



2015 Annual Meeting

June 3-4, 2015 | UGA Hotel and Conference Center, Athens, GA

POSTER SUMMARY BY OUTCOME THEME – 🌱 denotes student poster



Increased carbon (C) sequestration from silvicultural and genetic enhancement of productivity and efficiency of fertilizer use, and resilience to climate variability and disturbance.

1. 🌱 **What to plant and where to plant it; modeling the biophysical effects of temperate forests on climate using the Community Earth System Model** *Benjamin Ahlswede and R. Quinn Thomas*
2. **The devil's in bulk density: considering and utilizing the NCSS database to estimate bulk density of forest soils** *Allan Bacon, Madison Akers, Josh Cuccinella, Sabine Grunwald, Eric Jokela, Marshal A. Laviner, Daniel Markewitz, Timothy Martin, and Jason Vogel*
3. 🌱 **The effect of throughfall reduction and fertilization on stomatal control of water use in loblolly pine over two-years at the Georgia Tier III installation** *Stan Bartkowiak, Lisa Samuelson, Mary Anne McGuire, and Robert Teskey*
4. 🌱 **Estimating transpiration and growth efficiency in loblolly pine (*Pinus taeda*) plantations using the 3-PG model** *Bruce Barros Souza, Robert Teskey, Carlos Gonzalez-Benecke, Lisa Samuelson, Eric Ward, Stan Bartkowiak, and Eric Jokela*
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11. **Litter decomposition in the Virginia Tier III site** *Andy Laviner and Tom Fox*
12. 🌱 **Impacts of drought and geographical positions on loblolly pine (*Pinus taeda* L.) tree ring width and water use efficiency: methodology and preliminary results** *Wen Lin, Asko Noormets, JC Domec, John King, Ge Sun, and Steve McNulty*
13. 🌱 **Exome capture in a population of *Pinus taeda* L.** *Mengmeng Lu, Konstantin Krutovsky, C. Dana Nelson, Tomasz Koralewski, Tom Byram, Carol Loopstra*

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Engaged and literate public with the capacity to make informed, practical decisions related to climate, forest ecosystems, and forest management.

27. 🌱 **The role of the agent: how Extension agents view their role in sharing climate-related information** *Margaret Clifford and Martha Monroe*
28. 🌱 **Cultural cognition and climate change education: why consensus is not enough** *Kristen Kunkle and Martha Monroe*
29. 🌱 **Measuring and fostering hope among high school students about climate change** *Christine Li and Martha Monroe*

30. **Linking educators and students to forests in a changing climate** *Martha Monroe, Kristen Kunkle, Christine Jie Li, Annie Oxarart, and Tracey Ritchie*

31.  **Methods for measuring systems thinking in high school students** *Tracey Ritchie and Martha Monroe*



Public policy that supports sustainable management of planted pine under future climate scenarios.

32.  **Using climate and genetic diversity data to prioritize conservation seed banking** *John Hastings, Mark Megalos, Robert Jetton, Kevin Potter, Frank Koch*

33.  **Evaluating nonindustrial private forest landowner participation in carbon sequestration** *Puskar Khanal, Donald L. Grebner*

34. **Effects of trace gases within Pinus taeda L. plantations in the Piedmont soils of the Southeast United States** *Dan Markewitz, Carla Gann*

35. **Modeling the impacts of historic climate change and extreme droughts on water yield and productivity of the National Forest system (NFS) over the conterminous U.S.** *Ge Sun, Shanlei Sun, Peter Caldwell, Steve McNulty, and Yang Zhang*



Enhanced capacity for regional, interdisciplinary collaboration among climate and forest scientists and Extension and education professionals.


36. **TerraC – PINEMAP's data management system: demonstration** *Khori Battle, Carlos Gonzalez-Benecke, Sabine Grunwald, and Timothy Martin*

37. **PINEMAP's Decision Support System: demonstration** *Heather Dinon Aldridge, Ryan Boyles, Corey Davis*



Enhanced connections between corporate and noncorporate forest landowners and forestry and climate researchers and education and outreach professionals.

38. **PINEMAP's Outreach Efforts: Educating Foresters and Influencing Changes on the Ground** *Leslie Bobby, William Hubbard, Eric Taylor, and Mark Megalos*

39.  **Southern Foresters' Climate Observations: What, Where, and Implications for Continuing Education** *Rachel Greene, Mark Megalos, William Hubbard, Leslie Bobby, Hilary Cole*



A more robust and resilient forest-based economy in the Southeast U.S.

40.  **Assessing Climate Change Impacts on Wildfire Risk in the United States** *Hyunjin An, Jianbang Gan, and Sung Ju Cho*

41.  **Producing an understory cover map over a large region using heterogeneous lidar datasets** *Ranjith Gopalakrishnan, Valerie Thomas, and Randolph Wynne*

POSTER ABSTRACTS BY OUTCOME THEME – 🌱 denotes student poster



Increased carbon (C) sequestration from silvicultural and genetic enhancement of productivity and efficiency of fertilizer use, and resilience to climate variability and disturbance.

1. 🌱 **What to plant and where to plant it; modeling the biophysical effects of temperate forests on climate using the Community Earth System Model** *Benjamin Ahlswede and R. Quinn Thomas*

Forests influence local climate through biophysical processes such as albedo and evapotranspiration. It is well established that boreal forests have a warming effect by reducing albedo and tropical forests have a cooling effect by increasing evapotranspiration. However the influence of temperate forests on climate is less certain. Previous model experiments have shown that adding temperate forests warms the land surface on average. However, some non-model studies that examine these effects at the sub-biome level show a latitudinal gradient of effects presumably due to differences in climate while other studies show variation in biophysical effects due to forest type that is independent of climate. Using the Community Earth System Model, we explore spatial variation in the direction and magnitude of the climate response to changing forest cover in temperate regions. To examine the sensitivity of climate to the forest-type we ran simulations using three land-cover compositions: 100% needle-leaf evergreen trees, 100% broad-leaf deciduous trees and 100% grass cover (i.e., non-forest). To understand the effect of latitude, we then separated grid cells into 12 clusters based on pre-land-use change precipitation and temperature and repeated the land-cover composition simulations for each cluster independently. Annually, we found that needle-leaf evergreen trees had warmer surface temperatures than both deciduous trees and grassland ecosystems. However, we did find a gradient in the magnitude of the biophysical effect on surface temperature due to variations in background climate and albedo. Seasonally in North America, needle-leaf evergreen trees show a strong warming influence on surface air temperature throughout the year with the smallest warming influence occurring in the late fall. In contrast, due to seasonal variations in albedo and evapotranspiration, broad-leaf trees have a moderate warming influence throughout most of the year, but a cooling influence in late summer to early fall. Our results help better understand how land-cover change in the temperate region influences climate and highlights how temperate forests can be managed to have a biophysically cooling influence on land-surface temperature.

2. **The devil's in bulk density: considering and utilizing the NCSS database to estimate bulk density of forest soils** *Allan Bacon, Madison Akers, Josh Cuccinella, Sabine Grunwald, Eric Jokela, Marshal A. Laviner, Daniel Markewitz, Timothy Martin, and Jason Vogel*

Soil bulk density (Db) is a physical soil property required to estimate elemental contents of soils. Unfortunately, compared to sampling for chemical analyses, accurately sampling soil Db is challenging and laborious, especially at depths greater than a few decimeters. In the absence of direct Db estimates an often employed tactic is to use the National Cooperative Soil Survey (NCSS) database, which contains more than 20,000 Db observations from various depths across the United States and largely underpins USDA Soil Survey Geographic (SSURGO) data. We use random forest algorithms to construct Db pedotransfer functions from direct Db estimates across the PINEMAP Tier II network ($n > 1200$) and direct Db estimates in the NCSS database ($n > 2500$, after subsampling geographically and taxonomically to conform with the PINEMAP Tier II network) to accomplish three goals: (1) predict missing Db records in the PINEMAP Tier II network, (2) quantify the uncertainty associated with using NCSS data to estimate Db across this network, and (3) understand how this uncertainty influences estimates of soil carbon content. Our analysis shows that there is significant potential for NCSS data to overestimate Db in forest soils, presumably due to a NCSS bias towards agricultural soils, which in turn leads to an overestimate of soil carbon contents. We discuss the propagation of artificially high Db into soil carbon content estimates and evaluate its effects on ecosystem carbon budgets across the PINEMAP Tier II network.

3. 🌱 **The effect of throughfall reduction and fertilization on stomatal control of water use in loblolly pine over two-years at the Georgia Tier III installation** *Stan Bartkowiak, Lisa Samuelson, Mary Anne McGuire, and Robert Teskey*

Loblolly pine (*Pinus taeda* L.) plantations produce 16% of the global industrial wood supply and therefore reductions in productivity associated with climate variability may have significant economic impacts in the Southeastern United States. The objective of this project was to determine whether stand-level water use is influenced by the main and interactive effects of throughfall reduction and fertilization to better understand the potential impact of climate variability on loblolly pine productivity. We hypothesized that greater leaf area and related soil water depletion in response to fertilization

would increase the impact of throughfall reduction on canopy level processes. The Tier III experimental design is a factorial combination of throughfall (ambient versus throughfall reduction) and fertilization (control versus fertilized) treatments. Sap flow measurements were initiated in November 2012. In 2013, a wetter than normal year, an interactive effect of fertilization and throughfall treatments on monthly transpiration on a ground area (E_G) and leaf area (E_L) basis, average midday canopy stomatal conductance (G_S), and leaf-specific hydraulic conductance (K) was observed. Throughfall reduction decreased monthly E_G , E_L , G_S , and K only in the fertilization treatment, most likely because of increased LAI from fertilization and isohydric regulation of water loss. However, preliminary analyses of data collected in 2014, a drier year that received 25% less precipitation than 2013, indicate that the main effect of fertilization treatment reduced E_G , E_L , G_S , and K , regardless of throughfall reduction treatment. These results indicate that greater leaf area associated with fertilization may increase sensitivity of canopy-level water use to reduced soil moisture availability. Analysis of whole-canopy water use (i.e. transpiration and stomatal conductance) estimated from sap flux measurement provides (1) physiological understanding of underlying regulatory mechanisms controlling productivity and (2) water relation parameters for the Physiological Principles to Predict Growth (3-PG) and Water Supply and Stress Index (WaSSI) models.

4. 🌳 Estimating transpiration and growth efficiency in loblolly pine (*Pinus taeda*) plantations using the 3-PG model *Bruce Barros Souza, Robert Teskey, Carlos Gonzalez-Benecke, Lisa Samuelson, Eric Ward, Stan Bartkowiak, and Eric Jokela*

The pine forests in the southeastern USA are responsible for providing ecosystem and economic services, including clean water, CO₂ sequestration, fiber and wood products. However, there are increasing concerns regarding climate change and its effect on water use. Most climate predictions indicate that drought frequency and severity is expected to increase in the region. We are using the hybrid process model, 3-PG, to understand how these drought events will impact transpiration, productivity and carbon pools of loblolly pine plantations. The model was calibrated and validated using measurements of sap flow and growth from four locations (Georgia, Virginia, Florida and Oklahoma) representing a wide range in edaphic and climatic conditions in the southeastern region. At each location there were four different treatments (control, fertilization, throughfall reduction and combined throughfall reduction and fertilization). The growth efficiency predictions by the 3-PG model showed a small bias for the Georgia and Florida sites, where the drought treatment showed a higher value in the Georgia site 7.78 m³.ha⁻¹.year⁻¹/unit of LAI, while in Florida a higher value was achieved by the fertilized treatment 8.85 m³.ha⁻¹.year⁻¹/unit of LAI. Accurate transpiration predictions were also observed. For example, comparing predicted and observed values of transpiration for the control treatment at the Georgia site produced a R² of 0.94 and RMSE of 0.1443 mm H₂O. At the Virginia site, a comparison of observed and predicted transpiration for the control treatment had a R² of 0.85 and RMSE of 1.204 mm H₂O. These results were consistent at both monthly and yearly time steps. The 3-PG model was also able to capture the seasonal pattern of LAI (leaf area index) well on the two sites tested (Georgia and Florida, control treatment). Simulated drought had significant effects on biomass growth and water use, indicating that climate change may have substantial effects on the water and carbon sequestration under different management regimes and intrinsic site conditions.

5. 🌳 Soil heterotrophic respiration in southern pine plantations: seasonality, microbial communities, and models *Robert Brown, Daniel Markewitz, Lawrence Morris, Miguel Cabrera*

In order to determine the effectiveness of southern pine plantations in sequestering atmospheric carbon, we must know the amount of fixed CO₂ that is subsequently lost due to heterotrophic microbial activity in the soil. Furthermore, this heterotrophic proportion of total soil respiration must be quantified as it changes between different operational treatments, ecoregions, and seasons. These proportions are necessary to accurately determine net ecosystem productivity from net primary productivity, thus helping to estimate the amount of carbon accumulated by the ecosystem. The research aims to quantify heterotrophic contributions to total soil respiration in the Piedmont and Upper Coastal Plain ecoregions under control, fertilizer, and herbicide treatments over an annual cycle. Heterotrophic respiration (R_h) is separated in the field from autotrophic root respiration (R_a) by using metal root-excluding collars and CO₂ efflux measurements are made monthly over 90 days. Following final measurements, roots are excised to 30 cm below each point, dried, and weighed to account for differences in rooting mass. A soil sample of the top 10 cm at each point is also taken and measured for microbial biomass. Collars are re-installed to begin the next 90-day seasonal rotation. Soil respiration is also being modeled at these sites to predict heterotrophic respiration. Preliminary results in Piedmont and Upper Coastal Plain ecoregions indicate R_h of 78 and 82% during winter with little effect of fertilization but a large decrease in herbicide plots. Microbial biomass did not vary greatly among treatments or between exclusion collars relative to control collars, but did differ between ecoregions. Finally, initial modeling efforts in a generic pine plantation estimate seasonal R_h of 20 to 90%, values that exceed empirical measures. These preliminary efforts suggest R_h is a substantial pathway of CO₂ return to the atmosphere in a range of pine ecosystems. We intend to determine what

proportion of fixed carbon is lost due to soil microbial activity in different scenarios which will allow models to more accurately determine net primary productivity, or carbon sequestration.

6. Conversion of natural forests to managed forest plantations decreases tree resistance to prolonged droughts *Jean-Christophe Domec, John King, Eric Ward, A. Christopher Oishi, Sari Palmroth, Andrew Radecki, Dave Bell, Guofang Miao, Michael Gavazzi, Daniel Johnson, Steve McNulty, Ge Sun, Asko Noormets*

Throughout the southern US, past forest management practices have replaced large areas of native forests with loblolly pine plantations and have resulted in changes in forest response to extreme weather conditions. However, uncertainty remains about the response of planted versus natural species to drought across the geographical range of these forests. Taking advantage of a cluster of unmanaged stands (85-130 year-old hardwoods) and managed plantations (17-20 year-old loblolly pine) in coastal and Piedmont areas of North Carolina, tree water use, cavitation resistance, whole-tree hydraulic (K_{tree}) and stomatal (G_s) conductances were measured in four sites covering representative forests growing in the region. We also used a hydraulic model to predict the resilience of those sites to extreme soil drying. Our objectives were to determine: (1) if K_{tree} and stomatal regulation in response to atmospheric and soil droughts differ between species and sites; (2) how ecosystem type, through tree water use, resistance to cavitation and rooting profiles, affects the water uptake limit that can be reached under drought; and (3) the influence of stand species composition on critical transpiration that sets a functional water uptake limit under drought conditions. The results show that across sites, water stress affected the coordination between K_{tree} and G_s . As soil water content dropped below 20% relative extractable water, K_{tree} declined faster and thus explained the decrease in G_s and in its sensitivity to vapor pressure deficit. Compared to branches, the capability of roots to resist high xylem tension has a great impact on tree-level water use and ultimately had important implications for pine plantations resistance to future summer droughts. Model simulations revealed that the decline in K_{tree} due to xylem cavitation aggravated the effects of soil drying on tree transpiration. The critical transpiration rate (E_{crit}), which corresponds to the maximum rate at which transpiration begins to level off to prevent irreversible hydraulic failure, was higher in managed forest plantations than in their unmanaged counterparts. However, even with this higher E_{crit} , the pine plantations operated very close to their critical leaf water potentials (i.e. to their permissible water potentials without total hydraulic failure), suggesting that intensively managed plantations are more drought-sensitive and can withstand less severe drought than natural forests.

7. Comparing the carbon allocation patterns of different genotypes of loblolly pine (*Pinus taeda* L.) under intensive silvicultural practices *Yuan Fang*

Productivity of southern pine plantation has increased substantially due to improved silvicultural practices, including genetic improvement. It does increase aboveground carbon (C) sequestration, but effects on belowground C are poorly understood. How sensitive of belowground C to differences in genetic are less clear. To address these issues, our objective is to quantify total belowground C allocation (TBCA) of four loblolly pine genotypes (three clones and one open pollinated) in one year observation period, by measure the soil carbon flux, and litterfall once a month. We do expect the clone with broad crown has a higher soil C flux due to the positive correlation between root areas and projected canopy area. The moderate crown ideotype may be the most productive due to less canopy competition and less soil C flux.

8. Alternative approaches to breeding value predictions within family *Adam Festa and Ross Whetten*

The goal of this study is to increase the selection intensity within loblolly pine breeding programs, by assessing the relationship between unique patterns of family gene expression and parental breeding values (BV). We hypothesize that selection intensity can be increased in pine breeding programs under two conditions -first, that there are genetic differences among families in gene regulatory networks, and second, that those differences are correlated with family mean performance in field tests of progeny. Currently, selections for advanced generations of loblolly pine are made on the basis of family mean phenotype, where phenotypically superior individuals are selected from top-performing families, and progeny tested to screen for those trees that have the best BVs. However, there is little confidence that phenotypically superior selections from a progeny test will carry forward the traits intended from the family, because many traits of interest to breeders have low individual-tree heritability. In order to estimate the BV of a tree, a BLUP (Best linear unbiased predictor) analysis is conducted where phenotype and pedigree data are utilized to help define the genetic covariance among a set of families from a mating design. It is reasonable to suspect that variation in family mean phenotypes can be partially accounted for by differences in gene structure, and partially by gene regulation patterns. Sequencing DNA copies of messenger RNA is a means to collect information on both types of differences. Using covariance structures based on variation in gene structure or gene regulation in a BLUP analysis instead of, or in addition

to, the standard numerator relationship matrix, may provide a higher prediction accuracy of BV's. To test this hypothesis, we have chosen 43 different parents, from a wide geographic distribution, with pre-existing progeny phenotype data available from field tests across multiple sites. Seeds (open-pollinated or pollen-mix in 37 cases, controlled-cross in 6 cases) from each of these parents were grown in a greenhouse, and seedlings were harvested at 3 months for RNA extraction and sequencing, which is still underway. The RNA expression results from these families will be used to create covariance matrices reflecting shared genetic variation in coding sequences on one hand, and shared variation in gene regulatory networks on the other. Cross-validation of BLUP models using these covariance matrices, as well as a standard numerator relationship matrix, will be used to test the hypothesis that phenotypic variation can be accurately modeled by covariance of these classes of genetic variation. This analysis should provide insight into the value of using RNA expression patterns as another screening effort in selecting individuals as parents for future breeding populations.

9. 🌱 Effects of cultural intensity, planting density, physiographic region and canopy level on leaf $\delta^{13}\text{C}$ and nitrogen in mature loblolly pine stands *Miles Ingwers, Dehai Zhao, Michael Kane, Daniel Markewitz, and Robert Teskey*

A better understanding of water relations and crown attributes is needed to maintain sustainable production of Loblolly pine (*Pinus taeda* L.) plantations. To further explore this subject we investigated the effects of cultural intensity, planting density, physiographic region and canopy level on $\delta^{13}\text{C}$, a surrogate for water use efficiency (WUE) and percent nitrogen content (N) in needles. Mature 15 and 16 year-old trees from three sites each in the Coastal Plain and Piedmont physiographic regions in the southeastern USA were used in this experiment. Cultural treatments consisted of "high intensity" and "low intensity" treatments with the "high intensity" treatment receiving a greater nutrient input and competition control relative to the "low intensity" treatment. Planting densities consisted of five different levels (1480, 2220, 2960, 3700 and 4400 trees ha^{-1}) while canopy height corresponded to the lower, middle, and bottom third of each canopy. Both $\delta^{13}\text{C}$ and N were significantly affected by canopy height and marginally affected by planting density ($p=0.063$) with the largest differences occurring between 1480 and 4400 trees ha^{-1} planting densities. Cultural intensity significantly affected N but not $\delta^{13}\text{C}$. Physiographic region had no significant effect despite considerable variation among installations, suggesting local factors may play an important role in $\delta^{13}\text{C}$. No significant interactions were found among treatments. These findings demonstrate that in mature stands, WUE is not affected, or only marginally affected, by cultural intensity, planting density or physiographic region while WUE and N at a needle level are largely determined by placement in the canopy.

10. Supporting loblolly pine deployment and procurement decisions: A modeling approach *Tomasz Koralewski, Thomas Byram, Hsiao-Hsuan Wang, William Grant*

Minimum temperature has been identified as a climate variable well correlated with loblolly pine (*P. taeda* L.) growth, and a limiting factor for the northward species seed movement in general (Schmidtling 1994). Water availability, another important factor related to climate, drastically declines at the western edge of the species distribution range. Therefore, drought seems to be the major limiting factor that prevents the loblolly pine range expansion in the west. These two parameters, represented as mean minimum temperature of the coldest month and growing season precipitation, along with their respective variance measures, were identified as main parameters that should be considered when analyzing potential seed movement scenarios. We used a recently proposed method, the Categorical Universal Response Function (CURF), to identify both the optimal candidate planting sites for given planting material (deployment) and the source location of the best candidate material for a given planting site (procurement). The method was shown to perform well for the data originating from the Geographic Seed Source Study (GSSS, Western Gulf Forest Tree Improvement Program), that spanned five westernmost states in the loblolly pine range.

11. Litter decomposition in the Virginia Tier III site *Andy Laviner and Tom Fox*

Forest litter has been shown to be both a source and sink for carbon and nitrogen in pine plantations at different points within a rotation. Major factors that have been correlated to litter decomposition include sun light, temperature, moisture, and litter nutrient status. In this experiment, three meter by three meter throughfall excluders were constructed using ten centimeter wide troughs evenly spaced to cover thirty percent of the ground area. These excluders were installed in the treated buffer of the control and fertilized treatments of the Virginia Fertilization by Throughfall Exclusion Experiment. Under each excluder and in the adjacent buffer area, twenty-one 10 cm by 25 cm litter bags were filled with 14g each of both brown litter collected in litter traps during the Fall of 2013 and green litter collected from live branches from each treatment in the main experiment. Three litter bags with each tissue type will be collected at

installation, 2, 4, 6, 10, 14 and 18 months. Mass loss and nutrient content will be determined after each collection. Our hypotheses include:

- 1) Green foliage will decompose at a faster rate due to more favorable C:N ratio.
- 2) Decomposition rates will be slower under throughfall exclusion due to lower moisture and light levels.
- 3) Nitrogen will be immobilized in litter.

12. 🌳 Impacts of drought and geographical positions on loblolly pine (*Pinus taeda* L.) tree ring width and water use efficiency: methodology and preliminary results *Wen Lin, Asko Noormets, JC Domec, John King, Ge Sun, and Steve McNulty*

As natural archives, tree rings provide combined information of past environmental processes and the responses from trees. Using the techniques of tree ring width measurements and cross-dating, α -cellulose extraction, and stable isotope analysis on loblolly pines cores collected from 107 Tier II sites, we are able to study the impacts of drought and geographical positions on tree growth and water use efficiency. The objectives for this study are: a) calculate the correlation between drought indices and tree ring width at each site and find out the drought index with highest correlation, b) test if there is a spatial relationship to such correlation, c) infer water use efficiency of trees at selected years with contrasting wetness using stable isotope technique, and d) establish a relationship between water use efficiency and drought, with consideration of geographical position. Here we present an update on this study, including the methodology of high-throughput method for α -cellulose extraction from resinous softwood, and preliminary results on radial growth increment

13. 🌳 Exome capture in a population of *Pinus taeda* L. *Mengmeng Lu, Konstantin Krutovsky, C. Dana Nelson, Tomasz Koralewski, Tom Byram, Carol Loopstra*

Loblolly pine, *Pinus taeda* L., is one of the most widely planted and commercially and ecologically important tree species in North America. We took an association genetics approach, using a population of 376 clonally replicated unrelated trees, to test 3938 single nucleotide polymorphisms (SNPs) for association with phenotypic variation in total tree height, specific leaf area and branch angle after three growing seasons. Data on phenotypic traits were collected in Saucier, Mississippi with support from the PINEMAP Undergraduate Fellowship Program. Best linear unbiased prediction (BLUP) was used with a spatial adjustment to remove environmental variation from phenotypic data derived from the field. After correction for multiple testing, no SNPs were detected to be associated with specific leaf area and branch angle; while two SNPs were associated with the total height. The flanking sequences of these two SNPs are related to the transcription factor Bhlh123-like and glucose-6-phosphate dehydrogenase 6. To expand the current SNPs pool, we applied the Nimblegen SeqCap EZ method to capture exon-targeted genome sequences in this population of 376 loblolly pine trees. 196,068 exon regions (\approx 51Mb) that were annotated by the PineRefSeq project were used to design probes. Adjacent coverage showed 90.2% of the exon regions were covered. Ten samples were multiplexed before capture. After capturing the targeted sequences, the libraries were sequenced using the Illumina HiSeq 2500. The capture efficiency analysis showed the percentage of on-target reads is above 70% and the mean sequencing depth of target region is approximately 60X. The preliminary SNP analysis showed 4,449,832 SNPs were discovered by GATK with the filtering condition "at least 5 reads for each sample". Among these SNPs, 54.86% were located in coding regions; 4.39% were located in 3' or 5' untranslated regions; and 40.75% were located in unannotated regions. Our results illustrate the efficiency of sequence capture for re-sequencing genomes of great size, and the SNPs discovered will be a valuable resource for downstream analyses.

14. 🌳 Fertilization and throughfall reduction effects on controls of litter decomposition *Kristin McElligott, John Seiler, and Brian Strahm*

Heterotrophic soil respiration is one of the largest fluxes in the terrestrial carbon (C) cycle and ultimately constrains ecosystem carbon storage. Forest management and altered precipitation regimes are expected to influence extracellular enzyme activity, decomposition, and soil CO₂ efflux, thereby ultimately affecting the net C balance of forest ecosystems. Extracellular enzymes produced by soil microorganisms control nutrient cycling and litter decomposition by hydrolyzing polymeric compounds, yet enzyme production and activity is partially dependent on N availability. Forest fertilization will alter litter quality and decomposition dynamics while simultaneously increasing litter C inputs; however, the mechanisms of decomposition responses from increased nutrient availability remain ambiguous and the combined effects of fertilization and reduced precipitation are unknown. The objectives of this study are to evaluate the interactive effects of fertilization and throughfall reduction on extracellular enzyme activity and litter quality that ultimately control litter

decomposition, and understand the contribution of this flux to total soil respiration. Litter and soil samples were collected from the VA PINEMAP Tier III treatment plots, and assayed for enzyme activity using fluorometric and colorimetric microplate analysis. Litter exclusion treatments were used to measure total, mineral, and litter CO₂ efflux. Litter quality will be evaluated using litter nutrient and lignin content. We expect that (1) fertilization will increase the abundance of C-degrading enzymes but decrease the abundance of N- and P-degrading enzymes and (2) reduced throughfall will inhibit potential enzyme activities in unfertilized, and to a lesser extent, fertilized plots. Results from this study could be used to infer shifts in decomposition dynamics, total soil CO₂ efflux, and ecosystem C storage.

15. 🌳 Variations in carbon flux partitioning in loblolly pine plantations over stand development *Guofang Miao, Asko Noormets, Michael Gavazzi, Jean-Christophe Domec, John King, Ge Sun, and Steve McNulty*

Carbon flux partitioning in most ecosystem models is currently done using constant ratios. However, recent evidence suggests that this may not be true, which have implications for environmental responses of different processes and as a result fixed ratios might bias the prediction on carbon pools and fluxes. This simplification might be more biased in plantation ecosystems as trees at different ages respond differently to changes in environmental conditions and exhibit dynamic patterns over stand development. Along with the deployment of canopy eddy covariance technologies and ground continuous measurements, high frequency data of flux components provide us an opportunity to refine the understanding of ecosystem processes and the connections between them. With 11 site years of canopy fluxes and soil effluxes collected from one young (2008-2012, age 5-9) and one mature (2005-2010, age 13-18) loblolly pine (*Pinus taeda*) plantations in eastern North Carolina, USA, we estimated gross ecosystem production (GEP), ecosystem respiration (Re), belowground respiration (Rs), and aboveground plant respiration (R_{agp} = Re - Rs) of the pine plantations when trees age. The ratios of respiratory components to GEP were then calculated at monthly and annual scales to investigate the variations in flux partitioning. The annual total fluxes of GEP and Re indicated that the young stand was more dynamic and sensitive to water variability than the mature stand. Both GEP and Re continued increasing in the young stand during the study period, but remained nearly constant in the mature stand. The ratios of annual Re to GEP were nearly constant at both stands with lower production efficiency in the young stand. When Re was partitioned into Rs and R_{agp}, both annual total fluxes of Rs and R_{agp} and ratios of these components to GEP exhibited more remarkable inter-annual variations than those of Re in both stands. The resultant constant ratio of Re to GEP implied that Rs and R_{agp} might act oppositely, which might also be related to the variations in carbon allocation to aboveground and belowground components. In addition, monthly variations exhibited a lag effect between total fluxes and ratios, that is, total fluxes of GEP, Re and components generally peaked during June and July while ratios peaked during August and September. During growing seasons, the monthly variations in ratios of Re to GEP were mainly controlled by Rs in the mature stand and by both Rs and R_{agp} in the young stand. These opposite trends between Rs and R_{agp} as well as the variations in the flux partitioning raise questions about whether the constant ratio of Re to GEP is a short-term or long-term pattern and how these trends evolve with the changes in environmental conditions. These findings also emphasize explicitly the importance of variations in flux partitioning for a better understanding of the long-term role of plantations in global carbon cycle.

16. Effects of forest management on productivity and carbon sequestration: a review and hypothesis *Asko Noormets, D Epron, JC Domec, Steve McNulty, Tom Fox, Ge Sun, and John King*

With an increasing fraction of the world's forests being intensively managed for meeting humanity's need for wood, fiber and ecosystem services, quantitative understanding of the functional changes in these ecosystems in comparison with natural forests is needed. In particular, the role of managed forests as long-term carbon (C) sinks and for mitigating climate change require a detailed assessment of their carbon cycle on different temporal scales. In the current review we assess available data on the structure and function of the world's forests, explore the main differences in the C exchange between managed and unmanaged stands, and explore potential physiological mechanisms behind both observed and expected changes. Two global databases that include classification for management indicate that managed forests are about 50 years younger, include 25% more coniferous stands, and have about 50% lower C stocks than unmanaged forests. The gross primary productivity (GPP) and total net primary productivity (NPP) are the similar, but relatively more of the assimilated carbon is allocated to aboveground pools in managed than in unmanaged forests, whereas allocation to fine roots and rhizosymbionts is lower. This shift in allocation patterns is promoted by increasing plant size, and by increased nutrient availability. Long-term carbon sequestration potential in soils is assessed through the ratio of heterotrophic respiration to total detritus production, which indicates that (i) the forest soils may be losing more carbon on an annual basis than they regain in detritus, and (ii) the deficit appears to be greater in managed forests. While climate change and management factors (esp. fertilization) both contribute to greater carbon accumulation potential in the soil, the harvest-related increase in decomposition affects the C budget over the entire harvest cycle. Although the findings do

not preclude the use of forests for climate mitigation, maximizing merchantable productivity may have significant carbon costs for the soil pool. We conclude that optimal management strategies for maximizing multiple benefits from ecosystem services require better understanding of the dynamics of belowground allocation, carbohydrate availability, heterotrophic respiration, and carbon stabilization in the soil.

17. The performance of range-wide soil respiration models at individual sites with long-term autochamber measurements
Asko Noormets, Guofang Miao, John Seiler, Chris Oishi, Sari Palmroth, Ram Oren, Michael Gavazzi, Ge Sun, Steve McNulty, and John King

The estimation of NEP across the PINEMAP domain requires range-wide estimation of heterotrophic respiration, which in turn is derived from total soil CO₂ efflux. However, understanding of range-wide variability and its main controls is limited, and only few studies have analyzed its dynamics in a systematic manner. Yet, even those studies have relied on instantaneous soil surface CO₂ efflux measurements, and contain significant uncertainties about temporal variability. Here we report the performance statistics of the models first developed by Templeton et al. (2015) and Gough et al. (2005) at four different loblolly pine stands where soil CO₂ efflux was measured for multiple (3-10) years. Broadly, the regional models developed on instantaneous growing season flux rates significantly overestimate the fluxes observed with continuously running autochambers. Model performance and the options for correcting for the bias are explored.

18. Preliminary three year synthesis of throughfall reduction and fertilization effects on leaf physiology of loblolly pine in Georgia
Charles Pell, Lisa Samuelson, and Madison Akers

The objective of this study was to investigate the interactive effects of an approximate 30% reduction in throughfall and fertilization on physiological characteristics that affect loblolly pine productivity at the Tier III site in Georgia. Leaf area index (LAI), intercepted photosynthetically active radiation (IPAR), and leaf-level physiology were measured over three years of treatment. Fertilization increased growth, peak LAI, and peak IPAR all three years of the experiment (2012-2014) but no treatment effects on growth efficiency, defined as the slope of the relationship between annual volume increment and peak LAI, were observed. During the abnormally dry 2012 year, volume increment was the lowest in all treatments relative to the following two years and was possibly in response to drought stress in all treatments, indicated by lower rates of stomatal conductance (gs) and net photosynthesis in 2012. Peak LAI in 2014 was increased from 2.8 m² m⁻² to 3.7 m² m⁻² by fertilization and in 2014 gs was decreased 16% by fertilization, most likely in response to the increased LAI and greater canopy water use. Reduced gs from fertilization lead to increased leaf intrinsic water use efficiency (WUE) derived from leaf 13C isotope discrimination measurements. Throughfall reduction reduced peak LAI from 3.6 m² m⁻² to 3.0 m² m⁻² in 2014 after three years of throughfall treatment, but no effect of throughfall reduction on leaf-level gas exchange was observed in 2014. However, throughfall reduction increased leaf WUE in 2014, indicating reduced gs not detected by instantaneous leaf gas exchange measurements. These results support the extensive literature showing positive effects of fertilization on early stand growth in response to increased LAI and IPAR, and also supports an isohydric strategy in loblolly pine to limit leaf-level and canopy-level water loss and increase water use efficiency.

19. Modeling the effects of throughfall reduction on soil water content in a loblolly pine plantation of the southeast U.S.
Ji (Jill) Qi, Daniel Markewitz, and David Radcliffe

In the Southeast U.S., changing climate conditions are predicted to be warmer and drier, resulting in more severe drought and drier soil moisture conditions. Access to water reserves in deep soil during drought periods helps the forest buffer the deleterious effects of water deficits. A research site was established in Taliaferro County, Georgia to test the effect of throughfall reduction on soil water content and forest productivity. The objective of this research is to model the soil moisture dynamics to predict the future hydrologic effects of throughfall reduction on the forest. A model was designed to simulate daily changes (March 2013 to Apr 2015) in the vertical distribution of soil water using HYDRUS 1-D. This model consists of 8 soil material layers: 0-10, 10-20, 20-50 and 50-300cm in 50 cm increments, with respective soil hydraulic parameters. Soils were sampled at eight corresponding depths to test for texture, Ksat, and van Genuchten parameters. Other model inputs include precipitation, evapotranspiration, root distribution and soil volumetric water content. Using time domain reflectometry, soil VWCs were measured approximately monthly from March 2013 to Apr 2015 at: 0-10, 0-30, 0-60, 0-90, 200 and 300 cm. In the absence of inverse fitting of parameters, the root mean square error between the model predicted value and field TDR measurements is 7.6%. The model predicted values were only able to explain 38.4% of the measured values. Soil VWCs were measured at the same intervals in the throughfall exclusion plots. These data will be used for model validation and to assess changes in the depth of root water uptake with drying.

20. 🌱 DayCent Calibration at the PINEMAP Tier 3 Monitoring Network *C. Wade Ross, Sabine Grunwald, Stephen J. Del Grosso, Wendell Cropper, Stefan Gerber, Leda Kobziar*

Process-based models are important tools used to study biogeochemical exchanges between Earth's biospheres. These models allow us to advance our understanding of complex ecosystem level processes and provide the opportunity to gain insight into interactions that may not be possible to examine through experimentation alone. Mechanistic models are particularly useful for management decisions as they are grounded in ecological, rather than statistical theory. Additionally, these models are well suited for forecasting an ecosystem's response to unknown future scenarios, such as changes in land use, land management, disturbance events, and climate. However, mechanistic models need to be properly calibrated to the area of interest to ensure reliable results are generated. This is typically achieved by adjusting input parameters to match conditions present at the site. Once the model has been properly calibrated, confidence while extrapolating to future scenarios is high relative to empirical models due to the underlying causal relationships mechanistic models are built on. The objective of this research was to calibrate DayCent, a mechanistic model of intermediate complexity, to the PINEMAP Tier III monitoring network. To calibrate DayCent, output was calibrated in the following order: soil water content, crop yields and plant growth rates, soil organic carbon levels, and N loss vectors. Model performance was evaluated by comparing simulated output to data obtained from the Tier III monitoring network in addition to open source data available to the general public. Measurements of net primary production (NPP) and soil carbon were primarily used for model calibration.

21. 🌱 Effect of nutrient amendment and weed control on litter decomposition in intensively managed southern pine stands *Praveen Subedi*

In order to ensure the sustained productivity of managed southern pine ecosystems, long-term nutrient supply to the site should be maintained. As litterfall decomposition is one of the major drivers of nutrient supply to the soil, understanding litter decomposition dynamics and finding ways to improve litter decomposition may improve soil nutrient availability. We plan to establish a series of studies in North Florida to investigate: a) how nutrient amendment and competing vegetation control in the previous rotation affect variation in litter chemistry (carbohydrates, phenols, lignin, N and P fractions) and decomposition rates in the second rotation, and b) how micronutrient addition influences activities of soil enzymes associated with litter decomposition. The outcomes of these experiments may improve our understanding of litter decomposition dynamics in relation to nutrient amendment, especially micro-nutrients, in southern pine stands.

22. Fertilization intensifies drought stress: water use and stomatal conductance of *Pinus taeda* in a midrotation fertilization and throughfall reduction experiment *Eric J. Ward, Jean-Christophe Domec, Marshall A. Laviner, Thomas R. Fox, Ge Sun, Steve McNulty, John King, and Asko Noormets*

While mid-rotation fertilization increases productivity in many southern pine forests, it remains unclear what impact such management may have on stand water use. We examined the impact of nutrient and water availability on stem volume, leaf area, transpiration per unit ground area (E_c) and canopy conductance per unit leaf area (G_s) of a pine plantation during its 8th and 9th growing seasons. Treatments consisted of a factorial combination of throughfall reduction (30% reduction in throughfall versus ambient) and fertilization (a complete suite of essential nutrients) beginning in April 2012. Overall, our results indicate that despite unusually high rainfall in the study period and a lack of leaf area index (LAI) response, both E_c and G_s decreased in response to fertilization and throughfall reduction. Fertilization increased stem volume increment 21% in 2013. Treatment differences were greatest in the growing season of 2013, when E_c was on average 19%, 13% and 29% lower in the throughfall reduction (D), fertilization (F) and combined treatment (FD) than the control (C), respectively. The responses of G_s to volumetric soil water content (VWC) indicate that lower E_c in F was associated with a decrease relative to C in G_s at high VWC. Decreases of G_s in D relative to C were associated with lower VWC, but little change in the response of G_s to VWC. Decreases observed in FD resulted from a combination of these two factors. The pattern of G_s responses in the different treatments suggests that structural or physiological changes underlie this fertilization response, possibly in fine root area or hydraulic conductivity. In the short term, this led to large increases in the water use efficiency of stem production, which could suggest greater resiliency to minor water stress. However, impacts on long-term sensitivity to drought remain a concern, as the E_c reduction triggered by the fertilization treatment was of comparable magnitude to the 30% throughfall exclusion treatment and the greatest reductions were found in the combined treatment.

- 23. 🌐 An annotated dense genetic map for loblolly pine and extent of linkage disequilibrium in three genotype-phenotype discovery populations** *Jared Westbrook, Vikram Chhatre, Le-Shin Wu, Srikar Chamala, Leandro Gomide Neves, Patricio Muñoz, Pedro J. Martínez-García, David Neale, Matias Kirst, Keithanne Mockaitis, C. Dana Nelson, Gary Peter, John Davis, and Craig Echt*

A consensus genetic map for loblolly pine was constructed by merging three previously published maps with a map from a pseudo-backcross between loblolly pine and slash pine. The consensus map positioned 3700 markers via genotyping of over 1200 individuals from four pedigrees. Functional predictions for nearly 3500 mapped EST markers were improved by alignment to full-length loblolly pine transcripts. Alignments to the loblolly pine genome mapped over 3000 scaffold sequences onto the 12 linkage groups. The consensus genetic map was used to compare the extent of genome-wide linkage disequilibrium in an association population of distantly related individuals (ADEPT2), a multiple-family pedigree used for genomic selection studies (CCLONES), and a full-sib quantitative trait locus mapping population (BC1). Weak linkage disequilibrium was observed in CCLONES and ADEPT2. Average squared correlations, R^2 , between genotypes at SNPs less than 1 cM apart was less than 0.05 in both populations, and R^2 did not decay substantially with genetic distance. By contrast, strong and extended linkage disequilibrium was observed among BC1 full-sibs where average R^2 decayed from 0.8 to less than 0.1 over 53 cM. The consensus map and analysis of linkage disequilibrium establish a foundation for comparative association and QTL mapping between genotype-phenotype discovery populations.

- 24. Considering nutrition, genetics, and soil morphology as they relate to loblolly pine needle and shoot dieback** *Duncan Worrall, Allan Bacon, Eric Jokela, and Timothy Martin*

Across the southeastern United States young intensively managed loblolly pine (*Pinus taeda*) plantations are plagued by a syndrome called needle and shoot dieback (NSD). NSD kills needles, and in the most severe cases terminal buds, thus lowering primary production of young stands and potentially wood quality of older stands. Although the underlying causes of NSD are unknown prior research suggests first, that a nutrient limitation/imbalance is involved and second, that trees can “grow out” of NSD once belowground C allocation allows them to exploit a deeper soil nutrient pool. We are investigating NSD occurrence at multiple PINEMAP Tier II installations that are part of the two year old FBRC-SSIGNS trials. These installations were established on Spodosol soils, which contain coarse textured, nutrient poor surface horizons above a comparatively nutrient rich subsoil Bh horizon. Preliminary results indicate that additions of N+P+macronutrients (K, Ca, Mg, and S) can significantly ($p < 0.05$) decrease NSD occurrence and severity and also that certain genotypes are significantly ($p < 0.05$) less susceptible than others. These effects however vary greatly between installations suggesting that an underlying environmental factor governs NSD occurrence and severity, including its response to culture and genetics. We’ve hypothesized that the depth to the Bh horizon is this factor, and that this edaphic property controls nutrient availability and thus NSD in these young pine stands both within and between installations. We are initiating chemical analyses of foliage (which will identify potential nutrient deficiencies/imbances related to NSD) and soils (which will characterize how nutrient availability varies with the depth to the Bh horizon). We are also creating continuous prediction maps of the depth to the Bh horizon to determine the degree of spatially correlated to NSD at the individual tree and landscape levels.

- 25. 🌐 Fertilization decreases soil CO₂ efflux and total below-ground carbon flux in a loblolly pine (*Pinus taeda*) plantation** *Jinyan Yang, Cody Luedtke, Katherine Akers, Mary McGuire, Lisa Samuelson, Charles Pell, Doug Aubrey, and Robert Teskey*

Soil CO₂ efflux (E_s) is an important component of forest ecosystem carbon budgets and net ecosystem CO₂ exchange. Total below-ground carbon flux (TBCF) is the sum of metabolic fluxes to support root production, respiration, root exudates, herbivory and symbionts. However, little is known about how E_s and TBCF will respond to decreasing soil moisture and changes in soil fertility. The experiment design was a 2 X 2 factorial combination of fertilization and throughfall reduction replicated in four blocks. The CO₂ efflux from autotrophic (E_A), heterotrophic (E_H) and mycorrhizal hyphae (E_{MH}) were separated with trenched plots lined with different materials. We took monthly measurement of E_s and its components and litterfall along with soil temperature and soil moisture in a loblolly pine plantation Washington, GA in 2014. Our objectives were to (1) quantify impacts of throughfall reduction and fertilization on E_s and its components, and (2) determine TBCF response to throughfall reduction and fertilization treatments. There were no significant differences for seasonal means of E_s , E_H and E_{MH} . Fertilization significantly decreased E_s by 22% and E_A by 37%. There were no significant throughfall exclusion effects on E_s or its components. The E_H was dominant contributor to E_s in all treatments, ranging from 62 to 67% while E_{MH} was less than 15% of E_s . Fertilization slightly decreased TBCF but increased annual litterfall and coarse root production. Throughfall reduction increased TBCF mainly by increasing fine root production. We

concluded that nutrient supply and water availability had different effects on E_s and TBCF, and that TBCF was more sensitive to fertilization and throughfall reduction treatments than E_s .

26. 🌱 Effects of climate change and forest management on wood mass loss in southeastern U.S. loblolly pine forests *Yang Zhang, Jason Vogel, and Jason West*

Wood debris is an important C pool in forest ecosystems. Understanding the response of wood decomposition to climate change is necessary for studying forest soil carbon cycling. The productivity of managed pine forests in the southeastern US has been improved in part through nutrient management over the past 50 years. Although significant uncertainty exists, climate change may drive a reduction of rainfall of 10%-30% by 2080 for the region. In managed forests that undergo periodic harvesting, the forest can become a source of C when decomposer activity increases C loss from residual wood. We analyzed wood decomposition in response to fertilization, reduced precipitation, location, time, and sites. Our early results showed that fertilization stimulated wood decomposition in OK site but tended to inhibited wood decomposition at the FL site after one year. Higher woody mass loss in FL compared to OK, GA and VA may be explained by higher temperature and precipitation. In FL and OK, wood mass by Macro-invertebrates was much higher compared to GA and VA. Interestingly, we found fertilization reduced mass loss of woods with macro-invertebrates' tunnels in FL but increased mass loss of woods with macro-invertebrates' tunnels in OK. Our data indicated that in OK future drought would cause slower substrate decomposition but higher substrate mass loss by fertilization. In FL, fertilization may cause lower substrate mass loss. Decomposition also showed a spatial pattern where wood substrate close to the tree decayed faster than wood far from the tree both in OK and FL. High spatial variability exists among or within sites, indicating the complexity of wood decomposition at both macro and micro scales.



Engaged and literate public with the capacity to make informed, practical decisions related to climate, forest ecosystems, and forest management.

27. 🌱 The role of the agent: How Extension agents view their role in sharing climate-related information *Margaret Clifford and Martha Monroe*

Analysis of survey responses from participants in the September 2014 Southeast Region Extension Climate Academy workshop reveals that perceived climate-related informational needs are related to agents' climate change perspective(s). Climate-related professional development programs for Extension agents can better incorporate their needs and this research focuses on what those needs are and how to better address them. This summer of 2015, approximately 20 agents who participated in the SRECA workshop will be interviewed to better understand how they communicate complex scientific information to diverse audiences, any climate-related changes to their programming or discourse after the workshop, and what educational methods could best meet their climate-related informational needs.

28. 🌱 Cultural cognition and climate change education: why consensus is not enough *Kristen Kunkle and Martha Monroe*

Integrating climate change into education programs can be difficult, as the issue remains controversial and highly politicized among the public. Educators vary in their willingness to address climate change and their self-reported knowledge of the topic. While support for integrating climate change into formal science education is increasing among some educators, a diversity of opinions remains among them. This study tests the theory of cultural cognition by suggesting that the same psychological mechanisms that lead to confirmation bias over socially disputed scientific evidence will prevent educators from teaching about anthropogenic climate change if it does not fit their cultural worldview. An online survey with quantitative and qualitative measures was used to evaluate science educators' intentions to support climate change education, assess if and how those intentions and desired curriculum content vary according to self-identified worldview values, and explore the barriers and advantages of integrating elements of cultural significance into climate change education resources. The results of the study suggest that worldview values and personal beliefs about climate change have a significant influence on respondents' intentions to support climate change and preferred climate change curriculum content. Respondents of diverse perspectives agreed that climate change education can provide valuable opportunities to engage students in real world issues, but formal educators perceive limited ability to provide these opportunities given the time and curriculum constraints of the education system. The processes and results of this research can be adapted and applied to diverse environmental and political issues that require a focus on effective communication strategies.

29. 🌱 Measuring and fostering hope among high school students about climate change *Christine Li and Martha Monroe*

Education programs that aim to effectively address climate change should nurture hope as well as increase understanding about the issue. We applied hope theory in the design of 14 activities for secondary science teachers and measured climate change knowledge and hope among high school students who participated in the activities. High school students (n=924) from 24 schools in the southeastern United States completed pre-and post-activity surveys that assessed knowledge, hope, decision making skills and systems thinking skills. Data suggest that there was a significant increase in hope concerning climate change, decision making skills, and systems thinking skills. Knowledge of forest management, carbon cycle, the role of forests in mitigating climate change, life cycle assessment, and product externalities was also significantly increased.

30. Linking educators and students to forests in a changing climate *Martha Monroe, Kristen Kunkle, Christine Jie Li, Annie Oxarart, and Tracey Ritchie*

Southeastern Forests and Climate Change is an education module for secondary science educators about climate change impacts on southern forest ecosystems, the role of forests in sequestering carbon, and strategies for reducing greenhouse gas emissions and adapting to changing climatic conditions. The module is framed around PINEMAP research and includes 14 experiential activities, background information, step-by-step instructions, modifications and enrichment suggestions, correlations to national science standards, and online training resources and materials. Using Project Learning Tree's (PLT) network of state coordinators, facilitators, and educators in the Southeast, a total of 94 people were trained at three regional workshops held in North Carolina, Arkansas, and Florida in 2014 and early 2015. These "train-the-trainer" workshops introduced the module to facilitator teams from 12 states and 36 educators. At each workshop, pre and post surveys were distributed to participants. Paired t-tests suggest that all three workshops significantly increased participants' self-efficacy in teaching about climate change. In addition, participants (n=85) indicated that it is very likely that they will use this educational resource in their future work, will recommend this educational resource to their colleagues, and will expand the coverage on climate change in their work. Several participants provided open-ended comments that indicated their satisfaction with the materials and the workshop. Since being finalized in September 2014, more than 2,500 printed books have been shipped to PLT state coordinators, facilitators, educators, and other stakeholders, and more than 150 people have registered on the website to access the module materials. Mini-grants totaling \$26,000 have been distributed to 11 states through PLT to assist with upcoming educator workshops. In total, this first round of workshops aims to reach almost 1,000 educators in the region. This poster will describe the training workshops and provide information about state plans to implement the module.

31. 🌱 Methods for measuring systems thinking in high school students *Tracey Ritchie and Martha Monroe*

Systems thinking has become a hot topic in science education, environmental education and other disciplines as an instructional strategy that will help students better understand the relationships that exist in complex systems. But what defines a systems thinker? How can we tell if our students are successfully thinking in terms of systems? What can educators do to help their students think systematically? This poster will discuss the methodology for a mixed methods research study that will attempt to measure systems thinking skills in high school students. Over 1,500 students from across the southeastern United States will be participating in five systems-based activities in the spring of 2015. The activities focus on forest and climate systems and the connections between the two. In addition, half of the students will receive further instruction on systems thinking skills through five additional activities that were not related to the content, but focused on skill building. Pre and post surveys and student interviews were designed to assess the level of systems thinking in the students. The data will be analyzed to better understand the development of systems thinking skills and establish how to meaningfully measure the presence of the skills through assessment of vocabulary used, complexity of relationships discussed, and the demonstration of understanding of system dynamic principles.



Public policy that supports sustainable management of planted pine under future climate scenarios.

32. Using climate and genetic diversity data to prioritize conservation seed banking *John Hastings, Mark Megalos, Robert Jetton, Kevin Potter, Frank Koch*

Hemlock Woolly Adelgid (HWA) is sweeping the native range of Eastern and Carolina Hemlock at an alarming rate. Now infesting 19 states and over 400 counties, HWA poses a threat that the eastern US native cannot handle. The current biological and chemical methods for protecting these keystone species are expensive and time consuming, and despite our best efforts hemlocks are losing the battle. For the long-term preservation of the species genetic conservation may be the best solution. With this in mind, it is critical to prioritize seed collection and the preservation of genetic integrity within Hemlock's more diverse populations. Using GIS, areas of significant genetic diversity can be located and protected. Temporal projected climate models can also be used to display a minimum temperature threshold below which significant HWA dieback occurs, and the poleward migration of that threshold.

33. 🌱 Evaluating nonindustrial private forest landowner participation in carbon sequestration *Puskar Khanal, Donald L. Grebner*

US forests, including forestland under Nonindustrial Private Forest (NIPF) ownership, are an important biological carbon sink that provide a low cost climate change mitigation option. With appropriate carbon sequestration strategies such as longer rotation and management changes, there is a potential to increase the storage of atmospheric carbon in forest land. In the Southern US, where 70% of forest land is under private ownership, participation of this dominant ownership group is crucial for the success of such a strategy. However, there are concerns related to participation by NIPF landowners in a carbon sequestration program that requires landowners to implement different forest management strategies. The goal of this study is to understand what motivates NIPF landowners in this region to implement a delayed harvest or longer rotation strategy for sequestering additional carbon and to help mitigate climate change. The study estimates NIPF probability of participation in a carbon sequestration program using data from a regional survey of NIPF landowners with 735 responses. The analytical results suggest that survey respondents were concerned about management requirements and carbon revenue from program participation. Forest landowner age, education, climate change attitude, land acreage, ownership objective and membership to landowner associations affect their decision to delay final harvest. This study suggests that policy makers should consider these reasons affecting Southern landowner's likelihood of participation in potential climate change mitigation and carbon sequestration programs.

34. 🌱 Effects of trace gases within *Pinus taeda* L. plantations in the piedmont soils of the southeast United States *Dan Markewitz, Carla Gann*

Loblolly pine plantations are often fertilized with Nitrogen (N) two to three times during a ~30 year rotation with up to 500 kg-N/ha. The amount of nitrous oxide (N₂O) efflux, a potent greenhouse gas, in response to N fertilization within pine plantations is of interest as is the interaction of fertilization with changing climate (i.e., reduced rainfall). The effect of fertilization on tree growth and water utilization may also influence the efflux of methane (CH₄), another greenhouse gas. The objective of this study is to evaluate the effect of N fertilization and water availability on the annual efflux of N₂O and CH₄ in loblolly pine plantations. The study site is a 6-year-old loblolly pine plantation near Washington, Georgia. This site consists of a throughfall exclusion (drought) x fertilization study with four replicates of control, fertilized only, throughfall exclusion only, and fertilized and throughfall exclusion. Sampling was initiated in 2012 and has continued through 2014 using a static chamber approach. Gas sampling occurred every three months after fertilization. In an effort to assess the role of different N fertilizers on N₂O efflux a small secondary study sampled a ~18-year-old loblolly pine site in Athens, Georgia that received treatments of urea, diammonium phosphate (DAP), and ammonium nitrate (NH₄NO₃), all compared to a control (no treatment). There were two replicates of each treatment per block and there were a total of three blocks. Gas samples were collected once a week after fertilization for six weeks. After these six weeks, samples were collected every month after that with all sampling occurring between July 2013 and 2014.

35. Modeling the impacts of historic climate change and extreme droughts on water yield and productivity of the National Forest system (NFS) over the conterminous U.S. *Ge Sun, Shanlei Sun, Peter Caldwell, Steve McNulty, and Yang Zhang*

Quantifying the impacts of droughts on the U.S. National Forests (NFs) is necessary to develop sound forest management plans to mitigate and adapt to climate change. This study applied a water balance model (WaSSI) to 170 National Forests (NFs) over the conterminous U.S for examining how long-term climatic change and extreme climate events impacted forest water yield and productivity. Our model predicted that mean water yield decreased by 5% while mean productivity increased by 10% between 1961-2012 across the NFs. Overall 32% of NFs showed a significant increasing trend in forest gross ecosystem productivity (GEP), while 5% of the NFs had a significant decreasing trend. This study also suggested that the extent and severity of drought events occurring in the NFs had an increasing trend during the past 50 years. Taking

the 170 NFs as a whole, the top-five droughts were characterized by a 261 mm/yr (or 30%) reduction in precipitation, that resulted in reductions in evapotranspiration by 55 mm/yr (or 10%), water yield by 154 mm/yr (or 49%) and GEP by 121 gC/m²/yr (or 10%). However, distribution of these changes varied spatially due to differences in vegetation types, weather, and geography. Overall, this study provided an assessment of historic impacts of droughts on forest watershed hydrology and productivity across a diverse geographic region using a consistent database. The study also identified forest watersheds that were severely influenced by historical drought, and provided a reference to develop appropriate adaptation strategies for potential future extreme droughts on forest ecosystem services of NFs.



Enhanced capacity for regional, interdisciplinary collaboration among climate and forest scientists and Extension and education professionals.

36. TerraC – PINEMAP Data Management System: demonstration *Khori Battle, Carlos Gonzalez-Benecke, Sabine Grunwald, and Timothy Martin*

TerraC is the centralized data management system used in the PINEMAP project. It serves as a data archive for all data produced as part of the project, documents all datasets with meta-data, and facilitates data sharing, management, and downloading of data to be used in all aim groups. The redesigned TerraC system (<http://TerraC.ifas.ufl.edu>) provides direct access to project data tables that deliver data derived from PINEMAP Tier I (legacy experiments, COOP data), Tier II (active experiments, regional scale), and Tier III (Throughfall exclusion and fertilization experiments). The TerraC structure encompasses PINEMAP's forest cooperative data, estimated (calculated) data such as stem volume and net primary productivity, as well as spatial extractions to tier site locations from geospatial environmental layers. Extractions include environmental covariates derived from the Idaho Climate Data, PRISM (Parameter-elevation Relationships on Independent Slopes Model) Climate Data, NARCCAP (North American Regional Climate Change Assessment Program), Soil Moisture (European Space Agency), Topographic Data, gSSURGO (gridded Soil Survey Geographic Data), and MACA (Multivariate Adaptive Constructed Analogs) data. PINEMAP participants can access field trials' plot and individual tree data from specific research sites. Whereas Tier I data are available as complete sets, Tier II and III data are in flux and are uploaded into TerraC after QA/QC check by the Data Liaison Manager as soon as they are submitted. Meta-data templates have been developed for all tier datasets identified as core data of the PINEMAP project.

37. PINEMAP's Decision Support System: demonstration *Heather Dinon Aldridge, Ryan Boyles, Corey Davis*

The latest version of the DSS, including the Seedling Deployment tools and the Extreme Minimum Temperature Risk tool, will be available for viewing and demonstration. The DSS developers will also be available to answer questions about the tools and site development, the beta testing process, and using the MACA data output in models and analysis.



Enhanced connections between corporate and noncorporate forest landowners and forestry and climate researchers and education and outreach professionals.

38. PINEMAP's outreach efforts: educating foresters and influencing changes on the ground *Leslie Boby, William Hubbard, Eric Taylor, and Mark Megalos*

PINEMAP's ultimate goals are to influence changes on the ground (direct forest management), that will increase carbon sequestration, reduce fertilizer use and ensure more resilient forests. Educating foresters who either directly manage land themselves, or provide guidance to forest landowners is key towards achieving PINEMAP goals. To this end, the PINEMAP Aim 6 team has co-hosted and developed a series of workshops throughout the southern region, which have been framed around PINEMAP themes and research and included numerous PINEMAP researchers as speakers. Response to the workshops was very good, with at least 70% of respondents (and often more), indicating that they gained knowledge and would be making management changes in response to what they had learned. These foresters either own or assist in managing millions of acres and indicated in evaluations that they would be implementing many of the suggested changes learned from the workshop on significant portions of their land. Additional workshops are planned for the rest of this year.

39. 🌳 Southern foresters' climate observations: what, where, and implications for continuing education *Rachel Greene, Mark Megalos, William Hubbard, Leslie Boby, Hilary Cole*

We surveyed professional foresters in the southern United States to identify how frequently they observe sixteen climate variables related to forest management and how those responses vary across the South. We found that in their lifetimes, southern foresters have noticed an overall change in climate, longer dry periods and/or drought conditions, greater frequency and/or severity of invasive plant infestations, warmer winters, and hotter summers with higher frequency than other variables. Observations of climatic change are generally observed with the highest frequency by foresters from Oklahoma, Florida, and Kentucky, and lowest frequency by foresters from Mississippi and Alabama. Observations of drier planting, drought, fire, and invasive plants exhibited positive spatial autocorrelation (i.e., states in closer proximity had more similar responses than states far away). These findings can inform Extension programming and facilitate development of materials tailored to address the observations and concerns of foresters on a state-by-state basis.



A more robust and resilient forest-based economy in the Southeast U.S.

40. 🌳 Assessing climate change impacts on wildfire risk in the United States *Hyunjin An, Jianbang Gan, and Sung Ju Cho*

We examined the statistical association of wildfire risk with climatic conditions and non-climate variables in 48 continental U.S. states. Because the response variable “wildfire risk” is a fractional variable bounded between zero and one, we use a non-linear panel data model to recognize the bounded nature of the response variable. We estimate the non-linear panel data model (fractional probit) using the Generalized Estimating Equation (GEE) approach to ensure that the parameter estimation is efficient. The statistical model, coupled with the future climates projected by Global Climate Models (GCMs), is then employed to assess the impact of global climate change on wildfire risk. Our regression results show that wildfire risk is positively related to spring, summer, and winter temperatures and human population density whereas it is negatively associated with precipitation. The projection results based on GCMs and the regression model indicate that climate change will intensify wildfire risk throughout the entire U.S., especially in the South Central region, posing an increasing wildfire threat and thus calling for more effective wildfire management strategies. We will discuss the utility of Generalized Estimating Equation (GEE) method in wildfire analysis. This study not only advances the modeling approach but also reveals the impact of climatic conditions and demographics on wildfire activity and provides projections of wildfire risk under climate change. Our modeling results foster a better understanding of the linkage between wildfire risk and climatic conditions and can aid in developing more effective wildfire response strategies under climate change.

41. 🌳 Producing an understory cover map over a large region using heterogeneous lidar datasets *Ranjith Gopalakrishnan, Valerie Thomas, and Randolph Wynne*

We assessed the efficacy of using a heterogeneous lidar dataset (over 90 separate projects) to estimate forest understory cover over a large region. We developed a random forest based model that yielded RMSEs of ~20% live shrub cover, and helped identify significant understory lidar metrics.