PINEMAP Year 3 Progress Report 2
April 2014
Aim 1 (Silviculture & 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

Products

Peer-reviewed publications

Akers, M.K., M. Kane, D. Zhao, R.O. Teskey, and R.F. Daniels. 2013. Effects of planting density and cultural intensity on stand and crown attributes of mid-rotation loblolly pine plantations. *Forest Ecology and Management* 310: 468-475.

Albaugh, T.J., L.C. Kiser, T.R. Fox, H.L. Allen, R.A. Rubilar, and J.L. Stape. Ecosystem nutrient retention following fertilization o*f Pinus taed*a. *Forest Science*, *in press*.

Albaugh, T.J., T.R. Fox, C.E. Blinn, H.L. Allen, R.A. Rubiliar, and J.L. Stape. 2013. Developing a new foliar-nutrient-based method to predict response to competing vegetation control in *Pinus taeda*. *Southern Journal of Applied Forestry* 37:196-201. DOI: http://dx.doi.org/10.5849/sjaf.12-025.

Albaugh, T.J., J.L. Stape, T.R. Fox, R.A. Rubilar, and H.L. Allen. 2012. Midrotation vegetation control and fertilization response in *Pinus taeda* and *Pinus elliottii* across the Southeastern United States. *Southern Journal of Applied Forestry* 36(1):44-53. doi: http://dx.doi.org/10.5849/sjaf.10-042

Albaugh, J.M., J.-C. Domec, C.A. Maier, E.B. Sucre, Z.H. Leggett, and J.S. King. 2014. Gas exchange and stand-level estimates of water use and gross primary productivity in an experimental pine and switchgrass intercrop forestry system on the Lower Coastal Plain of North Carolina, U.S.A. Agricultural and Forest Meteorology 192-193: 27-40. doi: http://dx.doi.org/10.1016/j.agrformet.2014.02.013

Battie-Laclau P., J.P. Laclau, , J.-C. Domec, M. Christina, J.P. Bouillet, et al. 2014. Effects of potassium and sodium supply on drought-adaptive mechanisms in *Eucalyptus grandis* plantations. *New Phytologist*, in Press.

Bryars, C., C. Maier, D. Zhao, M. Kane, B. Borders, R. Will, and R. Teskey. 2013. Fixed physiological parameters in the 3-PG Model produced accurate estimates of loblolly pine growth on sites in different geographic regions. *Forest Ecology and Management* 289: 501-514. doi: http://dx.doi.org/10.1016/j.foreco.2012.09.031

Campoe, O.C., J.L. Stape, T.J. Albaugh, H.L. Allen, T.R. Fox, R.A. Rubilar, D. Binkley. 2013. 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* 288: 43-48.

Carlson, C.A., T.R. Fox, H.L. Allen, T.J. Albaugh,R.A. Rubilar, and J.L. Stape. 2014. Growth responses of loblolly pine in the Southeast United States to midrotation applications of nitrogen, phosphorus, potassium and micronutrients. *Forest Science* 60:157-169. DOI: http://dx.doi.org/10.5849/forsci.12-158.

Comerford, N.B., A. Franzluebbers, M. Stromberger, L. Morris, D. Markewitz, and R. Moore. 2012. Ecosystem services derived from soil. *Soil Ecosystem Services – A SSSA Task Force Report*. Cincinatti, OH.

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

Fischer M., R. Fichot, J.M. Albaugh, R. Ceulemans, J.-C. Domec, M. Trnka, and J.S. King. 2014. Ecophysiology, above-ground productivity, and stand-level water use efficiency of *Populus* and *Salix* grown in short-rotation coppice for bioenergy. *In* Bhardwaj AK, Zenone T, Chen J (eds) *Sustainable biofuels: An ecological assessment of the future energy*, HEP deGruyter, Berlin, in press

Johnson D.M., C.R. Brodersen, M. Reed, J.C. Domec, R.B. Jackson. 2014. Contrasting hydraulic architecture and function in deep and shallow roots of tree species from a semi-arid habitat. *Annals of Botany*, in press, doi:10.1093/aob/mct294

Johnson, K.H., L.J. Samuelson, F.G. Sanchez, and R.J. Eaton. 2013. Soil carbon and nitrogen content and stabilization in mid-rotation, intensively managed sweetgum and loblolly pine stands. *Forest Ecology and Management* 302:144-153. doi: http://dx.doi.org/10.1016/j.foreco.2013.03.016

Johnsen, K.H., Keyser, T., Butnor, J., Gonzalez-Benecke, C., Kaczmarek, D., Maier, C., McCarthy, H., and Sun, G. 2013. Forest productivity and carbon sequestration of forests in the southern United States. In: Climate Change Adaptation and Mitigation Management Options (Ed. Jim Vose). CRC Press.

Jones, P.D. and T.R. Fox. 2013. Stem sinuosity in *Pinus taeda* stands: Is it a problem we need to be concerned with? *Forest Products Journal* 62:354-358

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* 76:2278-2288. doi: http://dx.doi.org/10.2136/sssaj2012.0118

Kiser, L.C. and T.R. Fox. 2013. Foliage and litter chemistry, decomposition, and nutrient release in *Pinus taeda*. *Forests*,4:137-154. Doi:10.3390/f4010137.

Mauriat M., G. Le Provost, P. Rozenberg, S. Delzon, N. Bréda, B. Clair, C. Coutand, J.C. Domec, T. Fourcaud, J. Grima-Pettenati, et al. 2014. Wood Formation in Trees. *In* Ramawat K.G., Mérillon J.P., Ahuja M.R. (eds) *Tree Biotechnology*, CRC Press, Boca Raton, FL, USA. 550p.

Manoli G., S. Bonetti, J.C. Domec, M. Putti, G. Katul, and M. Marani. 2014. Tree root systems competing for soil moisture in a 3D soil-plant model. Advances in Water Resources, in press.

McDowell N.G., R.A. Fisher, C. Xu, J.C. Domec, T. Hölttä, *et al.* 2013. Evaluating theories of drought-induced vegetation mortality using a multi-model-experiment framework. *Tansley Review New Phytologist* 200: 304-321. ***http://onlinelibrary.wiley.com/doi/10.1111/nph.12465/full.***

Noormets A., S.G. McNulty, J.C. Domec, M.J. Gavazzi, G. Sun, and J. King. 2012. The role of harvest residue in rotation cycle carbon balance in loblolly pine plantations. Respiration partitioning approach. *Global Change Biology* 18:3186-3201.

Palmroth, S., G.G. Katul, C.A. Maier, E. Ward, S. Manzoni, and G. Vico. 2013. On the complementary relationship between marginal nitrogen and water use efficiencies among *Pinus taeda* leaves grown under ambient and enriched CO_2 environments. *Annals of Botany* 111: 467-477.

Rubilar, R.A., T.J. Albaugh, H.L. Allen, J.Alvarez, T.R. Fox, and J.L. Stape. 2013. Foliage development and leaf area duration in *Pinus radiata*. *Forest Ecology and Management* 304: 455-463.

Rubilar, R.A., T.J. Albaugh, H.L. Allen, J.Alvarez, T.R. Fox, and J.L. Stape. 2013. Influences of silvicultural manipulations on above- and below-ground biomass accumulation and leaf area in young *Pinus radiata* plantations at three contrasting sites in Chile. *Forestry* 86:27-38. doi: http://dx.doi.org/10.1093/forestry/cps055

Sabatia, C.A., T.R. Fox, and H.E. Burkhart. 2013. Extending a model system to predict biomass in mixed-species southern Appalachian hardwood forests. *Southern Journal of Applied Forestry* 37(2):122-126. doi: http://dx.doi.org/10.5849/sjaf.12-005

Samuelson, L.J., T.L. Eberhardt, S.M. Bartkowiak, and K.H. Johnsen. 2013. Relationships between climate, radial growth and wood properties of mature loblolly pine in Hawaii and a northern and southern site in the southeastern United States. *Forest Ecology and Management* 310: 786-795.

Stanturf, J.A., E.D. Vance, T.R. Fox, and M. Kirst. 2013. Eucalyptus beyond its native range: Environmental issues in exotic bioenergy plantations. *International Journal of Forestry Research*. doi: http://dx.doi.org/10.1155/2013/463030

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* 59:50-62. doi: http://dx.doi.org/10.5849/forsci.10-095

Subedi, S., M. Kane, D. Zhao, B. Borders, and 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. doi: http://dx.doi.org/10.1016/j.foreco.2011.12.008

Tyree, M.C., Seiler, J.R., and Maier, C.A**.** 2014. Contrasting genotypes, soil amendments, and their interactive effects on short-term total soil CO_2 efflux in a 3-year-old *Pinus taeda* L. plantation. *Soil Biology and Biochemistry* 69:93-100.

Ward, E.J., R. Oren, D.M. Bell, J.S. Clark, H.R. McCarthy, H. Seok-Kim, and J.-C. Domec. 2013. The effects of elevated CO2 and nitrogen fertilization on stomatal conductance estimated from scaled sap flux measurements at Duke FACE. *Tree Physiology*, 33 :135-151.

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* 124:717-729 http://dx.doi.org/10.1016/j.rse.2012.06.023

Zhao, D. and 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. doi: http://dx.doi.org/10.1016/j.foreco.2012.06.027

Zhao, D., M. Kane, B. Borders, S. Subedi, and 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. doi: http://dx.doi.org/10.1139/x11-166

Theses/Dissertations

Heim, B.C. 2014. Partitioning soil respiration in response to drought and fertilization in loblolly pine: laboratory and field approaches. M.S. Thesis, Virginia Tech, Blacksburg, Va.

Clarke, J.E. 2013. Physiology and growth of a 6-year-old loblolly pine (*Pinus taeda* L.) plantation in response to rainfall exclusion and fertilization treatments. M.S. Thesis, Auburn University, Auburn, AL. (Samuelson)

Zhai, L. 2013. Finding Ideotypes by Examining Interactions among Silvicultural Intensity, Genotype, and Environment for Full-Sib Loblolly Pine Families. M.S. Thesis, Texas A&M University, College Station, TX. (Vogel)

Other publications

Audio/video products

- OSU PINEMAP Video, OSU SunUp TV, October 13, 2012 http://sunup.okstate.edu/category/seg/2012seg/101312-pinemap

Events/Activities

Presentations

Author(s)/Presenter(s)	Title	Type	Date	Venue/Location
Akers, M.	PINEMAP Overview Presentation	Presentation (Meeting)	July 17-18, 2013	Plantation Management Research Cooperative Annual Advisory Committee Meeting, Athens, GA
Albaugh, T.J., T.R. Fox, J.L. Stape, C. Alvares, M. Yanez	Silviculture of varietal *Pinus taeda* – Spacing and silviculture effects on varieties with different crown ideotypes	Presentation (Meeting)	June 3-7, 2013	Contact Meeting of the Forest Productivity Cooperative, Reynolds Homestead, VA
Albaugh, T.J., T.R. Fox, J.L. Stape, R.A. Rubilar, J. Alvarez, J.M. Vose	RAFES: Remote Assessment of Ecosystem Stress	Presentation (Meeting)	June 3-7, 2013	Contact Meeting of the Forest Productivity Cooperative, Reynolds Homestead, VA
Albaugh, T.J., T.R. Fox, J.L. Stape, C. Alvares, M. Yanez	Silviculture of varietal *Pinus taeda* – Spacing and silviculture effects on varieties with different crown ideotypes	Presentation (Meeting)	May 26-30, 2013	Contact Meeting of the Forest Productivity Cooperative, Rio Negrinho, BR
Albaugh, T.J., T.R. Fox, J.L. Stape, R.A. Rubilar, H.L. Allen	Effects of imazapyr rate and application method in mid-rotation *Pinus taeda* stands	Presentation (Meeting)	March 5-7, 2013	17th Biennial Southern Silvicultural Conference, Shreveport, LA
Albaugh, T.J., H.L. Allen, T.R.Fox, C.A. Carlson	Identifying optimal rates and frequencies of nutrient application to achieve and maintain high rates of production in forest plantations	Presentation (Meeting)	October 15-18, 2012	Advisory Council meeting of the Forest Productivity Cooperative, Chapel Hill, NC
Albaugh, T.J., T.R. Fox, H.L. Allen, J.L. Stape, and R.A. Rubilar	SETRES water use efficiency	Presentation (Meeting)	June 12-14, 2012	Contact meeting of the Forest Productivity Cooperative, Pineville, LA
Albaugh, T.J., T.R.Fox, J.L. Stape, R.A. Rubilar, H.L. Allen	Effects of imazapyr rate and application method in mid-rotation Pinus taeda stands	Poster Presentation	March 5-7, 2013	17th Biennial Southern Silvicultural Conference, Shreveport, LA
Albaugh, T.J., T.R.Fox, J.L. Stape	Silviculture of varietal Pinus taeda spacing and silvicultural effects on varieties with different crown ideotypes	Presentation (Meeting)	October 15-18, 2012	Advisory Council meeting of the Forest Productivity Cooperative, Chapel Hill, NC
Alvarez, J., C. Alvarez, J.Stape, T.R. Fox, R.	Potential productivity modeling in South America and US	Presentation (Meeting)	October 15-18, 2012	Advisory Council Meeting of the Forest

Rubilar, T. Albaugh				Productivity Cooperative, Chapel Hill, NC
Bartkowiak, S.M., IV and L.J. Samuelson	Effects of a 30% reduction in precipitation on transpiration and hydraulic properties of 7-year-old loblolly pine	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Bartkowiak, S.M., IV and L.J. Samuelson	Potential impacts of climate change on transpiration and hydraulic properties of 7-year-old loblolly pine	Poster Presentation	August 5-9, 2013	98th Ecological Society of America Meeting, Minneapolis, MN
Caudill, B., M. Wightman, G. Lokuta, T.A. Martin, and E.J. Jokela	Characterization of top 20cm of soil profile for PINEMAP Tier III site in Taylor Co., FL	Presentation (Conference)	March 5-7, 2013	17th Biennial Southern Silvicultural Conference, Shreveport, LA
Clark, J.E., S. Bartkowiak, and L.J. Samuelson	Impact of rainfall manipulation and fertilization on light and water use efficiency in 6-year-old loblolly pine	Presentation (Conference)	August 5-10, 2012	97th Ecological Society of America Annual Meeting, Portland, OR
Clark, J.E. and L.J. Samuelson	Ecophysiological Responses of Loblolly Pine to Rainfall Manipulation and Fertilization at the Georgia Tier III site	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Clark, J.E. and L.J. Samuelson	Ecophysiological Responses of Loblolly Pine to Rainfall Manipulation and Fertilization at the Georgia Tier III site	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Clark, J.E. and L.J. Samuelson	Early Impacts of Rainfall Manipulation and Fertilization on the Ecophysiology of Lobolly Pine at the Georgia PINEMAP Tier III Experiment	Poster Presentation	March 5-7, 2013	17th Biennial Southern Silvicultural Conference, Shreveport, LA
Clark, Z., M. Kane, D. Markewitz, D. Zhao, and M. Akers	Effects of Site and Silvicultural Practices on Non-Planted Vegetation Composition, Abundance and Development in Loblolly Pine (Pinus taeda) Plantations	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Clark, Z., M. Kane, D. Zhao, D. Markewitz, and M. Akers	Effects of site, stand density, cultural intensity and site preparation techniques on non-planted vegetation attributes and developmental patterns in loblolly pine (*Pinus taeda*) plantations.	Presentation (Meeting)	July 2013	Plantation Management Research Cooperative Annual Advisory Committee Meeting, Athens, GA

Clark, Z., M. Kane, D. Zhao, D. Markewitz, and M. Akers	Effects of site, stand density, cultural intensity and site preparation techniques on non-planted vegetation attributes and developmental patterns in loblolly pine (*Pinus taeda*) plantations.	Presentation (Meeting)	January 2014	Southeastern Society of American Foresters Annual Meeting, Panama City Beach, FL
Domec, J.C., J.S. King, J. Ogee, A. Noormets, J. Warren, F.C. Meinzer, G. Sun, Jordan-Meille, E. Martineau, R.J. Brooks, J.P. Laclau, P.B. Laclau, and S.G. McNulty	Convergence of the effect of root hydraulic functioning and root hydraulic redistribution on ecosystem water and carbon balance across divergent forest ecosystems	Presentation (Meeting)	December 3-7, 2012	45th AGU Fall Meeting, San Francisco, CA
Domec JC, Noormets A, King JS, McNulty SG, Sun G, Palmroth S, Swenson J, Oren R.	Reduced hydraulic redistribution under future climate will affect root water uptake and ecosystem carbon balance across divergent forest ecosystems	Presentation (Meeting)	May 14-15, 2013	DOE TES/SBR Joint Investigators Meeting
Domec J.C., A. Noormets J.S. King, S.G. McNulty, and G. Sun	Convergence of the effect of root hydraulic functioning and root hydraulic redistribution on ecosystem carbon balance and drought-induced vegetation mortality across divergent forest ecosystems	invited presentation (meeting)	May 14-15, 2013	DOE TES/SBR Joint Investigators Meeting.
Fox, T.R.	PINEMAP Pine Integrated Network: Education, Mitigation and Adaptation Project: Mapping the future of pine management in a changing world	Presentation (Meeting)	October 15-18, 2012	Advisory Council Meeting of the Forest Productivity Cooperative, Chapel Hill, NC
Fox, T.R., J.L. Stape, J. Seiler, T. Albaugh, M. Yanez, N. Bonzey, L.C. Kiser, and J. Zerpa	Varietal Silviculture of Loblolly 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)	Presentation (Meeting)	June 26-28, 2012	NSF Center For Advanced Forestry 2012 Meeting
Fox, T.R., J. Raymond, and A. Werner	Use of 15N to Trace Applied Fertilizer Nitrogen in Douglas-Fir, Loblolly Pine and Walnut Forest Plantations to Evaluate Fertilizer Uptake Efficiency and Ecosystem Fate	Presentation (Meeting)	October 15-18, 2012	Advisory Council Meeting of the Forest Productivity Cooperative, Chapel Hill, NC
Fox, T.R., R. Harrison, B. Vance, D. Briggs, E.	Use of ^{15}N to Trace Applied Fertilizer Nitrogen in Douglas-	Presentation (Meeting)	June 26-28, 2012	NSF Center For Advanced Forestry

Turnblom, A. Himes, J. Zerpa, K. Littke, B. Strahm, J. Raymond, A. Werner, J. Stape, and D. Jacobs	Fir, Loblolly Pine and Walnut Forest Plantations to Evaluate Fertilizer Uptake Efficiency and Ecosystem Fate			2012 Meeting
Fox, T., R. Wynne, and D. Markewitz	Soil properties and processes that control soil carbon accumulation; Forest and carbon storage; Managing forests in the face of an uncertain climate	Webinar	January 24, 2012	Webinar for Spring 2012 PINEMAP Distance Graduate Course
Fox, T.R., T.A. Martin, and G.F. Peter	Leveraging 50 years of university-corporate-government forestry research cooperation	Presentation (Conference)	October 21-24, 2012	Soil Science Society of America Annual Meeting, Cincinnati, OH
Gavazzi, M.J., S.G. McNulty, A. Noormets, and E. Treasure	Management effects on soil respiration in North Carolina coastal plain loblolly pine plantations	Presentation (Meeting)	December 3-7, 2012	45th AGU Fall Meeting, San Francisco, CA
He, D., Vogel, J.G., Jokela E.J., Ruan, H., Hockaday W.C., and E.A.G. Schuur.	The effect of genetic selection and fertilization on the chemical characteristics of soil organic matter in managed loblolly pine forests as determined with nuclear magnetic resonance (NMR)	Presentation (Meeting)	Nov. 11th, 2013	Soil Science Society of America Meeting, Tampa Bay, FL.
Heim, B.C., J.R. Seiler, and B.D. Strahm	Response of heterotrophic and autotrophic soil respiration to simulated drought in managed southern pine forests	Presentation (Conference)	October 21-24, 2012	Soil Science Society of America Annual Meeting, Cincinnati, OH
Heim, B.C., J.R. Seiler, and B.D. Strahm	Loblolly pine heterotrophic and autotrophic soil respiration as influenced by fertilization and reduced throughfall.	Presentation (Conference)	March 4-7, 2013	17th Biennial Southern Silvicultural Research Conference, Shreveport, LA
Kiser, L.C. and T.R. Fox	Site and silvicultural effects on root growth and nutrient content of 4 loblolly pine (Pinus taeda L.) clones	Presentation (Conference)	October 21-24, 2012	Soil Science Society of America Annual Meeting, Cincinnati, OH
Laviner, A. and T. Fox	Soil Water Supply in the Virginia Throughfall Exclusion by Fertilization Experiment	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Laviner, A. and T. R. Fox	Water Relations in a Throughfall Exclusion Experiment in a Loblolly Pine Plantation	Poster Presentation	June 16-20, 2013	North American Forest Soils Conference, Whitefish, MT
Lin, W., A. Noormets, J.-C. Domec, J. King, G. Sun, and S. McNulty	A conifer-friendly high-throughput α-cellulose extraction method to analyze $\delta^{13}C$ and $\delta^{18}O$ isotope ratios	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Lin, W., A. Noormets, J.-	A conifer-friendly high-	Presentation	December 3-7,	45th AGU Fall

C. Domec, J. King, G. Sun, and S. McNulty	throughput α-cellulose extraction method to analyze $\delta^{13}C$ and $\delta^{18}O$ isotope ratio analysis	(Meeting)	2012	Meeting, San Francisco, CA
Lin, W., A. Noormets, J.-C. Domec, J. King, G. Sun, and S. McNulty	A conifer-friendly high-throughput α-cellulose extraction method to analyze $\delta^{13}C$ and $\delta^{18}O$ isotope ratios	Poster Presentation	March 9, 2013	Graduate Student Research Symposium of North Carolina State University, Raleigh, NC
Lokuta, G., A. Milligan, B. Gottloeb, T. Martin, and E. Jokela	PINEMAP Florida Tier III Site Overview	Poster Presentation	February 13, 2013	REACCH Second Annual Meeting, Portland, OR
Luedtke, C.M., M.K. Akers, and R.O. Teskey	Soil CO_2 efflux and tree carbon relations in a loblolly pine plantation [poster]	Poster Presentation	May 15-16, 2012	PINEMAP Annual Meeting, Atlanta, GA
Luedtke, C.L., D.P. Aubrey, M.A. McGuire, and R.O. Teskey	Dissolved [CO_2] in xylem sap of C3 annuals, shrubs, vines, and bamboo	Poster Presentation	August 9, 2012	Ecological Society of America Annual Meeting, Portland, OR
Qi, Ji (Jill) and D. Markewitz	Effect of Drier Summers on Deep Soil Carbon	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Maggard, A.O, C. Meek, R. Will, D. Wilson, T. Hennessey, J. Pike, C. Ausmus, and J. Vogel	Preliminary leaf gas exchange and soil CO_2 efflux results for loblolly pine (Pinus taeda L.) plantations experiencing partial rainfall exclusion and fertilization in Oklahoma	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Maggard, A., C. Meek, R. Will, D. Wilson, T. Hennessey, J. Pike, C. Ausmus, J. Vogel, and J. West	Preliminary leaf gas exchange and soil CO_2 efflux results for loblolly pine (Pinus taeda L.) plantations experiencing partial rainfall exclusion and fertilization in Oklahoma	Presentation (Conference)	March 4-7, 2013	17th Biennial Southern Silvicultural Research Conference, Shreveport, LA
Maggard, A.O., CR. Meek, R.E. Will, D.S. Wilson, and T.C. Hennessey.	Drought and carbon stress mortality in loblolly pine (*Pinus taeda* L.).	Poster Presentation	October 24-26, 2013.	Society of American Foresters annual meeting. Charleston, SC.
Maier, C. D. McInnis, and K. Johnsen	Partitioning root and heterotrophic respiration from soil CO_2 efflux in clonal loblolly pine plantations that differ in growth efficiency and carbon allocation	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA

Maier, C. D. McInnis, and K. Johnsen	Partitioning root and heterotrophic respiration from soil CO_2 efflux in clonal loblolly pine plantations that differ in growth efficiency and carbon allocation	Poster Presentation	August 4-9, 2013	98th Ecological Society of America, Minneapolis, MN
Maier, C.A., K. Johnsen, and P. Dougherty	Effect of Harvest Residue Management on Nutrient Cycling and Tree Growth in a Young Loblolly Pine Plantation	Presentation Symposium	November 27-28, 2012	IUFRO Symposium "Nutrient Dynamics of Planted Forests" Vancouver, WA
Maier, C.A.	Effects of harvest residue management on tree productivity and carbon pools in clonal loblolly pine stands	Presentation Meeting	October 15-17, 2012	Annual Meeting of the Forest Nutrition Cooperative, Chapel Hill, NC
Maier, C.A.	Ecophysiological differences in tree carbon gain and water use for two fast growing loblolly pine ideotypes that differ in carbon allocation.	Presentation Meeting	September 17-18, 2013	Forest Biology Research Cooperative, Perry, FL
Maier, C.A., K.H. Johnsen, P. Dougherty, T. Albaugh, and S. Patterson	Ecophysiological differences in tree carbon gain and water use for two fast growing loblolly pine ideotypes that differ in carbon allocation	Presentation Meeting	December 9-12, 2013	American Geophysical Union, December 9-12, San Francisco, CA
Markewitz, D., M. Kane, M. Akers, J. Qi, and J. Lord	N_2O Fluxes under managed pine in response to throughfall and fertilization: Study Initiation	Presentation (Conference)	October 21-24, 2012	Soil Science Society of America Annual Meeting, Cincinnati, OH
Markewitz, D. and L. Boby	PINEMAP: Assessing the role of pine plantations in climate change adaptation and mitigation	Presentation (Meeting)	August 2012	Warnell Seminar Series The University of Georgia, Athens, GA.
Markewitz, D. and L. Boby	PINEMAP: Southern Pines, Carbon, and Climate Change	Webinar	January 9, 2013	Georgia Initiative for Climate and Society, The University of Georgia
Markewitz, D. and L. Boby	PINEMAP:Assessing the role of pine plantations in climate change adaptation and Mitigation	Presentation (Seminar)	August 23, 2012	UGA Warnell School of Forestry and Natural Resources Seminar Series, Athens, GA
McCarthy, H.R., R. Oren, D. Kim, P. Tor-ngern, K.H. Johnsen, and C.A. Maier	Harvesting Duke FACE: improving estimates of productivity and biomass under elevated CO_2.	Presentation (Meeting)	December 9-12, 2013	American Geophysical Union, December 9-12, San Francisco, CA
Meeks, A., J.L. Stape, and T. Albaugh	Incorporating mid-rotation competing vegetation into the 3-PG model for Loblolly pine plantations in the Southeastern United States	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA

Minick, K. T.R. Fox, B.L. Strahm, E. Sucre and Z. Leggett	Soil Organic Matter Fractions in Loblolly Pine Forests Intercropped with Switchgrass in Coastal North Carolina	Presentation (Meeting)	October 15-18, 2012	Advisory Council Meeting of the Forest Productivity Cooperative, Chapel Hill, NC
Minick, K.J., B.L. Strahm, T.R. Fox, E. Sucre, and Z. Leggett	Switchgrass growth in southern loblolly pine forests alters soil organic carbon and N fractions under bedded rows of pine trees	Presentation (Conference)	October 21-24, 2012	Soil Science Society of America Annual Meeting, Cincinnati, OH
Nichols, L., T.R. Fox, B. L. Strahm, J. Seiler, E. Sucre, and Z. Leggett	The impact of low molecular weight organic acids and dissolved organic carbon on microbial biomass in a loblolly pine and switchgrass intercropped system	Presentation (Conference)	October 21-24, 2012	Soil Science Society of America Annual Meeting, Cincinnati, OH
Noormets A., S.G. McNulty, G. Sun, J.C. Domec, M.G. Gavazzi, and J.S. King.	The effect of management on forest carbon fluxes	Presentation (meeting)	December 9-13, 2013	AGU Fall Meeting, San Francisco, CA
Noormets A., J.C. Domec, J.S. King, S.G. McNulty, and G. Sun.	Convergence of the effect of root hydraulic functioning and root hydraulic redistribution on ecosystem carbon balance and drought-induced vegetation mortality across divergent forest ecosystems	Presentation (meeting)	August 3-9, 2013	ESA 98th Annual Meeting, Minneapolis, MN
Noormets A., J.C. Domec, G. Sun, M. Gavazzi, S. McNulty, J.S. King, and I. Thompson..	Soil carbon budget and sustainability of timber production on the coastal plain.	Invited presentation (meteing)	November 14, 2013	Weyerhaeuser Catchlight Energy Sustainability Studies Meeting, New Bern, NC
Noormets A., G. Miao, J.C. Domec, S.G. McNulty, G. Sun, and J.S. King	CO_2 and CH_4 exchange in an undisturbed coastal forested wetland in North Carolina	Presentation (Meeting)	December 3-7, 2012	45th AGU Fall Meeting. San Francisco, CA
Qi, J. and D. Markewitz.	Effect of Drier Summers on Deep Soil Carbon and Hydrology	Interactive Webinar	September 13, 2013	PINEMAP Internal Webinar Series
Qi, J. and D. Markewitz.	Drier Summers: Effects on Deep Soil Carbon and Hydrology	Poster Presentation	November 3-6, 2013	Soil Science Society of America Annual Meeting Tampa, FL
Qi, J. and D. Markewitz.	Drier Summers: Effects on Deep Soil Carbon and Hydrology	Poster Presentation	February 24-25, 2014	Soil Science Society of Georgia Annual Meeting Athens, GA
Qi, J. and D. Markewitz.	Drier Summers: Effects on Deep Soil Carbon and Hydrology	Poster Presentation	February 19-21, 2014	Symposium of Warnell School of Forestry and Natural Resourses, UGA

Qi, J. and D. Markewitz.	Effects of Drier summers on Deep Soil Carbon	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Raymond, J. and T.R. Fox	Uptake of ^{15}N labeled fertilizer in loblolly pine plantations	Presentation (Meeting)	October 15-18, 2012	Advisory Council Meeting of the Forest Productivity Cooperative, Chapel Hill, NC
Raymond, J. and T.R. Fox	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)	Presentation (Meeting)	June 26-28, 2012	NSF Center For Advanced Forestry 2012 Meeting
Samuelson, L.J. and J. Clark	Early impacts of rainfall manipulation and fertilization of the ecophysiology of loblolly pine at the Georgia PINEMAP Tier 3 experiment	Presentation (Meeting)	December 3-7, 2012	45th AGU Fall Meeting. San Francisco, CA
Sun G., Y. Fang, P. Caldwell, A. Noormets, J.C. Domec, S.G. McNulty, J.S. King, S. McLaughlin, J. Uddling, and J. Chen	Environmental Controls of Ecosystem Evapotranspiration (ET): Why generalized ET models do not work for forests?	Presentation (Meeting)	December 3-7, 2012	45th AGU Fall Meeting. San Francisco, CA
Vogel, J., R.E. Will, D.S. Wilson, M. Wigley, J.B. West, and L. Zhai	Implementation of the PINEMAP carbon sampling protocol for six Tier II plots in the Western Gulf Region	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Wang, Y. and R. Teskey	Sensitivity analysis of 3-PG model for Pinus taeda (loblolly pine) [poster]	Poster Presentation	August 5-10, 2012	Ecological Society of America 97th Annual Meeting, Portland, OR
Ward, E.J., J.C. Domec, G. Sun, S. McNulty, J. King, and A. Noormets	Transpiration and Canopy Conductance at the Virginia Tier 3 Site	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Ward, E.J., J.C. Domec, G. Sun, S. McNulty, J. King, and A. Noormets	Transpiration and Canopy Conductance of Loblolly Pine with Fertilization and Throughfall Exclusion	Poster Presentation	June 5, 2013	North Carolina State University Post-Doctoral Research Symposium, Raleigh, NC
Ward, E.J., J.C. Domec, G. Sun, S. McNulty, J. King, and A. Noormets	Transpiration and Canopy Conductance of Loblolly Pine with Fertilization and Throughfall Exclusion	Poster Presentation	August 9, 2013	Ecological Society of America Annual Meeting, Minneapolis, MN
Thompson I., A. Noormets, M. Gavazzi, and Z. Legget	Root decomposition study	Presentation	August 27, 2013	Weyerhaeuser-NCSU Co-operators Meeting
Ward, E.J	Sap Flux Sensor Networks at Tier 3 Sites	Interactive Webinar	February 15, 2013	PINEMAP Internal Webinar Series

Ward, E.J.	Pine Integrated Network: Education, Mitigation, and Adaptation Project (PINEMAP)	Presentation (Seminar)	November 14, 2013	Triangle Climate & Landscape Researchers, Raleigh, NC
Ward,E.J., D.M. Bell, J.S. Clark, H.R. McCarthy, H.-S. Kim, J.-C. Domec, A. Noormets, S. McNulty, G. Sun, and R. Oren.	Stomatal conductance at Duke FACE: Leveraging lessons from 11 years of scaled sap flux measurement for region-wide analyses.	Poster Presentation	December 9, 2013	American Geophysical Union, Fall Meeting, San Francisco, CA
Werner, A. and T.R. Fox	Uptake efficiencies of ^{15}N enriched enhanced efficiency fertilizers in a Pinus taeda L	Presentation (Conference)	October 21-24, 2012	Soil Science Society of America Annual Meeting, Cincinnati, OH
Werner, A. and T.R. Fox	Use of Stable Isotopes to Trace the Fate of Applied Nitrogen in Forest Plantations to Evaluate Fertilizer Efficiency and Ecosystem Impacts	Presentation (Meeting)	June 26-28, 2012	NSF Center For Advanced Forestry 2012 Meeting
Wightman, M.	Loblolly pine water relations in response to fertilization and throughfall exclusion	Presentation (Meeting)	September 26-27, 2012	Forest Biology Research Cooperative Annual Advisory Council Meeting, Gainesville, FL
Wightman, M., T. Martin, E. Jokela, C. Gonzalez, and W. Cropper	The Impact of Fertilization and Throughfall Exclusion on Loblolly Pine Growth and Water Use	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Wightman, M., T. Martin, E. Jokela, C. Gonzalez-Benecke, and W. Cropper	The impact of fertilization and throughfall exclusion on loblolly pine growth and water use	Presentation (Conference)	March 4-7, 2013	17th Biennial Southern Silvicultural Research Conference, Shreveport, LA
Wightman, M., T. Martin, E. Jokela, C. Gonzalez-Benecke, and W. Cropper	The impact of fertilization and throughfall exclusion on loblolly pine growth and water use	Poster Presentation	April 2-3, 2013	Sustaining Economies and Natural Resources in a Changing World: Key Role of Land Grant Universities Symposium
Wang, Y. and Teskey, R.O.	Using 3-PG lob model to predict southeastern region Pinus taeda (loblolly pine) productivity	Presentation (Conference)	March 5-7, 2013	17th Biennial Southern Silvicultural Research Conference, Shreveport, LA
Will, R.	Preliminary results from Tier III studies	Presentation (Meeting)	April 24, 2013	PINEMAP 2013 Annual Meeting, Athens, GA
Will, R.	Advancing silviculture in an era of climate change: An overview of PINEMAP	Presentation (Meeting)	May 15, 2013	Western Gulf Forest Tree Improvement Program, Contact Meeting, Idabel, OK

Will, R.E.,	Mid-rotation Management Under Extreme Stressors.	Presentation (Meeting)	Dec. 12 2013.	Western Gulf Sivlicultural Technology Exchange. Shreveport, LA
Will, R., C. Meeks, R. Heinemann, R. Holeman	Tier III PINEMAP field tour	Presentation (Field Tour)	May 15, 2013	Western Gulf Forest Tree Improvement Program, Contact Meeting, Idabel, OK
Wilson, E.	Drought Stress and Loblolly Pine Leaf Physiology: Using Carbon Stable Isotope Analysis to Examine Water Use Efficiency and Mesophyll Conductance	Interactive Webinar	September 13, 2013	PINEMAP Internal Webinar Series
Wilson, E., J.B. West, and J.G. Vogel	The effects of water stress on mesophyll conductance in loblolly pine (Pinus taeda L.) needles	Presentation (Meeting)	March 23, 2012	Ecological Integration Symposium, College Station, TX
Wilson, E., J. West, and J. Vogel	The effects of water stress on variability in mesophyll conductance of loblolly pine (Pinus taeda L.) leaves	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Wilson, E., J.B. West, and J.G. Vogel	The effects of water stress on mesophyll conductance in loblolly pine (*Pinus taeda* L.) needles	Presentation (Meeting)	March 23, 2012	Ecological Society of America Meeting, 2013, Minneapolis, MN
Yanez, M., T.R. Fox, and J. R. Seiler	Assessing leaf-level physiology on loblolly pine varieties under different silvicultural treatments	Presentation (Meeting)	October 15-18, 2012	Advisory Council Meeting of the Forest Productivity Cooperative, Chapel Hill, NC
Yang, J., C.M. Luedtke, M.K. Akers, and R.O. Teskey	Throughfall exclusion and fertilization effects on soil CO_2 efflux at a loblolly pine plantation in Georgia	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Zhai, L.	Finding ideotypes by examining interactions among silvicultural intensity, genotype, and environment for full-sib loblolly pine families	Presentation (Meeting)	March 23, 2012	Ecological Integration Symposium, College Station, TX
Zhang, Y.	Effects of climate change and forest management on belowground carbon cycling	Presentation (Meeting)	2013	Department of Ecosystem Science and Management Seminar Series,

				College Station, TX
Zhang, Y., J. West, and J. Vogel	Effect of climate change, forest management and genetic differences on soil carbon sequestration in southeastern US loblolly pine forests	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Zhang, Y., J. West, R. Will, and J. Vogel	Effects of fertilization and drought on substrate decomposition and inorganic nitrogen concentration in a managed loblolly pine forest	Poster Presentation	Dec. 10th	American Geophysical Meeting
	PINEMAP Presentation	Presentation (Meeting)	June 13-14, 2012	FPC Annual Contact Meeting, Alexandria, LA
	PINEMAP Presentation	Presentation (Meeting)	October 16, 2012	Concepcion Forest Productivity Cooperative Annual Advisory Committee Meeting, Chapel Hill, NC
	PINEMAP Overview Presentation	Presentation (Meeting)	January 26, 2012	Texas Center for Climate Studies
	PINEMAP Presentation	Presentation (Meeting)	September 27, 2012	Forest Biology Research Cooperative Annual Advisory Council Meeting, Gainesville, FL

Trainings, workshops, and courses

Experiments, surveys, and data collection

Tier I legacy experiments

The Tier I legacy network consists of hundreds of existing silviculture experiments and growth-and-yield plots that blanket the region and provide extensive, spatially explicit information on regional variability and productivity. Industry/university cooperative research installations to include in the Tier I legacy experiments have been identified and archived data from these sites has been uploaded into the TerraC database.

Tier II active experiments

The Tier II active experiments network consists of 127 sites distributed throughout the Southeast. These sites were selected to represent the range of climate, geology, and soil conditions in the Southeast and span a range of plantation ages (5 to more than 25 years) covering a progression of

stand development. Principal treatments represented in the network include planting density, thinning, fertilization, and competition control. Sampling on all or a subset of locations in this network include biomass and carbon inventory; soil sampling; wood core sampling for $^{13}C/^{18}O$ analysis to determine water use efficiency; and assessments of soil carbon emissions, nitrous oxide emissions, and nitrogen uptake efficiency. Data collection from Tier II sites is ongoing.

To date, tree increment cores have been collected from 46 Tier II sites. The cores are being analyzed for growth rate, ^{13}C isotopic composition as a function of drought intensity.

At VA subregion, 4 Tier II sites have been measured for total soil surface CO2 emissions (SR) and its heterotrophic component by using paired deep and shallow respiration collars, installed every three months in quadruplicate in ambient and fertilized treatment. The relative contribution of auto- and heterotrophic respiration to total soil surface emissions varies both by site and by time of year. The autotrophic component has a more pronounced seasonality, ranging from about 30% of SR in spring and summer to less than 5% in fall and winter, when the majority of SR is of microbial origin. The partitioning also depends on soil type and physiographic region, but due to incomplete sampling to date, the extent of these effects remains unclear.

Tier III throughfall exclusion x fertilization experiments

The Tier III throughfall exclusion x fertilization network is made up of four research sites situated at the edges of the native range of loblolly pine. The four sites, located in McCurtain County, Oklahoma; Taylor County, Florida; Taliaferro County, Georgia; and Buckingham County, Virginia, capture the current range-wide variability of climate, precipitation, and productivity. The research sites range in planting date from 2003 to 2008, are unthinned, and were planted with a mix of genetic sources appropriate for each region. Treatments at the four Tier III sites consist of a factorial experiment:

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

Researchers at each Tier III site are measuring tree and stand growth, above and below ground carbon, changes in soil nutrient and water availability, whole-tree water use, leaf area development and canopy light capture, and soil carbon dioxide (CO_2) efflux (partitioned into autotrophic and heterotrophic respiration). Additional information on Tier III research efforts is provided below.

- Foliage collected in January 2013 at the Virginia Tier III installation and October 2013 at the Georgia Tier III installation (Samuelson) has been analyzed for ^{13}C to determine treatment differences in water use efficiency.
- Dendrometer bands were installed at all sites to monitor seasonal tree growth.
- Sap flux density at each Tier III site is being monitored by a network of thermal dissipation sensor probes. There are five such sensors per plot, for a total of 320 trees monitored across all four Tier III sites. Data from these sensors are measured every 60 seconds and averaged every 30 minutes.
- A research study is being conducted using fertilizers enriched or labeled with the stable

isotope ^{15}N to track the fate of applied fertilizer N in plantation forests. 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.

- Heterotrophic (Rh) and autotrophic (Ra) components of soil respiration were measured on 3 (Florida, Oklahoma and Virginia) of 4 Tier III sites. A cross site synthesis of this data was conducted.
    - Despite the diversity of soil types, stand ages, seasons, and treatments (fertilization and throughfall reduction) across the Tier III sites, the proportion of soil respiration from Ra was remarkably consistent and averaged 16%.
    - When evaluating each site-by-season combination independently, there were very few significant fertilization or throughfall treatment effects.
    - When analyzed collectively, there were no significant differences across sites or seasons on the Rh contribution to soil respiration.
    - Considering the clay content at the GA Tier III site, the root severing with steel pipes method was not suitable for the Rh/Ra separation. Instead, traditional trenched plots(30cm X 30cm X 35cm) with mesh screen were installed, allowing for better water and CO2 diffusion. In total, there were 16 trenched subplots for each treatment.
- Precipitation is collected monthly (began July 2012). It will undergo δ^2H and $\delta^{18}O$ isotope analysis.
- Jill Qi, a PhD student at the University of Georgia, initiated soil C incubation study on soil layers ranging from 0-300 cm with samples from the Georgia Tier III location. She is simulating wetting and drying cycles in all samples to mimic field conditions. She has hypothesized that increased drying and wetting in deep subsoil due to changing climate will accelerate carbon mineralization.
- At the Georgia and Oklahoma Tier III sites, leaf-level gas exchange is being periodically measured to determine the effects of treatments on net photosynthesis and leaf conductance.
- At the Oklahoma Tier III site, a study has been installed to withhold rainfall until tree mortality. This will determine the limits of loblolly pine to drought stress and the mechanisms related to mortality.
- Teri Medsker, a MS student at Oklahoma State University, initiated a study to examine soil moisture influences on nutritional controls of productivity at the Oklahoma Tier III site.
- At the Georgia Tier III site,-trace greenhouse gas samples have been collected quarterly since pre-treatment. (Akers)

MILESTONES

Finalize standardized measurement protocols

Protocols for carbon sampling, tree core collection, biomass sampling, precipitation collection for isotopes, GHG flux, and heterotrophic and autotrophic soil respiration, and IPAR-LAI protocols have been finalized and uploaded to the PINEMAP intranet site where they will serve as a reference for field work and data collection on Tier II and III sites. Standardized metadata and spreadsheets have been created . Terra C database templates for Tier III data have been finalized.

Assessment of Tier III treatment effects

Foliar nutrient concentrations

At all four sites, fertilization increased foliar Nitrogen when measured one year after application. Foliar phosphorus was increased at three of four sites.

Soil moisture

When periodic measurements from the 2013 growing season were averaged, the throughfall reduction treatments reduced soil volumetric water content in the 0-12 cm from 13.3 to 9.4 % at Virginia, 24.2 to 19.8 % at Georgia, 6.6 to 4.9 % at Florida, and 10.8 to 8.5 % at Oklahoma. However, the throughfall diversion structures did introduce some spatial variability in soil moisture, especially in the surface 0-10 cm soil depth, where the soil directly under the troughs remained quite dry, while regions underneath the central gap between troughs and areas just outside the trough had wet-up and dry-down patterns more similar to ambient soil. However, at deeper levels, these patterns were muted, and there was less pronounced variation relative to position below the troughs.

		2012 Foliar N	2012 Foliar P
Site	Treatment	(mg g^{-1})	(mg g^{-1})
	Control	11.8 (0.1) a	0.92 (0.05) a
Virginia	TR	11.8 (0.2) a	0.94 (0.06) a
	F	16.8 (0.2) b	1.27 (0.06) b
	TR + F	17.1 (0.6) b	1.07 (0.02) b
	Control	14.5 (1.0) cb	0.95 (0.04) b
Georgia	TR	13.1 (0.6) c	0.98 (0.04) b
	F	17.0 (0.3) a	1.23 (0.06) a
	TR + F	16.1 (0.1) ab	1.04 (0.03) b
	Control	13.5 (0.1) c	1.10 (0.00) a
Florida	TR	14.0 (0.5) c	1.13 (0.05) a
	F	16.4 (0.2) a	1.13 (0.03) a
	TR + F	15.2 (0.1) b	1.05 (0.03) a
	Control	12.9 (0.3) a	0.85 (0.04) a
Oklahoma	TR	12.8 (0.1) a	0.82 (0.02) a
	F	14.8 (0.3) b	0.96 (0.03) b
	TR + F	14.6 (0.3) b	0.94 (0.05) b

Table 1. Dormant season measurements of foliar nitrogen (N) and phosphorus (P) concentrations one year after treatment initiation. TR = throughfall reduction treatment, F = Fertilization treatment. Different letters next to means within a site indicates differences $p < 0.05$. Numbers in parentheses are standard errors.

Leaf-level physiology

Leaf gas exchange and leaf water potential were measured from July 2012 through July 2013 at the Georgia Tier III installation. A significant drought occurred in 2012 and rainfall exclusion decreased stomatal conductance (g_s) and light-saturated net photosynthesis (P_{net}) in 2012 in the fertilized and non-fertilized treatments. Predawn water leaf potential in 2012 decreased on average from -0.65 MPa in the ambient rain treatment to -0.71 MPa in the exclusion treatment. In contrast, during the wetter year of 2013 no significant effects of rainfall exclusion treatment on g_s and P_{net} measured during the growing season were observed.

Leaf area index and intercepted photosynthetically active radiation

In 2012 and 2013, fertilization increased peak LAI, with greater enhancement by fertilization observed in 2013 (Figure 1). Throughfall exclusion had no significant effect on LAI in 2012 or 2013.

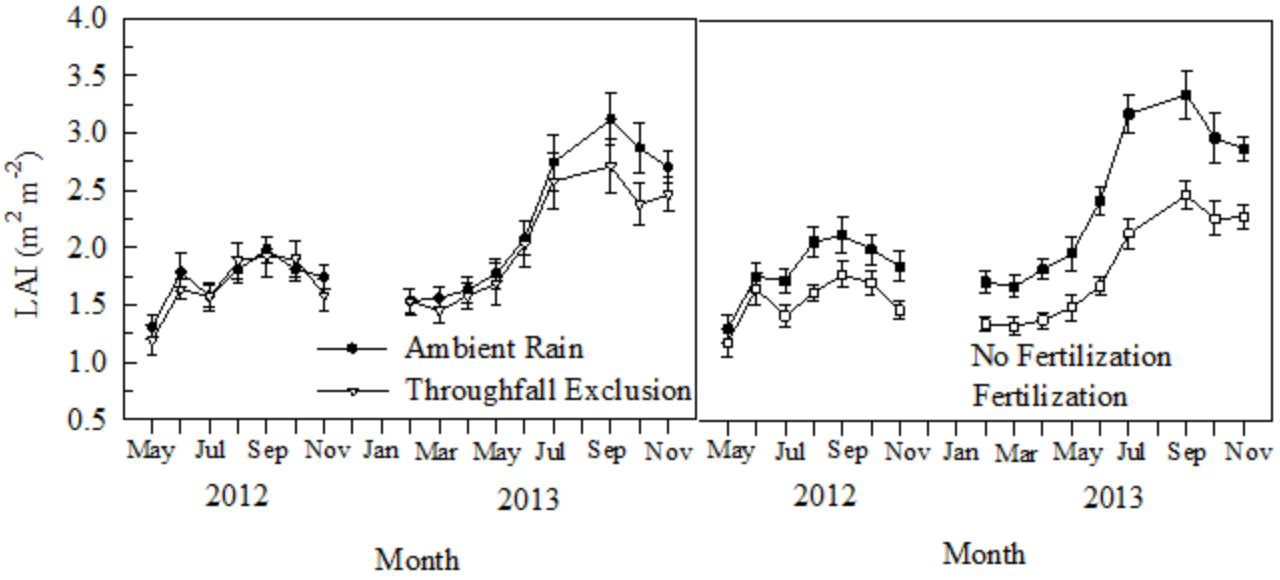

Figure 1. Response of Leaf Area Index (LAI) to fertilization and throughfall exclusion treatments at the Georgia Tier III installation.

Soil heterotrophic and autotrophic respiration

Following the results presented last year from the summer 2012, where installation of root severing cores to separate soil heterotrophic and autotrophic respiration at the Virginia Tier III site demonstrated confidence in the methodology, the technique was deployed across three of the four Tier III sites (VA, OK, FL). Despite the diversity of soil types, stand ages, seasons, and treatments (fertilization and throughfall reduction), the proportion of soil respiration from Rh was remarkably consistent (Figure 2). When evaluating each site-by-season combination independently, there were very few significant ($p < 0.05$) interaction (Jul-13, Oklahoma) or main effects (asterisks) of fertilization or throughfall reduction. Further, when analyzed collectively, there were no significant differences across sites or seasons on the Rh contribution to soil respiration.

Perhaps most surprising was the estimated Rh proportion itself. Given the general lack of observed differences across sites, seasons, and treatments, a single regional estimate of 0.840 ± 0.026 is provided as the Rh proportion of soil respiration. The robustness of this estimate will greatly aid the modeling of NEP across the range of managed loblolly pine. Without the need to account for site- or stand-specific characteristics to estimate Rh, modeling efforts can focus on improving NPP estimates alone.

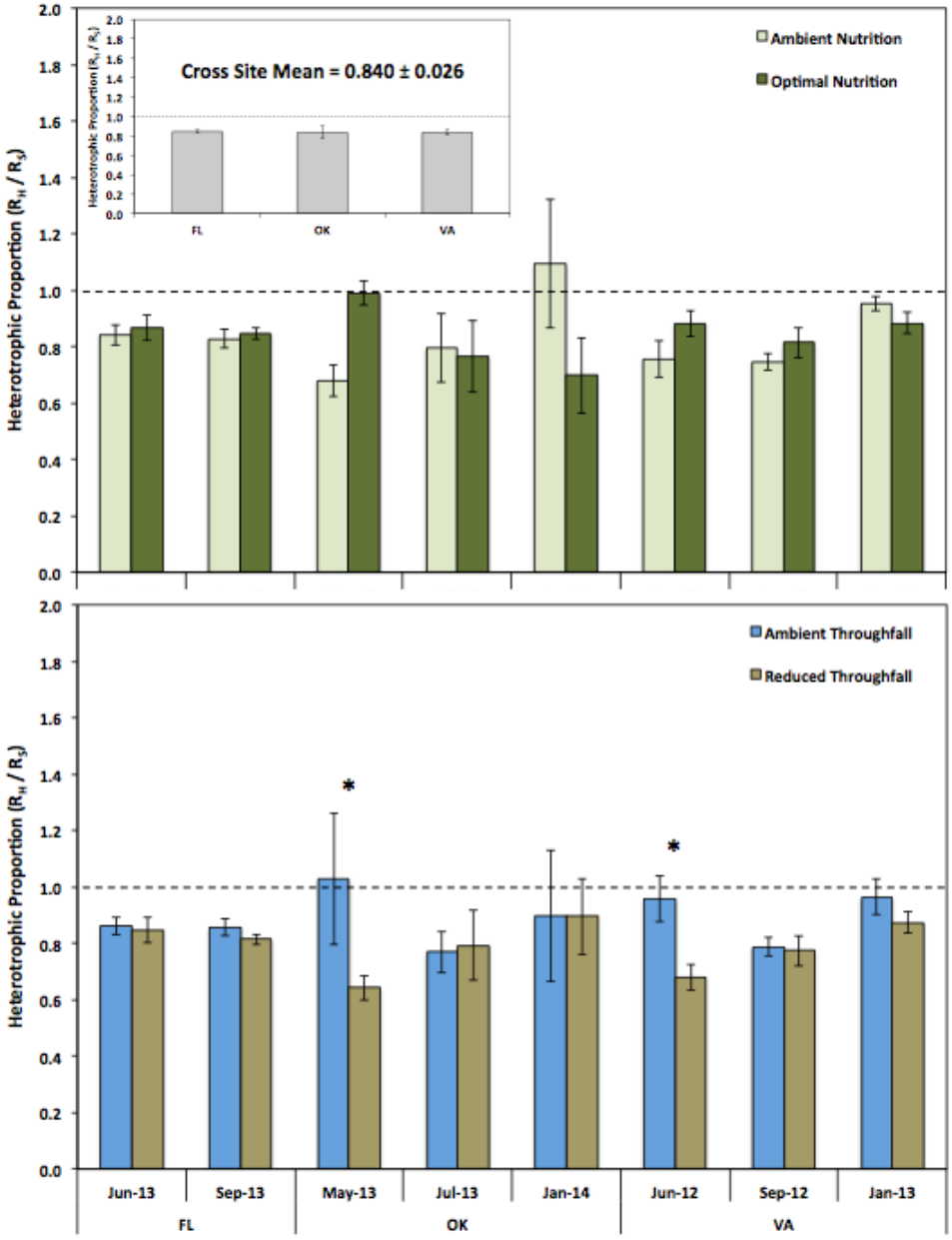

Figure 2. Proportion of total soil respiration (RS) that is from heterotrophic, microbial respiration (RH) at the PINEMAP Tier III sites in Florida (FL), Oklahoma (OK), and Virginia (VA) at multiple points in time. Upper panel shows main effect of fertilization; lower panel shows main effect of throughfall reduction. Inset provides site and regional means. Asterisks represent significant main effect differences ($p < 0.05$).

Fate of applied fertilizer nitrogen

A research study is being conducted using fertilizers enriched or labeled with the stable isotope ^{15}N to track the fate of applied fertilizer N in plantation forests. Because only a small percentage of ^{15}N exists in the environment, enriching fertilizers with this isotope allows an accurate accounting of the movement of N derived from the fertilizers. The use of ^{15}N allows us to calculate how much and how quickly crop trees incorporate N applied from fertilizers. Additionally, because large N losses to the atmosphere can occur when using conventional fertilizers (urea), we are investigating whether enhanced efficiency fertilizers are able to reduce these gaseous losses. Enhanced efficiency fertilizers are treated with polymer coatings to slow the release of N to the soil solution, or with chemicals that inhibit urease (such as NBPT or CUF), a catalyzing enzyme of urea hydrolysis. We are also investigating the seasonal timing of fertilization, which is traditionally conducted in late winter or early spring when plant available N may be less limiting compared to summer months. Finally, we are examining how much fertilizer derived N is retained by understory competition.

Eighteen sites were established near existing research studies across the entire range of loblolly pine plantations in the southern United States. Five fertilizer treatments were applied at two different times (late winter and summer in 2011 and once in late winter in 2012) in 100 m^2 circular plots with similar characteristics. Five additional plots were installed at the Tier III sites in Virginia and Georgia to investigate the impact of retaining the understory vegetation. After fertilizer application, measurements were taken to estimate gaseous and leaching losses of N. Foliar sampling was conducted every 6 weeks to estimate N uptake over the growing season. All components of the ecosystem were sampled at the end of the growing season to calculate the location of ^{15}N.

Field experiments with isotopically labeled fertilizer N in managed loblolly pine (*Pinus taeda* L.) forests across the southern U.S. showed total soil and tree system N recovery ranged from 58 to 100% the first year after fertilization (Figure 3) The forest floor still contained 40 to 80% of the applied N at the end of the first year. Volatilization losses were less with enhanced efficiency N fertilizers compared to urea.

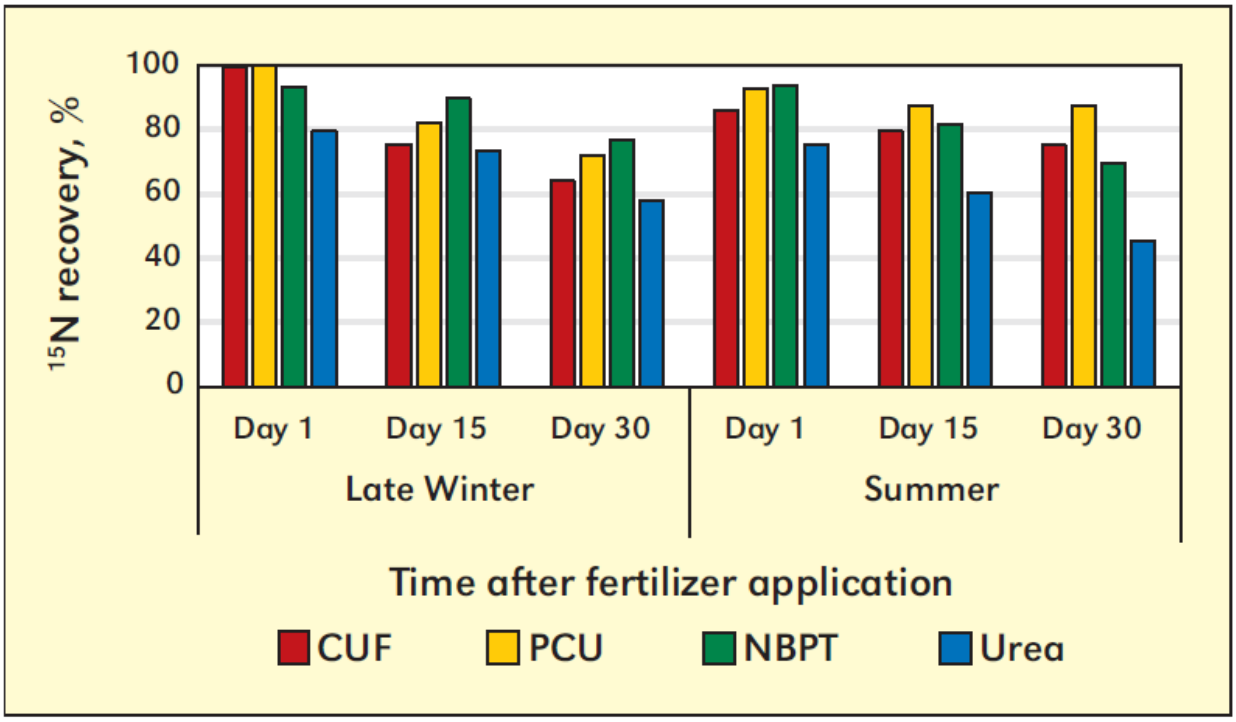

Figure 3. Graphs comparing the percentage of N (%N) attributed to fertilizer uptake from winter and summer 15N fertilizer application at the Virginia 15N site, located adjacent to the Virginia Tier III site. Both application periods indicate that foliage contains the largest levels of N attributed to the fertilizer for the aboveground portion of the crop tree at this site.

Sap flux density

Sap flux density at each Tier III site is being monitored by a network of thermal dissipation sensor probes. There are five such sensors per plot, for a total of 320 trees monitored across all four Tier III sites. Data from these sensors are measured every 60 seconds and averaged every 30 minutes. A preliminary cross-site comparison of sap flux data from Tier 3 sites in VA, GA and FL was made for the 2013 growing season (April-September), which is included in the Year 3 Annual Report. Below is more detail on the sites in VA and GA.

Sap flux density at the Virginia Tier III Installation

Employing measurements from the network of environmental and sap flux sensors, we estimated the canopy-averaged transpiration per unit ground area (E_C) and daytime stomatal conductance (G_S) of each treatment using a hierarchical Bayesian state-space model of G_S responses to photosynthetically active radiation (*PAR*), vapor pressure deficit of the atmosphere (VPD) and volumetric water content of the soil (*VWC*). We found an initial increase of 8% and 16% E_C in the fertilized treatments with (FD) and without (F) throughfall displacement, respectively, relative to the control (C) in June and July 2012. This was followed by decreases in E_C of these treatments in some later months. Due partially to differences in leaf area index (*LAI*) between treatments, we detected differences in G_S in FD with 95% confidence, but not in F, when compared to C. During the 2013 growing season, monthly E_C estimates

were on average 6% and 13% lower in F and FD, respectively, and monthly G_S estimates for FD were 20% lower than in C. If fertilization were shown to reduce belowground allocation at this site or xylem conductivity in the roots or stem, while resistance to cavitation by drought increased, it would explain the pattern in E_C and G_S we observed, where differences are large at high soil moisture, but virtually non-existent at low soil moisture (Fig. XX). This suggests that investigations into these factors could be of interest at Tier III sites. An increasing trend in *LAI* of all treatments indicates that treatment effects on tree water relations are likely to continue to develop as these stands approach canopy closure.

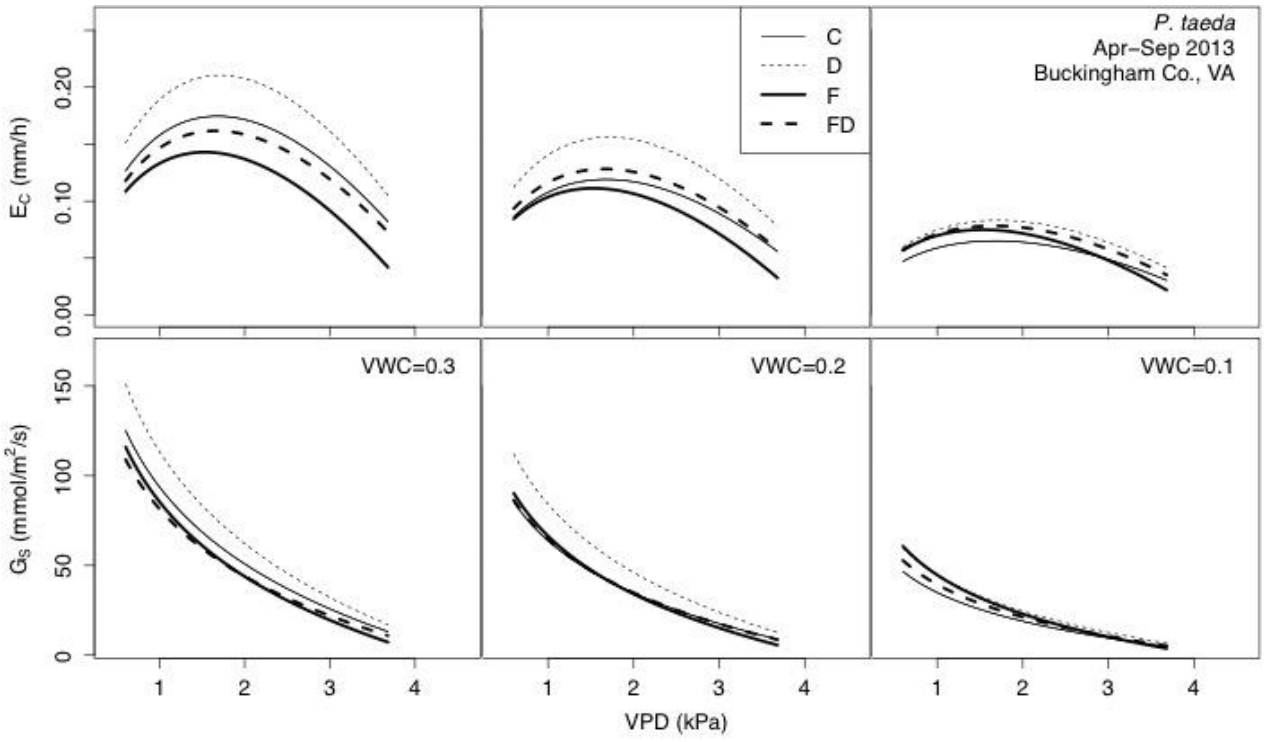

Figure 4. Mean responses of canopy transpiration per unit ground area (E_C) and canopy-averaged stomatal conductance per unit leaf area (G_S) to vapor pressure deficit (*VPD*) at three different volumetric water contents of the soil (*VWC*), under saturating light conditions, as inferred from posterior process parameters for the 2013 growing season. E_C values assume mean leaf area index for the model period. Treatments: control (C), throughfall displacement (D), fertilization (F) and combined (FD).

Sap flux density at the Georgia Tier III Installation

Average daily variation in sap flux density (J_S) is shown in Figure 5. A significant interactive effect of rain exclusion and fertilization treatments was detected for monthly daytime averaged J_S and monthly transpiration on a ground (E_G) and leaf area (E_L) basis. Fertilization significantly increased J_S and E_G only in ambient rainfall treatment: J_S was increased from an average of 33 g m^{-2} s^{-1} to 37 g m^{-2} s^{-1} and E_G was increased on average from 70 to 92 mm $month^{-1}$ by fertilization (Figure 6). In contrast, in the rain exclusion treatment fertilization decreased J_S from an average of 33 g m^{-2} s^{-1} to 30 g m^{-2} s^{-1} . Fertilization decreased E_L on average by 27% in the rain exclusion treatment but fertilization had no effect on E_L in the ambient treatment. These results indicate a more conservative water use strategy at the whole plant level such that increased leaf area with fertilization is resulting in a greater sensitivity to water availability in rain exclusion treatment.

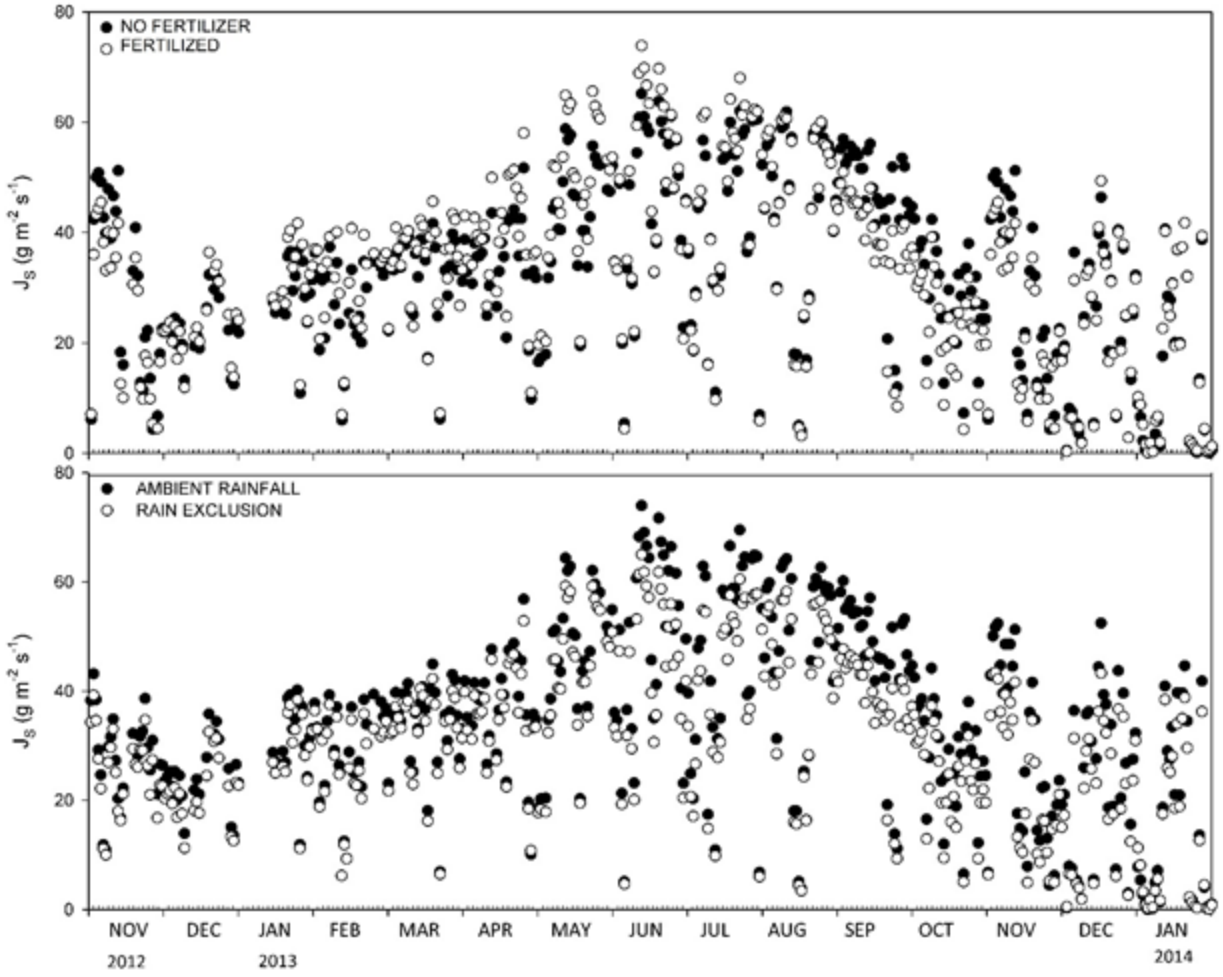

Figure 5. Daytime average sap flux density (J_S) in response to rain exclusion and fertilization treatments from November 2012 to January 2014 at the Georgia Tier III installation.

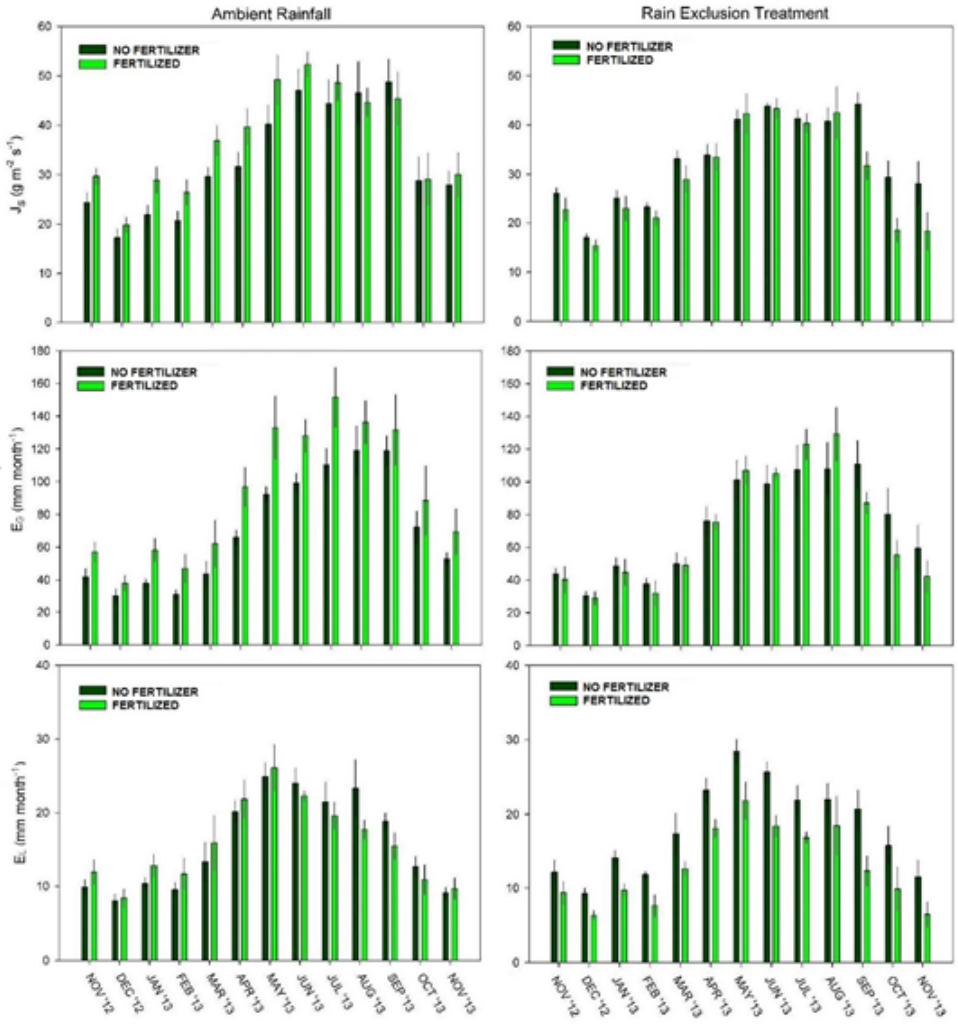

Figure 6. Monthly average daily sap flux density (J_S) and and the monthly sum of transpiration on a leaf area (E_L) or ground area (E_G) basis in response to fertilization in the ambient rain or rain exclusion treatment from December 2012 to November 2013 at the Georgia Tier III installation.

Initial C and nutrient baselines estimated from existing Tier I data

Data from the Tier I sites has been included in the TerraC system and is being used by the Aim 3 group to model carbon and nutrient content in the Tier I sites with a range of models.

Assessment of climate, soil, and management impacts on soil GHG flux

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.

Three measurement cycles (March-June, July-October, and October-January) have been completed. Sf ranged from 3.4 umol m^{-2} s^{-1} in March to greater than 15 umol m^{-2} s^{-1} in July. The +LR treatments increased Sf by 15% (p=0.04) compared to -LR treatments. Clone had no effect on Sf and there was no clone x LR interaction; however, there was a strong clone x season interaction (p=0.008), where Sf was 17% greater in the BC clone in July. The root exclusion pipe significantly reduced Sf and the response magnitude varied with season. The Ra/Sf was greater in the summer (0.32) than in the spring (0.13) or fall (0.22). There were no clone, LR, or clone x LR effects on Ra. Similarly, clone had no effect on Rh; however, +LR increased R_h 25% (p=0.0001). These early results suggest that genotype and management can alter Sf, Ra, and Rh.

At three of the Tier III sites (VA, OK, GA), vented static chambers have been installed for the seasonal measurement of soil-atmosphere nitrous oxide (N_2O) and methane (CH_4) greenhouse gas fluxes. Preliminary data from the VA site show an increase in N_2O emissions and a decrease in CH_4 uptake following fertilization that have been sustained through June 2013 (second growing season following treatment). While throughfall reduction alone does not have a significant impact on the soil fluxes of these greenhouse gasses, the interacting effects of fertilization and throughfall reduction appear to exacerbate the increase in N_2O production and decrease in CH_4 consumption (Fig. 7).

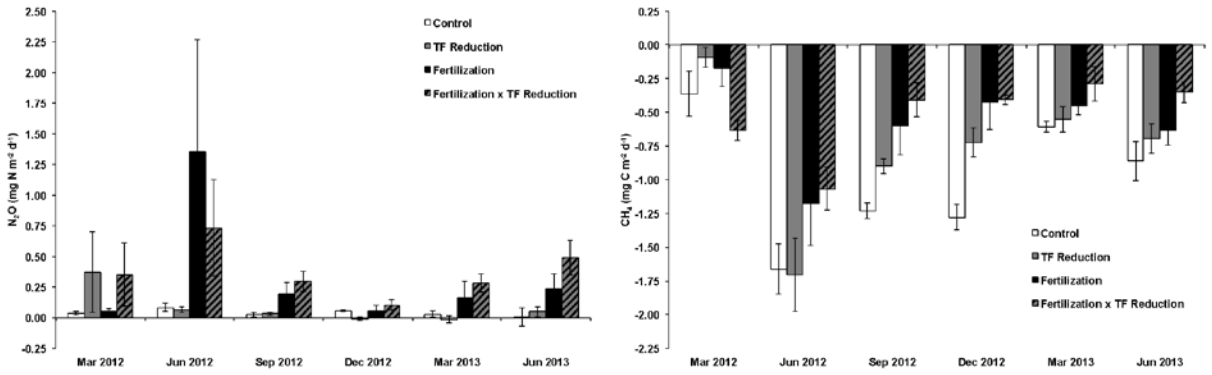

Figure 7. Nitrous oxide (N_2O; left) and methane (CH_4; right) soil-atmosphere fluxes from the VA Tier III site. Error bars represent ±standard error of the mean.

Regionalize estimates of WUE for application in 3-PG and WaSSI

Wood cores from a subset of the Tier II sites have been collected for 13C isotope analysis to determine WUE in the PINEMAP region.

Monthly WUE values were derived for the period 2007-2009 for mid-rotation and young stands at the Parker Track site, and 2001-2008 for the Duke Forest site. It appears that WUE had little variation across the year, but WUE varied across stand age. Younger stand has lower values (1.97) than mid rotation (2.34) at the Parker Track site.

Determining FR Rating for Loblolly Pine Based on Site Index for Use in 3-PG Model

We calibrated soil fertility rating (FR) for loblolly pine plantation managed under controlled regime using site index. Then we used FR in 3-PG to predict loblolly pine yield and mortality. Of the 21 sites selected across the southeastern United States 3-PG predicted yield on 16 sites and mortality on 18 sites reasonably well. Largest discrepancies in stand volume simulation were observed in Piedmont. Where as in the Upper Coastal Plain and Eastern Gulf Coastal Plain yield simulation matched well. When observed stand volume and basal area at age 10 and stem number before thinning were compared against the simulated values, 75% of the variation in stand volume, 50% of the variation in basal area, and 86% of the variation in stem number were explained by simulated values.

BROAD IMPACTS

Provide a short narrative describing broad impacts (i.e., far-reaching and possibly unanticipated outcomes resulting from Aim work). Specifically, please highlight leveraged funds and/or partnerships with other projects/external collaborations.

TRAINING

Provide a comprehensive list of undergraduate and graduate students, postdocs, and technical/research personnel trained under this project and include a description of their research focus and/or role in the project.

A comprehensive list of all Aim 1 trainees is provided below. Please update as necessary and highlight in yellow any updates made for the April 2014 Progress Report.

Last name	First name	Position	University	Role
Akers	Madison	Research Staff	UGA	Coordinating baseline measurements on Tier II sites and overseeing installation and data collection on the Georgia Tier III site
Albaugh	Tim	Research Staff	NCSU	Evaluating impacts of weed control and fertilization on loblolly pine using the 3-PG model
Alvarez	Jose	Postdoc	NCSU	Evaluating changes in loblolly pine leaf area due to silvicultural treatments as a component of the 3-PG model
Ausmus	Casey	M.S. Student	OSU	Research focus: determine the effects of fertilizer and water availability on tree physiological processes
Baggett	Brittany	Undergraduate Intern	Univ. of W. FL	2013 Undergraduate Fellow; working with Adam Maggard at OSU
Bartkowiak	Stan	Ph.D. Student	Auburn	Research focus: measuring sap flux at the Georgia Tier III site
Clark	Joe	M.S. Student	Auburn	Research focus: assessing relationships among intercepted radiation, LAI, photosynthetic capacity, phenology, and productivity in loblolly pine
Clark	Zach	M.S. Student	UGA	Research focus: assessing developmental pattern of understory vegetation on Tier II installations
Cucinella	Josh	Research Technician	UF	Assists with site maintenance and data collection on Florida Tier III site.
Diamond	Amanda	Undergraduate Intern	VT	2013 Undergraduate Fellow; working with Madison Akers at UGA
Faison	Andrew	Undergraduate Intern	VSU	2012 Undergraduate Fellow; assisted 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.
Few	John	Undergraduate Intern	VSU	2013 Undergraduate Fellow; working with Asko Noormets at NCSU
Fields	Anthony	Undergraduate Intern	VSU	2013 Undergraduate Fellow; working with Maxwell Wightman at UF
Frye	Sam	Research Staff	VT	Assisting with soil CO2 efflux and N2O measurements and installation and data collection on Tier II and III sites.
Gonzalez	Carlos	Research Associate	UF	Ecophysiology and Carbon Balance Modeling; support of tree transpiration measurements for Tier III; use of 3PG model to assess the effect of climate change in productivity of loblolly pine plantations in SE U.S.
Gregory	Bethany	Undergraduate Intern	VT	2012 Undergraduate Fellow; helped Andy Laviner at Virginia Tech with a study on environmental manipulation of fertilization, drought, and thinning in loblolly pine plantations.
Hancock	Amanda	Undergraduate Research Assistant	TAMU	Carbon monitoring protocol implementation for Tier II sites.
He	Dongmei	Visiting Chinese PhD student	TAMU	Effect of soil aggregrates on soil C stabilization in different families of loblolly pine
Heim	Brett	M.S. Student	VT	Research focus: separating heterotrophic and autotrophic respiration components of soil CO_2 efflux

Last name	First name	Position	University	Role
Heinemann	Bob	Research Coordinator	OSU	Assists with site maintenance and data collection on Oklahoma Tier III site.
Holeman	Randy	Research Specialist	OSU	Assists with site maintenance and data collection on Oklahoma Tier III site.
Ingwers	Miles	Ph.D. Student	UGA	
Jackson	Colin	Undergraduate Intern	OSU	2013 Undergraduate Fellow; working with Jay Raymond at VT
Jarvis	Rebecca	Undergraduate Intern	VT	2012 Undergraduate Fellow; assisted Wen Lin at North Carolina State University with quantifying the growth rate of loblolly pine, and analyze its sensitivity to temperature and precipitation dynamics.
Kinnerly	Will	Undergraduate Intern	VT	2012 Undergraduate Fellow; helped Brett Heim at Virginia Tech with experimental manipulations of belowground metabolic activity in order to separate microbial respiration from plant respiration
Laviner	Andy	Ph.D. Student	VT	Coordinating baseline measurements on Tier II sites and overseeing installation and data collection on VA Tier III site; research focus is water use efficiency in loblolly pine
Lin	Wen	Ph.D. Student	NCSU	Research focus: water use efficiency in loblolly pine using 12C/13C ratios in wood
Lokuta	Geoffrey	Research Staff	UF	Coordinating baseline measurements on Tier II sites and overseeing installation and data collection on the Florida Tier III site
Luedtke	Cody	Ph.D. Student	UGA	Research focus: Soil CO2 efflux
Maggard	Adam	Ph.D. Student	OSU	Research focus: ecophysiology on Tier II and III sites
McElligott	Kristin	Ph.D. Student	VT	Research focus: mechanisms controlling total soil CO_2 efflux and heterotrophic and autotrophic soil respiration
Medsker	Teresa	M.S. Student	OSU	Research focus: belowground processes affected by fertilization and water availability
McConaghy	Scott	Undergraduate Intern	Kansas State	2013 Undergraduate Fellow; working with Yang Zhang at TAMU
Meek	Casey	Research Staff	OSU	Assisting with ecophysiological and process measurements at Tier II and III sites
Meeks	April	M.S. Student	NCSU	Incorporating competing vegetation in 3-PG model
Nagel	Greg	Undergraduate Research Assistant	TAMU	Carbon monitoring protocol implementation at Tier II sites
Parisher	Josh	Undergraduate Research Assistant	TAMU	Carbon monitoring protocol implementation at Tier II sites
Pell	Charles	M.S. Student	Auburn	Research focus: ecophysiology at the Georgia Tier III site.
Pike	Jason	Research Staff	OSU	Assisting with installation, maintenance, and data collection on Tier III sites
Qi	Jill	Ph.D. Student	UGA	Research focus: soil water and deep soil carbon responses under rain throughfall treatment at Tier III sites
Raymond	Jay	Ph.D. Student	VT	Research focus is N uptake efficiency of enhanced efficiency N fertilizers using 15N stable isotopes
Rutemiller	Paul	Undergraduate Intern	VT	2013 Undergraduate Intern; working with Chris Maier at the USFS
Ryland	Rachel	Undergraduate Research Assistant	UGA	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
Seyle	Jacob	Undergraduate Research Assistant	NCSU	Assists with processing soil samples from Tier2 soil respiration plots in the northern subregion, makes sapflow probes for Tier 3 installations, analyzes growth responses of trees at Tier 2 sites to historic drought events. /AN/
Sherrod	Charles Allen	Undergraduate Research Assistant	UGA	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
Shrestha	Raj	Postdoctoral Research Scientist	VT	Soil greenhouse gas (CO2, N2O, CH4) flux across soil moisture and management gradients

Last name	First name	Position	University	Role
Barros	Bruce	M.S. Student	UGA	Research focus: Transpiration predictions with 3-PG model (Tier III)
Stebler	Elaine	Research Staff	OSU	Coordinating baseline measurements on Tier II sites and overseeing installation and data collection on the Oklahoma Tier III site
Stokes	Tom	Research Staff	Auburn	Assisting with data collection on Tier II and III sites
Subedi	Santosh	Ph.D. Student	VT	Research focus: identifying an improved method to determine fertility rating for 3-PG
Thompson	Ian	Undergraduate Research Assistant	NCSU	Heterotrophic respiration, coarse woody decomposition, making sapflow probes for Tier 3 sites. /AN/
Wightman	Maxwell	M.S. Student	UF	Research focus: Ecophysiology of drought response on FL Tier III site
Wigley	Madison	Undergraduate Research Assistant	TAMU	Carbon monitoring protocol implementation for Tier II sites
Wilson	Elizabeth	M.S. Student	TAMU	Research focus: understanding the effects of mesophyll conductance on isotopic signatures in leaves
Yang	Jinyan	Ph.D. Student	UGA	Research focus: Heterotrophic and autotrophic components of soil respiration
Zhai	Lu	MS	TAMU	Research focus: Family and culture effects on ecosystem C and N dynamics
Zhang	Yang	Ph.D. Student	TAMU	Research focus: Carbon and nitrogen cycling response to drought at the OK Tier III site