability for high-throughput sequencing 	
Quarter 4 (12/1/12- 2/28/13)	Continue Phenotyping for response to fertilizer.	

Aim 3 Members

Name	Institution	Role	E-mail address
Tom Byram	Texas A&M University	Co-PI; Aim 3 Leader	t-byram@tamu.edu
Ross Whetten	North Carolina State University	Co-PI; Aim 3 Leader	rosswhet@ncsu.edu
John Davis	University of Florida	Co-PI; Aim 3 Member	jmdavis@ufl.edu
Jason Holliday	Virginia Tech	Co-PI; Aim 3 Member	jah1@vt.edu
Fikret Isik	North Carolina State University	Co-PI; Aim 3 Member	fikret_isik@ncsu.edu
Kurt Johnsen	U.S. Forest Service	Co-PI; Aim 3 Member	kjohnsen@fs.fed.us
Tomasz Koralewski	Texas A&M University	Postdoc; Aim 3 Member	tkoral@tamu.edu
Kostya Krutovsky	Texas A&M University	Co-PI; Aim 3 Member	k-krutovsky@tamu.edu
Carol Loopstra	Texas A&M University	Co-PI; Aim 3 Member	c-loopstra@tamu.edu
Steve McKeand	North Carolina State University	Co-PI; Aim 3 Member	steve_mckeand@ncsu.edu
Dana Nelson	U.S. Forest Service	Co-PI; Aim 3 Member	dananelson@fs.fed.us
Gary Peter	University of Florida	Co-PI; Aim 3 Member; Adaptation Integration Leader	gfpeter@ufl.edu



Year 1 Annual Report Aim 4 (Economics and Policy)

EXECUTIVE SUMMARY

The overall objective of the economics and policy group (Aim 4) is to conduct comprehensive life cycle analyses of regional forest management systems and multi-scale policy and economic analysis of market and non-market forest benefits and services to provide the framework necessary to guide land manager decision-making in future management and climatic conditions. These analyses will be used to evaluate regional tradeoffs and interactions among policy, climate scenarios, carbon/water/nutrient/energy footprints, forest management, and genetic deployment and to assess private landowner adoption of alternative approaches.

During year 1, Aim 4 completed three economic and policy assessments including a comprehensive literature review of existing policies and incentive programs that may have implications for carbon sequestration in southern pine plantations; a literature review on landowners' adaptation and mitigation strategies; and an assessment of the regional economic impact of business-as-usual assumptions using the Sub-regional Timber Supply Model—this analysis helped us establish a basis for evaluating economic impacts under different climate change and disturbance scenarios.

Aim 4 also established statistical relationships between climate variables and southern pine beetle (SPB) infestation risk and collected data for analyzing the role of adaptation in mitigating SPB outbreaks; estimated global warming impact of intensively managed loblolly pine plantations using life cycle assessment (LCA); developed a model for determining economic returns of loblolly pine plantations with carbon payments and under the risk of disturbances; implemented a survey in Florida to identify family forest landowners' willingness to accept carbon offset contracts; and collected wildfire data for modeling climate change impact on forest fire in cooperation with the USDA Forest Service.

In year 2, we will focus on several key tasks. First, we will design and implement a regional landowner survey. Second, we will write a review summarizing planted pine ecosystem functions and goods and services and update the review on carbon and climate change related policies and programs. Third, we will incorporate SPB risk estimates into the Sub-regional Timber Supply Model to evaluate economic impact. Fourth, we will expand the LCA to evaluate greenhouse gas consequences of forest mitigation activities and forest products. Fifth, we will develop a model to estimate the economic returns of loblolly pine plantations under climate change and with carbon payments and disturbance risk. Finally, we will strive to maximize integration of project activities within our Aim and with other Aims to develop effective and sensible policy and management recommendations for mitigating and adapting to climate change.

OUTCOMES/IMPACTS

Aim 4 activities contribute to project-level outcomes and impacts by providing the economic analysis that will underpin land manager decision-making in future management and climatic conditions. From the stand- to the regional-scale, economic impacts of disturbance, climate, management, and policy alternatives must form the basis of any viable and sustainable management change. Policy analysis will enable PINEMAP stakeholders to better assess management responses to future policy changes. Finally, the life cycle assessment (LCA) carried out in this Aim will provide the framework necessary to analyze the stand to regional carbon sequestration implications of changes in management regimes.

OUTPUTS

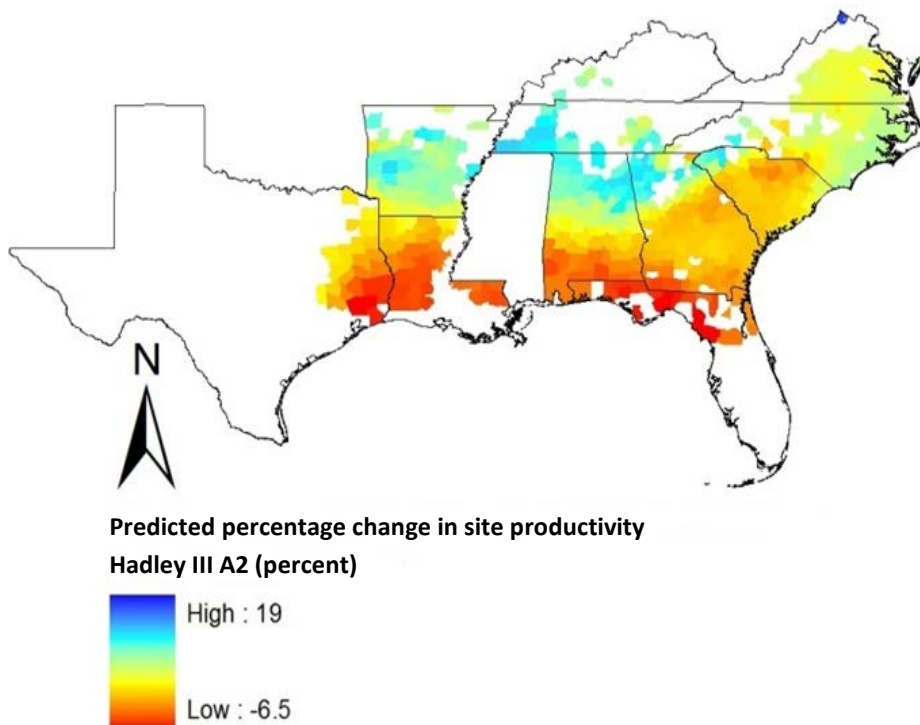
During year 1, Aim 4 contributed a number of outputs that advanced the overall project goals and objectives.

- Completion of a literature review on and evaluation and synthesis of existing policies and incentive programs that may have implications for carbon sequestration in southern pine plantations.
- Completion of a literature review on landowners' mitigation and adaptation strategies which will lead to and assist with the design of a landowner survey.
- Collection and modeling of data to identify relationships between southern pine beetle (SPB) outbreaks and climate variables. The climate change scenarios data which are being employed for project-wide modeling are being used to design simulation scenarios for assessing regional economic impacts via the Sub-regional Timber Supply Model. Additional data collection and modeling efforts are underway to evaluate the impacts of adaptation on alleviating the damage of SPB outbreaks.
- Collection and compilation of regional fire data for modeling, in collaboration with the USDA Forest Service.
- Assessment of the regional economic impacts under business-as-usual assumptions using the Sub-regional Timber Supply Model.
- Application of the LCA approach to evaluate emissions from various silvicultural activities.
- Incorporation of carbon payments/penalties to evaluate economic returns from slash pine plantations in the southern U.S.
- Development of a stand-level model to quantify net expected economic rents for landowners under the risk of catastrophic disturbances associated with future climate change such as increased hurricane, fire, or pest occurrences.

- The following papers were published or are currently in review/revision:
 - Abt, K., R. Abt, and C. Galik. Effect of bioenergy demands and supply response on markets, carbon and land use. *Forest Science*, in revision.
 - Huang, J., B. Abt., G. Kindermann, and S. Ghosh. 2011. Empirical analysis of climate change impact on loblolly pine plantations in the southern United States. *Natural Resource Modeling* 24(4):445-476. doi: 10.1111/j.1939-7445.2011.00098.x. (refer to Box 4a)
 - Susaeta, A.I., C.A. Gonzalez-Benecke, D.R. Carter, T.A. Martin, and E.J. Jokela. Economical sustainability of pinestraw raking in slash pine stands in the southeastern United States. *Ecological Economics*, in review.
 - Susaeta, A.I., D.R. Carter, S.J. Change, and D.C. Adams. The impact of hurricane risk on optimal forest management in southern U.S. pine plantations: Application of a generalized Reed model. *Forest Science*, in review. (refer to Box 4b)
- Aim 4 members presented at two national conferences as described below.
 - *The Value of Water Quality Protection Programs: A Meta-Analysis* (poster), M. Kreye, D.C. Adams, T. Borisova, and F. Escobedo, November 2- 6, 2011, Society of American Foresters National Convention, Honolulu, HI. The audience was composed of research, Extension, and education professionals and students; this poster increased awareness of policy design mechanisms and value related to co-generated ecosystem services from carbon programs.
 - *Valuing nutrient pollution prevention in well-conserved aquatic systems: A meta-analysis*, M. Kreye, D.C. Adams, T. Borisova and F.J. Escobedo, November 1-4, 2011, 38th Natural Areas Conference, Tallahassee, FL. The audience was composed of research, Extension, and education professionals and students; this poster increased awareness of policy design mechanisms and value related to co-generated ecosystem services from carbon programs.

Box 4a. Empirical analysis of climate change impact on loblolly pine plantations in the southern U.S.

This study used non-parametric methods to estimate climate influence on loblolly pine growth and yield in the southeastern states. The technique showed promise by capturing a statistically significant non-linear relationship between climate and yield using two different growth and yield models. By combining the models with potential future climate change scenarios, we found considerable spatial variation in potential future growth and productivity change on loblolly pine plantations in the South. This simulation will form the basis of future analyses of economic decisionmaking under altered climate scenarios.



Box 4b. The impact of hurricane risk on optimal forest management in southern U.S. pine plantations: Application of a generalized Reed model

Hurricanes are considered one of the main natural disturbances to forest ecosystems in the southern U.S. The frequency—the interval time between each hurricane, also known as the return period—of these catastrophic events in southern states is expected to increase. Hurricanes have the potential to cause substantial economic harm to forest landowners, and it is important to understand what changes in management might mitigate this altered risk. Return intervals can be defined based on the annual probability of return. For example, if the return period for a hurricane with certain intensity is 50 years, it implies that this type hurricane will pass two times in a period of 100 years or the probability of hurricane risk is 0.02 (1/50). We assessed the impact of hurricane return period on the optimal harvesting decision for forest landowners and found that increased current risk vs. increased future risk altered optimal harvest age. If we assume a typical harvest age for southern pines of 22 years, and the current hurricane risk increases to 0.04 (a return period of 25 years for hurricane of that intensity), a landowner should harvest before the stand reaches 22 years to avoid economic losses. On the other hand, future economic losses for landowners are associated with increased future hurricane risk of 0.04. Thus, a forest landowner should postpone the current harvest age of 22 years in order to offset the lower future economic returns associated with future increases in hurricane risk.

MILESTONES AND DELIVERABLES

During year 1, Aim 4 completed a variety of economic and policy assessments including assessments of policies and programs that may affect carbon mitigation in planted pine forests; landowners' mitigation and adaptation strategies; regional market impacts based on business-as-usual assumptions; and life cycle inventory for key physiographic regions. Progress on each of these assessments is summarized below.

A literature review was completed to identify and compile existing policies and incentive programs that may have implications for carbon sequestration in southern pine plantations. The review includes details of non-governmental programs (e.g., Climate Action Reserve) and will be expanded to include regional markets (e.g., Western Climate Initiative) and federal and state programs (e.g., Conservation Reserve Program).

A literature review was completed on landowners' mitigation and adaptation strategies, which will lead to and assist with the design of a regionwide landowner survey. Additionally, a survey instrument to estimate family forest landowners' willingness to accept carbon offset contracts using conjoint choice and best-worst valuation methods was developed and pretested. This survey is ready for distribution to family forest landowners in Florida.

To assess economic losses from altered disturbance risks, the relationships between southern pine beetle (SPB) outbreaks and climate variables were identified. The climate change scenario data which are being employed for project-wide modeling are being used to design simulation scenarios for assessing regional economic impacts via the Sub-regional Timber Supply Model. Additional data collection and modeling efforts are underway to evaluate the impacts of adaptation on alleviating the damage of SPB outbreaks. Moreover, Aim 4 is collaborating with the USDA Forest Service to collect and compile regional fire data for modeling. The Sub-regional Timber Supply Model was employed to assess the regional economic impacts under business-as-usual assumptions.

Aim 4 evaluated carbon emissions from various silvicultural activities using a detailed life cycle assessment approach. We have also incorporated carbon payments/penalties to evaluate economic returns from slash pine plantations in the southern U.S.

To facilitate progress toward a net present value (NPV) analysis and assessment of regional market impacts of adaptive management impacts, Aim 4 researchers developed a stand-level model to quantify net expected economic rents for landowners under the risk of catastrophic disturbances associated with future climate change such as increased hurricane, fire, or pest occurrences. Along with this model, we are developing a generalized version of the Faustmann model that includes payments/penalties for carbon sequestration/emissions for plantations with varying cutting cycles under different climate change scenarios.

BROAD IMPACTS

The current work by Aim 4 addresses several fundamental economic and policy aspects related to southern pine forests under potential climate change scenarios. The results from our LCA and regional economic impact analysis under the business-as-usual assumptions have established a basis to evaluate the impacts of mitigation and adaptation options. Broad impacts of Aim 4 research efforts will become more evident and significant as we integrate our LCA, economic and risk analyses, landowner studies, and policy evaluation. Such integration is likely to develop more effective and sensible policy and management recommendations for mitigating and adapting to climate change.

TRAINING

The following list summarizes graduate/undergraduate students and Postdoctoral Associates involved in Aim 4 research.

- Ernest Dixon, M.S. student, North Carolina State University. Ernest has split responsibilities between Aim 3 (genetics) and Aim 4; he is involved in discussions on market and valuation issues in estimating the benefits of genetic gain or reduction in variability.
- Puskar Khanal, Ph.D. student, Mississippi State University. Puskar's primary research focus is evaluating forest management practices that enhance carbon sequestration in stands and developing a survey instrument to determine small forest landowner's willingness to implement these practices and identify potential incentives that increase carbon sequestration at the stand level.
- Melissa Kreye, Ph.D. student, University of Florida. Melissa completed a literature review on the economic value of forest-based changes in water quality; conducted a meta-analysis of forest-based water quality values; and specified an econometric model that predicts willingness to pay for forest-based water quality. Using a benefit transfer method, she has applied the model to two representative sites.
- Jose Soto, Ph.D. student, University of Florida. Jose is assessing and summarizing competing programs and policies that incentivize carbon sequestration at the local, state, national, and international level. He has also developed, pre-tested, and implemented a survey of non-industrial private forest landowners to determine their willingness to accept payments for carbon offsets based on offset program characteristics. Results of this work will be used to predict participation rates in programs that incentivize changes in land use that increase carbon sequestration and will be integrated in a bioeconomic model of non-market ecosystem services produced under competing approaches for climate change adaptation and mitigation.
- Andres Susaeta, Postdoctoral Associate, University of Florida. Dr. Susaeta has primarily been involved in developing a forest stand-level model to assess expected economic rents for forest landowners under hurricane risks associated with future climate change conditions. He has also played a key role in developing an economic model to analyze carbon sequestration in loblolly pine plantations under various carbon subsidies and tax rates in the context of climate change.

COLLABORATIONS AND “INTEGRATED” KNOWLEDGE DEVELOPED

Aim 4 member Robert Abt is serving on the U.S. Environmental Protection Agency Science Advisory Board (SAB) for biogenic carbon. The SAB for biogenic carbon is tasked with assessing accounting options for biogenic carbon dioxide emissions from stationary sources, including case-by-case analysis of individual source-specific permitting contingent upon the U.S. land use sector’s remaining a “net sink” and differential treatment of feedstock via approaches reflecting feedstock-specific attributes. As a result of his participation in the biogenic carbon SAB, we are identifying valuable connections between PINEMAP research and the EPA carbon accounting framework.

Aim 4 members have been discussing ideas and opportunities for enhancing collaboration and integration within Aim 4 and with other Aims and projects. Such collaborations and opportunities will allow us to integrate the findings from our LCA, economic analyses, disturbance evaluation, landowner surveys, and policy reviews to formulate policy and management recommendations.

PLAN-OF-WORK FOR YEAR 2

The Aim 4 plan-of-work for year 2 (March 1, 2012 - February 28, 2013) (Table 4a) summarizes tasks and activities to be conducted/completed each quarter during year 2 to ensure delivery of overarching Aim 4 milestones and deliverables.

Table 4a. This work plan summarizes Aim 4 quarterly tasks and activities for year 2

Quarter	Task/Activity	People Responsible	Resources needed
Quarter 1 (3/1/12- 5/31/12)	Literature review and summary of ecosystem functions, goods and services	Adams, postdoc	LCA inventory analysis preliminary results
	Literature review and summary of climate change impacts on productivity of southern forestlands	Carter and Susaeta	
	Literature review of impacts of catastrophic events on southern forestlands under climate change conditions	Carter and Susaeta	
Quarter 2 (6/1/12- 8/31/12)	Complete review of pine management literature and commence initial development of landowner survey instrument	Grebner, graduate student	
	Assess the economic impact of climate change in terms of economic rents for forest landowners	Carter and Susaeta	Future productivity map of southern forest (3-PG outcomes) to select the representative zones for the economic modeling
	Compile southern pine beetle data for modeling adaptation	Dwivedi and Gan	

Quarter	Task/Activity	People Responsible	Resources needed
Quarter 3 (9/1/12-11/30/12)	Update summary of policies and programs affecting carbon mitigation; review of SE state programs and markets	Adams, postdoc	
	Complete LCA and the rankings of forest management practices to encourage carbon sequestration	Carter	
	Complete modeling regional market impacts and carbon accounting under the business-as-usual scenario	B. Abt	
	Assess the economic impact of SPB breakouts using the SRTS model	Gan and B. Abt	Predicted change in temperature and precipitation in the South
	Complete survey instrument	Grebner, graduate student	
	Assess the effect of mitigation practices on the economic rents for forest landowners given the increased probability of catastrophic events	Carter and Susaeta	Future productivity map of southern forest (3-PG outcomes) to select the representative zones for the economic modeling
	Complete LCA for forest mitigation activities and final forest products	Carter, Dwivedi, and Susaeta	
Quarter 4 (12/1/12-2/28/13)	Complete model development to gauge carbon sequestration in southern pine forests in light of different climate change scenarios including payments and penalties due to carbon sequestration/ emissions for plantations	Carter and Susaeta	Future productivity map of southern forest (3-PG outcomes) to select the representative zones for the economic modeling
	Compile wildfire data in the South for modeling	K. Abt and Gan	
	Implement survey	Grebner, graduate student	

Aim 4 Members

Name	Institution	Role	E-mail address
Jianbang Gan	Texas A&M University	Co-PI; Aim 4 Leader	j-gan@tamu.edu
Damian Adams	University of Florida	Co-PI; Aim 4 Leader	dcadams@ufl.edu
Karen Abt	U.S. Forest Service	Aim 4 Member	kabt@fs.fed.us
Robert Abt	North Carolina State University	Co-PI; Aim 4 Member	bob_abt@ncsu.edu
Douglas Carter	University of Florida	Co-PI; Aim 4 Member	drcart@ufl.edu
Puneet Dwivedi	Yale University	Aim 4 Member	puneet.dwivedi@yale.edu
Tom Fox	Virginia Tech	Co-PI; Aim 4 Member; Mitigation Integration Leader	trfox@vt.edu
Donald Grebner	Mississippi State University	Co-PI; Aim 4 Member	dgrebner@cfr.msstate.edu
Mike Kane	University of Georgia	Co-PI; Aim 4 Member	mkane@warnell.uga.edu
Gary Peter	University of Florida	Co-PI; Adaptation Integration Leader	gfpeter@ufl.edu
Andres Susaeta	University of Florida	Postdoc; Aim 4 Member	asusaeta@ufl.edu



Year 1 Annual Report Aim 5 (Education)

EXECUTIVE SUMMARY

The overall objectives of the education group (Aim 5) are to transfer research processes and findings to undergraduate and graduate students while building an appreciation for integrated, interdisciplinary research and enable secondary school life science teachers to introduce climate impacts on southern forests to their students. Aim 5 is developing educational resources and training programs to

- convey the value and relevance of southern forests and climate change impacts;
- engage undergraduate interns in research and teaching activities;
- prepare graduate students to address climate change mitigation and adaptation issues and engage in interdisciplinary research;
- contribute to a national educational network in the development and delivery of an inquiry-based high school module that introduces climate change and features select PINEMAP research findings.

During year 1, significant progress was made on Aim 5 projects. The PINEMAP distance graduate course was launched in spring 2012; twenty-three students from 8 institutions are enrolled in the course.

PINEMAP Undergraduate Internship Program announcements were publicized and distributed. Undergraduate students will complete a summer internship with PINEMAP-funded graduate students, enroll in a fall distance course in communication and inquiry-based science education, and develop lessons for secondary school classes. Graduate mentors will help build intern's research skills and work with them on the development and implementation of secondary school lessons.

Aim 5 is partnering with Project Learning Tree (PLT), a national environmental education program, on the development of a secondary module on climate change and southern pine forests. Activities will address how forests affect climate, how variations in climate affect forests, and how people can mitigate climate change with forests and manage forests to adapt to an increasingly variable climate. A logic model and scope and sequence was developed and 6 draft activities were developed and pilot tested. An initial needs assessment was conducted and an Education Advisory Committee was established.

During year 2, Aim 5 will complete a needs assessment for the PLT/PINEMAP Secondary Module, develop and pilot test activities, and obtain input and feedback from the Education Advisory Committee. The Undergraduate Internship Program will select and host the first cohort of interns in summer 2012 and we will conduct evaluation to guide future iterations. Finally, we will evaluate and revise the distance graduate course for a second offering in spring 2013.

OUTCOMES/IMPACTS

Aim 5 activities contribute to project-level outcomes and impacts through educating graduate and undergraduate students, along with high school teachers and students, on climate science, forestry, and interdisciplinary research. The PINEMAP distance graduate course, “Climate and Forests,” is being offered for the first time during the spring 2012 semester (January-May). The course also provides a platform for faculty to interact and better understand the variety of interdisciplinary research, education, and outreach elements within the PINEMAP project. The PINEMAP Undergraduate Internship Program was launched with a request for applications from undergraduates and graduate students interested in mentoring undergraduates. Initial plans and a structure for designing the PLT/PINEMAP Secondary Module were completed.

OUTPUTS

During year 1, Aim 5 contributed a number of outputs that advanced the overall project goals and objectives.

- The first offering of the PINEMAP Distance Graduate Course, “Climate and Forests,” was launched in January 2012.
- PINEMAP Undergraduate Internship Program intern and graduate student mentor announcements and applications were publicized and distributed. Announcements, in addition to internal distribution to PINEMAP collaborators, were posted on southeastern university job boards and distributed through the National Association of University Forest Resources Programs e-mail listserv.
- A survey was sent to 1,024 high school teachers in the Southern Piedmont region of which 324 responses were received. The purpose of the survey was to determine the extent to which teachers are presenting forestry related concepts in their classes (including climate change and carbon sequestration) and to determine which attitudinal, personal, educational, and demographic variables best predict the frequency that teachers present forestry related concepts. This information is being used to inform and guide the development of the PLT/PINEMAP Secondary Module.
- An assessment of existing climate change educational resources was conducted. It suggests that life science teachers have few opportunities to teach about climate and ecosystems, especially with relevant examples to the southeastern U.S. A draft logic model and scope and sequence were prepared to guide the development of the PLT/PINEMAP Secondary Module.
- Graduate students in fall 2011 Environmental Education Program Development course at the University of Florida interviewed high school teachers and developed a survey to assess needs and perspectives on climate change. A revision of this survey is underway for broader implementation with secondary science teachers in the southeastern U.S.

- Six draft PLT/PINEMAP Secondary Module activities were developed and pilot tested in high school classrooms.
- The PLT/PINEMAP Secondary Module Education Advisory Committee was established. The first meeting was conducted in January 2012; the committee will continue to meet on a bimonthly basis. Twenty-four educators have joined the committee, representing a broad range of climate, forestry, education, curriculum development, and training expertise.
- The following paper was accepted and is currently in press:

Monroe, M. C. 2012. Enhancing both Cooperative Extension and national environmental education resources. *Journal of Extension*, in press.

- Aim 5 members presented at 2 national conferences and two other venues as described below.
 - *Unraveling public perceptions of climate change* (poster). Martha C. Monroe, May 16-18, 2011, National Workshop on Climate and Forests, Northern Arizona University, Flagstaff, AZ. Two-hundred forestry researchers and Extension agents attended this workshop. This poster was requested by five attendees based on the information it provides. It was also submitted to the eXtension Climate and Forests Community of Practice.
 - *High school science teachers and forestry education: How are they connected?* (poster), Shannon M. Fowler, John F. Munsell, and John R. Seiler, November 2-6, 2011, Society of American Foresters National Convention, Honolulu, HI.
 - An introduction to PINEMAP and the PLT Secondary Module was delivered by teleconference to the PLT state coordinators from southern states in August 2011 by Martha Monroe, Tim Martin, and Annie Oxarart.
 - An introduction to PINEMAP and the relevance of forests and climate in the South was conveyed to students enrolled in Environmental Education Program Development course at the University of Florida in September 2011 by Tim Martin and Martha Monroe.

MILESTONES AND DELIVERABLES

Aim 5 activities seek to transfer research processes and findings to undergraduate and graduate students as well as secondary education teachers and students. Aim 5 is developing and implementing a distance graduate course on climate and forests and interdisciplinary research, an undergraduate internship/graduate mentor program involving research and education/outreach efforts, and a high school module on climate and forests. Progress on these activities during year 1 is summarized below.

Distance Graduate Course

The PINEMAP distance graduate course, “Climate and Forests,” is being implemented during the spring 2012 semester (January-May). During year 1, a team of faculty developed the course syllabus (refer to Appendix 1) and goals and objectives (Box 5a) and launched the course web site (Figure 5a).

Live webinars spanning a range of PINEMAP research topics are conducted throughout the semester. In addition, students are required to complete two assignments during the course, a research-focused assignment and an interdisciplinary outreach assignment. For the research assignment, students in each PINEMAP Aim group will work with one or two faculty members to better understand the literature and research questions in their Aim. This exploration should enable any student to comfortably explain what we already know, why the research is proposed, and what questions the research is designed to answer. Students will explain their Aim research to the other students via a video, web site, readings, slide presentation, or other format of choice. For the interdisciplinary outreach assignment, students are assigned to four groups, each with an Extension faculty leader. Together they will identify a target audience of interest (such as private family landowners, youth, teachers, an undergraduate student club, or research cooperative members), understand their needs for information and skills, revise or develop a program or product, and implement and evaluate it. The vision is to explore the extension program development process, albeit on a small scale.

The graduate course will be evaluated via student and faculty surveys and discussions at the end of the semester. The evaluation results will be compiled, reviewed, and used during the summer and fall of 2012 to plan and revise the course for the second offering in spring of 2013. In addition, graduate students from the first course will be involved in determining how they would like to continue working together on interdisciplinary research questions and activities throughout the course of the PINEMAP project.

Twenty-three students from 8 universities enrolled in the first PINEMAP distance graduate course. In addition, an interdisciplinary team of 15 PINEMAP Co-PIs are assisting with course instruction and assignment coordination.

Box 5a. PINEMAP Distance Graduate Course Goals and Objectives

Course Goals

- Prepare graduate students to address climate change mitigation and adaptation issues in southern pine forests.
- Facilitate greater levels of integration by encouraging students to engage in the processes designed to enhance communication, cooperation, and collaboration among disciplines and across research, education, and extension functions.
- Build interdisciplinary research, education, and outreach capacity.

Course Objectives

- Increase understanding of climate, climate change, carbon cycle, carbon sequestration, and environmental controls on pine productivity.
- Increase understanding of the policy and economic realities driving regional pine forest management.
- Increase understanding of education and communication principles as applied to effective outreach strategies, the process of program development and evaluation, and the strategies used by Cooperative Extension to support changes in behavior.
- Gain an appreciation for the breadth and complexity of the PINEMAP project.
- Work with others outside of own research discipline to engage in education and extension aspects of the project.
- Be able to articulate the benefits and barriers to interdisciplinary research.

The screenshot displays the PINEMAP Education Portal in a Windows Internet Explorer browser. The page title is "The PineMap Education Portal" and the URL is "http://p.edcourse.pinemap.org/student/board.php?thread=22". The page features a navigation menu with "Course Content", "Discussion Board", and "Class Roster". The "Discussion Board" section is active, showing a thread titled "Jan. 24: The Impact of climate change on forest ecosystems". The thread includes four posts from participants: Jessica Ireland (Site Administrator), Adam Maggard (Student), Daniel Markewitz (Instructor), and Ranjith Copalakrishnan (Student). The posts discuss the impact of climate change on forest ecosystems, specifically focusing on carbon storage in wood products and the decomposition of wood products. The page also includes a "post to this thread" button and a "reply to this post" button for each post.

Figure 5a. Screenshot of the graduate course web site (PINEMAP Education Portal).

Undergraduate Internship Program

The PINEMAP Undergraduate Internship Program will be launched in the summer of 2012 with the first set of graduate student mentors and undergraduate interns announced in the spring. Undergraduate students selected to participate in the program will complete a summer internship with a PINEMAP-funded graduate student mentor in one of the following research disciplines: ecosystem ecology and silviculture, modeling, genetics, economics and policy, education, or extension. Interns will also enroll in a fall distance course in communication and inquiry-based science education and work with classmates and graduate mentors to develop engaging lessons for secondary school life science, biology, or social studies classes. Interns will visit classrooms in their communities to lead these inquiry-based activities. Graduate mentors in the program will learn to be mentors; help build the intern's research skills; and work closely with the intern as they develop secondary school lessons based on the research with which the interns assisted. Graduate students will also help interns develop a poster presentation as part of the fall distance education course on inquiry-based science education. To date, internship program announcements and applications have been publicized and distributed; interns and mentors will be selected in March 2012. Furthermore, the syllabus for the fall distance education course is in development.

Market Program

An internship announcement and call for proposals was developed to provide the details of the internship and the micro-grant, respectively, as well as direct interested individuals to the applications. The intern announcement was distributed in September 2011, both internally to the PINEMAP project-wide e-mail listserv and externally to southeastern natural resource programs and 1890 schools through relevant listservs and contacts. The opportunity was also advertised on multiple university job boards. The call for proposals announcing the graduate student micro-grant was also distributed to the PINEMAP project-wide e-mail listserv. Finally, a page on the PINEMAP web site was developed to host internship and micro grant program announcements, news updates, and application and proposal submission instructions.

Application and Selection Process

Aim 5 staff developed two applications for the program that are linked by research interests (i.e., the 6 PINEMAP Aim groups). The first application is for undergraduate students applying for internships. Undergraduate applicants from any discipline are eligible as long as they have an interest in one of the PINEMAP Aim groups. This specification allows for an interdisciplinary relationship between the graduate student mentor and intern, where each individual can provide a meaningful learning experience for the other. Intern applications include typical resume data, contact information for three professional references, and a 500-word essay regarding interest in a selected Aim research area. Prospective interns also must have a faculty member at their university

sponsor their enrollment in the undergraduate distance course. The second application, a micro-grant proposal, is directed at PINEMAP graduate students who want to be mentors to undergraduate interns. Micro-grant proposals are limited to two pages and include objectives for summer work, a description of the research methods and/or planned analysis, and a summary of skills that the undergraduate intern should possess. Proposals also include a brief description of how the interns' work could be translated into a public school presentation. The application/proposal process was closed in February 2012 at which time the selection process began.

An internship and undergraduate course committee was tasked with reviewing applications and selecting eligible submissions for awards. The committee was comprised of the Intern Program Coordinator, Aim 5 Leaders, and Co-PIs from various Aim groups. Primary selection criteria included strength of the application, academic standing, and the Aim research interest essay. Submissions were reviewed and ranked by committee members and the highest ranking applicants were awarded with an internship. A maximum of 6 summer internship awards will be announced in March 2012.

Graduate students interested in mentoring undergraduate interns submitted micro-grant proposals detailing objectives for intern work, methods interns will use, and a prospective educational project interns could incorporate into their fall distance course. Strong proposals in which the graduate student displayed a willingness to continue involvement after the summer internship were highly regarded. Applicants' proposals were reviewed and ranked by committee members, and the highest ranking proposals were awarded with a micro-grant. Graduate student mentors will be announced in March 2012.

Develop Undergraduate Intern Distance Course

The goal of the distance course is for undergraduate interns to effectively utilize learned communication and education skills while relating the importance of natural resources through inquiry-based educational presentations for secondary school classrooms. Course objectives are described in Box 5b.

Box 5b. Undergraduate Intern Distance Course Objectives

As a result of participating in the course, undergraduate interns will be able to

- learn principles of inquiry-based education and oral communication;
- improve education and oral communication skills;
- create effective inquiry-based secondary school lessons regarding natural resources;
- present lessons to local secondary school classrooms.

The distance course will be delivered synchronously weekly. Course materials such as the syllabus, notes, discussion boards, and supporting readings will be available via a course web site. Guest lecturers from disciplines such as public communication and education will present during the first third of the course. During the second third of the course, students will develop educational lessons and poster presentations that target specific state learning standards and use inquiry-based education principles learned during the course. Graduate student mentors will provide support in developing materials for hands-on activities and assist in reviewing and polishing presentations. During the last third of the semester, lessons will be implemented in local secondary schools. These presentations will be evaluated by the hosting secondary school teachers. The inquiry-based education and communication course is an opportunity for PINEMAP to disseminate project research to the broader public.

Project Learning Tree (PLT)/PINEMAP Secondary Module

PLT, an award-winning national environmental education program, is partnering with PINEMAP to develop a new secondary module on climate change and southern pine forests. Activities will address how forests affect climate, how variations in climate affect forests, and how people can mitigate climate change with forests and manage forests to adapt to an increasingly variable climate. A logic model and scope and sequence was developed during year 1 that outlines short-, medium-, and long-term outcomes, topics, key concepts, and learning objectives (see Appendix 2 and 3). The draft goals for the module are described in Box 5c.

Box 5c. PLT/PINEMAP Secondary Module Goals

The draft goals are for students to

- gain an appreciation for the role of forests in models of climate change;
- increase understanding of climate variability and change, carbon cycle, and carbon sequestration;
- increase understanding of how forest management could alter projections for climate change and improve resilience of southern pine forests;
- explore the role of consumer choices in climate change mitigation through life cycle analysis and product comparisons.

Assessment and Planning

As part of the needs assessment process, Aim 5 members researched existing climate change curricula and discovered there is little material currently available that explores ecosystem response to climate change within life science. It was determined that this is an ideal niche for the PLT/PINEMAP Secondary Module which will focus on forest impacts on climate and climate impacts on forests in the context of PINEMAP research. A draft needs assessment for science teachers which builds off of the survey of high school teachers in the Southern Piedmont region has been distributed to the PLT/PINEMAP Secondary Module Advisory Committee for input. A quantitative survey of high school science teachers in the Southern Piedmont region was conducted to examine attitudes and understanding of forestry as well as the extent to which they are teaching forestry and climate concepts (Box 5d). We will continue to interview and survey high school teachers in the Southeast as part of a second needs assessment, the formative evaluation, and the summative evaluation of the module.

Box 5d. Survey of High School Science Teachers in the Southern Piedmont

A quantitative survey of high school science teachers in the five state Southern Piedmont region of the United States (Virginia, North Carolina, South Carolina, Georgia, and Alabama) investigated attitudes and understanding of forestry, as well as the extent to which they are teaching forestry and climate concepts. An invitation to participate in an online survey was sent to 1,095 teachers; 324 surveys were completed (34% response rate).

The results provide insight into the way teachers think about climate change and carbon storage in the context of southern conifer management. Survey results show that teachers believe that forests play an important role in climate change prevention and teach about the role of carbon storage. In addition, results show that teachers who identify themselves as “liberal” more frequently teach students about climate change ($p < .01$) and the importance of forests in climate mitigation ($p < .001$) than those who identify themselves as “conservative.” Female teachers, and those in Georgia and Virginia, were more likely to teach about climate and carbon than male teachers and those in the other states. This suggests teachers will find our module theme important, but also that the concepts must be presented with care to resonate with conservatives and liberals alike.

Module Development

Students in the fall 2011 Environmental Education Program Development course at the University of Florida developed and pilot tested 5 draft activities for the PLT/PINEMAP Secondary Module.

- *Climate Controversy*: In this investigative activity, student groups work together to understand how different viewpoints on climate change may influence landowner decisions about pine plantation management in the Southeast.
- *Climate and Feedback Loops*: Students learn about positive and negative feedback loops and create systems diagrams to illustrate how forests could be impacted by climatic change and how climate is impacted by changes in forest ecosystems.
- *Carbon in the Ecosystem*: Using trees on the school grounds, students measure tree size and then calculate the amount of carbon stored in each tree and in the entire forested area. Students then compare this amount to how much carbon is stored in grassland, an agricultural area, and a pine plantation of similar sizes.
- *Climate Variability and Forests*: Student groups read different USDA Forest Service fact sheets explaining a current research topic and challenges associated with climate change and forests in the Southeast and take turns “teaching” what they have learned to others using a jigsaw method.
- *What makes a product environmentally friendly?* Student groups use a web-quest to research life cycle information for a particular product, and then participate in a debate where each group develops a persuasive argument as to why their product is more environmentally-friendly (e.g., plant-based vs. metal utensils). Students generate a framework of questions to guide the selection of “green” items.

An additional activity, *Life Cycle Analysis of Lawn Furniture – A play in three acts*, was developed to explain life cycle analysis and the opportunity consumers have to exercise their choice of products. The play allows students to investigate life cycle data for wood, aluminum, and plastic resin outdoor lawn furniture. Additional activities or extensions may explore how modeling, genetics, policy, and economics play a role in helping people mitigate climate change and adapt to climate variability.

Advisory Committee

A PLT/PINEMAP Secondary Module Education Advisory Committee was formed during year 1. Members of the committee represent formal and non-formal educators and PINEMAP partners from across the Southeast, including high school and community college teachers who focus on biology, environmental science, forestry, economics, or policy; PLT state coordinators; university educators who work on curriculum development or teacher education; and representatives from national and

PLT/PINEMAP Education Advisory Committee members include Project Learning Tree state coordinators, science teachers, university faculty, and members of the Climate Literacy Network.

regional education programs. The committee will provide critical feedback and guidance to ensure creation of high-quality materials that are both relevant and useful. The first Education Advisory Committee meeting was conducted in January 2012, and future meetings will take place on a bimonthly basis. See Appendix 4 for a complete list of the Education Advisory Committee members and their affiliation.

BROAD IMPACTS

Although the target audience for the distance graduate course is M.S. and Ph.D. students working on PINEMAP research, all collaborators (Co-PIs, staff, and Postdoctoral Associates) are invited and encouraged to participate in course webinars and contribute to online discussion boards. A resulting impact of wide-scale participation in the graduate course is that collaborators from all facets of the project are exploring new fields of knowledge and engaging in interdisciplinary thought processes and conversations.

Our work to advertise the Undergraduate Internship Program has enabled several schools which do not have forestry programs to encourage their students to apply, including Historically Black Colleges and Universities such as Virginia State University.

In identifying members for the PLT/PINEMAP Secondary Module, we contacted the Climate Literacy Network with a request for volunteers and were overwhelmed with the interest, support, and quality of engagement. We are tapping networks beyond forestry and environmental education, including experts in the National Oceanic and Atmospheric Administration, the National Center for Atmospheric Research, and other national climate science programs in the U.S.

Undergraduate and graduate students in the fall 2012 Environmental Education Program Development course at the University of Florida were involved in the initial development of activities for the PLT/PINEMAP Secondary Module, and this proved to be a fortuitous opportunity. Students learned about climate change and forest impacts related to PINEMAP research and also gained practical experience in product development and evaluation.

TRAINING

The following graduate students, Postdoctoral Associates, and technical staff are involved in Aim 5 research and program development efforts.

- Stephanie Hall, M.S. student, University of Florida. Stephanie is helping to develop and pilot test activities for the PLT/PINEMAP Secondary Module and will conduct research on how to best introduce potentially divisive and contested concepts in secondary school curricula.

- John Kidd, Undergraduate Intern Program Coordinator, Virginia Tech. John is developing the selection criteria, matching students, awarding proposals, developing the fall course, and working with local teachers to set up school presentations for the Undergraduate Internship Program.
- Annie Oxarart, Environmental Education Program Coordinator, University of Florida. Annie is working on the development of the PLT/PINEMAP Secondary Module, including assisting with the needs assessment, development and pilot testing of activities, and oversight of the Education Advisory Committee.
- Richard Plate, Postdoctoral Associate, University of Florida. Dr. Plate is assisting with the development and evaluation of activities for the PLT/PINEMAP Secondary Module.

In addition, as previously mentioned, there are 23 students from 8 universities enrolled in the spring 2012 distance graduate course (Table 5a).

Table 5a. PINEMAP graduate students enrolled in spring 2012 distance course.

Name	Degree	Institution
Rajesh Bawa	PhD	Virginia Tech
Joe Clark	M.S.	Auburn University
Alfredo Farjat	Ph.D.	North Carolina State University
Ranjith Gopalakrishnan	Ph.D.	Virginia Tech
Nabin Gyawali	Ph.D.	Virginia Tech
Stephanie Hall	M.S.	University of Florida
Brett Heim	M.S.	Virginia Tech
Puskar Khanal	Ph.D.	Mississippi State University
Andy Laviner	Ph.D.	Virginia Tech
Soyoung Lee	Ph.D.	Texas A&M University
Wen Lin	Ph.D.	North Carolina State University
Mengmeng Lu	Ph.D.	Texas A&M University
Cody Luedtke	Ph.D.	University of Georgia
Adam Maggard	Ph.D.	Oklahoma State University
Jill Qi	Ph.D.	University of Georgia
Jay Raymond	Ph.D.	Virginia Tech
C. Wade Ross	Ph.D.	University of Florida
Beth Stein	Ph.D.	Virginia Tech
Aaron Vuola	M.S.	North Carolina State University
Maggie Wang	Ph.D.	University of Georgia
Maxwell Wightman	M.S.	University of Florida
Lu Zhai	M.S.	Texas A&M University
Jianxing Zhang	Ph.D.	University of Florida

COLLABORATIONS AND “INTEGRATED” KNOWLEDGE DEVELOPED

Several examples of conceptual integration and new research questions have arisen through our integrated work in Aim 5. For example, the core essence of Stephanie Hall’s Master’s thesis question was developed from a better appreciation of the intricacies of the climate question and the conflicting perceptions held by the public. While science teachers may be responsible for presenting “just the facts,” if students have preconceptions about the validity of the facts around climate change projections, they will be predisposed to ignore or reject this information (much of the research on misconceptions in science education support this assumption). Because of the strong correlation between religious and political views and climate perceptions, however, the procedures to address a scientific misconception may not be helpful. We will be testing Kahneman and Tversky’s (1982) anchoring heuristic with two different approaches to lessons about climate to discern which has a greater chance of increasing students’ ability to learn information. We are also in the early stages of identifying theoretical questions that will help inform our evaluation of the effect of PINEMAP on interdisciplinary research activity.

PLAN-OF-WORK FOR YEAR 2

The Aim 5 plan-of-work for year 2 (March 1, 2012 - February 28, 2013) (Table 5b) summarizes tasks and activities to be conducted/completed each quarter during year 2 to ensure delivery of overarching Aim 5 milestones and deliverables.

Table 5b. This work plan summarizes Aim 5 quarterly tasks and activities for year 2.

Undergraduate Internship Program		
Quarter	Task/Activity	People Responsible
Quarter 1 (3/1/12- 5/31/12)	Announce winners of intern micro-grant program	Seiler
	Facilitate undergraduate intern transitions to host universities	Kidd
	Maintain the intern program web site and update as needed with information for internships and the undergraduate distance course	
	Continue development of undergraduate distance course	
Quarter 2 (6/1/12- 8/31/12)	Weekly monitoring of summer 2012 undergraduate intern program participants	Seiler, Kidd, Sriharan
	Monthly online meetings with interns and graduate student mentors	
	Finalize undergraduate distance course syllabus	Seiler, Kidd, Sriharan,
	Recruit secondary school teachers and introduce intern program	Samuelson, etc.

Quarter	Task/Activity	People Responsible
Quarter 3 (9/1/12-11/30/12)	Conduct undergraduate distance course on education	Seiler, Kidd, Sriharan, Samuelson, etc.
	Finalize secondary school teachers for hosting interns' educational presentations	
	Send solicitation for summer 2013 intern program	Seiler, Kidd
	Send solicitation for summer 2013 intern micro-grant program	
	Examine public speaking, inquiry-based learning, and effective presentation principles	Aim 5 Interns
	Develop and deliver inquiry-based educational presentations	
Quarter 4 (12/1/12-2/28/13)	Support undergraduate presentations in secondary school classrooms	Seiler, Kidd, Sriharan, Samuelson, etc.
	Evaluate goals, objectives, structure, and format of internship program and modify as necessary	
	Conduct follow-up evaluation with intern program participants and undergraduate course participants and modify as necessary	
Quarter 4 (12/1/12-2/28/13)	Select winners of intern micro-grant program	Seiler, Kidd, Sriharan, Samuelson, etc.
	Select winners of undergraduate intern program	
March 2013	Announce winners of micro-grant and undergraduate intern programs	Seiler
Distance Graduate Course		
Quarter	Task/Activity	People Responsible
January-May 2012	Launch course	Ireland and Monroe and Course Instructors
	Obtain evaluation input from students and faculty on future graduate student interactions and next course offering.	
Quarter 2 (6/1/12-8/31/12)	Compile and review evaluations and student/faculty input; plan for second version of course scheduled for spring 2013 as well as future graduate student activities and interaction within PINEMAP	Monroe, Ireland, Martin, Peter, Fox
September-December 2012	Revise course syllabus, structure, themes, and overall goals/objectives based on evaluations and student/faculty input	Monroe, Ireland, Martin, Peter, Fox
	Identify instruction and assignment coordinators/teams; work with instruction and assignment teams to finalize course syllabus, structure, and themes	
January-April 2013	Launch second version of course	TBD
	Obtain evaluation input from students and faculty	
Summer 2013	Reflect on evaluations and future needs to support graduate student interaction and involvement in PINEMAP	All PINEMAP collaborators

PLT/PINEMAP Secondary Module		
Quarter	Task/Activity	People Responsible
Quarter 1 (3/1/12- 5/31/12)	Launch needs assessment with high school science teachers Develop, revise, and pilot test activities	Monroe, Oxarart, Hall
Quarter 2 (6/1/12- 8/31/12)	Pilot test activities with high school students at summer camp Continue to develop, revise, and pilot test activities Summarize needs assessment findings	Stenstrup, Monroe, Oxarart
Quarter 3 (9/1/12- 11/30/12)	Continue to develop, revise, and pilot test activities Begin plans for formative evaluation Develop training workshop for teachers (online and in person)	Stenstrup, Monroe, Oxarart
Quarter 4 (12/1/12- 2/28/13)	Complete training workshop Develop formative evaluation tools Continue to develop plans for formative evaluation	Stenstrup, Monroe, Oxarart
Spring 2013	Conduct training workshop Launch formative evaluation	Stenstrup, Monroe, Oxarart

Aim 5 Members

Name	Institution	Role	E-mail address
Martha Monroe	University of Florida	Co-PI; Aim 5 Leader; Education/Extension Integration Leader	mcmonroe@ufl.edu
John Seiler	Virginia Tech	Co-PI; Aim 5 Leader	jseiler@vt.edu
John Kidd	Virginia Tech	Internship Program Coordinator; Aim 5 Member	jbkidd@vt.edu
Annie Oxarart	University of Florida	Environmental Education Coordinator; Aim 5 Member	oxarart@ufl.edu
Shobha Sriharan	Virginia State University	Co-PI; Aim 5 Member	ssriharan@vsu.edu



Year 1 Annual Report Aim 6 (Extension)

EXECUTIVE SUMMARY

The overall objective of the Extension group (Aim 6) is to develop extension programming that combines regional climate expertise and forest management outreach to deliver knowledge and state-of-the-art information, resources, and management decision support tools to forest landowners, resource managers, and policy makers. The extension goal is to demonstrate and disseminate emerging knowledge, practices, and decision support tools to enable corporate and non-corporate landowners to increase forest carbon sequestration, nitrogen fertilizer efficiency, and forest resilience under changing climate.

During year 1, Aim 6 conducted a survey of over 4,000 Extension professionals across the region; fostered collaboration and development of partnerships among forestry Extension agents and state climatologists in the southeastern U.S.; initiated creation of state Extension teams to guide the development and dissemination of PINEMAP Extension programs and materials; worked with partners in the multi-state Southeast Climate Consortium and other PINEMAP Aim groups to plan the Decision Support System; initiated a number of important outreach efforts including participation in forestry research cooperative meetings; drafted fact sheets that translate PINEMAP research topics to landowners; and initiated an internal webinar series to promote understanding of climate science and collaboration and knowledge sharing among the interdisciplinary PINEMAP team.

During year 2, Aim 6 will continue to work on several “baseline” survey instruments for various groups to determine existing knowledge, needs, beliefs, interests, attitudes, and learning preferences about climate and forest interactions. We will conduct several outreach activities across the South, both face-to-face and technology assisted, and use lessons learned to improve extension programming and outreach activities. Furthermore, we will continue to strengthen relationships with educators, researchers, and stakeholders by organizing state and regional advisory teams and developing outreach materials such as fact sheets and web-based training/education modules. A primary focus will be developing and pilot testing the user interface for the web-based, open-source Decision Support System. Finally, we will tailor evaluation and impact methods and metrics to measure success and determine how we will document change in behavior.

OUTCOMES/IMPACTS

Aim 6 activities contribute to project-level outcomes and impacts through development and dissemination of informational products and tools which provide stakeholders with knowledge and skills needed to address planted pine climate change mitigation and adaptation issues. We conducted a survey of climate change perceptions among Extension faculty and agents across the region. We are developing partnerships among state climatologists and Extension foresters and establishing a PINEMAP Extension network in the Southeast. These partnerships and networks will be critical to the efficient and effective dissemination of PINEMAP Extension programs and products. Programs and products being developed include a Decision Support System (DSS), a web-based, open-source set of current and future decision support tools directed at the innovative management of southern pine; eXtension modules for the Climate Science and Forests Interaction Community of Practice (CoP); and additional resources such as fact sheets and web-based education modules.

OUTPUTS

During year 1, Aim 6 contributed a number of outputs that advanced the overall project goals and objectives.

- Twelve draft fact sheets were developed for dissemination to stakeholders.
- Aim 6 implemented an internal webinar series for PINEMAP collaborators using the Elluminate webinar program (see Figure 6a and Box 6a). This webinar series serves as an educational resource to facilitate the sharing of knowledge among PINEMAP team members on a variety of topic areas. The webinars have proven to be a valuable tool to promote knowledge exchange and collaboration among all facets of the project and provide an opportunity for collaborators to efficiently come up to speed on topics important to PINEMAP research which are outside of individuals' specific areas of expertise. During year 1, seven webinars were conducted with a total of 171 participants.
- Aim 6 members, together with faculty from Aims 4 and 5, developed and implemented a survey of southeastern U.S. Extension faculty perceptions of climate change. The survey was launched on a rolling basis as state Extension administrators signed on, beginning in August 2011 with Georgia and continuing with Louisiana in January 2012. To date, eight states have participated with a total population of 4,133. Our response rate has been extremely good, ranging from 62% to 79% in each state.
- Aim 6 members presented at a number of national conferences and stakeholder meetings as summarized below.
 - *PINEMAP Extension goals and objectives*, Bill Hubbard, May 18, 2011, National Workshop on Climate and Forests, Flagstaff, AZ. The audience was composed of Extension professionals with natural resources interest and USDA Forest Service researchers and technology transfer experts.

- *Introduction to climate, climate variability, and climate change in the Southern U.S.*, Heather Dinon, September 30, 2011, Forest Biology Research Cooperative Annual Advisory Council Meeting, Gainesville, FL. This presentation generated a useful discussion about audience needs regarding information on climate impact on forest systems.
- *AFRI PINEMAP climate change grant: College of Natural Resource's role in advancing pine plantation management for a changing future*, Mark Megalos, October 11, 2011, North Carolina State University. The audience was composed of undergraduate students and faculty from the Department of Forest and Environmental Resources. Students were challenged to see how forest management strategies could be used to mitigate and adapt to anticipate climate changes in the future.
- *AFRI PINEMAP climate change grant: College of Natural Resource's role in advancing pine plantation management for a changing future*, Mark Megalos, October 24, 2011, North Carolina State University. The audience was composed of graduate students and faculty from the Department of Forest and Environmental Resources. Faculty and cooperators were informed of the intent, collaboration and extent of the PINEMAP project.
- *An integrated approach to climate variability Extension delivery*, Bill Hubbard, November 1, 2011, Society of American Foresters National Convention, Honolulu, HI. The audience was composed of forestry and natural resources experts. Participants gained awareness of the PINEMAP project and several partners expressed interest in working with the PINEMAP Extension team.
- *An overview of Pine Integrated Network: Education, Mitigation, and Adaptation Project (PINEMAP)* (poster), Heather Dinon, November 3, 2011, Southeast Climate Consortium (SECC) 2011 fall planning meeting, Tallahassee, FL. The audience was composed of SECC members and graduate students within SECC universities. An introduction to the PINEMAP project was provided and partnerships were initiated.
- *PINEMAP: Pine Integrated Network: Education, Mitigation and Adaptation Project*, Leslie Boby, December 8, 2011, Forest Modeling Research Cooperative Annual Meeting, Amelia Island, FL. The presentation provided an overview of the PINEMAP project to members of the Forest Modeling Research Cooperative.
- *Climate Education Materials With Sector-Focused Context*, Heather Dinon, January 24, 2012, 21st Symposium on Education as part of the 92nd American Meteorological Society Annual Meeting, New Orleans, LA. The audience was composed of members of the meteorological community with an active interest in education. This presentation provided an introduction to the NCSU agriculture climate education modules and future efforts to expand to other sectors, such as forestry, were discussed in an effort to build partnerships for this task.

- *A Regional Approach to Addressing Impacts of Climate Variability and Climate Change on Forest Production in the Southeast U.S.*, Heather Dinon, January 25, 2012, 7th Symposium on Policy and Socio-Economic Research as part of the 92nd American Meteorological Society Annual Meeting, New Orleans, LA. The audience was composed of members of the meteorological community with an active interest in the policy-science interface. An introduction to the PINEMAP project was provided and partnerships were initiated.
- Aim 6 members collaborated with Aim 5 on the PINEMAP distance graduate course and coordinated and hosted a webinar on high-resolution climate model projections in southern U.S. with Dr. Katharine Hayhoe, Research Associate Professor/Atmospheric Scientist, Texas Tech University.
- The Extension team's information technology specialist designed and launched the project-wide web site (www.pinemap.org).

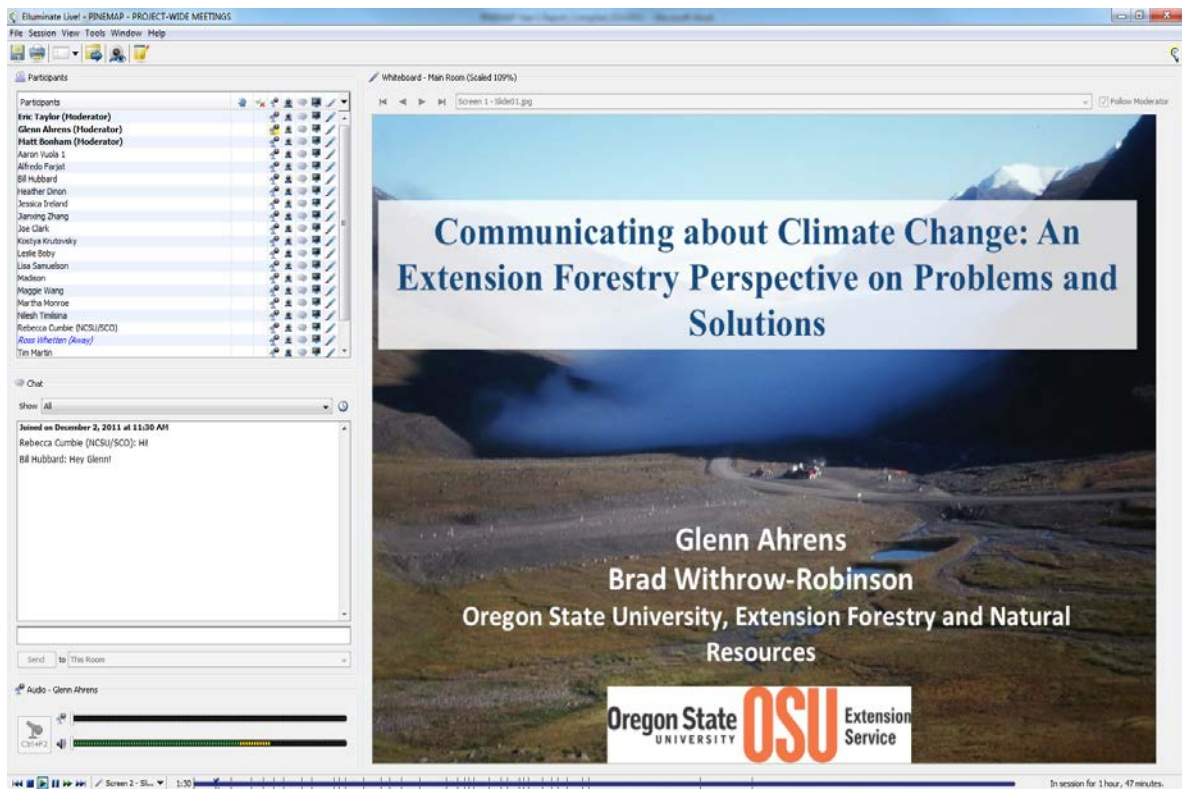


Figure 6a. PINEMAP Internal Webinar Series screenshot.

Box 6a. PINEMAP Internal Webinar Series

- *Understanding the Link Between Weather and Climate*, Heather Dinon, October 7, 2011
- *Understanding the Causal Factors of Drought, Expected Patterns and Impact on Forested Landscapes*, Ryan Boyles and Eric Taylor; October 21, 2011
- *Tier III Site Locations and Objectives*, Andy Laviner, Madison Akers, and Geoff Lokuta, November 4, 2011
- *Communicating Forest/Climate Science and Interactions*, Glenn Ahrens, Oregon State University, December 2, 2011
- *Basic Climate Change Concepts and Definitions*, Barry Keim and Ryan Boyles, January 20, 2011
- *The effect of soil texture and nocturnal transpiration on root water uptake and consequences for the future carbon and water budgets of southern U.S. pine plantations*, Jean-Christophe Domec, February 3, 2012
- *The Drivers of Climate and Climate Variability*, Ryan Boyles and David Zierden, February 17, 2012

MILESTONES AND DELIVERABLES

The Extension Aim group will demonstrate and disseminate emerging knowledge, practices, and tools developed by PINEMAP to influential educators who will help share this information with landowners and resource managers, enabling them to make informed decisions. Progress toward this goal during year 1 is summarized below.

Audience Assessment

Audience assessment plays a critical role in determining needs and will guide the development of PINEMAP Extension programs and products. During year 1, extensive progress was made in regards to PINEMAP Extension program audience assessment. A survey was developed and delivered to Extension faculty in the 1890 and 1862 institutions in Georgia, Alabama, Florida, North Carolina, Virginia, Louisiana, Texas, and Mississippi. The survey was designed to assess attitudes, beliefs, practices, and interest in global warming and climate change programs and programming. A total of 2,418 completed surveys were returned as of February 2012, resulting in a 62-79% response rate in the various states. Initial analysis in the first seven states suggests that Extension faculty perceptions cover the same range of responses that the American public shows in the Global Warming's Six Americas surveys (Leiserowitz *et al.* 2010) with a slight shift to the right (see Figures 6b and 6c). A number of other studies suggest political preference is a strong predictor of perceptions on climate, which may account for regional and career-based differences in perceptions. Additional analysis will be conducted in year 2 and several publications are planned.

In addition to the survey, Aim 6 members conducted informal focus groups with forest landowners in Leon and Madison counties in Florida which helped to provide some basic understanding of forest landowner perceptions of climate change. This work was conducted in collaboration with the Southeast Climate Consortium’s Row Crop Working Group Coordinator, who has conducted similar focus groups with farmers.

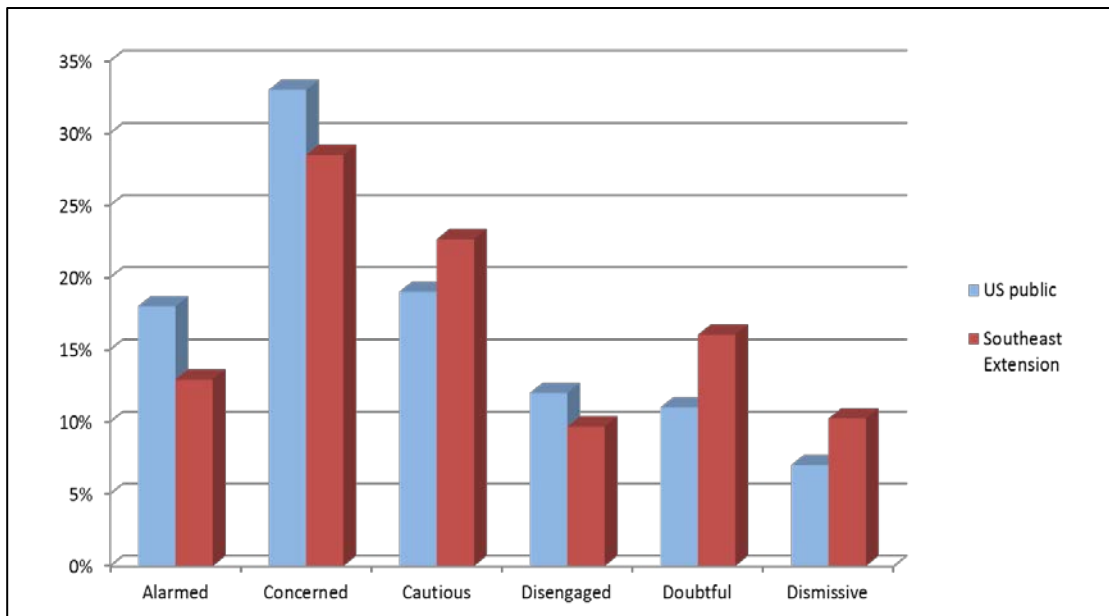


Figure 6b. As a whole, Extension faculty in the Southeast mirror the public in perceptions of climate change, with a skew to the right.

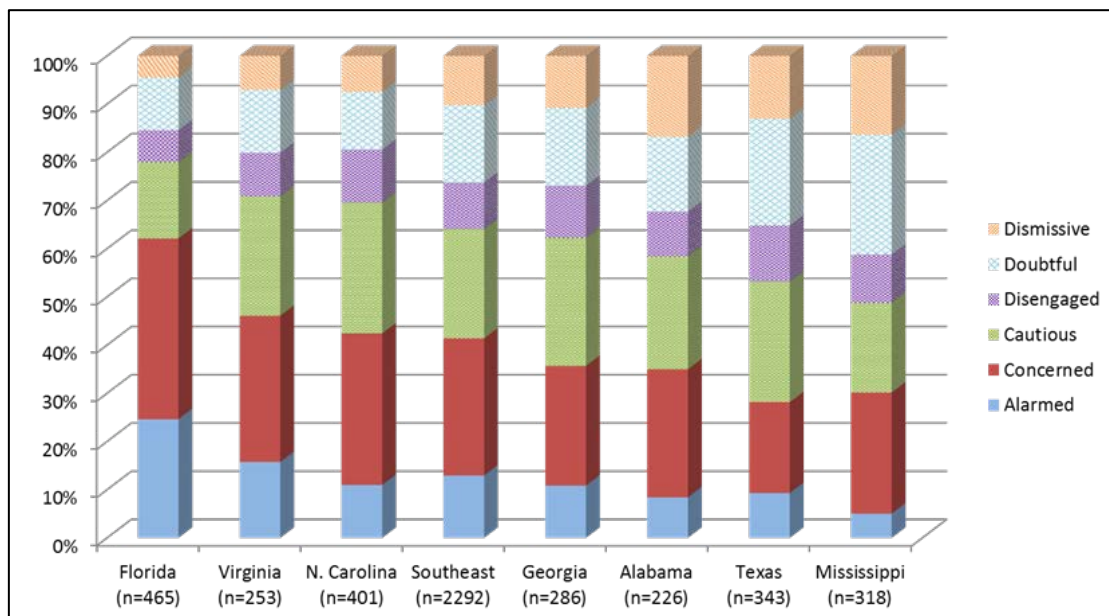


Figure 6c. States vary dramatically, with more FL, VA, and NC respondents in the alarmed, concerned, and cautious categories than the other states.

State Climatologist/Extension Partnerships

An important Aim 6 milestone is the development of partnerships and networks to facilitate efficient and effective dissemination of PINEMAP Extension programs and products to stakeholders throughout the southeastern U.S. During year 1, Aim 6 made progress toward the development of forestry Extension/state climatologist partnerships and the establishment of a regional PINEMAP Extension network.

State climatologists are an excellent resource for forestry Extension faculty and are being linked to each PINEMAP state Extension team.

State climatologists, primarily located at participant universities, have a common mission to support the advancement of climate information and science application and education. These scientists serve as a truly local resource for stakeholders as well as state forestry science and Extension faculty. Moreover, these climatologists actively communicate and network through the American Association of State Climatologists (AASC). Aim 6 is working on the establishment of a forestry Extension/state climatologist network which will collectively develop and review materials, provide oversight and input on research and education activities, and collaborate on regional training workshops.

Specifically, state climatologists will support the proposed research, extension, and outreach activities in the following ways:

1. **Local training:** Each state climatologist will become a member of the PINEMAP state Extension project delivery team to help plan and execute local workshops and distance education training programs that are developed at either the state or regional level. Climatologists will review materials to ensure the climate science is effectively communicated and serve as the state resource for questions and information.
2. **Climate expertise to support research:** State climatologists have diverse academic disciplinary training—many are also experts in climate modeling, use of remote sensing, air chemistry, and applications of climate to production agriculture and forestry. These scientists will be available as resources for the PINEMAP research teams to help use climate science effectively in experimental design, application models, and genetic studies.
3. **Integrating climate and forestry research with extension expertise:** PINEMAP Extension products require that forest researchers and climatologists provide the content and state Extension specialists provide guidance on the distribution system and strategies that will increase understanding of climate change and its effects on southern pine forest productivity. As a result, the development and implementation of the extension products are the essence of integration. A central mechanism for this integration is the DSS which requires contributions from forest and climate researchers and Extension specialists so that it is accurate as well as useful. The DSS is explained further below.

During the American Association of State Climatologists (AASC) annual meeting in July 2011, Aim 6 members introduced the southern state climatologists to PINEMAP and provided them with a one-page handout containing more details about their specific role in the project. Aim 6 also organized and conducted three regional teleconferences with state climatologists. These meetings introduced state climatologists to Aim 6 team members in their state. The state climatologists showed a great deal of interest in and enthusiasm for working with forestry Extension agents, and these meetings were a critical first step toward implementing and strengthening forestry Extension/state climatologist partnerships in the South. In addition, Aim 6 is planning the development of a “Forestry 101” training for state climatologists in the spring/summer of 2012.

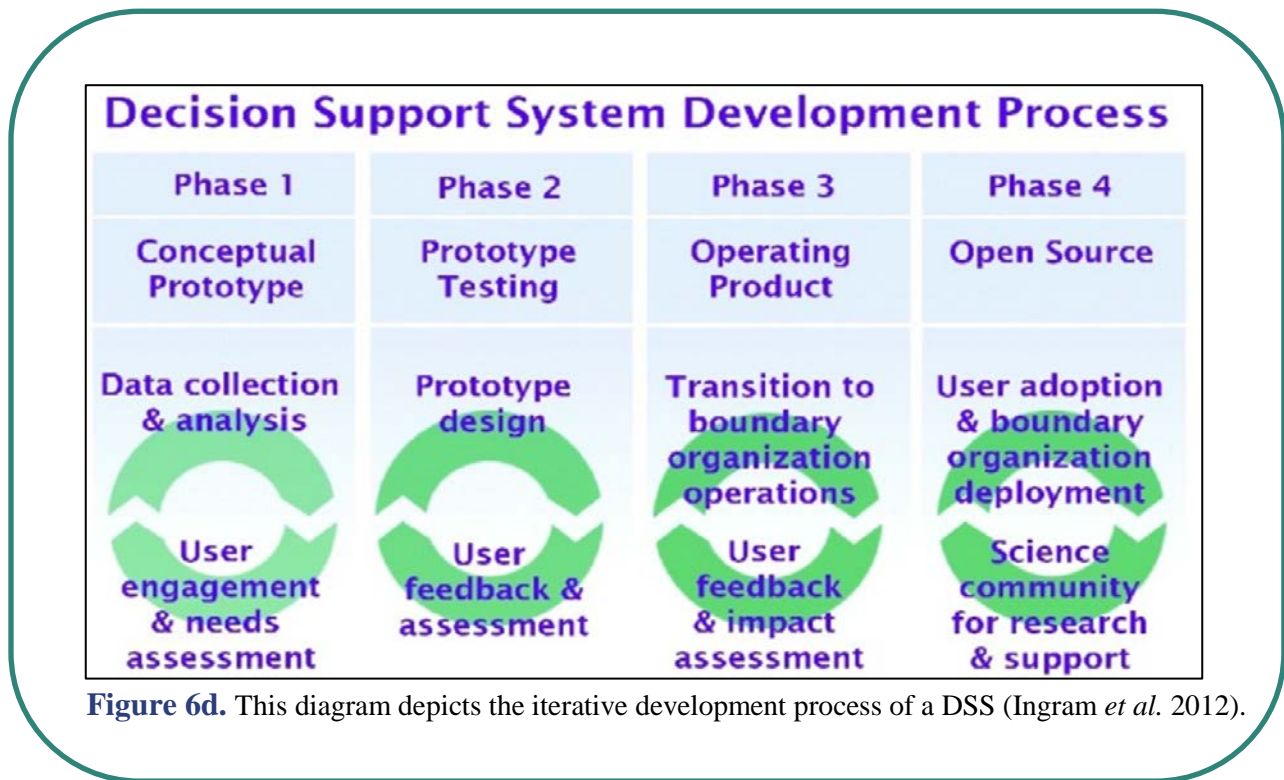
State Extension Teams

To effectively deliver PINEMAP Extension products and programs, a regionally coordinated effort will be most effective. Accordingly, Extension professionals within the project’s region were invited to participate on state Extension teams which will play a critical role in the deployment of PINEMAP Extension materials and programs. Currently, Extension professionals are being identified as a lead for each of the states in the PINEMAP region. These leads will form the PINEMAP Extension Advisory Team. This team will advise on the structure and makeup of the state teams’ membership (i.e., identifying members from industry, non-governmental organizations, universities, etc.) and will provide guidance on program development, implementation, and evaluation. During year 1, Aim 6 conducted an initial webinar with state Extension contacts to introduce them to PINEMAP and provide an opportunity for open discussion about extension deliverables and effective methods to actively engage state Extension units at key junctures in the development and implementation of programs.

Extension Programs/Products

Decision Support System

A central approach for establishing an environment of interaction and feedback among PINEMAP researchers, Extension specialists, and stakeholders is the development of a Decision Support System (DSS) which will convey PINEMAP research results through a web-based, open-source set of decision support tools. Our approach is modeled on work undertaken in the Southeast Climate Consortium (SECC, <http://seclimate.org/>), a group that uses advances in climate science, including improved capabilities to forecast seasonal climate and long-term climate change, to provide scientifically sound information and decision support tools, primarily for agricultural systems. The PINEMAP DSS will be developed iteratively and interactively in four phases across the project period, involving co-PIs from all 6 Aim groups (see Figure 6d).



The DSS will enable forest managers and landowners to understand management options for adapting forests to improve carbon mitigation as climate changes. In addition to the DSS, the seed source deployment models being developed necessitate engagement of geneticists and climate specialists. A needs assessment with a stratified sample to elicit responses from underserved landowners, those living in different climate zones, and those with varying levels of education and financial resources will help shape both the extension products and the research questions so that we are able to respond to each audience appropriately. The DSS will be directed to the innovative management of southern pine and will integrate research results from the genetics, silviculture, modeling, and economics groups. During year 1, Aim 6 began the initial planning stages for the DSS, including working with collaborators from the research Aim groups and the SECC to determine the best design and implementation scheme. During year 2, the user interface for the DSS will be developed and pilot tested.

eXtension Modules

Another product being developed is online learning modules for the eXtension, a national Internet-based educational network. Aim 6 has initiated conversations with eXtension leadership as well as the Climate Science and Forests Interaction Community of Practice (CoP). This CoP does not currently have materials related to southern forests and climate science, so this is an ideal niche for PINEMAP modules within the eXtension network.

Fact Sheets

Aim 6 has begun drafting PINEMAP Extension fact sheets during year 1 which will be disseminated to stakeholders in year 2 (see Box 6b).

Box 6b. PINEMAP Extension Fact Sheets

- *To Plant or Not To Plant: New Timber Stand Drought Risk Assessment*, Eric Taylor and Matthew Bonham
- *Water Cycle in Forested Lands with Emphasis on Silvopasture Systems*, Shareika Williams and Gwendolyn Boyd
- *Invasive Plants and Your Forest*, Christina Temple and Mark Megalos
- *Forest Health and Resiliency*, Christina Temple and Mark Megalos
- *Mitigation and Adaptation*, Joshua Idassi
- *Glossary of Climate Terms*, Mark Megalos and Heather Dinon
- *Assessing Forest Vulnerability*, Mark Megalos and Heather Dinon
- *Southern U.S. Drought*, Ryan Boyles and Heather Dinon
- *Climate Oscillations: Impacts to Forestry*, Heather Dinon and Ryan Boyles
- *Introduction to Weather and Climate*, Heather Dinon and Ryan Boyles
- *Herbicide Use Considerations*, Eric Taylor
- *Minimizing Forest Insect/ Disease Risk: A Practical Landowner Guide*, Mark Megalos

BROAD IMPACTS

As a result of year 1 activities and accomplishments, a number of unforeseen partnerships and collaborations with outside projects emerged which provide excellent opportunities for knowledge exchange, interdisciplinary integration, and mutually beneficial collaboration. These partnerships are described below.

- Aim 6 members were invited to participate on an advisory board for the proposed Western Conifer AFRI climate change CAP.
- Aim 6 members are providing input and joint leadership in Association of Natural Resources Extension Professionals (ANREP) Climate Science Initiative and presenting at the Biannual ANREP Conference in May 2012.
- Aim 6 is developing a partnership with the Climate Literacy Partnership in the Southeast (CLiPSE) project to exchange knowledge, ideas, and tools regarding climate change communications and education.
- Aim 6 members from Texas Agrilife Extension are building upon relationships with the Texas Forest Service to open up opportunities for in-service training, regional meetings, landowner workshops, and field days.

- Aim 6 is collaborating with the Integrated Biomass Supply Systems (IBSS) project, Southeast Climate Consortium (SECC), USDA Forest Service climate change efforts, and Society of American Foresters (SAF)—these collaborations promote an active exchange of knowledge and research results.
- Aim 6 members are working with SECC to conduct focus groups with forest landowners to better understand motives and barriers to developing a Working Group on climate and forests.

The climate perceptions survey implemented in coordination with Aim 4 is generating quite a buzz among the Extension community in the southeastern states. Not only are the Extension Directors within the participating states interested in the data, but other climate projects are anxious for our results. In addition, people outside the South are interested in the results. In our analysis, we plan to develop predictive models to suggest why people perceive climate change as they do and what might determine Extension faculty's willingness to engage in climate programming. Neither development was anticipated when we launched the project.

TRAINING

The following graduate students and technical staff are involved in Aim 6 research and program development efforts.

- Leslie Boby, Extension Associate, Southern Regional Extension Forestry. Leslie is assisting with formation of regional Extension teams and a PINEMAP Extension Advisory Board; participating in and presenting at research cooperative meetings; and facilitating internal and external PINEMAP research dissemination. Planned work includes developing and evaluating written and web-based (i.e., eXtension, webinars, etc.) educational materials and disseminating resources and materials to forestry stakeholders.
- Matthew Bonham, Extension Assistant, Texas AgriLife Extension. Matt is assisting with formation of state Extension teams; implementing, coordinating, and hosting the PINEMAP internal webinar series; initiating the Texas Forest/Woodland Advisory Panel; contributing to regional fact sheets and extension modules in the areas of forest management and climate interactions; reviewing current eXtension materials to identify knowledge gaps; and creating several feedback instruments to gauge the effectiveness of outreach activities and identify areas for improvement.
- Heather Dinon, Applied Climatologist, State Climate Office of North Carolina. Heather is facilitating interaction between PINEMAP team members and state climatologists across the region through activities such as presentations in the internal webinar series and research cooperative meetings and weather/climate conferences. Other involvement includes development of the DSS, creation of fact sheets, and guidance on the best climate datasets for PINEMAP.

- Richard Plate, Postdoctoral Associate, University of Florida. Dr. Plate is assisting with data analysis for the Extension climate perceptions survey.
- Christina Temple, M.S. candidate, North Carolina State University. Christina is developing two fact sheets on adaptation related to forest pests and invasives.
- Aaron Vuola, M.S. candidate, North Carolina State University. Aaron is working on data analysis of the Extension climate perceptions survey results for North Carolina.
- Deborah Wojcik, Postdoctoral Associate, University of Florida. Dr. Wojcik is assisting with survey development and data analysis for the Extension climate perceptions survey.

COLLABORATIONS AND “INTEGRATED” KNOWLEDGE DEVELOPED

During year 1, PINEMAP leadership discussed the need for a clear and standardized message and tone to be used in communications to stakeholders regarding climate change. Aim 6 members have been discussing the best way to clarify information for presentation. These initial discussions have jump-started the iterative process of developing a unified message on climate change for PINEMAP Extension personnel, as well as general PINEMAP researchers and staff. This message is audience-specific and will depend on the topic, as well as audience perspective and objective.

In addition, Aim 6 is facilitating collaborative dialogue and participation in interdisciplinary conversations and thinking via the internal webinar series and collaboration on the planning and development of the DSS.

PLAN-OF-WORK FOR YEAR 2

The Aim 6 plan-of-work for year 2 (March 1, 2012 - February 28, 2013) (Table 6a) summarizes tasks and activities to be conducted/completed each quarter during year 2 to ensure delivery of overarching Aim 6 milestones and deliverables.

Table 6a. This work plan summarizes Aim 6 quarterly tasks and activities for year 2.

Quarter	Task/Activity
Quarter 1 (3/1/12- 5/31/12)	<p>Audience assessment—develop several “baseline” survey instruments that establish the existing knowledge levels, needs, beliefs, interests, attitudes, learning preferences, etc. regarding climate variability and forest interactions for various groups.</p> <ul style="list-style-type: none"> • Complete final draft of document that lists surveys, their purpose, and how they serve the needs of the project • Administer the survey to state agency foresters • Administer the Extension needs assessment (team engagement)—serves to motivate the Extension specialists to disseminate PINEMAP information • Final draft of the landowner survey • Internally distribute initial results from the southeastern Extension staff survey
	<p>Internal assessment—final draft document on how we determine evaluation and impact methods and metrics to measure success.</p> <ul style="list-style-type: none"> • Extension activities • Internal webinar series
	<p>Outreach activities: <i>note:</i> lessons learned for outreach activities will be used to improve upcoming outreach activities throughout the Southeast.</p> <ol style="list-style-type: none"> 1. Poster presentation at Southeast Society of American Foresters meeting 2. Plan, organize, and implement Drought Seminar 3. Plan, organize, and implement Forest Pest Seminar 4. Plan, organize, and implement Central Texas Woodland Resiliency Seminar 5. Presentations at multiple landowner workshops 6. Weather, climate, and climate change discussions with undergraduates in 1890 land-grant institutions 7. Speak at Cooperative Forest Genetics Research Program annual meeting-- audience includes industry and contractor professionals as well as academic researchers 8. Lead a special climate change session and Extension climate perception survey session at the Association for Natural Resource Extension Professionals biannual meeting—there will also be representation by state climatologists at this meeting 9. Participate in Western Gulf Silvicultural Technology Exchange Conference 10. Plan external webinar series 11. Develop promotional brochure 12. Participate in SCIPP webinar series

Quarter	Task/Activity
Quarter 1 (3/1/12-5/31/12)	Strengthen relationships with education, research, and stakeholders. <ol style="list-style-type: none"> 1. State/regional advisory planning meetings: <ol style="list-style-type: none"> a. Informational webinar for state Extension foresters b. Creation of regional advisory panels: <ol style="list-style-type: none"> i. Climate variability/resiliency education teams recruitment ii. Identify climatologists to assist in education efforts iii. State forestry personnel iv. Identify members for state focus group v. Identify members for regional focus group
	External outputs <ol style="list-style-type: none"> 1. Factsheets- two per quarter 2. Tailor web based climate education modules to a forestry audience - four per quarter 3. Complete analysis and submit articles on SE Extension perceptions of climate change
	Decision Support System (DSS) <ol style="list-style-type: none"> 1. Survey internal group for a list of existing tools and/or project output that can/should be integrated into DSS 2. Brainstorm ways to integrate 3. Develop/brainstorm a prototype with input from PINEMAP team at 2012 annual meeting
	Administrative Activities <ol style="list-style-type: none"> 1. Implement 6 internal webinar sessions 2. Conduct Aim 6 in-person planning meeting 3. Conduct 3 Aim 6 web conference meetings 4. Participate in monthly Executive Committee meetings 5. Complete all required reports, summaries, etc. 6. Maintain project web site 7. PINEMAP graduate course <ol style="list-style-type: none"> a. Coordinate Assignment 2 for PINEMAP graduate course b. Coordinate webinar on effective climate change extension programming, climate model projections, and DSS 8. Participate in PINEMAP annual meeting 9. Plan, organize, and implement State/Regional Extension Advisory Panel meetings 10. Participate in Climate Science Initiative Planning Meeting following ANREP conference
Quarter 2 (6/1/12-8/31/12)	Outreach activities <ol style="list-style-type: none"> 1. Attend/present at Plantation Management Research Cooperative meeting (audience includes industry and contractor professionals as well as academic researchers). 2. Participate in Western Gulf Woodlands Resiliency Clinic
	Strengthen relationships with researchers & stakeholders <ol style="list-style-type: none"> 1. Collect/distribute survey results and feedback from State/Regional Extension Advisory Panel meeting.

Quarter	Task/Activity
Quarter 2 (6/1/12- 8/31/12)	External outputs <ol style="list-style-type: none"> 1. Factsheets- two per quarter 2. Tailor web based climate education modules to a forestry audience -four per quarter 3. Contributions to Climate, Forest and Woodlands CoP- eXtension
	Administrative activities <ol style="list-style-type: none"> 1. Identify new strategies to strengthen cross-Aim efforts 2. Implement 6 internal webinar sessions 3. Conduct 3 Aim 6 web conference meetings 4. Participate in monthly Executive Committee meetings 5. Complete all required reports, summaries, etc. 6. Maintain project web site
Quarter 3 (9/1/12- 11/30/12)	Outreach activities <ol style="list-style-type: none"> 1. Attend Coop meetings: Forest Productivity Cooperative; Forest Biology Research Cooperative; Cooperative Tree Improvement Program; Forest Modeling Research Cooperative 2. Present at national Society of American Foresters meeting 3. Create 3 hours of web-based continuing education modules
	Strengthen relationships with research and stakeholders <ol style="list-style-type: none"> 1. Plan, organize, implement state/regional Extension Advisory Panel meetings
	Administrative activities <ol style="list-style-type: none"> 1. Identify new strategies to strengthen cross-Aim efforts 2. Implement 6 internal webinar sessions 3. Conduct 3 Aim 6 web conference meetings 4. Participate in monthly Executive Committee meetings 5. Complete all required reports, summaries, etc. 6. Maintain project web site
	External outputs <ol style="list-style-type: none"> 1. Factsheets- two per quarter 2. Tailor web based climate education modules to a forestry audience - four per quarter 3. Contributions to Climate, Forest and Woodlands CoP- eXtension
Quarter 4 (12/1/12- 2/28/13)	Administrative activities <ol style="list-style-type: none"> 1. Identify new strategies to strengthen cross-Aim efforts 2. Attend PINEMAP annual meeting 3. Implement 6 internal webinar sessions 4. Conduct 3 Aim 6 web conference meetings 5. Participate in monthly Executive Committee meetings 6. Complete all required reports, summaries, etc. 7. Maintain project web site 8. DSS: develop/brainstorm prototype with input from PINEMAP team
	External outputs <ol style="list-style-type: none"> 1. Factsheets- two per quarter 2. Tailor web based climate education modules to a forestry audience - four per quarter 3. Contributions to Climate, Forest and Woodlands CoP- eXtension

Quarter	Task/Activity
Additional Opportunities	<ul style="list-style-type: none"> - Presentations at state forestry association meetings - Distribute promotional brochure, displays, and factsheet at county, regional, state, and multi-state events - Involve state climatologists as appropriate - Host members for state focus group - Host members for regional focus group - DSS evaluation and formulation: engagement with stakeholders and coordination with internal project members (iterative process) - State/Regional Extension Advisory Planning Meetings (2 per year)

Aim 6 Members

Name	Institution	PINEMAP Role	E-mail
Bill Hubbard	Southern Regional Extension Forestry, University of Georgia	Co-PI; Aim 6 Leader	whubbard@sref.info
Eric Taylor	Texas AgriLife Extension, Texas A&M University	Co-PI; Aim 6 Leader	eltaylor@tamu.edu
Leslie Boby	Southern Regional Extension Forestry, University of Georgia	Extension Associate; Aim 6 Member	lobby@sref.info
Matt Bonham	Texas AgriLife Extension, Texas A&M University	Extension Assistant; Aim 6 Member	mlbonham@ag.tamu.edu
Gwendolyn Boyd	Alcorn State University	Co-PI; Aim 6 Member	gboyd@alcorn.edu
Ryan Boyles	State Climate Office of North Carolina	Co-PI; Aim 6 Member	ryan_boyles@ncsu.edu
Heather Dinon	State Climate Office of North Carolina	Applied Climatologist; Aim 6 Member	hadinon@ncsu.edu
Joshua Idassi	North Carolina A&T University	Co-PI; Aim 6 Member	joidassi@ncat.edu
Mark Megalos	North Carolina State University	Co-PI; Aim 6 Member	mark.megalos@ncsu.edu
Martha Monroe	University of Florida	Co-PI; Aim 6 Member; Extension/Education Integration Leader	mcmonroe@ufl.edu

Administrative Progress

Significant administrative milestones were accomplished during year 1. We established a schedule for and implemented monthly Project Management Team and Executive Committee meetings. The Project Management Team, made up of the Project Coordinator, Project Director, and Integration Leaders, meets monthly and is responsible for project-level planning and administration. The Executive Committee, made up of the Project Management Team, Aim Leaders, and Institutional Coordinators, meets monthly via web conference to discuss important administrative items, provide Aim group updates, and communicate integration needs.

In addition to the monthly Executive Committee meetings, PINEMAP will continue to host an in-person annual meeting for all project collaborators each year of the 5-year project. A kickoff meeting was held in Atlanta, Georgia in May 2011 (Box 7a). This meeting provided an opportunity for collaborators to meet and learn about the overall project goals and objectives. Aim groups also developed two year work plans and networked with other Aim groups to identify key areas for collaboration and integration. Our next annual meeting will take place in Atlanta in May 2012; the theme of this working meeting is ‘integration,’ with a focus on facilitating key areas for cross-Aim integration and interdisciplinary collaboration. In addition, Project Director Tim Martin and Integration Leaders Tom Fox, Gary Peter, and Martha Monroe presented a PINEMAP overview poster at the National Workshop on Climate and Forests, May 16-18, 2011 in Flagstaff, Arizona.

We developed and launched a project web site (www.pinemap.org) (Figure 7a) which has proven to be a valuable tool for publicizing the project—between October 2011 and February 2012, the web site received over 9,000 visits. In addition, an internal, password protected web portal was created to host important project-wide materials, including reports, progress tracking spreadsheets, and a project calendar. This web portal promotes collaboration and information sharing among project participants.

To ensure timely completion of milestones and deliverables and facilitate collaboration among the research, extension, and education Aim groups, the PINEMAP Project Management Team established project-level reporting guidelines and a quarterly reporting template. The PINEMAP reporting guidelines require Aim groups to submit progress reports on a quarterly basis. In addition, we are using SmartSheet, an online project management program, to track progress on quarterly and yearly Aim group milestones and deliverables. These approaches and tools enable us to efficiently and effectively track progress and report on Aim-level deliverables and milestones as well as identify key areas for integration and collaboration among the research, extension, and education components of the project

Box 7a. PINEMAP Project Kick-off Meeting

A diverse group of Co-PIs, each of whom had contributed to the NIFA PINEMAP conifer CAP proposal, met in Atlanta, Georgia May 2-3, 2011. The objective of the professionally-facilitated meeting was to establish a solid foundation to allow this large, interdisciplinary group to work together efficiently and creatively in order to accomplish the goals of the grant. This was the first of five annual meetings that will take place over the course of the project. More specifically, the initial meeting was expected to

- build relationships among the PIs and a sense of team work, especially within Aim groups and states, but also across groups;
- create a common understanding of the project scope, outcomes, and deliverables;
- consolidate realistic 1-2 year work plans for each of the 6 Aim groups;
- highlight the importance of the 3 integration themes and discuss strategies to develop these themes across Aim groups;
- clarify expectations for the Decision Support System, the distance graduate class, and the internship program and identify specific mechanisms to ensure coordination;
- clarify expectations for how participants will work together over the course of the grant;
- introduce governance needs and identify members for a committee to discuss issues and develop a strategy/document for subsequent approval.



Connections among the three NIFA climate change CAPs were forged before the respective projects were even funded. The corn, wheat, and southern pine CAP project directors met in Washington, DC in early 2011 during the NIFA kickoff event for the projects and quickly recognized the value in building and maintaining connection among the projects. The project Directors have regular conference call meetings and discuss project management and identify opportunities for collaboration and synergy. The directors are currently outlining plans for a manuscript on transdisciplinary agriculture research, and the annual meeting agendas for all three projects include opportunities for the other CAP directors to address project participants. Similarly, project coordinators and data management staff also meet regularly via teleconference.



Figure 7a. Screenshot of the PINEMAP web site.

Data Management

Site-specific data (Tier I, II, and III data sets)

The focus in year 1 has been to implement the conceptual framework for centralized storage and documentation of data collected/used in the project. A scalable database infrastructure for spatially and temporally explicit, site-specific measurements was created to accommodate Tier I, II, and III datasets (TerraC, <http://TerraC.ifas.ufl.edu>) (Figure 7b). These point measurements are mapped to specific geographic coordinates (latitude/longitude) and specific time scales (year, month, week, day, etc.). TerraC is a web-based application utilizing Microsoft SQL Server to store and maintain point carbon data (funded by the Florida Energy System Consortium). It allows users to freely upload/submit data for their own projects (e.g., PINEMAP Aim groups) as well as view and query shared or public data.

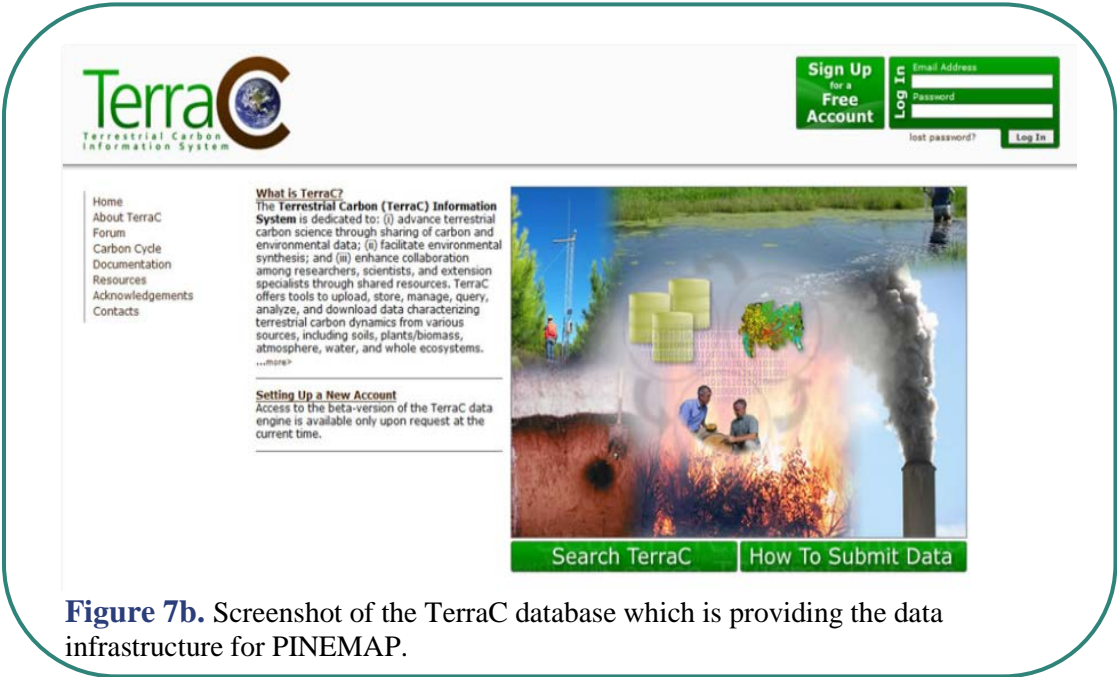


Figure 7b. Screenshot of the TerraC database which is providing the data infrastructure for PINEMAP.

To meet the data management needs/requirements of the PINEMAP project, the structure of TerraC was expanded to accommodate more disparate data types, units (e.g., concentrations, stocks, fluxes), and forms such as nitrogen in soils or leaf area index at different spatial scales (e.g., point, plot, or block) and temporal scales collected in different ecosystem components (e.g., soils, vegetation/forest, atmosphere, and whole ecosystem) under different management/treatments. Metadata fields accommodate each data entry. In addition, a redesign of the administrative tool in TerraC was necessary to enable secure management of archived data provided by university-corporate-governmental research cooperatives for use in PINEMAP. The aim is to protect and secure data as outlined in the PINEMAP Operating Principles and Guidelines. A few Tier I datasets were received and used as example templates to be integrated into the TerraC-PINEMAP database. The new administrative setup maintains the security of each of the individual datasets but gives oversight control to research cooperative directors, Aim Leaders, and PIs. This will not only allow individuals to maintain their own data (i.e., view, read, and write access), but will also allow Aim Leaders to view data submitted by others. With this effort, a new access request workflow is being simultaneously developed so that when users request access to other datasets in the project, the owners (e.g., research cooperatives for Tier I data) may easily grant or deny access. With the expected large amount of data coming in from Aim groups in years 2-5, we have implemented secure data backups (digital backups and redundant off-campus backups on tapes), as well as reporting on data tracking.

Geospatial data (raster, polygon, line, or point datasets)

Recently, the storage of large geospatial sets required for the project was established in close collaboration with the IT department at the Institute of Food and Agricultural Sciences at the University of Florida. These geospatial data covering the southeastern U.S., such as grids of historic climate data (e.g., Parameter-elevation Regressions on Independent Slopes Model, PRISM) as well as climate projections, are required by Aim groups to accommodate sub-projects. Data security, integrity, and file server backups have been implemented and a web interface allowing sharing of geospatial data with PINEMAP participants is underway. Clipping and extractions of geospatial climate data to Tier I, II, and III site locations will be enabled in the next phase.

PINEMAP Organization and Management

PINEMAP is organized and managed to facilitate communication and collaboration among project scientists across the region, foster integration across disciplines, establish accountability, guarantee deliverables, and maintain two-way information flow with stakeholders. One of the first actions of the PINEMAP Executive Committee, initiated at the May 2011 project kickoff meeting, was to establish a set of Operating Principles and Guidelines (Appendix 5). The goal for such was to obtain general agreement on a set of principles and processes the group agrees to follow in working with each other and to

establish guidelines for dealing with potentially difficult situations before those situations arise. The document addresses the following areas: general principles; project governance and general decisionmaking; decisionmaking on critical topics including scientific direction and budget changes; graduate student involvement; data sharing; and authorship (Box 7b).

Box 7b. General Principles from the PINEMAP Operating Principles and Guidelines Document

As a condition for participation in PINEMAP, we agree to adhere to these core values and principles:

- We will develop and support a culture of mutual respect and trust.
- We will adhere to rigorous scientific approaches and principles.
- We share a group commitment to building long-term capacity for cross-function work (Research + Extension + Education), which will require us to reach out beyond our disciplinary focus areas.
- We will hold ourselves and each other accountable to the goals and outcomes of the project with regard to data delivery, data sharing, and cross-aim collaboration, and will be responsive to requests for information, data, and collaborations.
- We will strive for full attribution of credit.
- We will be equitable in our dealings with each other.
- We will foster an environment conducive to intellectual stimulation and growth for all those involved in the project.

Structure and Integration

The project organizational structure facilitates achieving project goals and milestones in a timely fashion, assures that project direction remains relevant to stakeholders, and allocates resources appropriately. Elements of this plan include scientific leadership associated with Aims, Integration Leaders for mitigation, adaptation, and education/extension goals, Institutional Coordinators for those with multiple investigators, a Cooperative-Industrial Advisory Council, a Project Management Team, an Executive Committee, and an External Advisory Board (Figure 7c).

Accomplishing the long-term project outcomes, goals, and general milestones requires a strong team conducting disciplinary and interdisciplinary research. The nucleus of our team is the eight long-standing university-corporate-governmental research cooperatives, most of which were founded to provide deep disciplinary expertise. However, the applied nature of their research and demands from industry members for integrative knowledge and practical solutions has meant that research cooperative scientists have also conducted interdisciplinary research. To best leverage our strong disciplinary expertise and existing

research cooperative infrastructure, Co-Principal Investigators are organized into specific Aim groups to meet the general milestones. Aim groups are coordinated by two or more leaders distributed across institutions to promote integration among regional research cooperatives. Three Integration Leaders work with Aim Leaders to ensure we achieve the broader goals of adaptation, education/extension, and mitigation. The Aim Leaders facilitate the flow of information, needs, and outcomes among the researchers, education, and Extension specialists. Refer to the “Key Personnel” section below for details regarding leadership.

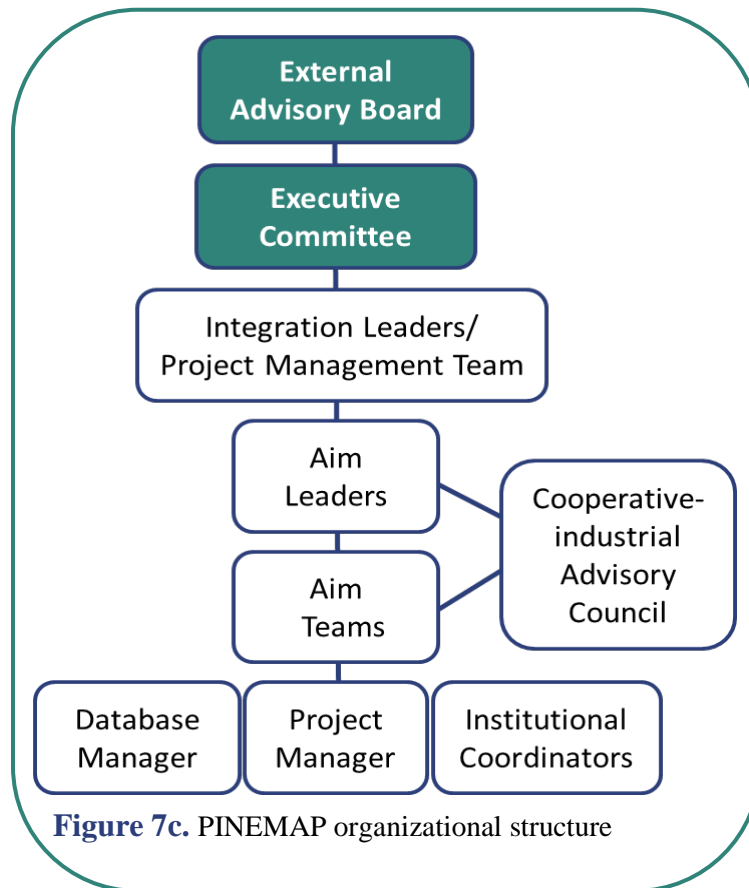


Figure 7c. PINEMAP organizational structure

Governance

Project-wide governance involving progress and performance and major changes to budgets or scientific direction rests with the Project Director, who chairs an Executive Committee consisting of the Integration Leaders and the Aim Leaders, plus a representative from each university not represented in the Integration Leader or Aim Leader groups (see Table 7a). The Executive Committee meets on a monthly basis via web conference. The Project Director, Project Coordinator, and Integration Leaders together form the Project Management Team which oversees project administration and coordination of Executive Committee and project-wide meetings and quarterly and annual reporting.

Table 7a. PINEMAP Executive Committee Members

Name	Role
Tim Martin	Chair
Martha Monroe	Aim 5 Leader, Education/Extension Integration Leader
Gary Peter	Adaptation Integration Leader
Tom Fox	Aim 1 Leader, Mitigation Integration Leader
Mike Kane	Aim 1 Leader
Randy Wynne	Aim 2 Leader
Steve McNulty	Aim 2 Leader
Tom Byram	Aim 3 Leader
Ross Whetten	Aim 3 Leader, NCSU Institutional Coordinator
Jianbang Gan	Aim 4 Leader
Damian Adams	Aim 4 Leader
John Seiler	Aim 5 Leader
Eric Taylor	Aim 6 Leader
Bill Hubbard	Aim 6 Leader
Lisa Samuelson	Auburn University Institutional Coordinator
Joshua Idassi	NCA&T Institutional Coordinator
Gwendolyn Boyd	ASU Institutional Coordinator
Don Grebner	MSU Institutional Coordinator
Rodney Will	OSU Institutional Coordinator
Shobha Sriharan	VSU Institutional Coordinator

External Advisory Board

The External Advisory Board provides guidance on program development, implementation, and evaluation. Members representing education, Extension, and research stakeholders have agreed to serve; the final composition of the board will be announced once all slots have been filled. The External Advisory Board will discuss progress periodically during Executive Committee meetings and meet in person yearly at the annual project meetings.

Cooperative-Industrial Advisory Council

The university-corporate-governmental research cooperatives (research cooperatives) continue their normal industry-directed research simultaneously with conducting activities within PINEMAP. The research cooperatives are organized with a director or team of co-directors who take advisement from the industrial members often through an industrial advisory committee. Within the research cooperatives, the advisory committee/council is chaired by an industry member who coordinates with all members, where full members of the research cooperatives rotate in this function. The cooperative-industrial advisory board is composed of the directors or a designee of each research cooperative and the current chair of the industry advisory committee/council for each research cooperative. The role of this committee is to work with the PINEMAP team to

ensure that existing and newly collected research cooperative specific data are made available to strengthen the science of the CAP but not undermine the ability of research cooperatives to best serve their current and future members. In addition, this board serves to vet tools and facilitate transfer of knowledge to their organizations.

Key Personnel Roles

Project Director: Tim Martin, Professor of Tree Physiology at the School of Forest Resources and Conservation (SFRC), University of Florida (UF), is the Project Director. Dr. Martin co-directs the multidisciplinary Forest Biology Research Cooperative and directs the UF Carbon Sciences Resource Center, a component of the UF and Florida State University's Florida Climate Institute. Dr. Martin directs the project to ensure that the long-term outcome, goals, and milestones are achieved on time while using resources efficiently and effectively.

- ***Project Coordinator:*** Jessica Ireland, PINEMAP Project Coordinator, based at UF, coordinates project activities, maintains the project web site and intranet site, facilitates communication among participants, organizes and coordinates project meetings and quarterly and annual reporting, assists with administrative paperwork, and manages progress tracking of milestones, deliverables, and tasks.
- ***Database Manager:*** Brandon Hoover, based at UF under the direction of Sabine Grunwald, UF Professor of GIS and Land Resources, manages the TerraC PINEMAP database and facilitates data analysis and data sharing among project participants.

Co-Project Directors: Co-Project Directors are organized into Integration Leaders, Aim Leaders, and Aim group members. Each broad integration theme (adaptation, education/extension, and mitigation) has a single leader, while Aim groups have two or more leaders distributed across institutions.

- ***Integration Leaders:*** These leaders facilitate integration across Aim groups to ensure delivery of knowledge, information, and materials that will help agriculture and forestry achieve adaptation, mitigation, and education/extension goals.
 - Gary Peter, Professor of Forest Genetics and Genomics, UF, leads the adaptation goals.
 - Martha Monroe, Professor of Environmental Education and Extension, UF, leads the education and extension goals.
 - Tom Fox, Professor of Silviculture and Forest Soils, Virginia Tech, leads the mitigation goals.

- ***Aim Leaders:*** The Aim Leaders are responsible for coordinating the research, education, and extension activities to ensure delivery of the information and materials for each Aim group. The Aim leaders also facilitate cross-university collaborations. Table 7b identifies the leaders of each Aim group.
- ***Aim Group Members:*** All PINEMAP collaborators are members of Aim groups designed to deliver and transfer the information and tools needed to foster increased mitigation, improve forest resilience, and train scientists, educators, and Extension professionals across the region. The Aim groups are: ecosystem ecology / silviculture, modeling, genetics and breeding, education, and extension.

Table 7b. PINEMAP Aim Leaders

Aim #	Leaders (University)
1	Tom Fox (Virginia Tech) Mike Kane (University of Georgia)
2	Randy Wynne (Virginia Tech) Steve McNulty (North Carolina State University/USDA Forest Service)
3	Ross Whetten (North Carolina State University) Tom Byram (Texas A&M University)
4	Jianbang Gan (Texas A&M University) Damian Adams (University of Florida)
5	Martha Monroe (University of Florida) John Seiler (Virginia Tech)
6	Bill Hubbard (Southern Regional Extension Forestry) Eric Taylor (Texas AgriLife Extension, Texas A&M University)

Institutional Coordinators: Institutional Coordinators oversee and coordinate the budgets and administrative paperwork for their respective institution. The Integration Leaders are: Mike Kane, University of Georgia; Tom Fox, Virginia Tech; Tim Martin, University of Florida; Steve McNulty, USDA Forest Service/North Carolina State University; Ross Whetten, North Carolina State University; Rod Will, Oklahoma State University; Jason Vogel, Texas A&M University; Joshua Idassi, North Carolina A&T University; Gwendolyn Boyd, Alcorn State University; and Lisa Samuelson, Auburn University.

Senior Advisor: Jim Jones, Distinguished Professor of Agricultural and Biological Engineering, UF, co-directs the Southeast Climate Consortium and the Florida Climate Institute. He advises the Project Director and Integration Leaders.

Directors of university-corporate-governmental research cooperatives: Most of the biologists on the project work with one or more of the university-corporate governmental research cooperatives. Research cooperative directors (Table 7c) are integrated across the Aim groups because of their role in knowledge transfer to their members.

Table 7c. University-corporate-governmental research cooperatives.

Research Cooperative	Director(s)
Cooperative Forest Genetics Research Program	Matias Kirst (UF) Gary Peter (UF) Greg Powell (UF)
Cooperative Tree Improvement Program	Steve McKeand (NCSU)
Forest Biology Research Cooperative	John Davis (UF) Eric Jokela (UF) Tim Martin (UF) Gary Peter (UF)
Forest Modeling Research Cooperative	Harold Burkhart (VT)
Forest Productivity Cooperative	Tom Fox (VT) Jose Stape (NCSU) Rafael Rubilar (UC, Chile)
Plantation Management Research Cooperative	Mike Kane (UGA)
Southern Forest Resource Assessment Consortium	Robert Abt (NCSU) Fred Cabbage (NCSU)
Western Gulf Forest Tree Improvement Program	Tom Byram (TX Forest Service, TAMU)

The PINEMAP project team includes over 50 Co-PIs from 11 land grant universities and the USDA Forest Service, as well as M.S. and Ph.D. students working in PINEMAP Aim groups, technical and administrative staff, and Postdoctoral Research Associates. Table 7d summarizes all PINEMAP team members as of February 2012 (including Co-PIs, staff, graduate students, and Postdoctoral Associates).

Table 7d. PINEMAP team members as of February 2012 (including Co-PIs, staff, graduate students, and Postdoctoral Associates).

Name	Institution	Aim Group/Role	E-mail
Karen Abt	USDA Forest Service	Aim 4, Co-PI	kabt@fs.fed.us
Robert Abt	NCSU	Aim 4, Co-PI	bob_abt@ncsu.edu
Damian Adams	UF	Aim 4 Leader; Co-PI	dcadams@ufl.edu
Madison Akers	UGA	Aim 1, Research Coordinator	akersm@warnell.uga.edu
Tim Albaugh	NCSU	Aim 1, Research Associate	Tim_albaugh@ncsu.edu
Jose Alvarez	NCSU	Aim 2, Postdoc	jalvarez@ncsfnc.cfr.ncsu.edu
Rajesh Bawa	VT	Aim 3, Ph.D. student	rajesh13@vt.edu
Leslie Boby	UGA/SREF	Aim 6, Extension Associate	lboby@sref.info
Matt Bonham	TAMU	Aim 6, Extension Assistant	mlbonham@ag.tamu.edu
Gwendolyn Boyd	Alcorn State	Aim 6, Co-PI	gboyd@alcorn.edu
Ryan Boyles	NCSU	Aim 2, 6, Co-PI	ryan_boyles@ncsu.edu
Harold Burkhart	VT	Aim 2, Co-PI	burkhart@vt.edu
Tom Byram	TAMU	Aim 3 Leader, Aim 2, Co-PI	t-byram@tamu.edu
Douglas Carter	UF	Aim 4, Co-PI	drcart@ufl.edu
Joe Clark	Auburn	Aim 1, M.S. student	JEC0037@auburn.edu
Wendell Cropper	UF	Aim 2, Co-PI	wcropper@ufl.edu
John Davis	UF	Aim 3, Co-PI	jmdavis@ufl.edu
Heather Dinon	NCSU	Aim 6, Applied Climatologist	hadinon@ncsu.edu
Ernest Dixon	NCSU	Aim 3, 4, M.S. student	edixon2@ncsu.edu
J.-C. Domec	NCSU	Aim 1, 2, Co-PI	jdomec@ncsu.edu
Puneet Dwivedi	Yale	Aim 4, Co-PI	puneet.dwivedi@yale.edu
Francisco Escobedo	UF	Aim 2, Co-PI	fescobed@ufl.edu
Alfredo Farjat	NCSU	Aim 3, Ph.D. student	aefarjat@ncsu.edu
Tom Fox	VT	Aim 1 Leader; Aim 4, Co-PI; Mitigation Integration Leader	trfox@vt.edu
Sam Frye	VT	Aim 1, Research Technician	samfrye@vt.edu
Jim Gan	TAMU	Aim 4 Leader, Co-PI	j-gan@tamu.edu
Carlos Gonzalez	UF	Aim 1, 2, Co-PI	cgonzabe@ufl.edu
Ranjith Gopalakrishnan	VT	Aim 2, Ph.D. student	ranjith7@vt.edu
Donald Grebner	MSU	Aim 4, Co-PI	dgrebner@cfr.msstate.edu
Sabine Grunwald	UF	Aim 1, 2, Co-PI	sabgru@ufl.edu
Nabin Gyawali	VT	Aim 2, Ph.D. student	nabin@vt.edu
Stephanie Hall	UF	Aim 5, M.S. student	blondiehall@ufl.edu
Brett Heim	VT	Aim 1, M.S. student	bheim@vt.edu
Tom Hennessey	OSU	Aim 1, Co-PI	tomhenn@okstate.edu
Jason Holliday	VT	Aim 3, Co-PI	jahl@vt.edu
Brandon Hoover	UF	PINEMAP Data Manager	hoover@ufl.edu
Bill Hubbard	UGA/SREF	Aim 6 Leader, Co-PI	whubbard@sref.info
Joshua Idassi	NC A&T	Aim 6, Co-PI	joidassi@ncat.edu
Jessica Ireland	UF	Project Coordinator	jjtireland@ufl.edu
Fikret Isik	NCSU	Aim 3, Co-PI	fikret_isik@ncsu.edu

Name	Institution	Aim Group/Role	E-mail
Kurt Johnsen	USFS	Aim 1, 3, Co-PI	kjohnsen@fs.fed.us
Eric Jokela	UF	Aim 1, Co-PI	ejokela@ufl.edu
Jim Jones	UF	Senior Advisor, Co-PI	jimj@ufl.edu
Mike Kane	UGA	Aim 1 Leader; Aim 2, 4, Co-PI	mkane@warnell.uga.edu
Puskar Khanal	MSU	Aim 4, Ph.D. student	pnk7@msstate.edu
John Kidd	VT	Aim 5, Undergrad Intern Program Coordinator	jbkidd@vt.edu
John King	NCSU	Aim 1, Co-PI	john_king@ncsu.edu
Tomasz Koralewski	TAMU	Aim 3, Postdoc	tkoral@tamu.edu
Melissa Kreye	UF	Aim 4, Ph.D. student	mkreye@ufl.edu
Kostya Krutovsky	TAMU	Aim 3, Co-PI	k-krutovsky@tamu.edu
Andy Laviner	VT	Aim 1, Research Coordinator	alaviner@vt.edu
Soyoung Lee	TAMU	Aim 4 Ph.D. student	eco3131@tamu.edu
Wen Lin	NCSU	Aim 1, 2, Ph.D. student	wlin@ncsu.edu
Geoff Lokuta	UF	Aim 1, Research Coordinator	bassman@ufl.edu
Carol Loopstra	TAMU	Aim 3, Co-PI	c-loopstra@tamu.edu
Mengmeng Lu	TAMU	Aim 3, Ph.D. student	mira0501@neo.tamu.edu
Cody Luedtke	UGA	Aim 1, Ph.D. student	luedtkec@warnell.uga.edu
Adam Maggard	OSU	Aim 1, Ph.D. student	adam.maggard@okstate.edu
Chris Maier	USFS	Aim 1, Co-PI	cmaier@fs.fed.us
Dan Markewitz	UGA	Aim 1, Co-PI	dmarke@warnell.uga.edu
Tim Martin	UF	PI/Project Director	tamartin@ufl.edu
Steve McKeand	NCSU	Aim 2, 3, Co-PI	steve_mckeand@ncsu.edu
Steve McNulty	USFS	Aim 2 Leader, Co-PI	steve_mcnulty@ncsu.edu
Corey Meek	OSU	Aim 4, Research Associate	
Mark Megalos	NCSU	Aim 6, Co-PI	mark.megalos@ncsu.edu
Martha Monroe	UF	Aim 5 Leader, Aim 6, Co-PI, Education/Extension Integration Leader	mcmmonroe@ufl.edu
Dana Nelson	USFS	Aim 3, Co-PI	dananelson@fs.fed.us
Asko Noormets	NCSU	Aim 1, 2, Co-PI	anoormets@gmail.com
John Nowak	USFS	Aim 2, Co-PI	jnowak@fs.fed.us
Annie Oxarart	UF	Aim 5, Education Coordinator	oxarart@ufl.edu
Gary Peter	UF	Aim 3, Co-PI, Adaptation Integration Leader	gfpeter@ufl.edu
Jason Pike	OSU	Aim 1, Research Technician	Jason.pike@okstate.edu
Richard Plate	UF	Aim 5, 6, Postdoc	richarp@ufl.edu
Jill Qi	UGA	Aim 1, Ph.D. student	qij@warnell.uga.edu
Jay Raymond	VT	Aim 1, Ph.D. student	jayer11@vt.edu
C. Wade Ross	UF	Aim 2, Ph.D. student	wader@ufl.edu
Benjamin Rusche	NCSU	Aim 3, undergraduate student	bdrusche@ncsu.edu
Lisa Samuelson	Auburn	Aim 1, Co-PI	samuelj@auburn.edu
John Seiler	VT	Aim 1, Aim 5 Leader, Co-PI	jseiler@vt.edu
Jose Soto	UF	Aim 4, Ph.D. student	josesoto@ufl.edu
Shobha Sriharan	VSU	Aim 5, Co-PI	ssriharan@vsu.edu

Name	Institution	Aim Group/Role	E-mail
Jose Stape	NCSU	Aim 1, 2, Co-PI	jlstape@ncsu.edu
Brian Strahm	VT	Aim 1, Co-PI	brian.strahm@vt.edu
Elaine Stebler	OSU	Aim 1, Research Associate	elaine.stebler@okstate.edu
Beth Stein	VT	Aim 2, Ph.D. student	bstein2@vt.edu
Tom Stokes	Auburn	Aim 1, Research Associate	stoketa@auburn.edu
Santosh Subedi	VT	Aim 1, Ph.D. student	subedis@vt.edu
Ge Sun	USFS	Aim 2, Co-PI	ge_sun@ncsu.edu
Andres Susaeta	UF	Aim 4, Postdoc	asusaeta@ufl.edu
Eric Taylor	TAMU	Aim 1, Aim 6 Leader, Co-PI	eltaylor@tamu.edu
Christina Temple	UGA	Aim 6, M.S. student	cltemple@ncsu.edu
Robert Teskey	UGA	Aim 1, 2, Co-PI	rteskey@uga.edu
Valerie Thomas	VT	Aim 2, Co-PI	thomasv@vt.edu
Nilesh Timilsina	UF	Aim 2, Postdoc	nilesht@ufl.edu
Jason Vogel	TAMU	Aim 1, Co-PI	jason_vogel@tamu.edu
Aaron Vuola	NCSU	Aim 6, M.S. student	ajvuola@ncsu.edu
Maggie Wang	UGA	Aim 2, Ph.D. student	wangy@warnell.uga.edu
Jason West	TAMU	Aim 1, Co-PI	jbwest@tamu.edu
Ross Whetten	NCSU	Aim 3 Leader, Co-PI	rosswhet@ncsu.edu
Maxwell Wightman	UF	Aim 1, M.S. student	mgwightm@ufl.edu
Rodney Will	OSU	Aim 1, Co-PI	rodney.will@okstate.edu
Duncan Wilson	OSU	Aim 1, Co-PI	duncan.wilson@okstate.edu
Deborah Wojcik	UF	Aim 6, Postdoc	deb.wojcik@ufl.edu
Randy Wynne	VT	Aim 2 Leader, Co-PI	wynne@vt.edu
Lu Zhai	TAMU	Aim 1, M.S. student	zhailu@neo.tamu.edu
Jianxing Zhang	UF	Aim 3, Ph.D. student	zhangjx04@ufl.edu

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 CO₂; 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. In the first year of the project, we accomplished deliverables and milestones that laid the foundation for successful completion of our mission.

- The ecosystem ecology / silviculture team is implementing a regionwide monitoring network to evaluate the effects of climate, soils, and management approaches on carbon sequestration rates of planted pine. The team installed four large manipulative field experiments along the edges of the native loblolly pine range to subject the species to environmental conditions that may occur in the future. The team also selected sites from existing research trials to provide regional baseline data on carbon, water, and nutrient storage rates as well as responses to climate and management. The TerraC terrestrial carbon information system was developed to archive and serve spatially-explicit PINEMAP datasets.
- The modeling team is applying a multi-scaled modeling program incorporating monitoring network data with spatially-explicit historical and predicted future climate data to assess alternative forest management approaches and the impacts on carbon sequestration and resilience to disturbance. The team established a standardized set of models and climate datasets and conducted initial regional-scale assessments to guide future analyses.
- The genetics team is developing guidelines to help growers understand where to plant specific southern pine seed sources given future climate scenarios and identify genes controlling traits such as growth, nitrogen responsiveness, cold hardiness, water usage, and resistance to southern pine beetle and fungal diseases. Analyses are underway of weather and climate response of over 500 loblolly pine families in studies across the region. The team has initiated a comprehensive assessment of current genotyping techniques.
- The economics and policy team is analyzing life-cycle carbon balance of regional forest management systems and conducting multi-scale analyses of market and non-market forest benefits and services under future management and climatic conditions. In year 1, the team completed key regional analyses of pine productivity responses to future climate scenarios and assessed optimal harvesting regimes for varying hurricane risk.

- The education team is creating resources and programs to educate high school students and teachers as well as university students about the relevance of forests, forest management, and climate impacts. The PINEMAP education program also engages university students in collaborative, interdisciplinary research aimed at solving complex societal problems. In year 1, the team launched a regionwide undergraduate internship program; coordinated a distance graduate education course to prepare students to address climate change mitigation and adaptation issues in southern pine forests; and partnered with the national Project Learning Tree education network to develop a module for high school students on southern pine forests and climate change.
- The extension team is disseminating emerging knowledge, practices, and PINEMAP decision support tools to enable corporate and non-corporate landowners to increase forest carbon sequestration, nitrogen fertilizer efficiency, and forest resilience under changing climate. The team has implemented a comprehensive audience assessment program, including a survey assessing climate change perceptions of over 4,000 Extension professionals across the region. Integrating efforts with state climatologists and Extension foresters has been a key focus.

In the second year, our focus on integration across disciplinary groups positions us to deliver the real-world outcomes embedded in our mission, which include the following:

- improved economic return and reduction of loss from catastrophic events;
- increased forest carbon sequestration and fertilizer efficiency;
- enhanced capacity for regional, multi-disciplinary collaboration among climate and forest scientists, Extension and education professionals, and graduate students;
- increased capacity for non-corporate forest landowner participation in C markets;
- increased deployment of adaptive strategies to ensure the sustainability of planted southern pines in advance of climatic changes;
- climate-smart audiences making informed decisions related to the southern planted pine system and consumption of forest products;
- diverse stakeholders, including landowners, secondary school teachers, and students, with a clearer understanding of adaptive forest management strategies and their role in climate change mitigation.

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**APPENDIX 1:
PINEMAP DISTANCE GRADUATE COURSE SYLLABUS**

Syllabus

Spring 2012 PINEMAP Distance Graduate Course: Climate and Forests

Course Coordinators:

Martha Monroe, Professor and Extension Specialist, School of Forest Resources and Conservation, University of Florida (mcmonroe@ufl.edu); Jessica Ireland, PINEMAP Project Coordinator, School of Forest Resources and Conservation, University of Florida (jjtireland@ufl.edu)

Course Goals:

- Prepare graduate students to address climate change mitigation and adaptation issues in southern pine forests.
- Facilitate greater levels of integration by encouraging students to engage in the processes designed to enhance communication, cooperation, and collaboration among disciplines and across research, education, and Extension functions.
- Build interdisciplinary research, education, and outreach capacity.

Course Objectives:

- Increase understanding of climate, climate change, carbon cycle, carbon sequestration, and environmental controls on pine productivity.
- Increase understanding of the policy and economic realities driving regional pine forest management.
- Increase understanding of education and communication principles as applied to effective outreach strategies, the process of program development and evaluation, and the strategies used by Cooperative Extension to support changes in behavior.
- Gain an appreciation for the breadth and complexity of the PINEMAP project.
- Work with others outside of own aim to engage in education and extension aspects of the project.
- Be able to articulate the benefits and barriers to interdisciplinary research.

Format:

- Students will register for 2 credits of independent study or special topics with their advisor at their home institution. Advisor will assign a grade (pass/fail or letter grade).
- Students will participate in webinars and web thread discussions, listen to presentations, read papers, interact in both the live and asynchronous discussions, work in small groups, and complete two assignments.
- Live course sessions will be broadcast via Elluminate on Tuesdays, 12-2 p.m. EST. To join the Elluminate sessions, click on this link:
<https://sas.illuminate.com/m.jnlp?sid=2010029&password=M.FCFC4F779D4D0037A078760AA2B6DF>
- Live class sessions will begin January 17 and conclude May 1.

Assignments:

Aim Group Assignment 1:

Students in each Aim will work with one or two faculty members to better understand the literature and research questions in their Aim. This exploration should enable any student to comfortably explain what we already know, why the research is proposed, and what questions the research is designed to answer. Groups are encouraged to go beyond the proposed research to discuss additional questions that may be of interest. Students will explain their Aim research to the other students via a video, web site, readings, PowerPoint, or other format of choice that will be loaded to the web site by March 2 to be viewed asynchronously during the weeks of March 5-19. Groups should develop discussion questions for their Aim and encourage students to ask additional questions to help them prepare their opportunity to clarify their presentation on March 27. An Assignment 1 worksheet will be available to help students review all the presentations and reflect on their own.

Assignment 1 coordinators: Aim 1: Mike Kane; Aim 2: Randy Wynne; Aim 3: Gary Peter and Jason Holliday; Aim 4: Bob Abt and Damian Adams; Aims 5 and 6: Martha Monroe

Interdisciplinary Group Outreach Assignment 2:

Students will be assigned to four groups, each with an Extension faculty leader. Together they will identify a target audience of interest (such as private family landowners, youth, teachers, an undergraduate student club, or forest industry coop members), understand their needs for information and skills, revise or develop a program or product, and implement and evaluate it during the month of April. The vision is to explore the Extension program development process, albeit on a small scale. Groups may develop and test a fact sheet or develop and give a presentation to a group of students, for example. All team members should be involved in evaluating the program/product in some way, so it should be something that can be implemented by everyone in the group in their local area. Please post your product (PowerPoint presentation, fact sheet, etc.) on the course web site by April 17 for feedback from the faculty team.

Assignment 2 coordinators: Bill Hubbard, Gwendolyn Boyd, Joshua Idassi, Mark Megalos

Course Schedule

Live Elluminate webinars will be held Tuesdays, 12-2 p.m. EST on the following days: Jan 17, Jan 24, Jan 31, Feb 7, Feb 14, March 27, April 3, April 17, April 24, and May 1. To join the live webinars, click on this link:

<https://sas.illuminate.com/m.jnlp?sid=2010029&password=M.FCFC4F779D4D0037A078760AA2B6DF>

Prior to January 17:

Review PINEMAP web site (www.pinemap.org); register on course web site (<http://gradcourse.pinemap.org>)

Jan 17: Welcome to PINEMAP; course overview and introductions

Coordinators: Martha Monroe and Jessica Ireland

Illuminate webinar, 12-2 p.m. EST: Tim Martin, Professor of Tree Physiology, School of Forest Resources and Conservation, University of Florida

To prepare for this week:

Send one PowerPoint slide that describes/illustrates you to Jessica Ireland

(jjtireland@ufl.edu) by January 12, 2012 and be prepared to introduce yourself on the webinar.

Jan 24: The impact of climate change on forest ecosystems

Coordinators: Tom Fox, Randy Wynne, and Dan Markewitz

Illuminate webinar, 12-2 p.m. EST: Soil Properties and Processes that Control Soil Carbon Accumulation Tom Fox, Professor of Forest Soils and Silviculture, Virginia Tech; Forest and Carbon Storage, Dan Markewitz, Professor, Soil Site Productivity, University of Georgia; Managing Forests in the Face of an Uncertain Climate, Randy Wynne, Professor of Forestry, Remote Sensing, Virginia Tech.

To prepare for this week, read:

- 1) Millar, C.I., N.L. Stephenson, and S.L. Stephens. 2007. Climate change and forests of the future: Managing in the face of uncertainty. *Ecological Applications* 17(8):2145-2151.
- 2) McKinley, D.C., M.G. Ryan, R.A. Birdsey, C.P. Giardina, M.E. Harmon, L.S. Heath, R.A. Houghton, R.B. Jackson, J.F. Morrison, B.C. Murray, D.E. Pataki, and K.E. Skog. 2011. A synthesis of current knowledge on forests and carbon storage in the United States. *Ecological Applications* 21(6):1902-1924.
- 3) Schmidt, M.W.I., M.S. Torn, S. Abiven, T. Dittmar, G. Guggenberger, I.A. Janssens, M. Kleber, I. Kogel-Knabner, J. Lehmann, D.A.C. Manning, P. Nannipieri, D.P. Rasse, S. Weiner, and S.E. Trumbore. 2011. Persistence of soil organic matter as an ecosystem property. *Nature* 478:49-56.

Jan 31: Climate model projections in the Southern U.S.

Coordinators: Ryan Boyles and Heather Dinon

Illuminate webinar, 12-2 p.m. EST: Climate projections: Where do they come from and what can we use them for? [Katharine Hayhoe, Research Associate Professor of Atmospheric Sciences, Texas Tech University](#)

To prepare for this week, read:

- 1) Intergovernmental Panel on Climate Change (IPCC). 2011. *Fact Sheet: IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*: http://www.ipcc.ch/news_and_events/docs/srex/SREX_fact_sheet.pdf
- 2) IPCC. 2007. *Summary for Policymakers: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC*. <http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf>
- 3) Risbey, J.S. and T.J. O'Kane. 2011. Sources of knowledge and ignorance in climate research. *Climatic Change* 108(4):755-773. ("Abstract," "Introduction," and "Conclusions" required; entire article optional)
- 4) Jonassen, R. and R. Pielke Jr. 2011. Improving conveyance of uncertainties in the findings of the IPCC. *Climatic Change* 108(4):745-753. (read "Abstract" and

Introduction” and review LMI-CLICKE web site:

<http://clicke.lmi.org/index.php/Home>)

- 5) National Wildlife Federation. 2011. *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment*.

http://training.fws.gov/CSP/Resources/climate_change/vulnerability_handouts_nov_2011/TOC_bookmarked.pdf (read pages 51-62, stopping at “Types of Response Models” and pages 68-71)

For more information/optional readings:

- 1) IPCC. 2011. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: A Special Report of Working Group I and Working Group II of the IPCC*. http://ipcc-wg2.gov/SREX/images/uploads/SREX-SPM_Approved-HiRes_opt.pdf
- 2) *Climatic Change*, Volume 108, Number 4. October 2011. *Special Issue: Guidance for Characterizing and Communicating Uncertainty and Confidence in the Intergovernmental Panel on Climate Change*. <http://www.springerlink.com/content/k2r46wj51481/>
- 3) Yohe, G. and M. Oppenheimer. 2011. Evaluation, characterization, and communication of uncertainty by the intergovernmental panel on climate change—an introductory essay. *Climatic Change* 108(4):629-639. (“Introduction” section required; entire article optional)
- 4) Morgan, M.G. and C. Mellon. 2011. Certainty, uncertainty, and climate change. *Climatic Change* 108(4):707-721. (read pages 707-708)

Feb 7: Southern Forest Futures: Comparing driving forces

Coordinator: Robert Abt

Illuminate webinar, 12-2 p.m. EST: [David N. Wear, Southern Research Station, USDA Forest Service](#)

To prepare for this week, read:

- 1) Wear, D.N. and J.G. Greis. 2011. *The Southern Forest Futures Project: Summary Report*. USDA Forest Service Southern Research Station. http://www.srs.fs.usda.gov/futures/reports/draft/summary_report.pdf

Feb 14: The biology, economics, and scale effects of carbon scoring woody biomass for energy

Coordinator: Robert Abt

Illuminate webinar, 12-2 p.m. EST: Robert Abt, Professor of Forestry, Department of Forestry and Environmental Resources, North Carolina State University

To prepare for this week, read:

- 1) EPA Science Advisory Board. 2011. *Accounting Framework for Biogenic CO₂ Emissions from Stationary Sources*. Washington, DC: U.S. EPA Office of Atmospheric Programs, Climate Change Division. [http://yosemite.epa.gov/sab/sabproduct.nsf/0/2F9B572C712AC52E8525783100704886/\\$File/Biogenic_CO2_Accounting_Framework_Report_LATEST.pdf](http://yosemite.epa.gov/sab/sabproduct.nsf/0/2F9B572C712AC52E8525783100704886/$File/Biogenic_CO2_Accounting_Framework_Report_LATEST.pdf)
- 2) Manomet Center for Conservation Sciences. 2009. *Biomass Sustainability and Carbon Policy Study, Chapter 5: Forest Carbon Modeling: Stand-Level Carbon Dynamics and Implications of Harvesting for Carbon Accumulation*. Brunswick, ME: Manomet Center for Conservation Sciences. http://www.manomet.org/sites/manomet.org/files/Manomet_Biomass_Report_Chapter5.pdf

- 3) Abt, R.C., C.S. Galik, and J.D. Henderson. 2010. *The Near-Term Market and Greenhouse Gas Implications of Forest Biomass Utilization in the southeastern United States*. Durham, NC: Climate Change Policy Partnership, Duke University. http://www.nicholas.duke.edu/ccpp/ccpp_pdfs/biomass.08.2010.pdf

Weeks of Feb 20 and 27: Assignment 1: Work with Aim teams and Aim coordinator to understand the theory, framework, and current issues in your Aim. Use your Aim Elluminate site as desired to work together on the assignment. Post assignment on the course web site by March 2.

Aim Coordinators:

Aim 1: Mike Kane

Aim 2: Randy Wynne

Aim 3: Gary Peter and Jason Holliday

Aim 4: Bob Abt and Damian Adams

Aims 5 and 6: Martha Monroe

Weeks of March 5 – 19: Two weeks of asynchronous work during the three week period of spring break. Review each of the posted aim programs from Assignment 1, respond to questions, and ask questions.

March 27: Discuss Assignment 1: Aim groups respond to questions and comments, clarify their program, and engage in additional discussion of Aim-based research.

Coordinators: Martha Monroe and Jessica Ireland

Live discussion via Elluminate webinar, 12-2 p.m. EST

April 3: Effective climate change Extension programming

Coordinator: Bill Hubbard

Elluminate webinar, 12-2 p.m. EST: Bill Hubbard, Southern Regional Extension Forester

To prepare for this week, read:

- 1) Butler, B.J., M. Tyrrell, G. Feinberg, S. VanManen, L. Wiseman, and S. Wallinger. 2007. Understanding and reaching family forest owners: Lessons from social marketing research. *Journal of Forestry* 105(7):348-357.
- 2) Kittredge, D.B. 2004. Extension/outreach implications for America's family forest owners. *Journal of Forestry* 102(7):15-18.
- 3) Snyder, L.B. and S.H. Broderick. 1992. Communicating with woodland owners: Lessons from Connecticut. *Journal of Forestry* 90(3):33-37.
- 4) Israel, G.D., A. Harder, and C. Winton Brodeur. 2011. *What is an Extension program?* (WC108). Gainesville: University of Florida Institute of Food and Agricultural Sciences. <http://edis.ifas.ufl.edu/wc108>
- 5) Monroe, M.C. & G. Hochmuth. 2007. *Scholarship in Extension program development: The role of the state specialist* (FOR 123). Gainesville, FL: University of Florida Institute of Food and Agricultural Sciences. <http://edis.ifas.ufl.edu/fr179>
- 6) Israel, G.D. *Using logic models for program development* (AEC360). 2001. Gainesville, FL: University of Florida Institute of Food and Agricultural Sciences. <http://edis.ifas.ufl.edu/wc041>
- 7) Diem, K.G. 2002. *A step-by-step guide to developing effective questionnaires and survey procedures for program evaluation & research* (FS995). New Brunswick, NJ: Rutgers

Cooperative Research & Extension, NJAES.

<http://njaes.rutgers.edu/pubs/publication.asp?pid=FS995>

Additional resources:

- 1) University of Wisconsin-Extension. 2001. *Cooperative Extension Program Planning in Wisconsin*.
<http://www.uwex.edu/ces/pdande/planning/pdf/ProgramPlanning.pdf>
- 2) University of Wisconsin-Extension. 2003. *Welcome to Enhancing Program Performance with Logic Models*.
<http://www.uwex.edu/ces/pdande/evaluation/pdf/lmcourseall.pdf>

April 10: Challenges to communicating about climate

Coordinator: Martha Monroe

To prepare for this week, review narrated PowerPoint asynchronously, post comments/questions on weekly discussion board, and read:

- 1) Center for Research on Environmental Decisions (CRED). 2009. *The Psychology of Climate Change Communication: A guide for scientists, journalists, educators, political aides, and the interested public*. New York. 1-48.
<http://cred.columbia.edu/guide/>
- 2) Somerville, R. C. J. and S. J. Hassol. 2011. Communicating the science of climate change. *Physics Today* 64(10):48-53.
- 3) Moser, S.C. and L. Dilling. 2007. Introduction, in Moser, S. C. and Dilling, L. (eds.) *Creating a climate for change: Communicating climate change and facilitating social change*. Cambridge UK: Cambridge University Press, 1-27.

April 17: PINEMAP Decision Support System (DSS)

Coordinator: Ryan Boyles

Illuminate webinar, 12-2 p.m. EST: Ryan Boyles, Director and State Climatologist and Heather Dinon, Applied Climatologist, State Climate Office of North Carolina

To prepare for this week, read:

- 1) Breuer, N.E., C.W. Fraisse, and P.E. Hildebrand. 2009. Molding the pipeline into a loop: The participatory process of developing Agroclimate, a Decision Support System for climate risk reduction in agriculture. *Journal of Service Climatology* 3, 1:1-12. <http://www.journalofserviceclimatology.org/articles/2009/Breuer-2009-JSC.pdf>
- 2) Greer, J.E., S. Falk, K.J. Greer, M.J. Bentham. 1994. Explaining and justifying recommendations in an agriculture Decision Support System. *Computers and Electronics in Agriculture* 11, 2-3:195-214.
- 3) Review AgroClimate web site: <http://agroclimate.org/about/>
- 4) Open-AgroClimate brochure: <http://open.agroclimate.org/wp/wp-content/uploads/2010/08/OAC-Brochure.pdf> and poster: <http://open.agroclimate.org/wp/wp-content/uploads/2010/11/Open-AgroClimate-Moving-Forward-Poster-v2.pdf>

April 24: Interdisciplinary research, adapting to a changing world

Coordinator: Gary Peter

Illuminate webinar, 12-2 p.m. EST: Gary Peter, Professor, Forest Genomics and Cell Biology, School of Forest Resources and Conservation, University of Florida

To prepare for this week, read:

- 1) Eigenbrode, S. D., M. O'Rourke, J.D. Wulfhorst, D.M. Althoff, C.S. Goldberg, K. Merrill, W. Morse, M. Nielsen-Pincus, J. Stephens, L. Winowiecki, and N.A. Bosque-Perez. 2007. Employing philosophical dialogue in collaborative science. *BioScience* 571:55-64.
- 2) National Research Council. 2009. *A New Biology for the 21st Century*. Washington, DC: The National Academies Press.
http://www.nap.edu/catalog.php?record_id=12764 (read pgs. 1-38)

May 1: Groups report on their extension programs (what they did, with whom, and what they learned); course evaluation, discussion, and feedback.

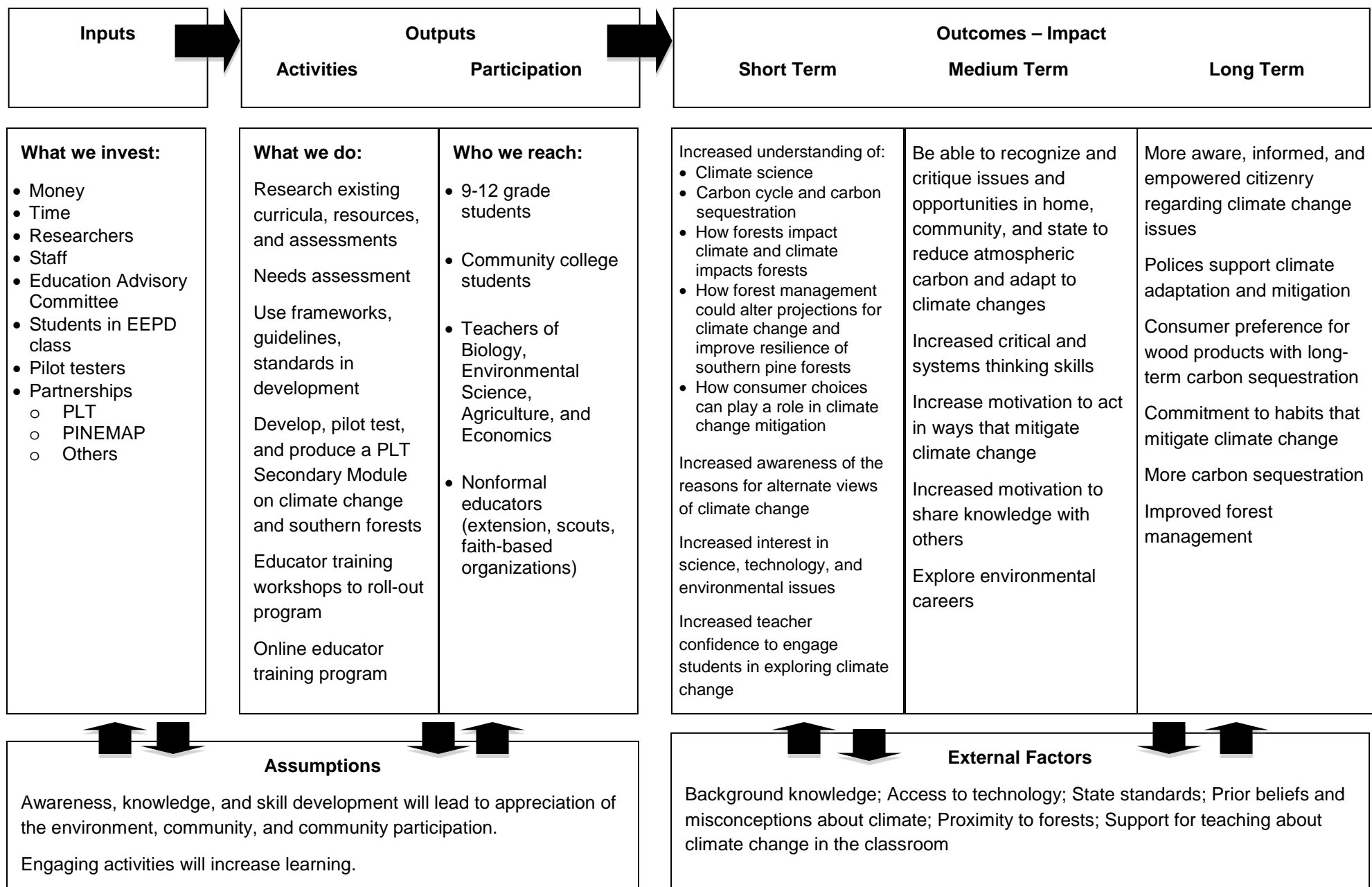
Coordinators: Martha Monroe and Jessica Ireland

Live discussion via Elluminate webinar, 12-2 p.m. EST

**APPENDIX 2:
PLT/PINEMAP SECONDARY MODULE LOGIC MODEL**

Logic Model for Project Learning Tree Secondary Module: Southern Forests and Climate Change

Situation: PINEMAP and PLT have partnered to develop a secondary module to address how forests affect climate, how variations in climate affect forests, and how people can mitigate climate change with forests and manage forests to adapt to an increasingly variable climate.



APPENDIX 3:
DRAFT PLT/PINEMAP SECONDARY MODULE SCOPE AND SEQUENCE

Section 1. Predicted climate changes will affect forest ecosystems.

(PLT Themes in Section 1: 1.3, 2.10, 3.3, 3.5, 4.3)

Topics	Students will be able to:	Key Concepts	Draft Activities and Ideas
Climate Change	Explain climate, weather, global warming, and climate change	Climate describes patterns in variables like temperature, wind, rainfall, humidity, etc. over long periods of time. It can be contrasted from "weather" which are short-term descriptions of the same variables. Global warming refers to the increase in global average temperature over time. Climate change refers to changes in global weather patterns which can impact temperature and precipitation extremes. Changes in climate will likely vary from region to region and are mainly due to the rise in global average temperature which can impact, for example, the water cycle. Climate change can also occur naturally due to changes in sunlight and other factors.	Introduction to the Module will explain many of these concepts. In addition, there are many existing resources and activities that we can suggest for educators who wish to expand their teaching of basic climate change and climate science. Idea: We should include an introductory activity that conveys background information on climate science and climate change.
	Explain evidence of climate change	Scientists generally agree that the human-induced increases in greenhouse gases in the atmosphere, such as CO ₂ , due to the burning of fossil fuels is causing or expediting global warming. The heat trapping properties of these gases have been scientifically demonstrated. Evidence of climate change includes sea level rise due to melting ice caps (e.g., about 1 foot sea level rise from 1930 to 2000 at Wilmington, NC), shrinking ice sheets (e.g., Greenland lost ~200 cubic km per year from 2002 to 2006), and retreating glaciers around the world.	Includes a slide presentation and small group discussions about multiple perspectives and the pieces of evidence these perspective use to bolster their claims.
	Describe diverse beliefs and perspectives regarding climate change	Diverse opinions about climate change tend to be attributed to: a) lack of knowledge of current evidence of change, b) belief that something as big as climate can't be changed by people, c) political position against changing behaviors to address climate change, which translates to denying that change is occurring, d) political position to delay decisions about addressing climate change, which translates to raising concerns about uncertainty, predictive models, change due to natural variability, and the high cost of action.	

Climate Change Impacts on Forests	Describe how predicted changes in climate may affect southern forest ecosystems	Changing temperatures and rainfall are likely to impact plant and animal species' ranges, decomposition and nutrient availability, insect pests and diseases, and wildfire frequency.	<p>EEPD Activity 1: Student groups read different USFS fact sheets explaining a current research and challenges associated with climate change and forests in the Southeast, and students take turns "teaching" what they have learned to others, using a jigsaw method.</p> <p>EEPD Activity 2: Feedback Loops. Students learn about positive and negative feedback loops and create systems diagrams to illustrate how forests could be impacted by climatic change and how climate is impacted by changes in forest ecosystems.</p> <p>Need an activity to understand how temperature change can affect an ecosystem differently than people</p>
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Section 2. Forests can be managed to thrive in a changing climate (adaptation).
(PLT Themes in Section 2: 2.3, 3.5, 3.6, 3.7, 4.9, 5.5)

Topics	Students will be able to:	Key Concepts	Draft Activities and Ideas
Forest Management	Describe how forest types and ownership influence decisions about forest management	In the Southeast, most forestland is privately owned. Providing a market for wood products makes owning a forest more economically desirable. Without those markets, private forest owners are likely to convert their land to more profitable uses (e.g., real estate development).	EEPD Activity 3: In this investigative activity, student groups work together to understand how different viewpoints on climate change may influence landowner decisions about pine plantation management in the Southeast.
	Describe what strategies forest landowners and managers can use to better manage their forests with predicted climate changes	For example, thinning overcrowded forest stands helps reduce stress on each tree, which creates a healthier, more resilient forest that can withstand pests and pathogens better.	Need activity on management
Genetics	Describe how genetic variation in species across their natural range can be used to develop traits to help trees tolerate climate change	Genetic variation in individuals and families make some trees more able to withstand climatic changes. Seedlings from selected parents are available for reforesting private lands	Need activity on genetics, if deemed appropriate

Section 3. Forests can be managed to reduce atmospheric greenhouse gas and to prevent greenhouse gas emissions (mitigation).
(PLT Themes in Section 3: 2.2, 3.1, 3.10, 4.1, 4.9, 5.4, 5.8)

Topics	Students will be able to:	Key Concepts	Draft Activities and Ideas
Carbon Sequestration	Diagram how carbon moves through the natural system Explain how carbon is sequestered in plants	Carbon is a basic building block of life. Plants use atmospheric CO ₂ to grow, converting that carbon into plant material. Carbon is stored in various places for different lengths of time. Burning fossil fuels taps a carbon source that has not circulated for a very long time.	Idea: Convert Water Wonders (PLT Activity 44) and the GLOBE Carbon activity to teach about carbon sources, sinks, and various steps and connections in carbon cycle in the southeastern forests.
	Measure the carbon in a tree	Carbon is stored in a plant during photosynthesis. Growing trees sequester carbon at a rapid rate. Differences in species and age account for different rates of sequestration. Tree height, diameter, and species can be used to estimate the amount of carbon in that tree.	EEPD Activity 4: Using trees on the school grounds, students measure tree size and then calculate the amount of carbon stored in each tree and in the entire forested area. Students then compare this amount to how much carbon is stored in a grassland, an agricultural area, and a pine plantation of similar sizes.
	Calculate the carbon that is sequestered in a forest	Process for using the species composition, average age and size of trees, and species-specific info to estimate how much carbon is stored in a particular forest.	Optional addition to previous activity: How many acres of forest do we need to sequester the carbon produced by the US/world in a year... How many acres of forest do we have...
	Compare sequestration potentials for forests, agriculture, and other land uses	Loss of forests means that much of the carbon that had been stored as plant material has been converted into atmospheric CO ₂ and other greenhouse gases and that forests will not be able to re-sequester that carbon.	
Policies and Incentives	Compare federal policies that could provide incentives for landowners to sequester more carbon	Economic markets and policies play a key role in the supporting landowners' ability to manage forests for climate change mitigation.	Need an activity if this is appropriate to include
	Explain how federal and state policy can change incentives to encourage changes in forest management change	Review existing policies, assess potential outcomes of proposed policies, create a new policy.	Need an activity if this is appropriate to include

Section 4. Consumer choices can play a role in reducing and preventing carbon emissions.

(PLT Themes in Section 4: 2.4, 2.7, 2.8, 2.11, 4.4, 5.9, 5.10, 5.12)

Topics	Students will be able to:	Key Concepts	Draft Activities and Ideas
<p style="text-align: center;">Life Cycle Analysis</p>	<p>Explain the phases of a product's life cycle</p>	<p>The production, shipping, and disposal components of the product's life cycle may have significant impacts on the total environmental impact of that product, in addition to the materials used in the product (feedstock).</p>	<p>EEPD Activity 5: Student groups use a web-quest to research life cycle information for a particular product, and then participate in a debate where each group develops a persuasive argument as to why their product is more environmentally-friendly (aluminum cans vs. plastic bottles; plant-based vs. metal utensils; glass vs. Styrofoam cups). Students generate a framework of questions to guide the selection of "green" items.</p> <p>Life Cycle Analysis Play: A three act play, where students investigate life cycle information for three types of outdoor lawn furniture (wood, aluminum, and plastic resin). Same information will be provided in another format for educators who do not want to do the play.</p> <p>Tutorial: Step-by-step instructions for how to access and use the National Renewable Energy Laboratory Database for life cycle analysis calculations. This tutorial would be for advanced courses.</p> <p>Need a wrap-it-up exercise?</p>
	<p>Identify the types of questions for each phase to ascertain a "good" product</p>	<p>A good, environmentally-friendly product means one that can be produced, maintained/used, and disposed of with minimal non-renewable resource use and pollution, and maximum carbon sequestration.</p>	
	<p>Explain how personal actions impact the global environment</p>		
<p style="text-align: center;">Product Comparisons</p>	<p>Compare the life cycles of products made from renewable and nonrenewable feed stocks; limited use items, and locally-produced items.</p>	<p>Products from renewable feedstocks are generally preferable to those from nonrenewable feed stocks. Items that are used and worn out, or reused by others, are preferable to trendy, fashionable items that are quickly discarded. Shipping complicates a LCA.</p>	
	<p>Explain the potential impacts of selecting products made from wood</p>	<p>Long-lived products made from wood will sequester carbon in the product. Increasing markets for wood could help forest landowners obtain a fair price for their trees.</p>	

**APPENDIX 4:
PLT/PINEMAP SECONDARY MODULE
EDUCATION ADVISORY COMMITTEE MEMBERS**

PLT/PINEMAP Education Advisory Committee Members

Name	Affiliation
Harold Anderson	Mississippi PLT Coordinator Mississippi Forestry Commission
Lisa Balazs	AP Environmental Science Teacher Indian Springs School
Mary Ball	Biology Department Instructor Carson-Newman College
Wendy-Lin Bartels	Southeast Climate Consortium, Florida Climate Institute University of Florida
Rob Beadel	Arkansas PLT Coordinator Arkansas Forestry Association
Susan Buhr	Director, CIRES Education and Outreach Group University of Colorado
Donna Charlevoix	Director of the Science and Education Division GLOBE Program
Chris Erwin	Alabama PLT Coordinator Alabama Forestry Association
Casey Harris	Texas PLT Coordinator Texas Forestry Association
Kris Irwin	Georgia PLT Co-coordinator Warnell School of Forestry and Natural Resources University of Georgia
Candace J. Lutzow-Felling	Director, Environmental Science Programs State Arboretum of Virginia
Babs McDonald	National Inquirer USDA Forest Service
Elizabeth McGovern	AP Environmental Science, Biology I Teacher Countryside High School
Brian Myers	Associate Professor and Associate Chair Agriculture Education and Communication University of Florida
Justina Osa	Professor and Chair Educational Administration and Supervision Virginia State University
Kristen Poppleton	Education Program Manager Will Steger Foundation
Jodi Riedel	Agriculture Education Teacher Wakefield High School
Sarah Sallade	GLOBE Carbon Cycle Science Education Specialist, Project Coordinator University of New Hampshire
Safiya Samman Heidi McAllister	Director, Conservation Education Program US Forest Service
John Seiler	Alumni Distinguished Professor Department of Forest Resources and Environmental Conservation, Virginia Tech
Becky Smith	CLiPSE (Climate Literacy Partnership in the Southeast) Dept. Finance and Economics, College of Business Mississippi State University
Peg Steffen	Education Coordinator Communications and Education Division, NOAA
Renee Strnad	NC PLT Coordinator, Extension Forestry North Carolina State University
Gabriole Van Bryce	Executive Director Dream in Green

**APPENDIX 5:
PINEMAP OPERATING PRINCIPLES AND GUIDELINES**

PINEMAP Operating Principles and Guidelines

First draft (6/14/2011; Tom Fox, Tim Martin, Martha Monroe, Gary Peter)

Feedback from Executive Committee + volunteers incorporated (08/24/2011)

Feedback from full group incorporated (09/02/2011)

Approval by Executive Committee (09/08/2011)

Revisions re: Coop. data, social science data, and authorship made by Project Management Team (2/1/2012)

Revisions approved by Executive Committee (02/09/2012)

The PINEMAP project is a large and diverse team of collaborators working together toward common goals. Whenever people work together, the potential for misunderstandings and conflict exists, even when all involved are well-intentioned. The purpose of this document is to formalize and record group consensus on the principles that we agree to follow in working with each other on this project, and to establish guidelines for dealing with potentially difficult situations before those situations arise. The document will address these areas:

- I. General Principles**
- II. Project governance and general decisionmaking**
- III. Decisionmaking on critical topics including scientific direction and budget changes**
- IV. Graduate student involvement**
- V. Data sharing**
- VI. Authorship**

I. General Principles

As a condition for participation in PINEMAP, we agree to adhere to these core values and principles:

- We will develop and support a culture of mutual respect and trust
- We will adhere to rigorous scientific approaches and principles
- We share a group commitment to building long-term capacity for cross-function work (Research + Extension + Education), which will require us to reach out beyond our disciplinary focus areas
- We will hold ourselves and each other accountable to the goals and outcomes of the project with regard to data delivery, data sharing, and cross-aim collaboration, and will be responsive to requests for information, data, and collaborations
- We will strive for full attribution of credit
- We will be equitable in our dealings with each other
- We will foster an environment conducive to intellectual stimulation and growth for all those involved in the project

II. Project Governance and General Decisionmaking

The governance structure of the project is described in detail in the project management plan (see Appendix). The Project Director is ultimately accountable to the funding agency for the execution of the project, and so has final decisionmaking authority. The Project Director will be responsible for the day-to-day operation of the project, and will regularly consult with the Integration Leaders and Aim Leaders regarding project progress and direction. The Executive Committee is composed of a cross-section of project collaborators intended to be representative both in terms of professional discipline and institutions. It will be consulted on all matters having project-wide impact.

III. Decisionmaking on critical topics

On topics which have project-wide impacts, such as changes in scientific direction or emphasis, or changes in budget or distribution of resources, the Project Director will work closely with the Executive Committee (EC) to reach decisions. The EC, as a representative body, will have the responsibility of assuring that decisionmaking is consistent with the project principles listed previously, and that major decisions of the Project Director are supported by group consensus. If good faith efforts cannot achieve consensus, the Project Director will make final decisions based on their interpretation of the project goals and principles.

IV. Graduate student involvement

Assumptions:

1. Graduate students play a key role in the CAP program (preparing future scientists) and serve the interests of each cooperating institution and major advisor.
2. Graduate students may be funded completely or partially by the CAP program, as determined by the major advisor.
3. Stipend amounts, benefits, and workloads will vary across these 11 institutions.
4. Decisions about coursework, program requirements, and scholarly contributions will be decided by the major advisor and advisory committee in keeping with department and institution guidelines, except as specified below.
5. One purpose of graduate student involvement in this project is to prepare future scientists to work in interdisciplinary teams, to conduct research, extension and education, and to make contributions to complex problems.
6. Grievances such as sexual harassment, plagiarism, work load, and personal differences will be addressed at the department or institution level, and not the CAP program.

As a part of creating this program, we agree that:

1. All graduate students engaged in PINEMAP are expected to actively participate in
 - program-wide activities, such as annual meetings (when possible), reports, and team activities
 - their aim team (see below)
 - at least one other aim team, preferably Extension or Education (see below)
 - a distance-based course for all graduate students (see below)
 - mentoring an undergraduate student, if one is selected and matched to their research activity (see below)
2. All graduate students will meet during the annual meetings of the CAP program to share their experiences across aims in this integrated research activity. Graduate students and their mentors should also seek out additional opportunities to network with other PINEMAP students, both within their home institutions and in other partner institutions.
3. Graduate students will present research findings at the PINEMAP annual meetings and/or other relevant conferences
4. Graduate students are encouraged to partner across aims to develop new insights, conduct integrative projects, write papers, and present findings.
5. Graduate students are expected to publish results
6. Authorship order of research papers that reflect work in which graduate students have provided the primary conceptual foundation shall be graduate student(s) first, followed by major advisor(s), and appropriate other individuals (see authorship policy).
7. Graduate student contributions on the secondary aim team will be acknowledged and noted, but may not automatically result in authorship.

Graduate students' role on their Aim Team

Graduate students will work closely with their advisor on one aim team to design and conduct their research as well as assist with other research as needed by the team. Graduate students are expected to be full members of the team, to offer insights, complete assignments, and assist with reports. Because graduate students will also be instrumental members of a second aim team, they are likely to be key links in the integration of team activities.

Graduate students' role on the secondary Aim Team

Graduate students are expected to also work on a second aim team, which is likely to be Extension or Education. In these capacities, they will be expected to write or review outreach materials or teaching activities, assist with the evaluation and revision of materials, make presentations to target audiences, and help with linkages across aims.

Graduate students' Distance Course

All graduate students will register for an introductory course offered through regional webinars and web-based discussions. Students will register for independent study or seminar credits in their own institution. The first cohort of graduate students will be expected to improve the course for subsequent cohorts and may take leadership roles. More senior graduate students will also present seminars to other students on their specific research. Students may use the course to begin interdisciplinary investigations and cross-aim linkages. They are likely to develop background web pages for each aim on the project web site and case studies that help inform others about their research topics. The course will be designed by a team of faculty.

Graduate students' role as mentor of an undergraduate intern

Graduate students will be able to apply for an undergraduate intern to assist with summer research for Summer 2012, 2013, and 2014. Successful applicants will learn to be mentors, to help build their intern's research skills, to design a component of their project that interns can launch and complete during the summer, assist their intern with data analysis and interpretation, and work closely in developing the intern's public school presentation. The interns will take a distance course in the fall on inquiry education and give presentations in local public school classrooms. Graduate students who host an intern will participate in the fall course and assist with the development of classroom presentations. They will work with interns until they are adequately prepared and performing successfully.

V. Data sharing

A significant advantage to the PINEMAP team is access to data and existing field trial that enhance ability to accomplish the NIFA required milestones. The cooperative data made available to the participants of the PINEMAP project represents a 50+ year, multimillion dollar investment by universities, state and federal agencies and the forest industry in the South. The cooperative directors must insure that these data are used appropriately and that the interests of the cooperative members are maintained.

Therefore, the following data access and publication policies were established for the PINEMAP project and approved by the PINEMAP executive committee.

All participants in the PINEMAP project, including PI's, research scientists, postdocs and graduate students are required to read and sign the data access and publication policy indicating that they agree to abide by these guidelines. Participants who have questions or encounter situations where the guidelines are unclear should contact the PINEMAP Lead PI, Dr. Tim Martin, for clarification and guidance. The PINEMAP executive committee and industrial advisory board may be consulted if necessary to address specific situations.

Access to Cooperative Research Sites and Sharing of Cooperative Data

The research cooperatives participating in the PINEMAP grant have agreed to provide access to field trials and make plot and individual tree data from selected research sites available to participants in the PINEMAP project according to the following policy:

1. To be included in the PINEMAP project, written requests for access to specific research sites and the plot and individual tree data from cooperative research trials must be made to the appropriate Cooperative Director by the PINEMAP Lead PI on behalf of the PINEMAP Executive Committee. Data requests need to be specific and include a proposed use for the data. Individual cooperatives will approve access to the research trials and data requested by the PINEMAP Project following the operating procedures of each cooperative.
2. Requests for Cooperative data by individual investigators will be referred for approval to the appropriate Cooperative director. Cooperative directors will, upon request, be provided with a list of individuals who have downloaded data from their respective Cooperatives.
3. Specific sites, treatments, plots and the associated data provided by the individual cooperatives will be made available to the PINEMAP project. Other cooperative sites or plots at a specific site and the associated data may be excluded from the PINEMAP project and will not be available to the PINEMAP participants.
4. Access to individual sites for collection of additional data must be approved by the organization responsible for each site. No site visits will be made unless approved by the organization responsible for each site. All PINEMAP participants must agree to the rules and regulations established by the organizations that control each site, including use of appropriate personal protective equipment. PINEMAP participants may be required to sign Right of Entry and Liability Waiver Forms by the organizations responsible for each site. No access will be allowed until the appropriate forms are signed.
5. The location of the individual study sites (latitude and longitude) will be provided to allow climate variable and soil types to be determined.
6. Site characterization data, such as soil series, soil chemical and physical properties, will be provided if available.
7. Establishment date, study design, plot size, and original spacing will be provided.
8. Information on silvicultural treatments, including site preparation treatments, fertilization, weed control, thinning and pruning will be provided. Individual cooperatives may elect to provide coded information on specific silvicultural treatments such as fertilizer rate or herbicide treatments applied.
9. Genetic identifiers will be coded by the individual cooperatives except for checklots. Checklot information will be provided so that relative performance of the coded improved genotypes can be compared to unimproved seed sources. The degree of genetic improvement (unimproved, 1st gen OP, 2nd gen OP, CP, Variety, etc.) will be provided. To the degree possible, the expected performance of the genotypes included will be provided using a classification system such as the NC

- State University Performance Rating System. If it serves to minimize confusion in PINEMAP publications, coding may conform to that used in previous publication(s) describing the particular study site.
10. Individual tree height, dbh, and tree condition code data will be released. Plot summaries will also be provided if available. Other data from the individual trees or the plots that has been collected may be made available if requested.
 11. Coop data included in the PINEMAP project is to be used only to address the specific objectives detailed in the proposal approved by NIFA. This includes use in growth and yield models and process models, economic analyses and Life Cycle Assessments conducted by participants in the PINEMAP project. The data may also be used to produce look-up tables, graphical summaries, management recommendations, and other summaries that are used in the education and outreach portions of the project. The data may be used to produce publications, models and Decision Support System tools related to the specific objectives of the PINEMAP project. However, analysis of data based on the experimental design of the original experiments for which the study was installed and any publication of the data is considered outside of PINEMAP and is prohibited.
 12. Plot and individual tree data will not be made available to anyone other than the participants in the PINEMAP project who have signed the data access guidelines. PINEMAP participants may not release any cooperative data to anyone not directly affiliated with the PINEMAP project.
 13. These data sharing and publication guidelines will remain in effect following the completion of the PINEMAP project.
 14. If the PINEMAP project is terminated prior to the five-year term agreed to by NIFA, all data will revert back to the individual coops that provided the data and any sharing of data will be at the discretion of the individual cooperatives based on their individual data sharing guidelines in effect at that time.
 15. Assuming that PINEMAP is funded through February 2016, data use and publications resulting from Cooperative data will not occur after August 31, 2018. At that time, all raw and summary Cooperative data, other than that included in existing publications, will be deleted or destroyed. The respective Cooperative directors will be notified when the data have been deleted or destroyed.

Release of Information Prior to Publication

The central outcome of PINEMAP is to influence landowner decisions to improve carbon mitigation and the adaptation and resilience of forests for a variety of climate scenarios. Thus, coops are expected to present PINEMAP information to their members as the information is developed, which will often occur before peer review publication. Consequently, all cooperatives providing significant contributions of data or study sites for a particular project will have similar access to significant results prior to publication and be able to present them to their members. Whenever possible, such presentations should include the principal PINEMAP researchers who have generated the new information.

Sharing New Data Collected / Generated as Part of the Project

Because of the integrated nature of the project, timely sharing of data among project participants is critical so that work is not delayed. During the development of Aim work plans, data needs for each Aim group should be identified, so that data sharing and exchange can be planned in advance. To facilitate project progress, newly-collected data should be posted to the TerraC data management system by the end of the quarter in which the data were collected.

Prior to submission to TerraC, all data will undergo quality assessment / quality control by the faculty member responsible for the data collection. This will ensure data quality and integrity consistent with existing scientific standards. All field and lab data created as part of this project will be included in the centralized database management system TerraC and documented with metadata (i.e., descriptions of the data) to allow wide sharing of the datasets.

Co-authorship decisions associated with publication of shared data should be made after consultation with the guidelines in the Authorship section.

New data generated as part of the NIFA-funded PINEMAP project will be made available to the broader (non-PINEMAP) community via appropriate community data archives, but not before project participants have had first opportunities for use of the data to meet project objectives. Policies for outside-PINEMAP data sharing will be developed by an *ad hoc* committee and will be inserted into this document at a later date.

Social science data collection

PINEMAP projects have the opportunity to collect data from human participants that can and should be shared by PINEMAP researchers. The IRB protocols should be written to allow datasets to be shared with colleagues and students after the individual identifiers have been removed to preserve anonymity and confidentiality. IRB approval should be modified if this was not considered prior to approval. PINEMAP colleagues and students who use data gathered by others should work with the originators to be clear on the assumptions and limitations of the data, to interpret results and comparisons appropriately, and to determine authorship and/or author order on publications.

VI. Authorship

Authorship of peer reviewed publications is one of the primary benefits derived from scientific collaboration. Discussions and decisions regarding authorship and author order of publications resulting from PINEMAP collaborations should occur early in the collaboration process. When in doubt about whether to offer authorship to a collaborator, participants should err on the side of inclusion. Authorship can always be declined if a participant feels they have not contributed sufficiently to merit authorship.

Because of the large size of the project and the use of shared data, the potential for redundant or similar papers to be developed independently is greater. PINEMAP colleagues and students who use data gathered by others should work with the originators to be clear on the assumptions and limitations of the data, to interpret results and comparisons appropriately, and to determine authorship and/or author order on publications. To avoid duplication of effort and enhance the potential for collaboration, it is critical that anticipated analyses and publications be posted to the PINEMAP “Planned Analyses and Publications” spreadsheet on the PINEMAP Intranet site.

Authorship Guidelines for Publications Based on Coop Data Included in PINEMAP Project

1. All PINEMAP participants should recognize the substantial investment of time and resources made by the individual cooperatives and the cooperative directors to create the research sites and data contributed to the PINEMAP project. It is likely that without the cooperatives and the efforts of the cooperative directors, the data made available to participants in the PINEMAP project would not exist. Consequently, when coop data is used for PINEMAP publications the directors of coops contributing data should be given the option of being included as an author. In addition, the source of the data should always be explicitly acknowledged.
2. It is customary when making a request for data from another scientist to offer co-authorship on all publications using the data. Therefore, publications from the PINEMAP project that use substantial amounts of data from a cooperative or multiple cooperatives, should offer authorship to the director(s) of that coop because the publication would not be possible without their efforts. For example, many of the publications from the PINEMAP will be similar to meta-analyses using data from multiple sources. These publications usually have multiple authors because the data used in the meta-analysis comes from multiple sources.
3. Individuals offered authorship on a specific publication can decide whether authorship is appropriate or whether acknowledgment is sufficient.
4. Publications arising from new research conducted on coop sites through the PINEMAP project that do not use substantial amounts of coop data should follow established guidelines of the science community typically followed for determining authorship. This includes many of the graduate student projects that will be conducted through the PINEMAP project.
5. Information on the ownership and organizations responsible for individual study sites will be coded to keep ownership information for individual sites confidential, and no information about the individual owners or organizations responsible for each research sites will be published in any manner other than acknowledgement of the support provided by the cooperative members.
6. It is appropriate to acknowledge the support of the cooperatives that provided access to sites and data in all publications from the PINEMAP project.
7. Standard acknowledgement of NIFA using the approved language is required for all publications arising from the PINEMAP project.



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SOUTHERN REGIONAL
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MISSISSIPPI STATE
UNIVERSITY



TEXAS A&M
UNIVERSITY



Virginia Tech
Invent the Future



Southeast
Climate Consortium



Improving Lives. Improving Texas.

University-Corporate-Governmental Research Cooperatives

Cooperative Forest Genetics Research Program | Cooperative Tree Improvement Program

Forest Biology Research Cooperative | Forest Modeling Research Cooperative

Forest Productivity Cooperative | Plantation Management Research Cooperative

Southern Forest Resource Assessment Consortium | Western Gulf Forest Tree Improvement Program