PINEMAP
Year 2 Interim Report
November 2012
Aim 1 – Silviculture and Ecophysiology

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

Peer-reviewed Publications (January-November 2012)

Albaugh, T.J., E.D. Vance, C. Gaudreult, T.R. Fox, H. L. Allen, J. L. Stape, and R.A. Rubilar. Carbon emissions and sequestration form fertilization of pine in the southeastern United States. *Forest Science* 58(5): 419-429. doi: http://dx.doi.org/10.5849/forsci.11-050

Albaugh, T.J., H.L. Allen, J.L. Stape, T.R.Fox, R.A. Rubilar, and J. Price. Intra-annual nutrient flux in *Pinus taeda*. *Tree Physiology* 31, advance access. doi: http://dx.doi.org/10.1093/treephys/tps082

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* 36(2):71-78. http://dx.doi.org/10.5849/sjaf.10-034

Bracho, R.G., G. Starr, H.L. Gholz., T.A. Martin, W.P. Cropper, and H.W. Loescher. 2012. Controls on carbon dynamics by ecosystem structure and climate for southeastern U.S. slash pine plantations. *Ecological Monographs* 82: 101-128. doi: http://dx.doi.org/10.1890/11-0587.1

Campoe, O.C., J.L. Stape, T. J. Albaugh, H. L. Allen, T.R. Fox, R. Rubilar, and D. Binkley. Fertilization and irrigation effects on tree level aboveground net primary production, light interception and light use efficiency in a loblolly pine plantation. *Forest Ecology and Management*, in press. doi: http://dx.doi.org/10.1016/j.foreco.2012.05.026

Domec J.C., Sun G., Noormets A., Gavazzi M., Treasure E., Cohen E., Swenson J.J., McNulty S. and J.S. King. 2012. 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*, 58:497-512

Domec J.C**.,** Ogée J, Noormets A., Jouangy J. Gavazzi M., Treasure E., Sun G., McNulty S. and J.S. King. 2012. Interactive effects of nocturnal transpiration and climate change on the root hydraulic redistribution and carbon and water budgets of Southern US pine plantations. *Tree Physiology* 32(6): 707-723. doi: http://dx.doi.org/10.1093/treephys/tps018

Jones, P.D. and T.R. Fox. 2012. Stem sinuosity in *Pinus taeda* stands: Is it a problem we need to be concerned with? *Forest Products Journal*, in press.

Kiser, L.C. and T.R. Fox. 2012. Soil accumulation of nitrogen and phosphorus following annual fertilization of loblolly pine and sweetgum on sandy sites. *Soil Science Society of America Journal.* doi: http://dx.doi.org/10.2136/sssaj2012.0118

Kiser, L.C. and T.R. Fox. Short Rotation Woody Crop Biomass Production for Energy. Chapter 6. In B. Singh (Ed.). *Biofuel Crop Sustainability*. John Wiley and Sons, in press.

Maier, C.A., K.H. Johnsen, P. Doughterey, 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* 58(5): 430-445. doi: http://dx.doi.org/10.5849/forsci.11-069

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.

Noormets A., S.G. McNulty, J.C. Domec, M.J. Gavazzi, G. Sun, J.S.King JS (2012) The role of harvest residue in rotation cycle carbon balance in loblolly pine plantations. Respiration partitioning approach. *Global Change Biology*, DOI: 10.1111/j.1365-2486.2012.02776.x. http://dx.doi.org/10.1111/j.1365-2486.2012.02776.x

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: http://dx.doi.org/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* 274:108-115. doi: http://dx.doi.org/10.1016/j.foreco.2012.02.017

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. 2012. 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* 26(3):951-961. doi: http://dx.doi.org/10.1007/s00468-011-0673-4

Subedi, S., M. Kane, D. Zhao, B. Borders, D. Greene. 2012. Cultural intensity and planting density effects on aboveground biomass of 12-year-old loblolly pine trees in the Upper Coastal Plain and Piedmont of the Southeastern United States. Forest Ecology and Management 267: 157-162.

Worsham, L., D. Markewitz, N.P. Nibbelink, L.T. West. 2012. A comparison of three field sampling methods to estimate soil carbon content. *Forest Science* 58(5): 513-522. http://dx.doi.org/10.5849/forsci.11-084.

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.

Zhao, D., M. Kane. 2012. Differences in growth dynamics of loblolly and slash pine plantations in the southeastern United States. Forest Ecology and Management 281: 84-92.

Zhao, D., M. Kane, B. Borders, S. Subedi, M. Akers. 2012. Effects of cultural intensity and planting density on stand-level aboveground biomass production and allocation for 12-year old loblolly pine plantations in the Upper Coastal Plain and Piedmont of the Southeastern United States. Canadian Journal of Forest Research 42 (1): 111-122.

Summarize ***Events/Activities*** (January 2012-current) as follows:

→ Provide a bulleted list of presentations (oral and poster) given at meetings or conferences. The format for citing presentations is as follows: Presenter(s)/Author(s). Date. Name/title of meeting/conference, location.

- Clark, J.E., S. Bartkowiak, and L.J. Samuelson. 2012. Impact of rainfall manipulation and fertilization on light and water use efficiency in 6-year-old loblolly pine (Poster presentation). 97th Ecological Society of America Annual Meeting, Portland, Oregon.

- Heim, B.C., J.R. Seiler and B.D. Strahm. 2012. Response of heterotrophic and autotrophic soil respiration to simulated drought in managed southern pine forests. SSSA International Annual Meeting, Cinncinatti, Ohio October 21-24.

- Markewitz D., M. Kane , M. Akers, J. Qi, and J. Lord. 2012. N2O Fluxes under managed pine in response to throughfall and fertilization: Study Initiation. Soil Science Society of America Annual Meeting. Cincinnati, Ohio.

- Fox, T.R. R. Harrison, B. Vance, D. Briggs, E. Turnblom, A. Himes, J. Zerpa, K. Littke, B. Strahm, J. Raymond, A. Werner, J. Stape, and D. Jacobs. 2012. Use of ^{15}N to Trace Applied Fertilizer Nitrogen in Douglas-Fir, Loblolly Pine and Walnut Forest Plantations to Evaluate Fertilizer Uptake Efficiency and Ecosystem Fate. NSF Center For Advanced Forestry 2012 Meeting. June 26-28, 2012.

- Fox, T.R., J.L. Stape, J. Seiler, T. Albaugh, M. Yanez, N. Bonzey, L.C. Kiser, and J. Zerpa. 2012. Varietal Silviculture of Lobolly Pine: Impacts of Crown Ideotype, Planting Density and Management Intensity on Physiology, Growth, and Uniformity of Clonal Stands in the Southern United States and Brazil (CAFS 08.01). NSF Center For Advanced Forestry 2012 Meeting. June 26-28, 2012.

- Werner, A. and T.R. Fox. 2012. Use of Stable Isotopes to Trace the Fate of Applied Nitrogen in Forest Plantations to Evaluate Fertilizer Efficiency and Ecosystem Impacts. NSF Center For Advanced Forestry 2012 Meeting. June 26-28, 2012.

- Raymond, J. and T.R. Fox. 2012. Use of Stable Isotopes to Trace the Fate of Applied Nitrogen in Forest Plantations to Evaluate Fertilizer Efficiency and Ecosystem Impacts (CAFS 10.33 Southeast Region). NSF Center For Advanced Forestry 2012 Meeting. June 26-28, 2012.

- Fox, T.R., J. Raymond, and A. Werner. 2012. Use of ^{15}N to Trace Applied Fertilizer Nitrogen in Douglas-Fir, Loblolly Pine and Walnut Forest Plantations to Evaluate Fertilizer Uptake Efficiency and Ecosystem Fate. Advisory Council Meeting of the Forest Productivity Cooperative. Oct 15-18, 2012. Chapel Hill, NC.

- Raymond, J. and T.R. Fox. 2012. Uptake of ^{15}N labeled fertilizer in loblolly pine plantations. Advisory Council Meeting of the Forest Productivity Cooperative. Oct 15-18, 2012. Chapel Hill, NC.

- Fox, T.R. 2012. PINEMAP Pine Integrated Network: Education, Mitigation and Adaptation Project: Mapping the future of pine management in a changing world. Advisory Council Meeting of the Forest Productivity Cooperative. Oct 15-18, 2012. Chapel Hill, NC.

- Minick, K. T.R. Fox, B.L. Strahm, E. Sucre and Z. Leggett. 2012. Soil Organic Matter Fractions in Loblolly Pine Forests Intercropped with Switchgrass in Coastal North Carolina. Advisory Council Meeting of the Forest Productivity Cooperative. Oct 15-18, 2012. Chapel Hill, NC.

- Alvarez, J., C. Alvarez, J.Stape, T.R. Fox, R. Rubilar, T. Albaugh. 2012. Potential productivity modeling in South America and US. Advisory Council Meeting of the Forest Productivity Cooperative. Oct 15-18, 2012. Chapel Hill, NC.

- Yanez, M., T.R. Fox, and J. R. Seiler. 2012. Assessing leaf-level physiology on loblolly pine varieties under different silvicultural treatments. Advisory Council Meeting of the Forest Productivity Cooperative. Oct 15-18, 2012. Chapel Hill, NC

- Nichols, L., T.R. Fox, B. L. Strahm, J. Seiler, E. Sucre, and Z. Leggett. 2012. The impact of low molecular weight organic acids and dissolved organic carbon on microbial biomass in a loblolly pine and switchgrass intercropped system. Soil Science Society of America International Annual Meeting. Cincinnati, Ohio. October 21-24, 2012.

- Raymond, J., T.R. Fox, and B.L. Strahm. 2012. The use of stable isotopes to evaluate the uptake efficiency of applied nitrogen fertilizer in southern loblolly pine plantations. Soil Science Society of America International Annual Meeting. Cincinnati, Ohio. October 21-24, 2012.

- Kiser, L.C. and T.R. Fox. 2012. Site and silvicultural effects on root growth and nutrient content of 4 loblolly pine (*Pinus taeda L*.) clones. Soil Science Society of America International Annual Meeting. Cincinnati, Ohio. October 21-24, 2012.

- Minick, K.J., B.L. Strahm, T.R. Fox, E. Sucre, and Z. Leggett. 2012. Switchgrass growth in southern loblolly pine forests alters soil organic carbon and N fractions under bedded rows of pine trees. Soil Science Society of America International Annual Meeting. Cincinnati, Ohio. October 21-24, 2012.

- Fox, T.R., T.A. Martin, and G.F. Peter PINEMAP: leveraging 50 years of university-corporate-government forestry research cooperation. 2012. Soil Science Society of America International Annual Meeting. Cincinnati, Ohio. October 21-24, 2012.

- Martin, T.A., T.R. Fox., M.C. Monroe, and G.F. Peter. 2012. The PINEMAP CAP: Mapping the future of southern pine management in a changing world. Soil Science Society of America International Annual Meeting. Cincinnati, Ohio. October 21-24, 2012.

- Werner, A. and T.R. Fox. 2012. Uptake efficiencies of 15N enriched enhanced efficiency fertilizers in a *Pinus taeda* L. Stand. Soil Science Society of America International Annual Meeting. Cincinnati, Ohio. October 21-24, 2012.

- Wang Y and Teskey RO. 2012. Sensitivity analysis of 3-PG model for Pinus taeda (loblolly pine). (Poster presentation.) Ecological Society of America 97th Annual Meeting, Portland OR.

→ Provide a short narrative describing any workshops, courses, and/or trainings conducted.

- Aim 1 team met in Athens, GA on April 3-5, 2012 to discuss Tier 2 measurement protocols and prepare for the PINEMAP annual meeting.
- PINEMAP annual meeting in Atlanta, GA on May 14-16, 2012.
- Presentation on PINEMAP to members of the Forest Productivity Coop at the annual Contact Meeting in Alexandria, LA on June 13-14, 2012.
- Presentations (3) on PINEMAP to members of the Plantation Management Research Coop at the Annual Advisory Committee Meeting in Athens, GA on July 19, 2012
- Presentation on PINEMAP as part of the University Georgia, Warnell School of Forestry and Natural Resources Seminar Series, Athens, GA, August 23, 2012
- Presentation on PINEMAP as part of the NCSU, Virginia Tech, University of Concepcion Forest Productivity Cooperative Annual Advisory Committee Meeting in Chapel Hill, NC on October 16, 2012.
- Workshop for PINEMAP industry members on the impacts of the 2011 drought on growth of loblolly pine in the south was held in Alexandria, LA on June 12, 2012.
- Aim 1 members participated in a meeting on 3PG modeling organized by Aim 2 on July 2, 2012 in Charlotte, NC.

→ Provide a short narrative describing experiments or surveys conducted and/or analyzed

1. Tier 1 – Legacy Experiments: Industry/University Cooperative Research installations to include in the Tier 1 – Legacy Experiments have been identified. Archived data from these sites has been transferred to PINEMAP for uploading into TerraC.
2. Tier 2 – Active Experiments: Industry/University Cooperative Research installations that will be included as Tier 2 – Active Experiments have been identified. Achived data from these sites has been transferred to PINEMAP for uploading into TerrC. One half of the sites have been selected where tree cores will be collected in 2012 for $^{13}C/^{14}C$ analysis to determine water use efficiency. The other half of the sites will be sampled in 2013. The sites where samples will be collected in 2012, 2013, 2014 and 2015 have been identified. Field work to collect the tree cores and the inventory biomass samples started in June 2012.
3. The four Tier 3 – Throughfall Exclusion and Fertilization Experiments were installed. Throughfall collectors were completed and the plots were fertilized. Chemical weed control was administered as needed. Sap flow monitors to measure evapotranspiration rates were installed at each site. Protocols for tree core collection, soil sampling, and biomass sampling have been finalized and uploaded to the PINEMAP website where they will serve as a reference for field work on the Tier 2 and Tier 3 sites. The soil procedure for measuring soil respiration and separating heterotrophic and autotrophic respiration are being tested. Weather stations were installed at each site to measure microclimate attributes.
4. Microclimate and sapflow data collection has been automated data are posted daily at http://www4.ncsu.edu/~anoorme/PINEMAP/index.html
5. Studies of N fertilizer uptake efficiency using ^{15}N labeled enhanced efficiency fertilizers were established at 28 sites in the South associated with Tier II Active Experiments in 2011 and 2012. Samples of ^{15}N in ecosystem components (trees,

understory vegetation, forest floor, and soil) were collected and are being analyzed using IRMS.

6. Studies of N_2O and NO_x emissions following nitrogen fertilization were established at a subset of the Tier III sites in 2012. Trace gas estimation for N_20 was completed 1 week prior to fertilization, 3 weeks and 8 weeks after fertilization. All gas samples have been analyzed.
7. Protocols for separating heterotrophic (Rh) and autotrophic (Ra) components of soil respiration are being tested in order to determine the final methods that will be used in remainder of the project.
    - Preliminary results on an ancillary research site where total soil CO_2 efflux was measured before and after root girdling using a 20 cm pipe suggest that pipes installed in the spring (March-May) reduced total soil CO_2 efflux and average of 17% and that total soil CO_2 efflux during this period was correlated with microbial biomass carbon.

- At the Tier III sites, precipitation is collected monthly (began July 2012). It will undergo δ^2H and $\delta^{18}O$ isotope analysis.

Milestones and Work Plan Progress

Provide a short narrative describing progress and accomplishments on the year 2 milestones and work plan tasks listed below. Please also describe any changes to the Aim 1 milestones and/or work plan.

Year 2 Milestones

→ Assessment of Tier III treatment effects (December 2012).

→ Leaf gas exchange, chlorophyll fluorescence and leaf water potential were measured from July through October 2012 at the Georgia Tier III installation. Rainfall exclusion has had a significant effect on light-saturated photosynthesis, leaf conductance, leaf water use efficiency and predawn water potential. Photosynthesis was reduced on average by 11% and leaf conductance by 22% in response to rainfall exclusion. Predawn leaf water potential was also lower and leaf water use efficiency was higher with rain exclusion. Preliminary sap flow data indicate a 22% reduction in total daily transpiration in response to the rain exclusion treatment, from 1.8 to 1.4 mm/day in October, which was due to a reduction in midday maximum sap flux density.

→ Fertilization increased Fv/Fm, most likely from increasing foliar N, but had no other significant effect on leaf or whole tree physiology. No interactions between treatments have been detected thus far.

→ Stand level LAI and IPAR have been monitored since May 2012. Fertilization increased average LAI from 1.56 to 1.83 and average IPAR from 57% to 63%. A trend towards an interaction between month and fertilization indicated a greater effect of fertilization on LAI and IPAR

beginning in July. Rainfall exclusion had no significant effect on LAI or IPAR.

→ At the GA site we measured baseline soil CO2 efflux on Feb. 9, 2012, and have been measuring soil CO2 efflux according to protocols since June 6, 2012.

→ Initial C and nutrient baselines estimated from existing Tier I data (January 2012).

→ Regional C, nutrient, H_20 baselines and responses to management from measured Tier II data (December 2012).

→ Assessment of climate, soil, and management impacts on soil GHG flux (December 2012).

Belowground Carbon Allocation of Two Loblolly Pine Varieties with Contrasting Aboveground Growth Efficiencies: Soil CO_2 efflux (Sf), microbial biomass carbon (MBC), and nitrogen (MBN) were measured in the spring and summer at the Cross Carbon Study near Cross, SC. The effects of clone (high and low growth efficiency) and silviculture (addition of logging residues (LR) to the soil at planting) on Sf, MBC, and MBN were examined using a 2x2 factorial treatment structure. Initial Sf measurements were made in the spring (March) and summer (July). Immediately after the initial measurement, a 10.7 cm diameter by 20 cm long pipe was installed in one of the two spots to exclude root respiration form Sf (pipe-exclusion method). The other spot served as the 'no-pipe' control. Soil CO_2 efflux was measured again in June and October 94 and 92 days, respectively after pipe installation. Following the final Sf measurement, the soil was collected from the 20 cm pipe and the adjacent control spot. Soil was brought back to the lab where soil organic matter, live and dead roots were sieved (>2 mm). A subsample of soil was process for chloroform fumigation and assayed for microbial biomass carbon (MBC) and nitrogen (MBN).

Sf was greater on average 19% in LR treatments compared to Control ($p=0.013$). There was also a significant treatment effect on the reduction of Sf in the root exclusion pipes. Approximately 90 days after pipe installation, Sf was reduced by 38.3% in the Control treatment compared to only 15.3% in the LR treatments (C vs LR: $p=0.02$). In the spring, MBC and MBN in the LR treatments were 27% ($p=0.02$) and 31% ($p=0.03$), respectively greater than in Control treatments. Pipe insertion reduced MBC by 20% (pipe vs no-pipe: $p=0.007$), but had no effect on MBN. These measurements will continue quarterly in year 3.

→ Regionalize estimates of WUE for application in 3-PG and WaSSI (December 2012).

Wood cores from a subset of the Tier II sites have been collected for C13 isotope analysis to determine WUE in the PINEMAP region.

Year 2 Work Plan Tasks

→ Develop standardized methods for baseline C inventory, baseline soil characterization, and baseline ecophysiology measures (June 2012).

- Standardized measurement protocols for tree core collection, soil sampling, and biomass sampling have been finalized and uploaded to the PINEMAP Intranet site where they will serve as a reference for field work on the Tier 2 and Tier 3 sites.
- Sap flow monitors to measure evapotranspiration rates were installed at each site. Protocols for tree core collection, soil sampling, and biomass sampling have been finalized and uploaded to the PINEMAP website where they will serve as a reference for field work on the Tier II and III sites.
- General IPAR-LAI sampling methods for Tier II and III sites have been uploaded to the intranet site.

→ Develop standardized methods for separating soil heterotrophic and autotrophic respiration (December 2012).

Protocols for separating heterotrophic (Rh) and autotrophic (Ra) components of soil respiration are being tested in order to determine the final methods that will be used in remainder of the project. Tests to evaluate the protocols for separating heterotrophic (Rh) and autotrophic (Ra) components of soil respiration have been installed at the Virginia Piedmont Tier 3 site. Results of the summer installation are shown in figure x. Respiration initially increased inside the collars but then became consistently lower than outside collars. Maximum reduction of R_A occurs approximately 65 days after root collar installation. Over time Rs rates decreased inside collars presumably due to a decrease in autotrophic respiration (R_A) due to a diminished C supply. It appears that this method works well for the partitioning of R_S needed to calculate C sequestration in managed pine forests. The percent decrease in R_A (1 - inside collar/adjacent to collar) across all treatments ranged from 20% - 40%, leaving R_H to account for 60 – 80% of R_S. Additionally at this early stage in the experiment there does not appear to be treatment or interaction effects on the partitioning of R_S. Average R_A across all treatments is 26%.

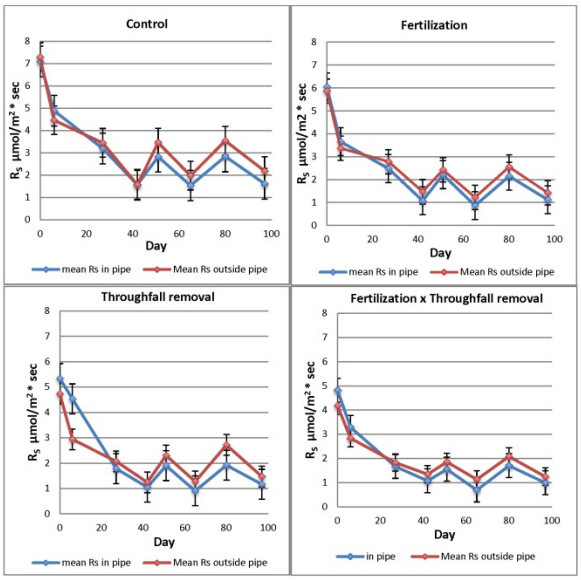

Figure 1. Soil CO_2 efflux over time during the summer of 2012 in all four treatments of the Virginia Piedmont Tier 3 PINEMAP installation as influenced by 35 cm deep collar (pipes) installation

→ Collect soil baseline data on Tier III sites (May 2012).

→ Forest floor and mineral soil samples were collected from the four Tier III research sites and is being processed. Forest floor and soil sampling (0-10, 10-20, 20-50, 50-100) and analysis prior to Exclusion x Fertilization treatment installation have been completed. Sampling included 8 points per plot that were composited to two points for per plot for analysis. Analysis have included digests of forest floor for C, N, Ca, Mg, K, Al, and trace metals and pH water and salt, total C and N, extractable cations (Ca, Mg, K, Al) as well as trace metals for all mineral soil horizons.

→ GA Site - We have installed TDR rods at 0-15, 0-30, 0-60, and 0-100 cm in two locations within each of the PINEMAP Exclusion x Fertilization study plots. Regular measurements were initiated in September 2012. We are currently constructing TDR cables for installation at 2 and 3 m depth.

→ Install studies to measure N fertilizer uptake efficiency using 15N labeled fertilizer at Tier II and Tier III sites (January 2013).

Studies of N fertilizer uptake efficiency using 15N labeled enhanced efficiency fertilizers were established at 28 sites in the South associated with Tier II Active Experiments in 2011 and 2012. Samples of 15N in ecosystem components (trees, understory vegetation, forest floor, and soil) were collected and are being analyzed using IRMS.

→ Install studies to measure N_2O and CH4 emissions following N fertilization (May 2012).

Studies of N_2O and NO_x emissions following nitrogen fertilization were established at a subset of the Tier III sites in 2012. At the GA Tier III Site - Trace gas sampling at the Exclusion x Fertilization experiment has been completed 4 times once prior to fertilization (Mar) and three times post fertilization (Apr, June, and Oct). We have also

completed a denitrification and nitrification assay for soils from this site. Rates of N2O efflux were very small and there were not significant differences by treatment.

As part of the trace gas sampling for N20 in Tier II locations two additional sites were sampled in October 2012. These sites are 22 and 18 years old managed pine. We measured paired plots that included control and HF plots that had received fertilizer annual for the duration of stand development. Surprisingly no difference in N2O efflux was observed between these plots.

→ Develop improved method to evaluate fertility rating (FR) in 3-PG (February 2013).
A method to determine FR rating based on the relationship between site index and modeled stand biomass production was developed and is being validated using data from Tier II sites.

→ Develop improved method to evaluate stomatal response functions to update 3-PG (March 2013).

→ 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.) (March 2013).

→ Forest floor and soil samples were collected at all four Tier III sites and analyses are underway. Soil moisture is being monitored. Trace gases and CO_2 soil efflux are being measured. Litter traps were installed and crown and foliar attributes are being assessed and sapflow is being monitored. A study of through fall as a proportion of total rainfall was installed at the VA Tier III site.

→ Identify subset of Tier II sites for additional ecophysiology measures (June 2012).
Half of the sites have been selected where tree cores will be collected for 13C/14C analysis to determine water use efficiency. Field work to collect the tree cores and the inventory biomass samples is ongoing. Studies of N fertilizer uptake efficiency using 15N labeled enhanced efficiency fertilizers were established at 28 sites associated with Tier 2 Active Experiments. Samples of 15N in ecosystem components (trees, understory vegetation, forest floor, and soil) were collected and are being analyzed using Isotope-ratio mass spectrometry (IRMS).

→ Wood samples for O and C isotope analysis from Tier II sites (September 2012).
Half of the sites have been selected where tree cores were collected for 13C/14C analysis to determine water use efficiency. Field work to collect the remainder of the tree cores will be completed in 2013.

→ Collect baseline data at Tier II sites to evaluate treatment effects on C and nutrient pools and fluxes (October 2012).

→ Measurements and samples (soil, forest floor) have been collected from a subset of the Tier II sites and the samples are in various stages of being processed.

→ Collect additional data on water and carbon fluxes at subset of Tier II sites previously identified (March 2013).

Broad Impacts & External Collaborations

Provide a short narrative describing broad impacts (i.e., far-reaching and possibly unanticipated outcomes resulting from Aim work, including contacts/collaborations with entities outside of PINEMAP).

The Forest Productivity Cooperative and PINEMAP organized a workshop for forest industry on the effects of drought on the growth and productivity of loblolly pine in the Western Gulf region of the South. The workshop presented data from empirical field trials that are part of the Tier II network, remote sensing approaches, and process modeling. This workshop was attended by over 75 industry foresters. This workshop demonstrated the key role that the field trial network established by PINEMAP coupled with the modeling work of PINEMAP has on our ability to understand the impacts of climate variability on growth and sustainable management of loblolly pine.

Training

Please list undergraduate and graduate students, postdocs, and technical personnel trained under this project and include a description of their research focus and/or role in the 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.
- Casey Ausmus, M.S. student, Oklahoma State University. Casey's research is to determine the effects of fertilizer and water availability on tree physiological processes.
- Stan Bartkowiak, M.S. student, Auburn University. Stan's research focus is measuring water fluxes at Tier III sites; developing improved methods to evaluate stomatal response to update 3-PG.
- 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.
- Zach Clark, M.S. student, University of Georgia. Zach's research focus is assessing developmental pattern of understory vegetation on Tier II installations.
- Andrew Faison, Undergraduate Intern from Virginia State University. Andrew is assisting Jay Raymond at Virginia Tech with investigating the mechanisms nitrogen dynamics and uptake efficiencies of N containing fertilizers in loblolly pine plantations using stable isotope (15N) techniques.

- 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.
- Bethany Gregory, Undergraduate Intern, Virginia Tech. Bethany is helping Andy Laviner with a study on environmental manipulation of fertilization, drought, and thinning in loblolly pine plantations.
- Amanda Hancock, undergraduate assistant, Texas A&M University, Carbon monitoring protocol implementation for Tier II sites.
- Brett Heim, M.S. student, Virginia Tech. Brett's research focus is separating heterotrophic and autotrophic respiration components of soil CO_2 efflux.
- Rebecca Jarvis, Undergraduate Intern from Virginia Tech. Rebecca is assisting Wen Lin at North Carolina State University with quantifying the growth rate of loblolly pine, and analyze its sensitivity to temperature and precipitation dynamics.
- Will Kennerly, Undergraduate Intern, Virginia Tech. Will is helping Brett Heim with experimental manipulations of belowground metabolic activity in order to separate microbial respiration from plant respiration.
- 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 $^{12}C/^{13}C$ 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, M.S. 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.
- Teresa Medsker, M.S. student, Oklahoma State University. Teresa's research will focus on belowground processes affected by fertilization and water availability.
- Casey Meek, Research Associate, Oklahoma State University. Casey is assisting with ecophysiological and process measurements on Tier III and Tier II sites.
- Greg Nagel, undergraduate assistant, Texas A&M University, Carbon monitoring protocol implementation for Tier II sites.
- Josh Parisher, undergraduate assistant, Texas A&M University, Carbon monitoring protocol implementation for Tier II sites.
- Jason Pike, Research Technician, Oklahoma State University. Jason is assisting with installation, maintenance, and data collection on Tier III 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. Jill attended the Soil Science Society Annual Meeting in Cincinnati, Ohio.
- 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.
- Rachel Ryland, summer undergraduate research assistant: Rachel has received training in field sampling of trace gases at the Georgia Tier III installation and has been trained in laboratory techniques for soil gas analysis on the gas chromatograph.

- Charles Allen Sherrod, summer undergraduate research assistant: Allen has received training in field sampling of soil at the Georgia Tier III installation and has been trained in laboratory techniques for soil sample preparation and analysis.
- 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.
- Madison Wigley, undergraduate assistant, Texas A&M University, Carbon monitoring protocol implementation for Tier II sites.
- Elizabeth Wilson, M.S. student, Texas A&M University. Elizabeth's research focus is understanding the effects of mesophyll conductance on isotopic signatures in leaves.
- Jingyan Yang, Ph.D. student, Univ. of Georgia, heterotrophic and autotrophic components of soil respiration.
- Lu Zhai, M.S. student, Texas A&M University. Lu's research focus is family and culture effects on ecosystem C and N dynamics.
- Yang Zhang, Ph.D. student, Texas A&M University. Carbon and nitrogen cycling response to drought at the Oklahoma Tier III site.

Collaborations and "integrated" knowledge developed

Provide a short narrative describing new ideas, research questions, or insights that have arisen through work and discussions with colleagues, stakeholders, and others. In addition, explain the extent to which you intend to incorporate this into PINEMAP milestones and/or your Aim work plan.

Needs from/linkages to other Aim groups

1. Provide a bulleted list outlining research results, data, products, or assistance that your Aim group needs from another Aim group.

2. Provide a bulleted list outlining research results, data, or products that your Aim group has compiled that have value or relevance to another Aim group (and note which Aim group).
    - Tier II data on tree growth and carbon sequestration is being collected and will be provided to Aim 2.

3. List any additional potential linkages to other Aim groups.
   Links to Aim groups working on decision support efforts within PINEMAP.

Leveraged funding/additional resources

Describe how PINEMAP funds were leveraged as well as any additional resources obtained. Please list amounts and sources.

- National Science Foundation, Center for Advanced Forestry Systems. $300,000 to Virginia Tech to renew NSF I/UCRC program for 2012-2017.
- Jill Qi is a PhD student participating in PINEMAP but is funded through a graduate assistantship from the University of Georgia.
- Elizabeth Wilson is a Master's student participating *i*n PINEMAP but is funded through a graduate assistantship from Texas &M University.
- Casey Ausmus is student participating in PINEMAP but is funded through a graduate assistantship from the Oklahoma State University.