

PINEMAP Year 3 Progress Report 2

April 2014

Aim 2 (Modeling)

OUTCOMES/IMPACTS

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

OUTPUTS

Products

Peer-reviewed publications

Albaugh, J.M., Domec, J.-C., Maier, C.A., Sucre, E.B., Leggett, Z.H., King, J.S. 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>

Amateis, R.L. and H.E. Burkhart. 2013. Relating quantity, quality, and value to planting density for loblolly pine plantations. *Southern Journal of Applied Forestry* 37(2):97-101. doi: <http://dx.doi.org/10.5849/sjaf.12-012>

Amateis, R.L., H.E. Burkhart, and G.Y. Jeong. 2013. Modulus of elasticity declines with decreasing planting density of loblolly pine (*Pinus taeda*) plantations. *Annals of Forest Science* 70:743-750.

Brooks, E. B., Wynne, R. H., Thomas, V. A., Blinn, C. E., and Coulston, J. W. 2014 On-the-fly massively multitemporal change detection using statistical quality control charts and Landsat data. *IEEE Transactions on Geosciences and Remote Sensing*, 52(5):1-17. doi: 10.1109/TGRS.2013.2272545 (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>

Burkhart, H.E. 2013. Comparison of maximum size-density relationships based on alternate stand attributes for predicting tree numbers and stand growth. *Forest Ecology and Management* 289:404-408. doi: <http://dx.doi.org/10.1016/j.foreco.2012.10.041>

- Caldwell, P.V., G. Sun, S.G. McNulty, E.C. Cohen, and J.A. Moore Myers. 2012. Impacts of impervious cover, water withdrawals, and climate change on river flows in the conterminous U.S. *Hydrology and Earth Systems Sciences* 16:2839-2857. doi: <http://dx.doi.org/10.5194/hess-16-2839-2012>
- Chapman, L.Y., S. McNulty, G. Sun and Y. Zhang, "Net Nitrogen Mineralization in Natural Ecosystems across the Conterminous US," *International Journal of Geosciences*, Vol. 4 No. 9, 2013, pp. 1300-1312. doi: 10.4236/ijg.2013.49125.
- Domec, J.C., G. Sun, A. Noormets, M. Gavazzi, E. Treasure, E. Cohen, J.J. Swenson, S. McNulty, and J. 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(5):497-512. doi: <http://dx.doi.org/10.5849/forsci.11-051>
- Gonzalez-Benecke, C.A., E.J. Jokela, and T.A. Martin. 2012. Modeling the effects of stand development, site quality, and silviculture on leaf area index, litterfall, and forest floor accumulations in loblolly and slash pine plantations. *Forest Science* 58(5):457-471. doi: <http://dx.doi.org/10.5849/forsci.11-072>
- Marion, D. A., G. Sun, P.V. Caldwell, C.R. Ford, Y. Ouyang, D.M. Amatya, B.D. Clinton, P.A. Conrads, S. Gull-Laird, Z. Dai, J.A. Clingenpeel, Y. Liu, E.A. Roehl, J.A. Moore Meyers, and C. Trettin. 2013. *Managing forest water quantity and quality under climate change in the Southern US*, in: *Climate Change Adaptation and Mitigation Management Options*, J. Vose, ed. CSC Press: Boca Raton, FL.
- Ross C.W., S. Grunwald, D.B. Myers. 2013. Spatiotemporal modeling of soil organic carbon stocks across a subtropical region. *Science of the Total Environment* J. 461-462: 149-157.
- Sabatia, C.O. and H.E. Burkhart. 2013. Height and diameter relationships and distributions in loblolly pine stands of enhanced genetic material. *Forest Science* 59(3):278-289. doi: <http://dx.doi.org/10.5849/forsci.11-093>
- Sabatia, C.O. and H.E. Burkhart. 2013. Modeling height development of loblolly pine genetic varieties. *Forest Science* 59(3):267-277. doi: <http://dx.doi.org/10.5849/forsci.11-103>
- Sabatia, C.O., 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>
- Zhang, F., J.M. Chen, J. Chen, C.M. Gough, D. Dragoni, and T.A. Martin. 2012. 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. doi: <http://dx.doi.org/10.1016/j.rse.2012.06.023>

Theses/Dissertations

Other publications

Sun, G., P.V. Caldwell, A.P. Georgakakos, S. Arumugam, J. Cruise, R.T. McNider, A. Terando, P.A. Conrads, J. Feldt, V. Misra, L. Romolo, T.C. Rasmussen, S.G. McNulty, and D.A. Marion. 2012. Impacts of Climate Change and Variability on Water Resources in the Southeastern US, in: *Southeastern Regional Technical Report to the National Climate Change Assessment, Water Resources*.
http://downloads.usgcrp.gov/NCA/Activities/NCA_SE_Technical_Report_FINAL_7-23-12.pdf

Audio/video products

Events/Activities

Presentations

Author(s)/Presenter(s)	Title	Type	Date	Venue/Location
Burkhart, H.E.	Initial tree spacing and thinning impacts on pine wood quality	Presentation (Meeting)	June 6, 2012	North Carolina Society of American Foresters meeting, Rocky Mount, NC
Burkhart, H.E.	Forest modeling and prediction in the information age	Presentation (Conference)	October 7, 2013,	IUFRO Conference, New Orleans, LA
Burkhart, H.E.	Estimating growth and yield of intensively managed southern pines.	Presentation (Meeting)	January 27, 2014,	Southeastern Society of American Foresters, Panama City, FL
Burkhart, H.E.	Planning initial spacing and thinning to optimize value	Presentation (Meeting)	March 13, 2012	Lexington County Forestry Association meeting, Batesburg-Leesville, SC
Burkhart, H.E.	Modelling genetic improvement effects on growth and value of forest plantations	Presentation (Conference)	June 6, 2013	Southern Forest Tree Improvement Conference, Clemson, SC
Burkhart, H.E. and R.L. Amateis	Plot installations for modeling growth and yield of loblolly pine plantations	Presentation (Conference)	September 20-21, 2012	International Workshop at Beijing Forestry University, Beijing, China
Caldwell, P.V., G. Sun, S.G. McNulty, E.C. Cohen, and J. A. Moore Myers	Modeling the individual and cumulative impacts of anthropogenic activities and climate change on water resources in data-rich and data-poor regions	Presentation (Conference)	September 24-27, 2012	HydroPredict 2012 International Interdisciplinary Conference on Predictions for Hydrology, Ecology, and Water Resource Management, Vienna, Austria
Caldwell, P.V., G. Sun,	Potential Impacts of Water	Presentation	September 30-	EcoSummit 2012 -

Author(s)/Presenter(s)	Title	Type	Date	Venue/Location
S.G. McNulty, E.C. Cohen, and J. A. Moore Myers	Withdrawals, Impervious Cover, and Climate Change on River Flows Across the Conterminous United States	(Conference)	October 5, 2012	Ecological Sustainability: Restoring the Planet's Ecosystem Services, Columbus, OH
Caldwell, P.V., G. Sun, S.G. McNulty, E.C. Cohen, and J. A. Moore Myers	WaSSI Ecosystem Services Model, Version 2.0	Web application	October 2012	
Caldwell, P.V., G. Sun, S.G. McNulty, E.C. Cohen, and J. A. Moore Myers	Water Supply Stress Index (WaSSI) Model, Forest Threat Factsheet no. 6, July 2012	White Paper/Fact Sheet	July 2012	
Caldwell, P.V., G. Sun, S.G. McNulty, E.C. Cohen, and J. A. Moore Myers	WaSSI Ecosystem Services Model, Version 2.0	User Guide	October 2012	
Caldwell, P.V., G. Sun, S.G. McNulty, E.C. Cohen, J. A. Moore Myers, and R. Bhattarai	Predicting the impact of global change on water supply stress in the conterminous U.S.	Presentation (Conference)	July 29-August 1, 2012	2012 ASABE Annual International Meeting, Dallas, TX
Fang, Y., J.L. Stape, T. Fox, T. Albaugh, and C. Maier	Simulating loblolly pine soil carbon dynamics for two contrasting Piedmont soils under different climate change scenarios	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Ford, C.R., S.H. Laseter, P. Caldwell, G. Sun, J.M. Vose	Drought, exurban expansion, and water yield in southern forest ecosystems (Published abstract, http://eco.confex.com/eco/2012/webprogram/Paper3288.html)	Presentation (Conference)	August 5-10, 2012	Ecological Society of America Annual Meeting in Portland, OR
Gopalakrishnan, R., R. Wynne, and V. Thomas	Efficacy of using heterogeneous LIDAR datasets in predicting tree heights over a large region	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Gopalakrishnan, R., V. Thomas, J. Coulston, and R. Wynne	Efficacy of using heterogeneous lidar in predicting canopy heights over a large region	Presentation (Conference)	October 9-11, 2013	SilviLaser 2013, Beijing, China
Gyawali, N. and H.E. Burkhardt	General response functions for silvicultural treatments and genetic improvement	Presentation (Meeting)	October 1-2, 2012	Northeast Mensurationists Organization meeting, State College, PA
McNulty, S.	Regional carbon sequestration and climate change: It's all about water	Presentation (Meeting)	April 24, 2013	PINEMAP 2013 Annual Meeting
Patarasuk, R., S. Grunwald, C.W. Ross, X Xiong, B. Cao, and B.	A Spatially-Explicit Landscape Modeling Approach to Assess the	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA

Author(s)/Presenter(s)	Title	Type	Date	Venue/Location
Hoover	Growth of Loblolly Pine Forests			
Ross, C.W., S. Grunwald, S. Gerger, L. Kobziar, and T. Schurr	Assessing the Effects of Drought and Fire Disturbance in Southern Pine	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Ross, C.W., S. Grunwald, S. Gerber, L. Kobziar, and T.A.G. Schuur	Modeling the effects of climate change on terrestrial carbon pools across the Southeastern U.S.	Poster Presentation	January 6-9, 2014	NIFA Climate Change Project Directors Meeting, Gainesville, Fl.
Sabatia, C.O. and H.E. Burkhart	A comparison of a non-parametric and a parametric approach for predicting loblolly pine site index from biophysical variables	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Timilsina, N., F. Escobedo, A. Abd-Elrahman, W.P. Cropper, Jr., S. Delphin, and S. Lambert	A framework for mapping carbon storage hotspots and determining optimal forest structure and management regime characteristics [poster]	Poster Presentation	August 7-12, 2011	96th ESA Annual Meeting, Austin, TX
Wang, Y. and R.O. Teskey	Using 3-PG lob model to predict southeastern region Pinus taeda (loblolly pine) productivity	Poster Presentation	April 24-26, 2013	PINEMAP Annual Meeting, Athens, GA
Ward, E.J., A. Noormets, J.-C. Domec, J. King, G. Sun, S. McNulty	Data-model integration in the PINEMAP project [poster]	Poster Presentation	October 10, 2012	RCN FORECAST Conference, Woods Hole, MA

Trainings, workshops, and courses

Experiments, surveys, and data collection

Aim 2 team members acquired a large collection (more than 30 separate mapping projects) of LIDAR data (from NOAA and USGS), covering a substantial amount of the PINEMAP region of interest. This enabled us to get LIDAR profiles for over 1600 FIA plots, distributed over several southern states (collaborating with USFS SRS, Knoxville). Preliminary results are quite promising: over all lidar projects, we observe a correlation of ~78% between the 85th percentile of lidar heights and field-measured height, with an RMSE of ~3.9 meters (n=1655). Using a subset of plots (n=281) with increased point density significantly reduces the RMSE to 2.7 meters.

The data management team (UF, Grunwald et al.) acquired a large suite of spatial data that were harmonized and standardized (see Table 1). The spatial data are described in more detail in:

Grunwald, S., Cao, B., Xiong, X., Ross, C.W., Patarasuk, R., Hempel, J., West, L.T., Andrews, S.S., Wills, S., and Loecke, T.D., 2013. Part II – Integration of data to work towards a Meta Soil Carbon Model in the U.S. pp. 6. Global Digital Soil Map Conference, Orleans, France.

Grunwald S., B. Cao, X. Xiong, C.W. Ross, R. Patarasuk, J. Hempel, L.T. West, S.S. Andrews, S. Wills and T.D. Loecke. 2014. Part II – Integration of data to work towards a Meta Soil Carbon Model in the U.S., p. 6. *In* Arrouays D., et al. (Eds.). 2013. Global Digital Soil Map. CRC Press, Washington D.C.

Table 1. Spatial data assembled for Pinemap study area in support of modeling.

Types	Soil-Environmental Variables	Data source Additional Information
Soils / Water	Soil order Soil suborder Soil group Soil subgroup Annual minimum water table depth Annual minimum water table depth from April to June Available water storage top 25 cm Available water storage top 50 cm Available water storage top 100 cm Available water storage top 150 cm Organic Matter (low) Organic Matter (representative) Organic Matter (high) Soil texture Drainage class (dominant) Hydrologic group (dominant)	Gridded Soil Survey Geographic Database (gSSURGO) (Natural Resources Conservation Service, NRCS) Legacy soil data <i>10 m spatial resolution</i>
Atmosp here	Precipitation Minimum temperature (Tmin) Maximum temperature (Tmax) Dew point temperature Mean temperature (average of Tmin and Tmax) Vapor pressure	Parameter-elevation Regressions on Independent Slopes Mode (PRISM) (Oregon State University) Period: 1970 to 2011 Monthly climatic data; Yearly averages of climatic data; Long-term (30 year) average of climatic data. Spatial resolution: ~4 km; 2.5 arcmin Spatial resolution (SE U.S.): 800 m; 30 arcsec
Atmosp here	Precipitation Maximum relative humidity Minimum relative humidity Mean specific humidity Mean downward shortwave radiation at surface Mean wind direction	Idaho Geospatial Data Center (University of Idaho) Period: 1971 to 2011 Daily climatic data; Monthly climatic data; Yearly averages of climatic data; Long-term (30 year) average of climatic data.

	<p>Minimum temperature</p> <p>Maximum temperature</p> <p>Mean wind speed</p>	<p>Spatial resolution: ~4 km; 2.5 arcmin</p>
Atmosphere	<p>Mean monthly solar radiation - Jan</p> <p>Mean monthly solar radiation - Feb</p> <p>Mean monthly solar radiation - Mar</p> <p>Mean monthly solar radiation - Apr</p> <p>Mean monthly solar radiation - May</p> <p>Mean monthly solar radiation - Jun</p> <p>Mean monthly solar radiation - Jul</p> <p>Mean monthly solar radiation - Aug</p> <p>Mean monthly solar radiation - Sep</p> <p>Mean monthly solar radiation - Oct</p> <p>Mean monthly solar radiation - Nov</p> <p>Mean monthly solar radiation - Dec</p> <p>Mean solar radiation</p> <p>Standard deviation solar radiation</p>	<p>North American Regional Reanalysis (NARR) – National Oceanic and Atmospheric Administration (NOAA)</p> <p>Temporal resolution: 30 yrs averages for each month</p> <p>Spatial resolution: 32 km</p>
Atmosphere	<p>Surface air temperature</p> <p>Precipitation</p> <p>Surface downwelling shortwave radiation</p> <p>Surface pressure</p> <p>Surface specific humidity</p> <p>Num. frost days</p> <p>Minimum monthly temperature</p> <p>Maximum monthly temperature</p> <p>Mean daily minimum temperature</p> <p>Mean daily maximum temperature</p>	<p>North American Regional Climate Change Assessment Program (NARCAAP)</p> <p>Historic climatic data (1971-2000);</p> <p>Climate change projections (5 different scenarios) (downscaled to the finest resolution in North America) 2041 - 2070</p> <p>Spatial resolution: 50 km</p>
Biota	<p>Existing Vegetation Cover (EVC)</p> <p>Existing Vegetation Height (EVH)</p> <p>Existing Vegetation Type (EVT)</p> <p>Biophysical Settings (BPS)</p> <p>Environmental Site Potential (ESP)</p> <p>Canopy Bulk Density (CBD)</p> <p>Canopy Base Height (CBH)</p> <p>Forest Canopy Cover (CC)</p> <p>Forest Canopy Height (CH)</p> <p>Fire Regime Groups (FRG)</p> <p>Mean Fire Return Interval (MFRI)</p> <p>Percent Low-severity Fire (PLS)</p> <p>Percent Mixed-severity Fire (PMS)</p> <p>Percent High-severity Fire (PRS)</p>	<p>LANDFIRE program (various agencies)</p> <p>Period: 2008</p> <p>Spatial resolution: 30m</p>

Succession Class (SCLASS) Disturbance 1999-2008	
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In addition, tier 1 and 2 inventory data were edited, harmonized and uploaded into the centralized database management system (TerraC) and made available to all project participants.

Spatial extractions of historic climate data and climate projections to tier 1 and tier 2 site locations were made and uploaded into TerraC. Bulk density (BD) data extractions to tier 2 sites from gSSURGO and development of pedo-transfer function for BD for soil carbon synthesis analysis is ongoing.

The database management team (Hoover and Grunwald) has coded/added meta data and variable schemas of tier 3 measurements (developed by Aim 1) to the TerraC database. New workflow sheets have been also added to TerraC to improve the GUI and restructuring of data tables based on the tier site hierarchy was completed.

MILESTONES

Improved process and hybrid models parameterized from network measurements

Using Tier 1 data sets from all states in the southeast, we have made significant progress validating the 3-PG model across the loblolly pine region. In this analysis we have used the 3-PG physiological parameters published in Byars et al. (2013). The Fertility Rating in 3-PG was set using site index estimated from 10 year height growth on the sites. Our analysis has shown that 3-PG can accurately estimate aboveground biomass and volume growth very well using this approach. We are currently working on a manuscript that describes our results.

Given the importance of the fertility rating to 3-PG, 23 study sites that were part of a loblolly pine fertilization study trial were selected across the southeastern United States from Virginia to Texas. The study sites selected were unfertilized, unthinned, and received no competition control measures during the study period. Using these site measurements and a volume-SI crosswalk, the relationship between FR and SI was developed as:

$$FR = 1.190 / (1 + e^{-(5.899 + 0.245 * SI)})$$

and used in 3PG to predict basal area and volume using 3PG. When linear regression was carried out between observed and 3PG-predicted values of basal area and volume using FR predicted using this equation, the R² value for basal area was found to be 0.88 and 0.93 for volume.

Analysis of sap flux data for stomatal responses to environmental drivers for Parker Tract Tier II site (Ameriflux Site US-NC2) has been completed for 2007-2009 and has begun for 2010-2012. These results will be analyzed in the same hierarchical Bayesian framework as data from the Duke FACE study (1998-2010) and integrated with those results, as well as those from Tier III sap flux data as it becomes available. These analyses will be used to update leaf area and water

use efficiency related parameters in WaSSI, including scenarios for stand density management, fertilization, drought and future atmospheric CO₂ concentrations. This process is expected to be complete and produce at least two manuscripts by May, 2014.

Improved growth and yield models with climate inputs and C balance (initial prototype)

Basal area and dominant height growth and survival models incorporating general response to silvicultural treatments for loblolly pine stands were developed using data from various silvicultural experiments across the Southeast. Growth models for treated stands were developed by multiplying baseline growth models with modifier response functions/multipliers accounting for effects of thinning, fertilization, and control of competing vegetation. All growth models were unbiased and had adequate performance in predicting basal area and dominant height following treatments. Models were developed to represent general growth trends in response to treatments.

In addition, preliminary model runs with DayCent (Century) model were made at test sites to model the C balance and impacts of climate change on soil C pools.

Improved growth and yield models with climate inputs and C balance (for regional simulations)

Using MACA downscaled climate data from historical and RCP45 and RCP85 scenarios, as well as SSURGO soil data, regional maps of site index (base age 25) were developed. These maps were produced for each year from 1980-2100 along both future scenarios, and for each year, a separate map was produced to represent four levels of stand management. These maps give site index values specific to the watersheds in the 12-digit hydrological unit code collection for the PINEMAP region. These site index values, in conjunction with management data, will be used as area-specific inputs for growth and yield models.

Regional map of potential climate or anthropogenic limitations to productivity (nutrients)

Chapman, L.Y., S. McNulty, G. Sun and Y. Zhang, "Net Nitrogen Mineralization in Natural Ecosystems across the Conterminous US," *International Journal of Geosciences*, Vol. 4 No. 9, 2013, pp. 1300-1312. doi: 10.4236/ijg.2013.49125.

Spatial Extractions

Climate data covering the time period from 1970 to 2013 has been extracted to Tier II geographic coordinates. This data, which includes precipitation, temperature, humidity, and solar radiation, among others, will be valuable in building models to identify relationships between climate and growth trends.

Modules for integration into DSS

In progress

Improved WaSSI model to Examine Climate change impacts on carbon and water tradeoffs at the HUC12 spatial scale

TRAINING

Last name	First name	Position	University	Role
Brooks	Evan	Postdoc	VT	Regional upscaling of growth and yield and 3-PG models for study timeframe and region
Cook	Madison	Undergraduate Intern	VSU	2013 Undergraduate Fellow; working with Jose Alvarez at NCSU
Fang	Yuan	Ph.D. Student	NCSU	Using G'DAY model to address nitrogen use efficiency in pine plantations
Gopalakrishnan	Ranjith	Ph.D. Student	VT	Research focus: Downloading and reformatting the NARCCAP scenarios for key climate variables from six models (GCM/RCM combinations)
Gyawali	Nabin	Ph.D. Student	VT	Modeling general response to silvicultural treatments in loblolly pine stands
Ross	C. Wade	Ph.D. Student	UF	Research focus: Investigating the response of soil carbon dynamics to changes in climate and fire disturbance in southern pine ecosystems with a process based model.
Sabatia	Charles	Postdoc	VT	Investigated growth and yield response to climate and soils variables using Tier 1 data.
Thapa, . 2014.	Ram	Ph.D. Student	VT	Modeling mortality of loblolly pine (<i>Pinus taeda</i> L.) plantations.
Wang	Maggie	Ph.D. Student	UGA	Research focus: Working on a research proposal to predict C pool dynamics for alternative land use, management, and climate scenarios at the stand level. The proposal is to link 3-PG and Century to examine forest ecosystem carbon sequestration.
Ward	Eric	Postdoc	NCSU	Measuring and modeling forest water and carbon cycles, including quantifying uncertainty in key processes; working with both Aim 1 and 2 to integrate data and models such as 3PG and WaSSI-C across scales; assisting with data collection and analysis of water fluxes at the Virginia Tier III site.