





# PINEMAP Goals

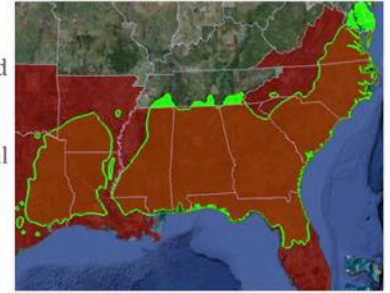
To create, synthesize, and disseminate the necessary knowledge to enable southern forest landowners

- to harness pine forest productivity to mitigate atmospheric CO<sub>2</sub>,
- to more efficiently utilize nitrogen and other fertilizer inputs,
- and to adapt their forest management approaches to increase resilience in the face of changing climate.



# PINEMAP Scope

Planted pine forests owned by corporate and non-corporate private landowners in the Atlantic and Gulf Coastal states from Virginia to Texas, plus Arkansas and Oklahoma.



# PINEMAP Synthesis Activities are Key to Achieving our Outcomes

- Regional modeling runs: 3-PG, WaSSI, G&Y, SRTS
- Integrating modeling with economic analysis
- Seed deployment tool development
- PINEMAP scenario development
- Decision Support System development
- Project Learning Tree module development
- Outreach / Extension / Tech Transfer
  - Corporate
  - Non-corporate
- Genotyping and gene discovery
- Regional analyses: Tier 2; sap flow; soil respiration



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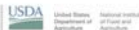
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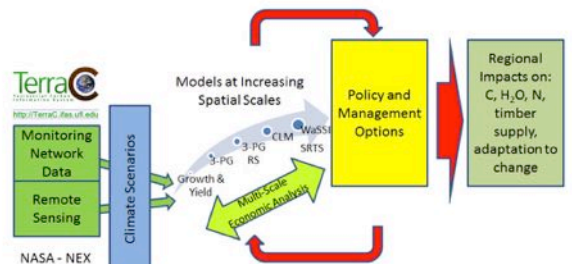
# PINEMAP Regional Modeling

*Suite of complementary models focused on understanding opportunities and risks under future predicted climate*

- Sub-regional Timber Supply Model (SRTS)
- Water Supply Stress Index (WaSSI)
- Growth and yield (climate-responsive)
- Physiological Principles Predicting Growth (3-PG)
- Community Land Model (CLM)



# Models Assess Scenarios and Estimate Regional Impacts





## Today's Webinar Objectives

1. Introduce PINEMAP stakeholders to the PINEMAP modeling program.
2. Familiarize stakeholders with the strengths, weaknesses, and capabilities of each model, and how they will be used in the project for the benefit of planted southern pine management.



## Today's Webinar Agenda

1. Introduction – Tim Martin, Univ. Florida
2. Climate and soils input dataset - Evan Brooks, VA Tech
3. Regional G&Y modeling - Harold Burkhardt, VA Tech
4. WaSSI - Ge Sun, U.S. Forest Service
5. 3-PG – Robert Teskey, Univ. Georgia
6. SRTS – Robert Abt, NC State Univ.
7. Wrap up and questions

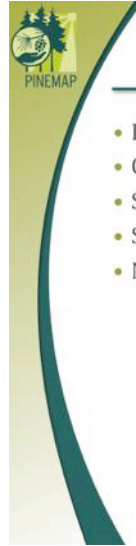




# Organizing Common Climate and Soil Input for Regional Models

Evan Brooks, Heather Dinon Aldridge, Ryan Boyles, and Corey Davis

PINEMAP is a Coordinated Agricultural Project funded by the USDA National Institute of Food and Agriculture, Award # 2011-68002-30165.



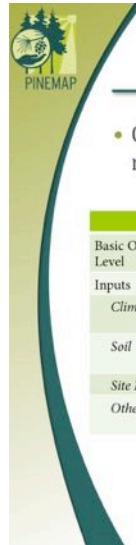
## Overview

- Background
- Climate
- Soils
- Site Index
- Next Steps



## Background

- Regional models of forest productivity (3-PG, G&Y, WaSSI, and CLM) require inputs from a variety of soil and climate-based datasets
- Different models require this data to be summarized differently
  - Spatial: WaSSI needs watershed units, CLM available only for 1x1 degree cells
  - Temporal: WaSSI and 3-PG need monthly time steps, G&Y only needs annual time steps



## Background

- Goal: keep input data as consistent as possible to maximize comparability of the models

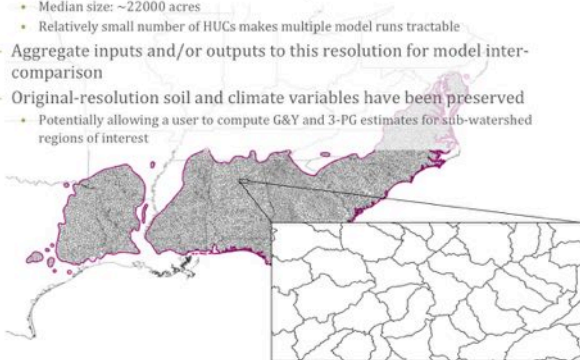
Regional Productivity Models

	3-PG	G&Y	WaSSI	CLM
Basic Operating Level	Stand (physiological)	Stand (statistical)	Watershed (statistical)	Grid-cell (1° x 1°) (physiological)
Inputs				
Climate	MACA, two scenarios	MACA, two scenarios	MACA, two scenarios	CCSM4, two scenarios
Soil	SSURGO	SSURGO	STATSGO	IGBP global soils map
Site Index	SSURGO	Estimated directly	--	--
Other	Species parameters	--	NLCD	Plant functional type parameters



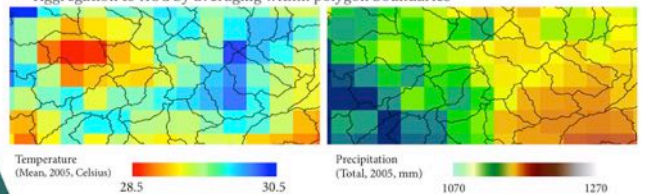
## Background

- Primary spatial unit for WaSSI, 3-PG, and G&Y was chosen to be 12-digit hydrological unit code features (HUCs) from the USGS
  - ~18000 HUCs across the PINEMAP region of interest
    - Median size: ~22000 acres
    - Relatively small number of HUCs makes multiple model runs tractable
  - Aggregate inputs and/or outputs to this resolution for model inter-comparison
  - Original-resolution soil and climate variables have been preserved
    - Potentially allowing a user to compute G&Y and 3-PG estimates for sub-watershed regions of interest



## Climate

- MACA climate data
  - 1/16 x 1/16 degree spatial resolution
  - Daily temporal resolution
  - 20 different climate models
    - One is derived from the model used by CLM
  - 2 climate scenarios
  - Raw variables include min/max temperature, precipitation, solar radiation
    - Derived variables are calculated for each model
- Aggregation to HUC by averaging within polygon boundaries



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Temperature (Mean, 2005, Celsius) 28.5 30.5

Precipitation (Total, 2005, mm) 1070 1270

## Climate

- Temporal aggregation depended on model requirements (MACA has daily resolution)
  - WaSSI
    - Monthly time step from 1950-2100
    - Mean temperature, total precipitation
  - 3-PG
    - Monthly time step from 1950-2100
    - Min/max temperature, total precipitation, average insolation, total frost days
  - G&Y
    - Annual time step from 1950-2100
    - Min/max temperature, total precipitation, growing season days, summer dryness index
- All spatio-temporal aggregation was done for each of the 20 climate models and 2 scenarios

## Climate

- Example:** variation in temperature estimates

Mean of differences (relative to the historical baseline) across all 20 climate models + historical

Mean +/- 1 standard deviation of differences across all 20 models + historical

## Inputs: Soil

- Soils data
  - USGS Soil Survey data (SSURGO), 2013 edition
    - Fine spatial resolution (some polygons as narrow as tens of meters)
    - Available water in the soil was derived from the "added value" table and joined directly to mapunit polygon features
    - Soil texture component polygon features were aggregated by weighted area to mapunit polygon features

Available Water in the Soil 0 270

Percent Sand 0 100

## Inputs: Soil

- Soil variables were treated as constant over time
  - Common variables between G&Y and 3-PG
    - Available soil water
    - Texture variables
      - Percent clay, sand, and silt
- Soil features aggregated by weighted area to HUC resolution
  - Water polygons were excluded from aggregation
    - Non-water area proportions per HUC were recorded

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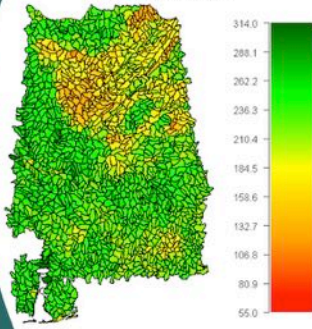
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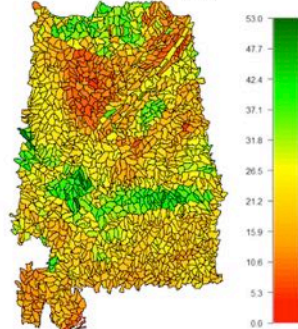


## Soils

Available Soil Water



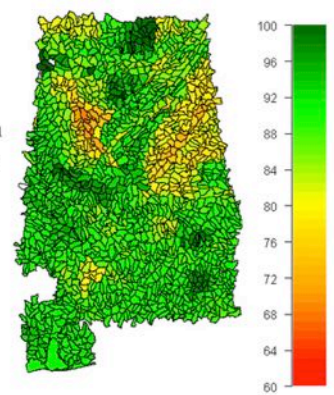
Percent Clay



## Site Index

- SSURGO site index estimates used
  - Drawn from 10m grid product
- We used only cells with a recorded representative site index value for Loblolly pine
  - Other grid cells were ignored
- Mean SI value for each HUC computed

Site Index (Mean)



## Next Steps

- Climate data is currently being processed
  - Almost complete for 3-PG requirements
  - G&Y and WaSSI input calculation is underway
- Soils and site index data are processed and ready for the PINEMAP region
- As input datasets are completed, we will perform regional model runs for each climate model and scenario
  - Estimate mean and standard deviation of productivity model results for each scenario by using all 20 climate models and baseline calculations



# Regionalization of Growth and Yield Models for Loblolly Pine

H.E. Burkhart, R.H. Wynne, N. Gyawali, R. Thapa, C.O. Sabatia, and E.B. Brooks

Pine Integrated Network: Education, Mitigation, and Adaptation project (PINEMAP) is a Coordinated Agricultural Project funded by the USDA National Institute of Food and Agriculture, Award #2011-68002-30185



# Typical Goals/Objectives When Developing Growth and Yield Models

- Provide accurate estimates of product yields for selected management regimes for evaluating silvicultural alternatives, updating inventories, and scheduling harvests.

Pine Integrated Network: Education, Mitigation, and Adaptation project (PINEMAP) is a Coordinated Agricultural Project funded by the USDA National Institute of Food and Agriculture, Award #2011-68002-30185



# Growth and Yield Modeling for PINEMAP

- Objective: Develop a region-wide modeling system for projecting future productivity for advanced genotypes, intensive silvicultural inputs, and changing climate.

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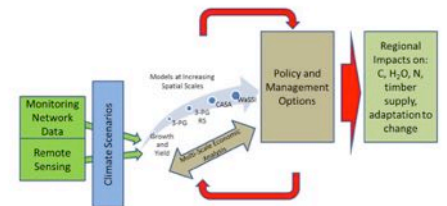
# PINEMAP

Pine Integrated Network: Education, Mitigation, Adaptation Project

PINEMAP integrates research, extension, and education to:

- Increase carbon sequestration
- Increase efficiency of nitrogen and other fertilizer inputs
- Adapt forest management approaches to increase forest resiliency and sustainability under variable climates.

## Models Assess Scenarios and Estimate Regional Impacts



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# Overall Approach

- Build a general model structure
- Incorporate response to silvicultural treatments
- Incorporate results from genetics group
- Link to climatic influences

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# Growth and Yield Model Structure

- Stand-level baseline equations for:
  - Dominant height
  - Basal area
  - Number of trees surviving
- Functions added for rate and duration of response to competition control, thinning, and fertilizer:

$$\hat{y} = \text{Base} \times \text{Response function}$$

Gyawali and Burkhart. 2014. Can. J. For. Res. (in press).

Pine Integrated Network: Education, Mitigation, and Adaptation project (PINEMAP) is a Coordinated Agricultural Project funded by the USDA National Institute of Food and Agriculture, Award #2011-68002-30185





## Incorporating Response to Silvicultural Treatments

Fit general response functions with duration and rate parameters to a selected data set for

- Thinning (FMRC regionwide thinning study)
- Competition Control (COMP Project)
- Fertilizer applications (FPC, Regionwide 13)

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## Regional Data on Response to Thinning, Competition Control, and Fertilizer



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## Regional Estimate of Future Productivity

- Base-line, stand-level growth models and response functions for silvicultural treatments
- Utilize results from universal response function analyses being conducted by genetics group as part of PINEMAP
- Relate site index to biophysical factors (soils and climate variables)
- Produce regional estimates of future pine productivity for anticipated genotypes, various management inputs, and climate scenarios.

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## Predicting Site Index using Biophysical Variables

Goal: Predict loblolly pine site index for a range of future climate scenarios.

Requires relating loblolly pine growth to climate, soil, and physiographic variables.

- Data from permanent growth plots established throughout the southeastern US were used to determine site index, the dependent variable.
- Climate, soil and physiographic values for each plot location were interpolated from publically-available data sets (total of 24 predictor variables).



Sabatia and Burkhart. 2014. For. Ecol. and Manage. 326: 142-156.

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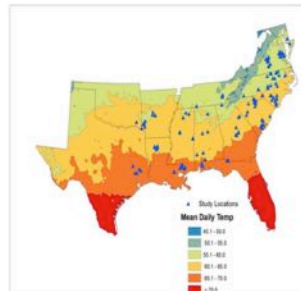


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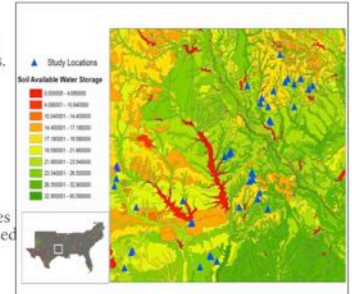


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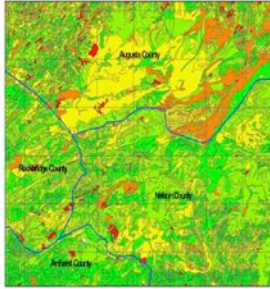


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## Scaling Up



Site Quality Classes

- Not Operable
- Very Low
- Low
- Average
- Good

0 15 30 Miles

Baseline site quality classes for loblolly pine in a portion of four counties in Virginia.

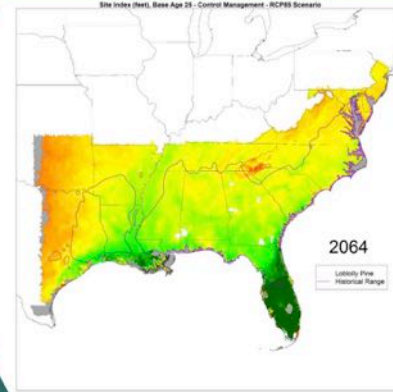
Pine Integrated Network: Education, Mitigation, and Adaptation project (PINEMAP) is a Coordinated Agricultural Project funded by the USDA National Institute of Food and Agriculture, Award #2011-68002-30185



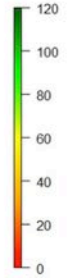
United States Department of Agriculture National Institute of Food and Agriculture



## Regionwide Site Index Map



Site Index (ft)



HUCS 12 digit resolution

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United States Department of Agriculture National Institute of Food and Agriculture



## Estimating Future Productivity

- Given an estimated distribution of baseline site index values can specify a planting density, age, genetic stock, silvicultural regime, and climate scenario to estimate regional productivity.

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United States Department of Agriculture National Institute of Food and Agriculture


**PINEMAP**

# Understanding the Interactions among Climate, Carbon, and Water by the WaSSI Model

Ge Sun, Steve McNulty  
 Eastern Forest Environmental Threat Assessment Center (EFETAC)  
 Southern Research Station  
 USDA Forest Service




PINEMAP is a Coordinated Agricultural Project funded by the USDA National Institute of Food and Agriculture, Award # 2011-68002-30185.

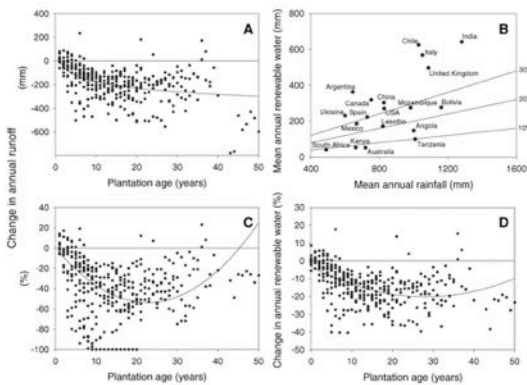


## Climate-Forest Carbon-Water

- Forests are carbon sinks (absorb 10-30% of US carbon emission)
- Source of clean water supply (>50% of water supply)
- Moderate climate, mitigate climate change impacts



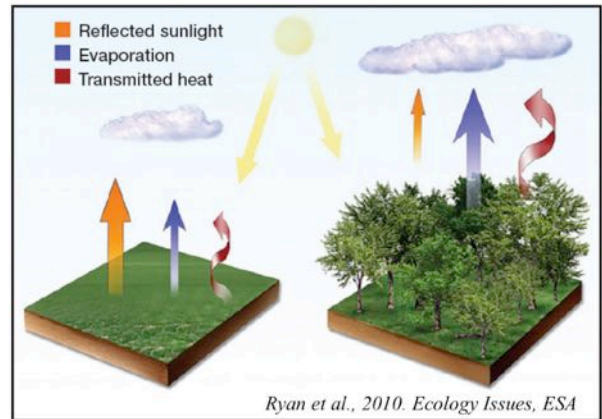
### Tradeoffs between Water and Carbon Sequestration (Jackson et al, 2005 Science)



Published by AAAS



### More trees, more warming?



**npr**

around the nation

### How Too Many Trees Contribute To California's Drought

by LAUREN SOMMER  
 October 14, 2014 5:09 AM ET

from HQED

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 Morning Edition 3 min 53 sec



Forests 2014, 5, 1409-1431; doi:10.3390/f5061409

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ISSN 1999-4907

www.mdpi.com/journal/forests

Article

### Analyzing Trade-Offs, Synergies, and Drivers among Timber Production, Carbon Sequestration, and Water Yield in *Pinus elliotii* Forests in Southeastern USA

Ronald Cademus <sup>1</sup>, Francisco J. Escobedo <sup>2,\*</sup>, Daniel McLaughlin <sup>2,†</sup> and Amr Abd-Elrahman <sup>3</sup>

<sup>1</sup> School of Natural Resources and Environment, University of Florida, P.O. Box 110410, Gainesville, FL 32611, USA; E-Mail: rcademus@hotmail.com

<sup>2</sup> School of Forest Resources and Conservation, University of Florida, P.O. Box 110410, Gainesville, FL 32611, USA; E-Mail: mclaughd@vt.edu

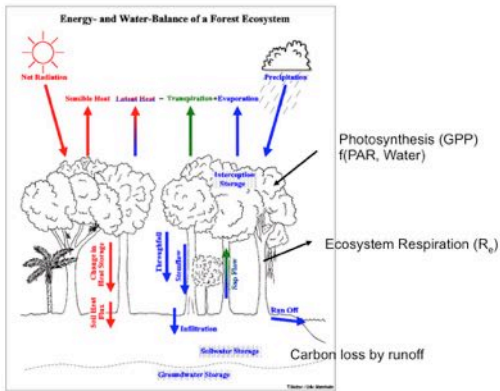
<sup>3</sup> Geomatics Program, School of Forest Resources and Conservation, University of Florida, 1200 N. Park Road, Plant City, FL 33563, USA; E-Mail: aamr@ufl.edu

<sup>†</sup> Current Address: Department of Forest Resources and Environmental Conservation, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, USA.

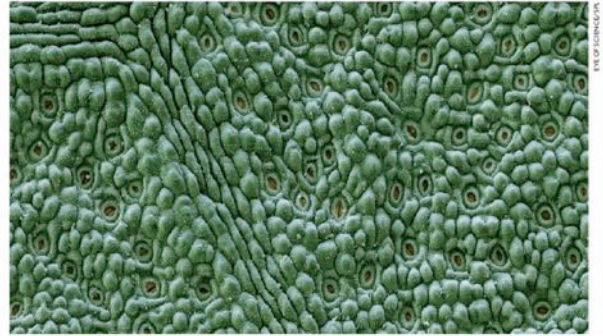
\* Author to whom correspondence should be addressed; E-Mail: fescobed@ufl.edu; Tel.: +1-352-846-0856; Fax: +1-352-846-1277.

Received: 13 February 2014; in revised form: 24 May 2014 / Accepted: 9 June 2014 / Published: 20 June 2014

## Energy, Water and Carbon Balances



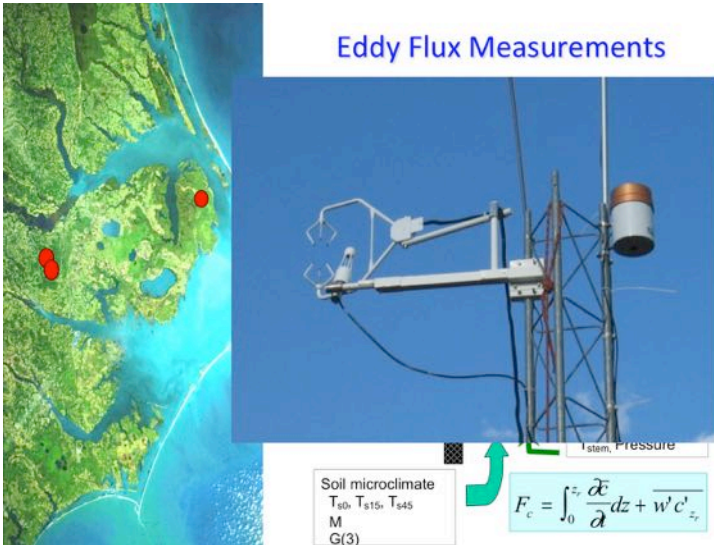
## Water and Carbon Coupling Processes



From Nature, Vol 439 Feb 2006

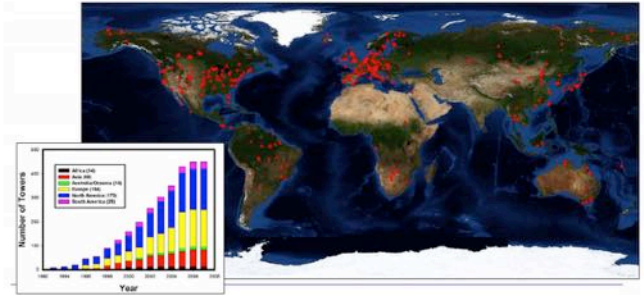
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## Eddy Flux Measurements



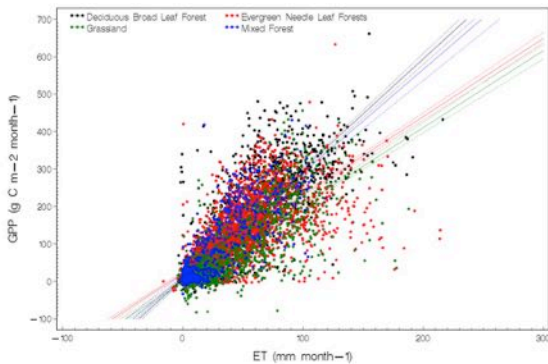
## Distribution of Flux Towers Worldwide

More than 550 towers from >10 regional networks and 46 countries worldwide



10

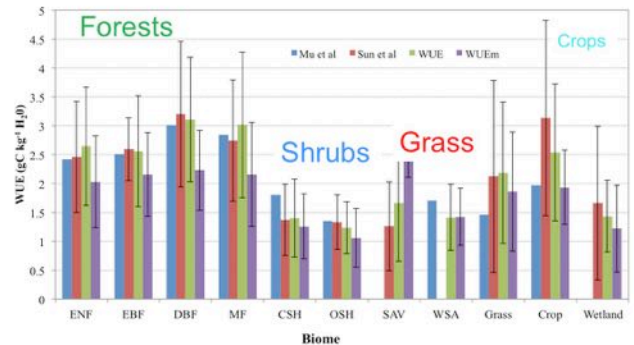
## Water and Carbon Coupling

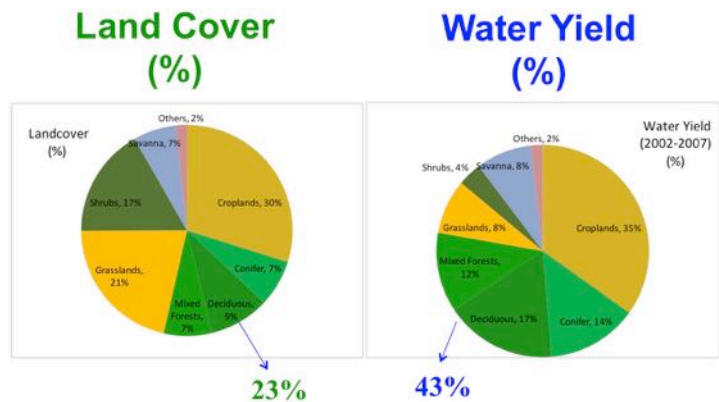
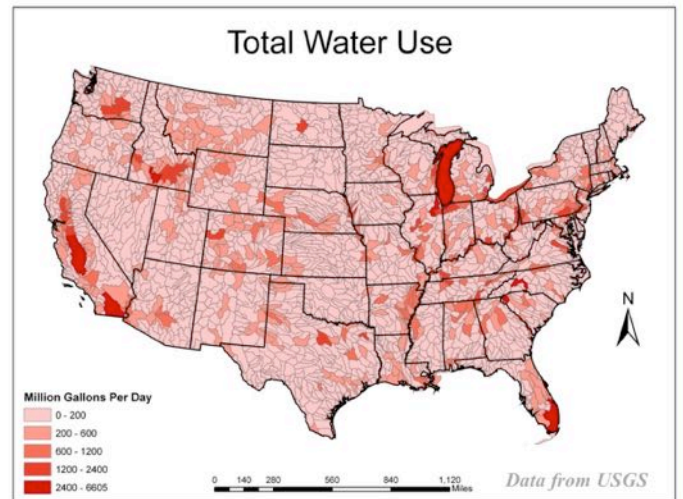
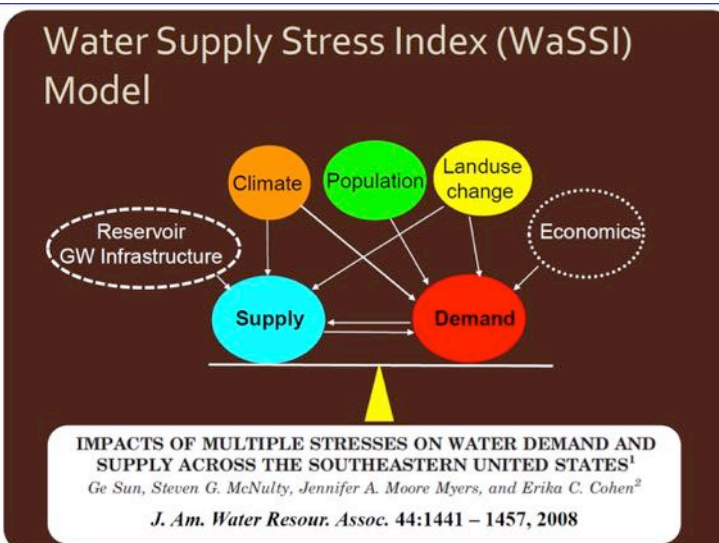
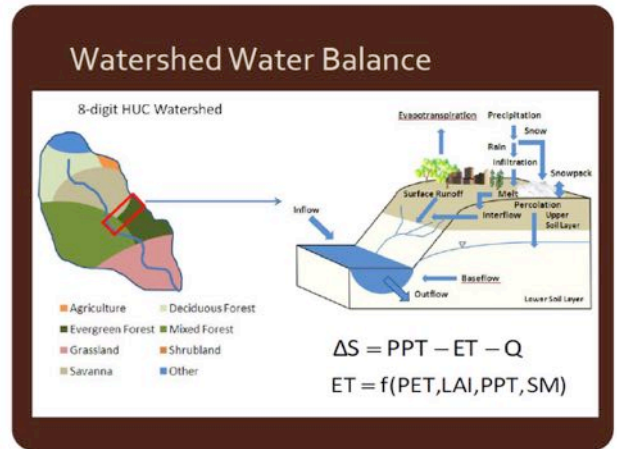
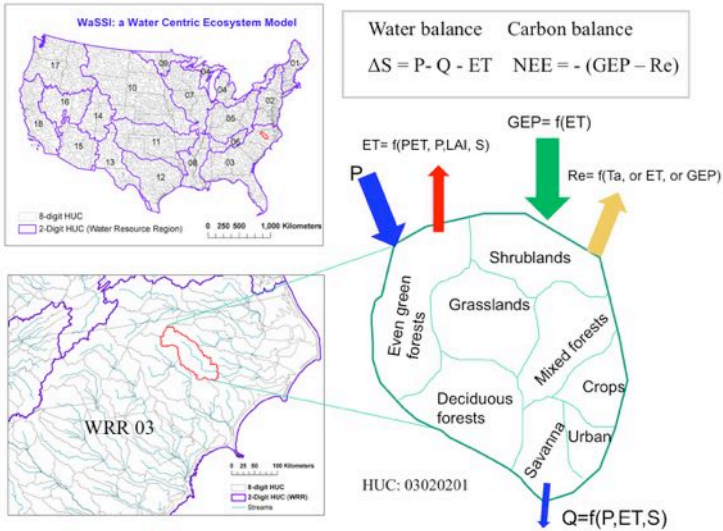


From Sun et al, JGR-Biogeosciences, 2011

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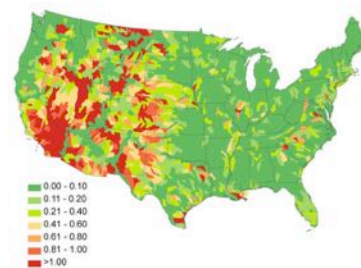
## Water Use Efficiency (gC/Kg H<sub>2</sub>O)



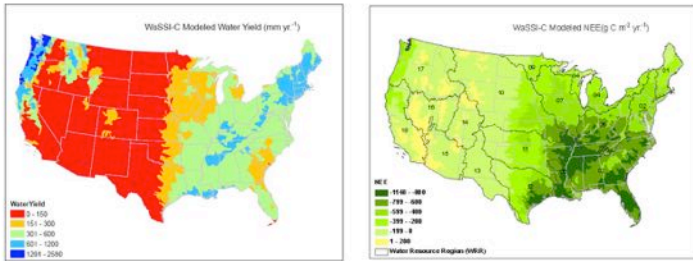


**Water Supply Stress Index (WaSSI)**

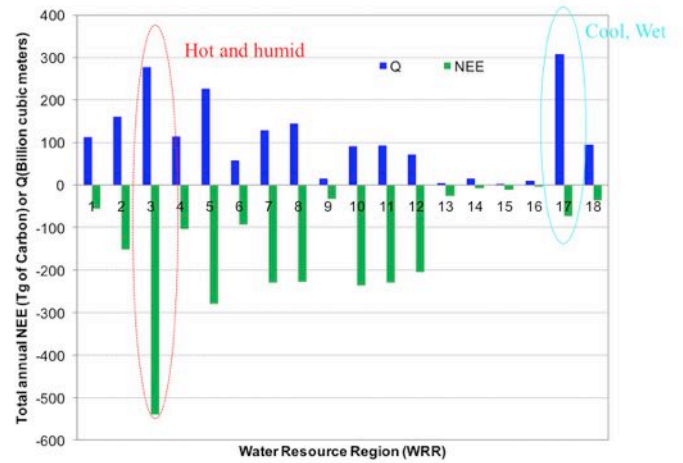
$$WaSSI = \frac{Demand}{Supply}$$



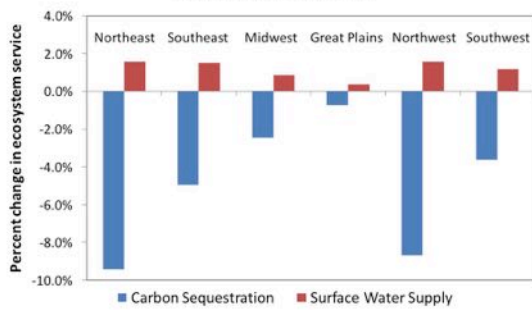
## Water and Carbon Fluxes (2000-2006)



Sun et al., JGR-116(2011)

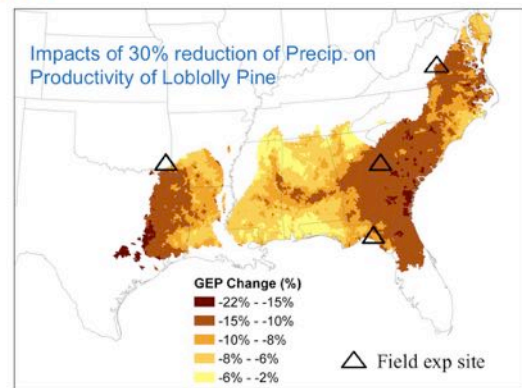


## Tradeoff between water and carbon due to 20% forest conversion



(Caldwell et al., 2011, USGS Scientific Investigations Report 2011-5169)

## Carbon Sequestration: It is all about water!

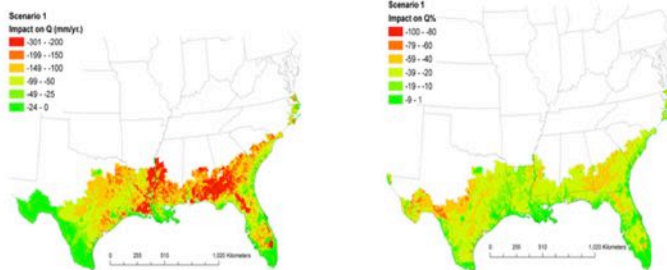


Home / Forest Science

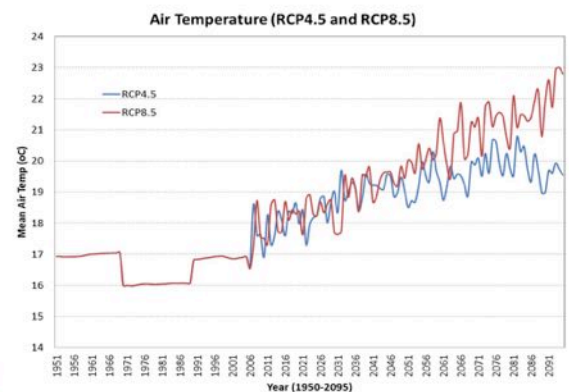


## Potential Implications for Expansion of Freeze-Tolerant *Eucalyptus* Plantations on Water Resources in the Southern United States

Authors: Vose, James M.; Miniati, Cheley F.; Sun, Ge; Caldwell, Peter V.

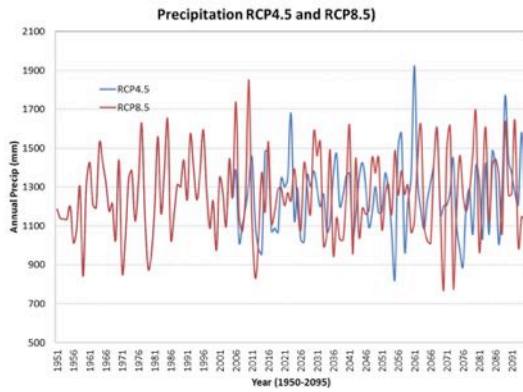


## Climate Change (1950-2095)

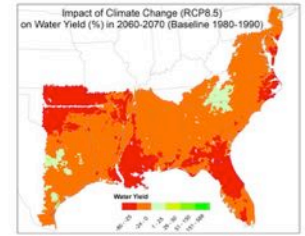
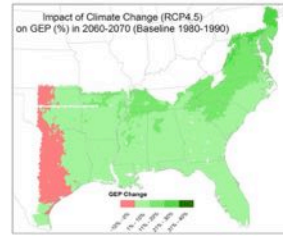




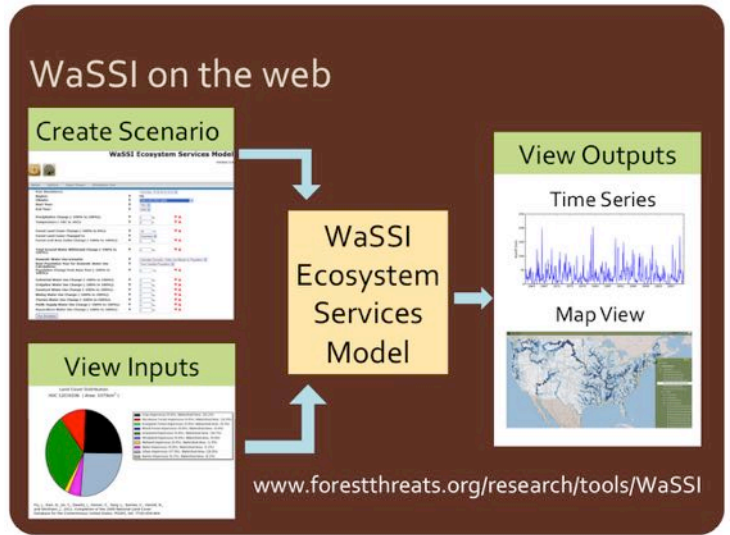
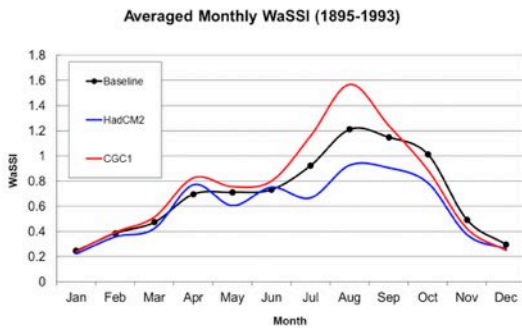
# Climate Change (1950-2095)



## Would Climate Warming Increase in Productivity, but Decrease of Water Yield?



## Seasonal Impacts



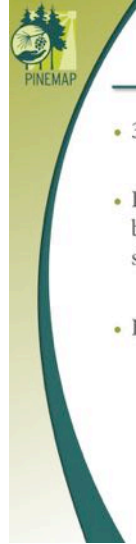
## Take Home Messages

1. Carbon-water-energy fluxes are tightly coupled; We need better understanding of tradeoffs and synergies among ecosystem services;
2. Climate change is hydrologic change; High variability and uncertainty of precipitation;
3. "Mitigation is about carbon; Adaptation is about water;
4. Understanding the feedbacks of climate, energy, carbon, and human actions for mitigation and adaptation.



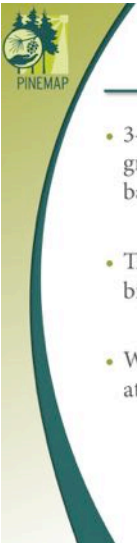
## Using 3-PG in PINEMAP

Robert Teskey  
University of Georgia



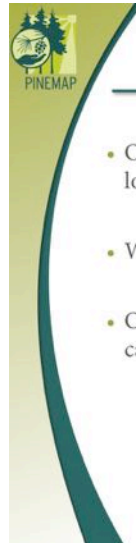
## What is 3-PG?

- 3-PG stands for Physiological Processes Predicting Growth
- It is a model that uses relatively simple representations of biological processes, and requires only a limited amount of site and weather data to run.
- It has been used world-wide to predict plantation growth.



## What is 3-PG?

- 3-PG was developed to bridge the gap between conventional growth and yield models and physiologically-based carbon balance models.
- The model predicts yearly growth over a rotation, including biomass, volume, DBH, and basal area.
- We have improved the model to also predict product classes at harvest: pulpwood, chip and saw and sawtimber.

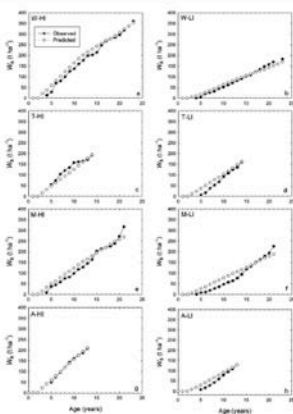


## How will we use 3-PG?

- Our goal is to predict biomass and volume for rotations of loblolly pine plantations across the region.
- We will compare current and future productivity.
- Output will be fed into other models to predict regional carbon sequestration from harvested wood.



## Initial Evaluation of 3-PG

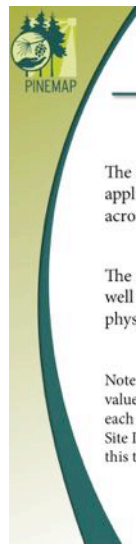


The model was calibrated on a single site (W-HI) that had very high growth rates.

It was then evaluated on 7 sites in GA.

The model has 47 physiological parameters. These were unchanged across the sites.

Bryars et al. (2013) *Forest Ecology and Management* 289: 501-514.

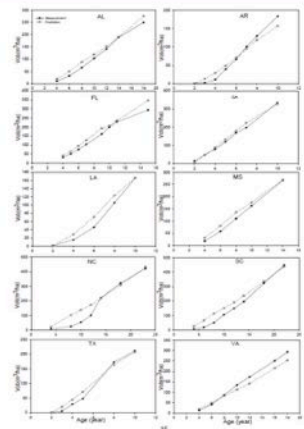


## Expanding to a regional evaluation of 3-PG

The same approach was applied to sites across the region.

The model performed well using the same physiological parameters.

Note: A fertility index (FR) value (0-1) needs to be specified for each site. We tested using Site Index to estimate FR in this trial.





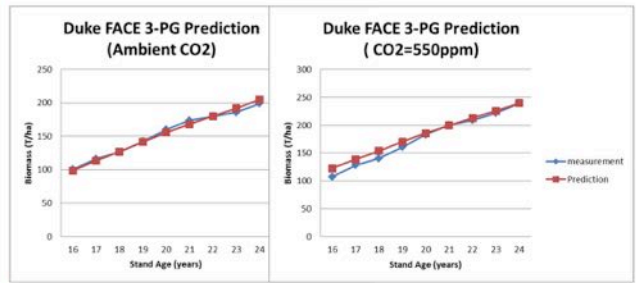
## Regional evaluation of 3-PG – using a future climate scenario



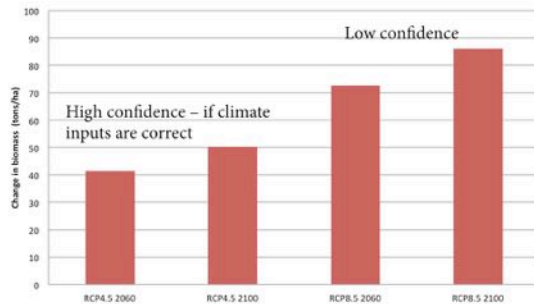
14 sites were included in our regional test



## We incorporated a CO<sub>2</sub> function into 3-PG



## Average change in biomass growth across all 14 sites.



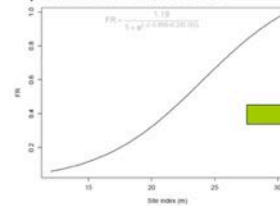
RCP 4.5 scenario caps emissions of CO<sub>2</sub> mid-century, reaching 538 ppm in 2100.

RCP 8.5 scenario continues CO<sub>2</sub> emissions at current rates, reaching 936 ppm in 2100.



## Next steps: Expanding regional predictions

Site Index – Fertility Rating developed by Santosh and Fox (VA Tech).



Our plan is to use Site Index to inform 3-PG about site-specific fertility (FR) across the entire region and run the model using down-scaled climate simulations.

We will predict plantation biomass and volume, convert that to product classes which will be fed into models (e.g., Dwidved's) to estimate potential carbon sequestration across the region in loblolly pine plantations.

## SRTS MODEL

## Two Key Contributions

- Plantations in Context
- Integrate Plot Level Science into Forest Inventory

## PLANTATIONS IN CONTEXT

### U.S. South Land Proportions

Natural Forest	49%
Plantation	12%
Agriculture	26%
Urban	13%

### Future of Plantations Depends On Their Ability To Compete in This Space

- Financial returns
- Landowner objectives
- Policies (ag, carbon)
- Ecosystem Services
- Risks (fire, pests, climate)
- **Markets (land, product)**

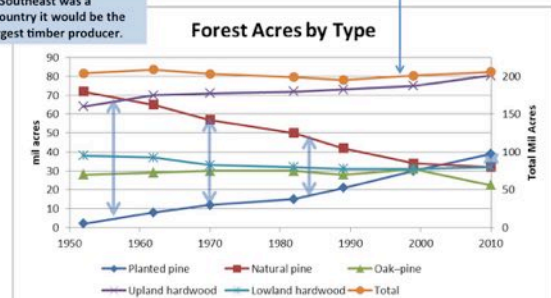
### AIM - 4

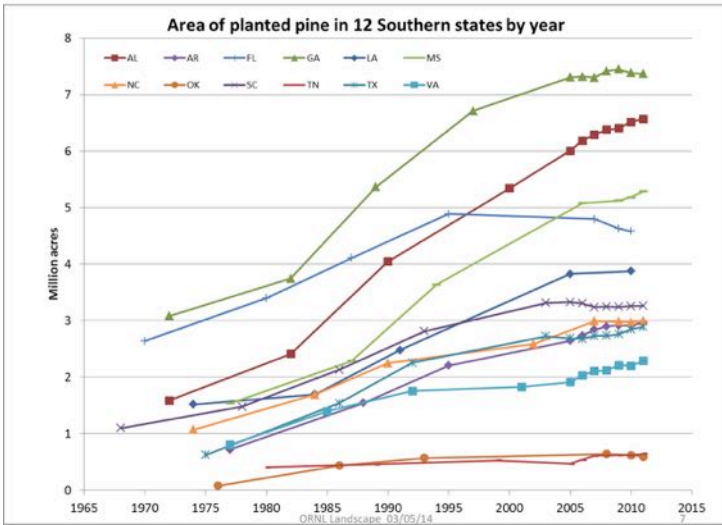
### Carbon Impact of Plantations Depends On:

- Area of Plantations (previous slide)
- Landuse Comparative Advantage
  - *e.g. agriculture vs. natural forests*
- **Management/Biology of Plantations**
- Time Scale
- Regional Scale
- Displacement/Leakage
- **Life Cycle Inventory (LCI)**
  - **Cradle to Grave Carbon Accounting**

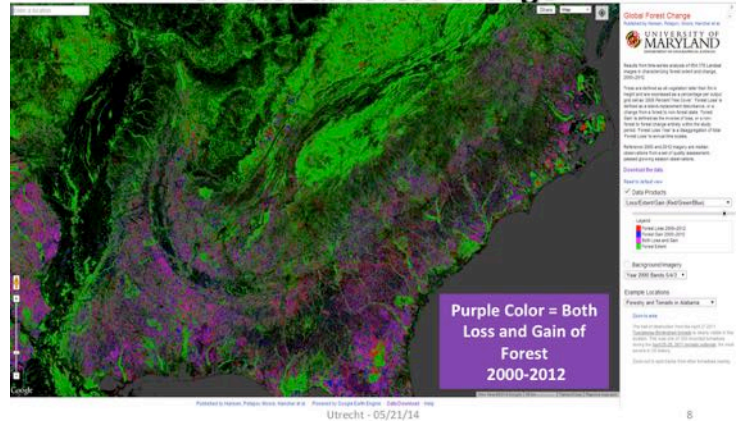
### Total Timberland Stable but Not Static

If the U.S. Southeast was a separate country it would be the world's largest timber producer.





## November Article in Journal "Science" on Global Forest Change



## What drives this change?

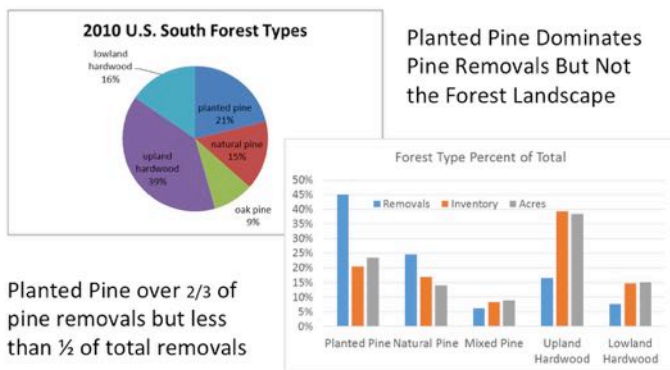
- “...we identified the rise in timber net returns as the most important factor driving the increase in forest areas between 1982 and 1997. This is consistent with reports that the increase in forests largely involved timberland acreage.” (Lubowski et al. 2008)
- This is a privately owned landscape where marginal agriculture competes with forest land both at the active (plantations) and passive (fallow agriculture) margins.

## IMPORTANCE OF MARKETS AND MANAGEMENT INTENSITY

12/03/2014

Utrecht

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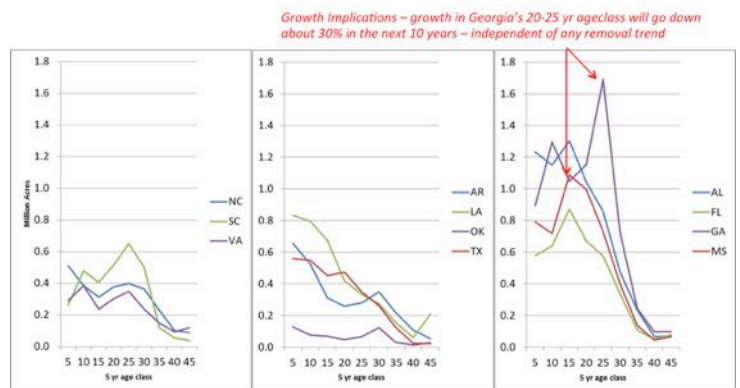


Planted Pine over 2/3 of pine removals but less than 1/2 of total removals

Packard Foundation

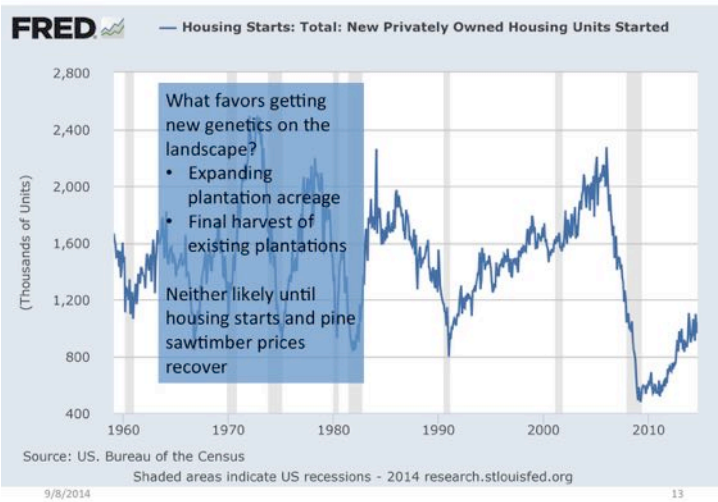
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## Role of Plantations – Age Class Structure By State



9/8/2014

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## INTEGRATING PLOT LEVEL FOREST SCIENCE OVER TIME AND LANDSCAPES

### Sub-Regional Timber Supply **SRTS**

- SRTS is a stumpage market simulation system that links a detailed inventory model built on the most recent FIA data to a market framework (*supply curves are shifted by product inventory*)
- Market parameters (elasticities) are based on published econometric results.
- Prices are linked to an empirical landuse model that simulates planting and total timberland adjustments to markets.

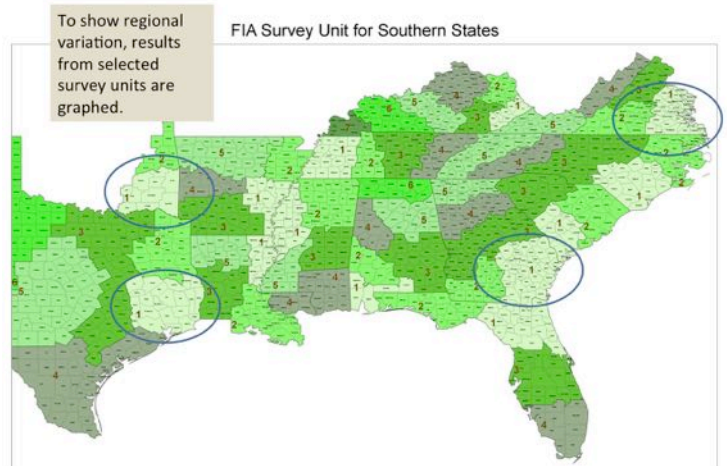
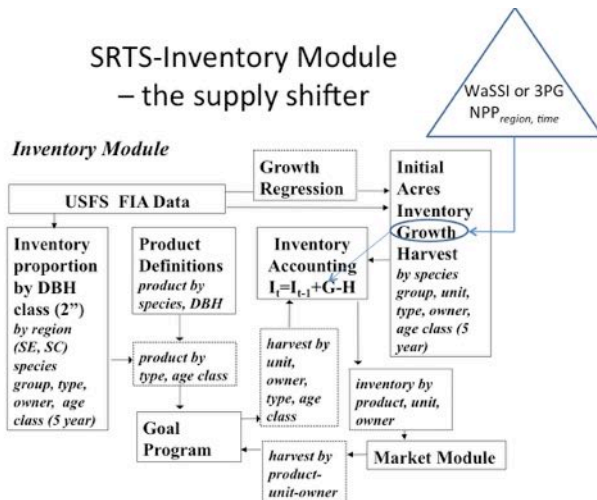
### SRTS Links Markets to Inventory

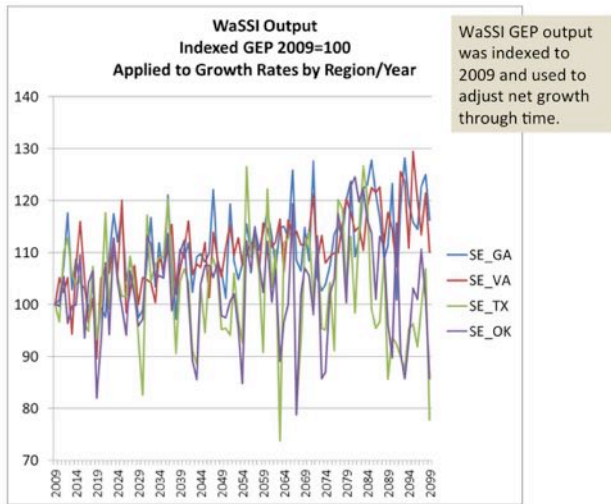
- Demand
  - (by product – demand trends exogenous)
- $Q_d = f(\text{Price, Demand Shifters})$
- Supply
  - (by product, region, owner) = 424 supply curves for a southwide run
- $Q_s = f(\text{Price, Inventory}_{t-1})$  ← Link to WaSSI is by adjusting net growth in the inventory module shown on the next slide
- Constant elasticity functional form
- Myopic expectations – depends on current price only

An empirical model whose coefficients are based on econometric relationships from the literature.

Link to WaSSI is by adjusting net growth in the inventory module shown on the next slide

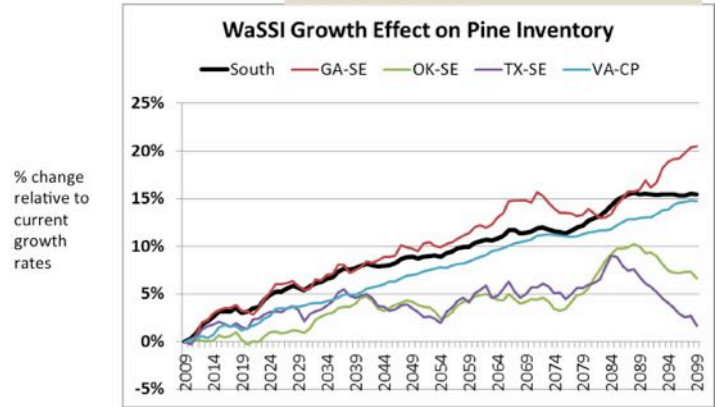
### SRTS-Inventory Module – the supply shifter





Since inventory is cumulative growth over long periods, the volatility in inventory is much less than growth.

Compared to using current growth rates, these results show that climate conditioned growth from WaSSI increases pine inventory over time for the South as a whole, with southeast GA and VA tracking the regional average, but OK and TX trending downward toward the end of the projection.



## Carbon Impact of Pine Plantations

- Depends on how pine plantations sequester carbon– Pinemap Core Science
- Also depends on:
  - When, where, and if we plant pine trees
  - Plantation’s role in the forest landscape
  - The carbon consequences of forest products
- We are using economic models to better understand this context

## Economic Models and Pinemap

- Better understanding of:
  - How markets and policies (carbon, ag, forest) can affect plantation sequestration
  - Integrate plot-based growth changes over time and across the southern landscape
    - Reducing harvest pressure on natural forest
    - Carbon consequences of conversion of natural forest
    - Sensitivity of growth vs hazards (pests, fire, hurricanes)