Aim 1 – Silviculture and Ecophysiology
PINEMAP Year 2 Final Progress Report
March 2013

This is the final Aim progress report for year 2 (March 2012-February 2013). Please update the outputs list and provide brief progress updates on milestones and work plan tasks as applicable. The information provided in these reports is used to track Aim-level outputs and outcomes over the course of the project and to fulfill NIFA reporting requirements via the annual continuation proposals and CRIS progress report.

Please return the updated report to Jessica Ireland no later than **March 22**.

Outputs

List ***Products*** developed/completed January 2012-current (including published, in press, or in review peer-reviewed publications; other written materials such as white papers, research summaries, fact sheets, or popular press articles; audio or video products; etc.).

A list of documented Aim 1 year 2 publications is provided below; please update as necessary and highlight in yellow any publications added to the list in the March 2013 Progress Report.

Peer-reviewed publications (January 2012-current)

Albaugh, T.J., T.R. Fox, C.A. Blinn, H.L. Allen, R. Rubiliar, and J.L. Stape. Developing a new foliar-nutrient based method to predict response to competing vegetation control in *Pinus taeda*. *Southern Journal of Applied Forestry*. *In press.*

Albaugh, T.J., E.D. Vance, C. Gaudreult, T.R. Fox, H. L. Allen, J. L. Stape, and R.A. Rubilar. 2012. Carbon emissions and sequestration from fertilization of pine in the southeastern United States. Forest Science. 58:419-429.

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

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.

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

Bryars, C., C. Maier, D. Zhao, M. Kane, B. Borders, R. Wil, and R. Teskey. 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*, in press.

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*, 288:43-48. doi: http://dx.doi.org/10.1016/j.foreco.2012.05.026

Carlson, C.A., T.R.Fox, H.L. Allen, T.A. Albaugh, J.L. Stape, and R.P. Rubilar. In Press. Growth responses of loblolly pine in the Southeast United States to midrotation applications of nitrogen, phosphorus, potassium and micronutrients. Forest Science.

Comerford, N, A.J. Franzluebbers, M. Stromberger, L. Morris, D. Markewitz, and R. Moore. Ecosystem Services Derived from Soil. *Soil Horizons*. *Accepted*.

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

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

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*, in press.

Jones, P.D. and T.R. Fox. 2012. Stem sinuosity in young and merchantable stands of *Pinus taeda* 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.* 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.

Kiser, L.C. and T.R. Fox. Short Rotation Woody Crop Biomass Production for Energy. 2013. 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

Rubilar, R., 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.

Sabatia, C.A., T.R. Fox and H. Burkhart. In Press. Extending a model system to predict biomass in mixed-species southern Appalachian hardwood forests. Southern Journal of Applied Forestry. DOI 10.5849/sjaf.12-005.

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

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: 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*, 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.

Williams, T.D., R. Moore, and D. Markewitz. Evaluating potential bias in media coverage of public debate over acid rain and chloroflourocarbons in the 1980s. *Applied Environmental Education and Communication*. 11(2):65-78.

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.

Events/Activities (January 2012-current)

→ 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. *Indicate poster presentations by placing [poster] at end of citation. *Highlight in yellow presentations added to the list in the March 2013 Progress Report.*

- Albaugh, T.J., T.R. Fox, H.L. Allen, J.L. Stape, and R.A. Rubilar. 2012. SETRES water use efficiency. Contact Meeting of the Forest Productivity Cooperative. Pineville, LA. June 12-14, 2012.
- Albaugh, T.J., H.L. Allen, T.R.Fox, C.A. Carlson. 2012. Identifying optimal rates and frequencies of nutrient application to achieve and maintain high rates of production in forest plantations. Advisory Council Meeting of the Forest Productivity Cooperative. Chapel Hill, NC. October 15-18, 2012.
- Albaugh, T.J., T.R.Fox, J.L. Stape. 2012. Silviculture of varietal *Pinus taeda* spacing and silvicultural effects on varieties with different crown ideotypes. Advisory Council Meeting of the Forest Productivity Cooperative. Chapel Hill, NC. October 15-18, 2012.
- Albaugh, T.J., T.R.Fox, J.L. Stape, R.A. Rubilar, H.L. Allen. 2013. Effects of imazapyr rate and application method in mid-rotation *Pinus taeda* stands. 17th Biennial Southern Silvicultural Conference. Shreveport, LA. March 5-7, 2013.

- 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.
- Caudill, B., M. Wightman, G. Lokuta, T.A. Martin, and E.J. Jokela. 2013. Characterization of top 20cm of soil profile for PINEMAP Tier III site in Taylor Co., FL. 17th Biennial Southern Silvicultural Conference. Shreveport, LA. March 5-7, 2013. [poster]
- 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.
- 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. Abstracts of the 97th Ecological Society of America Annual Meeting, Portland, Oregon.
- 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. 2012. Convergence of the effect of root hydraulic functioning and root hydraulic redistribution on ecosystem water and carbon balance across divergent forest ecosystems. The 45th AGU Fall Meeting. San Francisco, CA, December 3-7, 2012.
- 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.
- 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.
- 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.
- 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.
- Gavazzi M.J., S.G. McNulty, A. Noormets, and E. Treasure. 2012 Management effects on soil respiration in North Carolina coastal plain loblolly pine plantations. The 45th AGU Fall Meeting. San Francisco, CA, December 3-7, 2012.
- 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.

- Heim, B., J.R. Seiler, and B.D. Strahm. 2013. Loblolly pine hetertrophic and autotrophic soil respiration as influenced by fertilization and reduced throughfall. 17th Biennial Southern Silvicultural Research Conference, March 4 – 7, Shreveport, La.
- 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.
- Lin W., A. Noormets, J.C. Domec, J.S. King, G. Sun, and S.G. McNulty. 2012. A conifer-friendly high-throughput α-cellulose extraction method for $\delta^{13}C$ and $\delta^{18}O$ stable isotope ratio analysis. The 45th AGU Fall Meeting. San Francisco, CA, December 3-7, 2012.
- Luedtke, C.L., D.P. Aubrey, M.A. McGuire, and R.O. Teskey. 2012. Dissolved [CO_2] in xylem sap of C3 annuals, shrubs, vines, and bamboo. Ecological Society of America Annual Meeting. Portland, Oregon. August 9. [Poster]
- 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 17th Biennial Southern Silvicultural Conference. Shreveport, LA. March 5-7, 2013.
- Markewitz, D. and L. Boby. August 2012. PINEMAP:Assessing the role of pine plantations in climate change adaptation and Mitigation. Warnell Seminar Series The University of Georgia, Athens, GA.
- Markewitz, D. and L. Boby. January 2013. PINEMAP: Southern Pines, Carbon, and Climate Change. *Georgia Initiative for Climate and Society*, The University of Georgia.
- 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. [Poster]
- 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.
- 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.
- 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.
- 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.
- Noormets A., G. Miao, J.C. Domec, S.G. McNulty, G. Sun, and J.S. King. 2012. CO_2 and CH_4 exchange in an undisturbed coastal forested wetland in North Carolina. The 45th AGU Fall Meeting. San Francisco, CA, December 3-7, 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.

- 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.
- 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.
- Samuelson, L.J., and J. Clark. 2013. Early impacts of rainfall manipulation and fertilization of the ecophysiology of loblolly pine at the Georgia PINEMAP Tier 3 experiment. Abstracts of the 17th Biennial Southern Silviculture Research Conference, Shreveport, LA.
- Sun G., Y. Fang, P. Caldwell, A. Noormets, J.C. Domec, S.G. McNulty, J.S. King, S. McLaughlin, J. Uddling, and J. Chen. 2012. Environmental Controls of Ecosystem Evapotranspiration (ET): Why generalized ET models do not work for forests? The 45th AGU Fall Meeting. San Francisco, CA, December 3-7, 2012.
- Wang, Y. and Teskey, R.O. 2012. Sensitivity analysis of 3-PG model for Pinus taeda (loblolly pine). (Poster presentation.) Ecological Society of America 97th Annual Meeting, Portland OR.
- 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.
- 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.
- Wightman, M. 2012. Loblolly pine water relations in response to fertilization and throughfall exclusion. Forest Biology Research Cooperative Annual Advisory Council Meeting. September 26-27, 2012.
- Wightman, M., T. Martin, E.J. Jokela, C. Gonzalez-Benecke, and W. Cropper. 2013. The impact of fertilization and throughfall exclusion on loblolly pine growth and water use. 17th Biennial Southern Silvicultural Conference. Shreveport, LA. March 5-7, 2013.
- Wightman, M., T. Martin, E.J. Jokela, C. Gonzalez-Benecke, and W. Cropper. 2013. Sustaining Economies and Natural Resources in a Changing World: Key Role of Land Grant Universities Symposium, April 2-3, 2013. [poster]
- Wilson, E., J.B. West, and J.G. Vogel. 2013. The effects of water stress on mesophyll conductance in loblolly pine (*Pinus taeda* L.) needles. Ecological Integration Symposium, March 23rd, 2012. College Station, TX.
- 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
- Zhang, Y. 2013. Effects of climate change and forest management on belowground carbon cycling. Department of Ecosystem Science and Management Seminar Series, College Station, TX
- Zhai, L. 2013. Finding ideotypes by examining interactions among silvicultural intensity, genotype, and environment for full-sib loblolly pine families. Ecological Integration Symposium, March 23rd, 2012. College Station, TX

→ Provide a short narrative describing any workshops, courses, and/or trainings conducted.
Highlight in yellow items added to the list in the March 2013 Progress Report.

- 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.
- Presentation on PINEMAP to members of the Forest Biology Research Cooperative as part of the FBRC Annual Advisory Council Meeting in Gainesville, FL on September 27, 2012.

→ Provide a short narrative describing experiments or surveys conducted and/or analyzed.
Highlight in yellow items added to the list in the March 2013 Progress Report.

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 TerraC. One half of the sites have been selected where tree cores will be collected in 2012 for $^{13}C/^{18}O$ 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 were finalized tested and the first set of

cores were installed. Weather stations were installed at each site to measure microclimate attributes. Dendrometer bands were installed at all sites to monitor seasonal tree growth. Leaf area, IPAR, and LAI data are being collected.

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 finalized 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 in VA , precipitation is collected monthly (began July 2012). It will undergo δ^2H and $\delta^{18}O$ isotope analysis.
8. Jill Qi, a PhD student on the project, initiated soil C incubation study on soil layers ranging from 0-300 cm with samples from the Georgia Tier 3 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.
9. At the Georgia and Oklahoma Tier 3 sites, leaf-level gas exchange is being periodically measured to determine the effects of treatments on net photosynthesis and leaf conductance.
10. At the Oklahoma Tier 3 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.
11. Teri Medsker (MS student) initiated a study to examine soil moisture influences on nutritional controls of productivity at the Oklahoma Tier 3 site.

Progress Updates: Milestones and Work Plan Tasks

Provide a short narrative describing progress and accomplishments on the year 2 milestones and work plan tasks listed below.

Progress updates are carried over from the November 2012 Interim Report. Please provide additional progress updates as applicable for each milestone and work plan task under the March 2013 Progress Report heading.

Year 2 Milestones

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

November 2012 Interim Report:

- Leaf gas exchange, chlorophyll fluorescence and leaf water potential were measured from July 2012 through March 2013 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 CO_2 efflux according to protocols since June 6, 2012.

March 2013 Progress Report:

- Preliminary leaf gas exchange data from the Oklahoma site indicate a reduction in net photosynthesis and stomatal conductance in the rainfall exclusion plots, but no effect of fertilization.
- Preliminary soil CO2 efflux data from the Oklahoma site indicate a suppression due to fertilization.
- At the Georgia Tier III experiment, fertilization increased peak LAI from 1.7 to 2.1. At peak LAI, IPAR increased from 70% to 80% with fertilization.
- At the Georgia site, rainfall exclusion reduced leaf light-saturated photosynthesis, stomatal conductance and predawn water potential in both growing and dormant seasons. No interactive effects of rainfall manipulation and fertilization treatment on leaf-level physiology were observed. During the growing season, photosynthesis

was reduced on average by 10% and leaf conductance by 19% in response to rainfall exclusion. During the non-growing season, net photosynthesis and stomatal conductance were reduced on average by 9% and 15%, respectively, by the rainfall exclusion treatment.

- At the all 4 Tier III sites, sap flow was measured from November 2012 through February 2013 and average daily sap flux density (Js) and average daily canopy stomatal conductance (gs) were averaged by month. At the Georgia site, an interactive effect of rainfall manipulation treatment and fertilization treatment was detected for Js and Gs. Average Js was reduced from 44 to 35 g m^{-2} s^{-1} by rainfall exclusion only in fertilized plots. Fertilization reduced Gs from 84 to 61 mmol m^{-2} s^{-1} only in the rainfall exclusion treatment. These results indicate greater sensitivity to nutrient and water availability at the whole plant level.
- At the Virginia Tier III site, throughfall is being measured to determine the proportion of total rainfall that is being affected in the rainfall exclusion plots.
- At the Florida Tier III site, basal area growth from year one (pre-treatment) to year two was significantly greater for plots that had received fertilizer application. However, there was no apparent impact of fertilization on height growth. The throughfall exclusion treatment did not significantly affect basal area or height growth. The two treatments having received fertilization demonstrate higher rates of mean daily transpiration, though this relationship was not statistically significant.

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

Data from the Tier 1 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.

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

Field data was collected on carbon and nutrient content in the first set of Tier II sites using the protocols developed by Aim 1. Carbon efflux measurements that separate heterotrophic and autotrophic respiration are scheduled to begin in Tier II sites in 2013 based on the established protocol

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

<u>November 2012 Interim Report:</u>

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.

March 2013 Progress Report:

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 Rh 25% (p=0.0001). These early results suggest that genotype and management can alter Sf, Ra, and Rh.

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

November 2012 Interim Report:

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

March 2013 Progress Report:

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.

Year 2 Work Plan Tasks

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

November 2012 Interim Report:

- 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.

March 2013 Progress Report:

- Data quality control and processing for sap flux data has been standardized across PINEMAP sites and researchers using a program developed by Aim 1 members in the open source language R (R Foundation for Statistical Computing, Vienna, Austria). This program is being beta-tested by select research groups in the US and Australia for eventual public distribution.

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

November 2012 Interim Report:

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%.

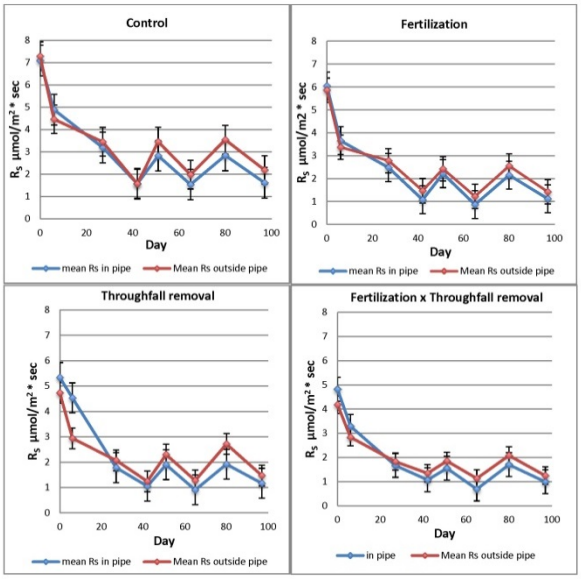


Figure 1. Soil CO_2 efflux over time during the summer of 2012 in all four treatments of the Virginia Piedmont Tier 3 PINEMAP installation as influenced by 35 cm deep collar (pipes) installation

March 2013 Progress Report:

The protocol has been finalized and posted on the PINEMAP website. The approach used by Heim et al. was adopted with minor modification. The first set of cores to separate Ra and Rh should be installed March/April 2013.

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

November 2012 Interim Report:

- 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.

March 2013 Progress Report:

All Tier III sites: near-surface wireless soil moisture probes have been installed. Much effort has been made to collect consistent and reliable data.

GA Site – TDR cables were installed at 2m and 3 m depths in each plot. Preliminary measurements were taken to allow proper calibration for soil moisture estimates.

Oklahoma site – TDR rods were installed at 5 locations in each plot to depths 0-12, 0-40, and 0-80 cm.

Florida site- TIG welding rods with RiserBond Instruments 1205CX TDR cable fault locator tested in order to implement deep profile soil moisture system based on GA and OK design.

Florida site- wired soil moisture probes were installed in throughfall exclusion plot to assess the effect of troughs on within plot microsite soil conditions. Probes were placed at multiple locations with respect to distance from tree row (in tree row, directly under trough, in gap between two troughs on same structure), multiple locations with respect to trough height (high end approaching 5 ft, low end approaching 3 ft), and multiple depths (0-10cm, 10-20cm).

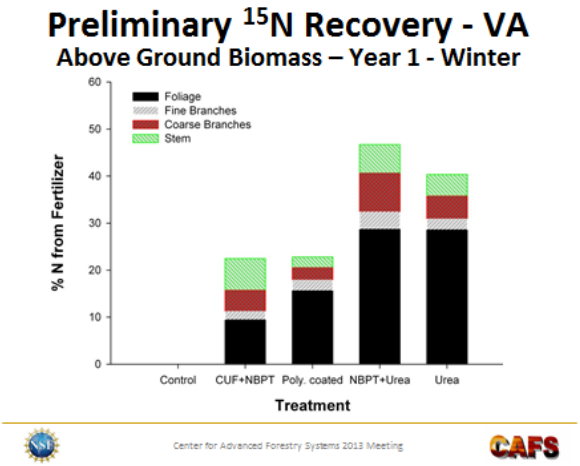
→ Install studies to measure N fertilizer uptake efficiency using ^{15}N labeled fertilizer at Tier II and Tier III sites (January 2013).

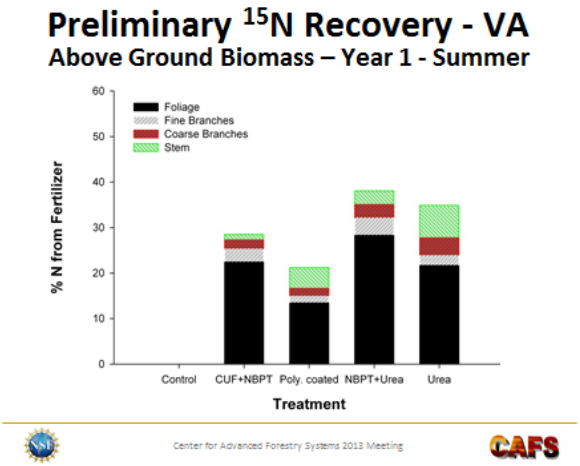
November 2012 Interim Report:

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.

March 2013 Progress Report:

Tree, understory, forest floor and soil samples were collected at the end of year 2 in the installations installed in 2011 and at the end of year 1 for the studies installed in 2012. Nitrogen uptake from the different fertilizers is being analyzed. Results from the site in Virginia adjacent to the Tier III site indicate that between 20% and 50% of the applied N was recovered in the overstory trees after one year following fertilization in the winter and between 20 to 40% was recovered in the overstory trees after one year following fertilization in the summer.





→ Install studies to measure N_2O and CH_4 emissions following N fertilization (May 2012).

November 2012 Interim Report:

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.

March 2013 Progress Report:

A PINEMAP undergraduate will continue trace gas sampling at the GA Tier III Site over the summer as part of a PINEMAP Internship Program project.

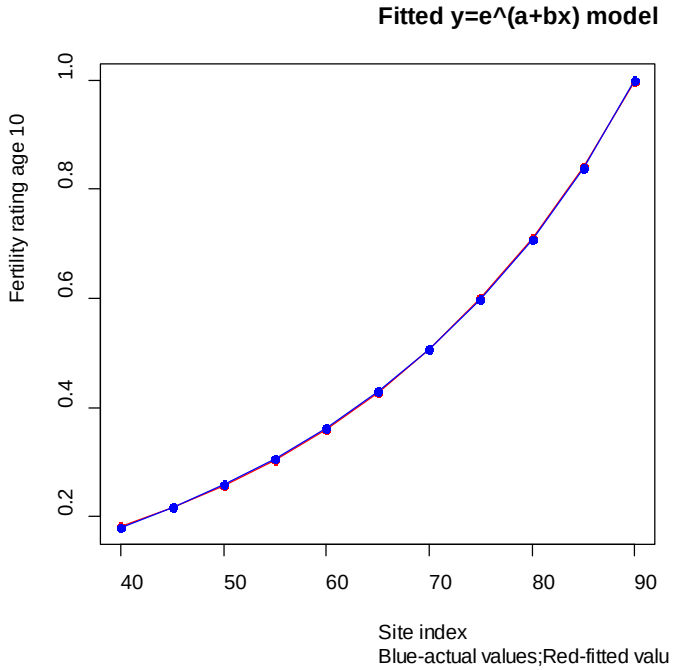
→ Develop improved method to evaluate fertility rating (FR) in 3-PG (February 2013).

November 2012 Interim Report:

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.

March 2013 Progress Report:

An equation has been developed to predict FR based on the site index of the stand. This predicted FR value is currently being tested in the 3PG model for sites included in the Tier II dataset.



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

March 2013 Progress Report:

- Initial sap flux data from Tier III site in Virginia (May 2012-Feb 2013) indicates little difference in monthly mean daytime water use of treatments. However, an

interaction between the effects of fertilization and throughfall displacement on J_S and G_C may form as stands increase leaf area over coming years (see Aim 1 'Research Story' on this topic.

- Future analyses will employ hierarchical modeling techniques using a Bayesian state-space framework[1] to quantify differences between half-hourly responses to light, atmospheric water demand and soil moisture.

→ 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).

November 2012 Interim Report:

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.

March 2013 Progress Report:

In addition the activities listed in the November report, manual dendrometer bands were installed on sapflux trees at all four Tier III sites and the installation of root exclusion cores for separating autotrophic and heterotropic respiration are underway.

→ Identify subset of Tier II sites for additional ecophysiology measures (June 2012).

November 2012 Interim Report:

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 ^{15}N labeled enhanced efficiency fertilizers were established at 28 sites associated with Tier 2 Active Experiments. Samples of ^{15}N in ecosystem components (trees, understory vegetation, forest floor, and soil) were collected and are being analyzed using Isotope-ratio mass spectrometry (IRMS).

March 2013 Progress Report:

Northern subregion Tier 2b sites have been selected

Three Tier II sites have been identified within the UGA/Auburn sub-region for more intensive ecophysiological measures.

→ Wood samples for O and C isotope analysis from Tier II sites (September 2012).

November 2012 Interim Report:

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.

March 2013 Progress Report:

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

November 2012 Interim Report:

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.

March 2013 Progress Report:

Measurements (standing live and dead stem survey, non-planted tree/shrub survey, coarse woody debris) and samples (soil, forest floor, understory vegetation) 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).

March 2013 Progress Report:

Northern subregion Tier 2b sites have been selected. Setting up of root exclusion collars and temperature and moisture probes is underway.