



Quantifying Carbon, Water and Energy Fluxes in Two Loblolly Pine Plantations in Eastern NC

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What is Eddy Flux?

- A technique to measure the vertical turbulent fluxes within atmospheric boundary layers.
- Statistical method that analyzes high frequency wind & atmospheric data series.
- Used to estimate heat, water and CO₂ exchange.



Eddies move a parcel of air that contains its own temperature, relative humidity and CO₂ concentration. This information, along with wind speed helps to determine the flux (the amount that flows through a unit area per unit of time)

What is Eddy Flux?

- Tower data is used to estimate the CO₂, water and energy fluxes, and micrometeorological data within the study area.

- Biophysical Site Characteristic:

- Carbon sequestration

- Tree and plant growth

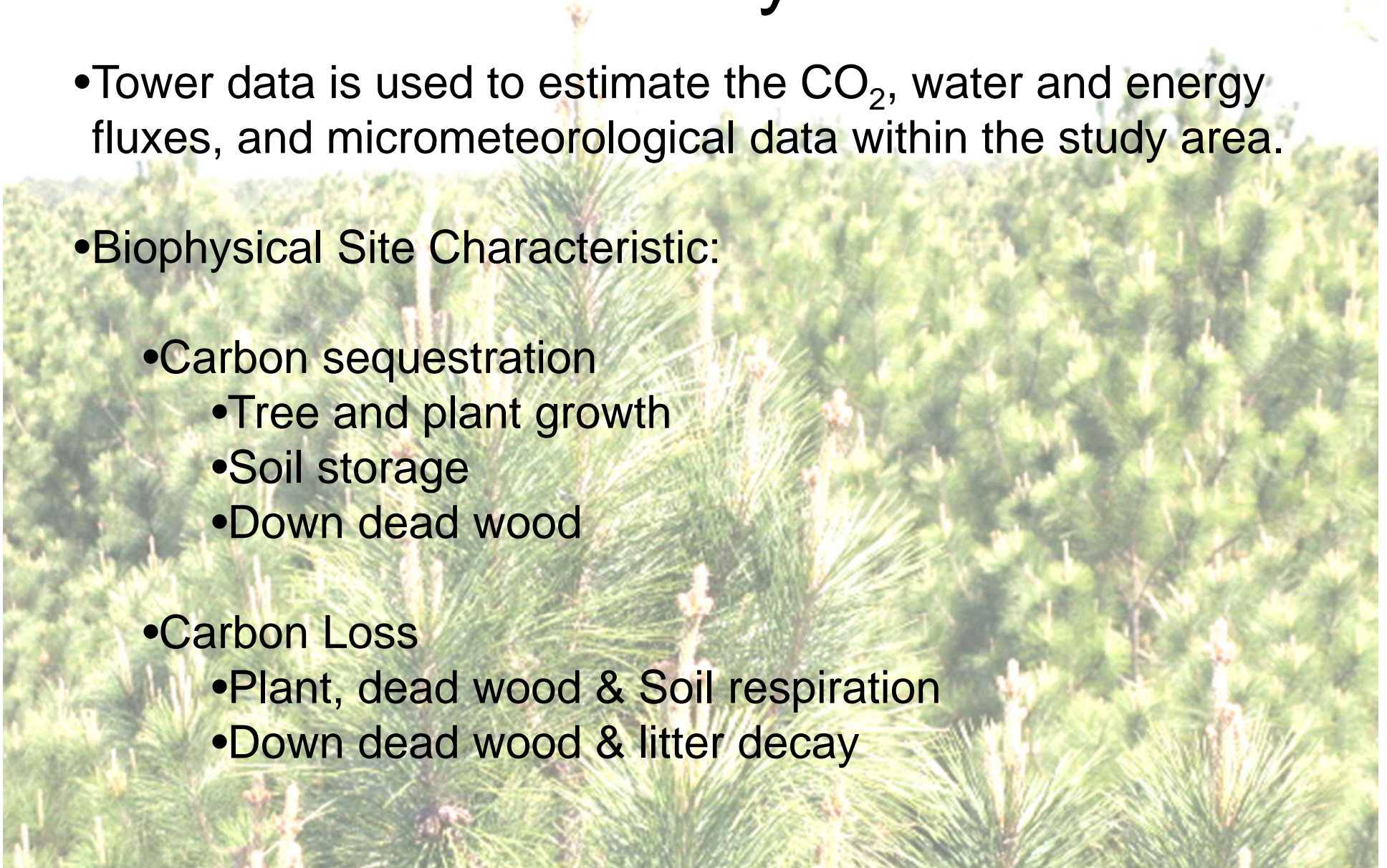
- Soil storage

- Down dead wood

- Carbon Loss

- Plant, dead wood & Soil respiration

- Down dead wood & litter decay

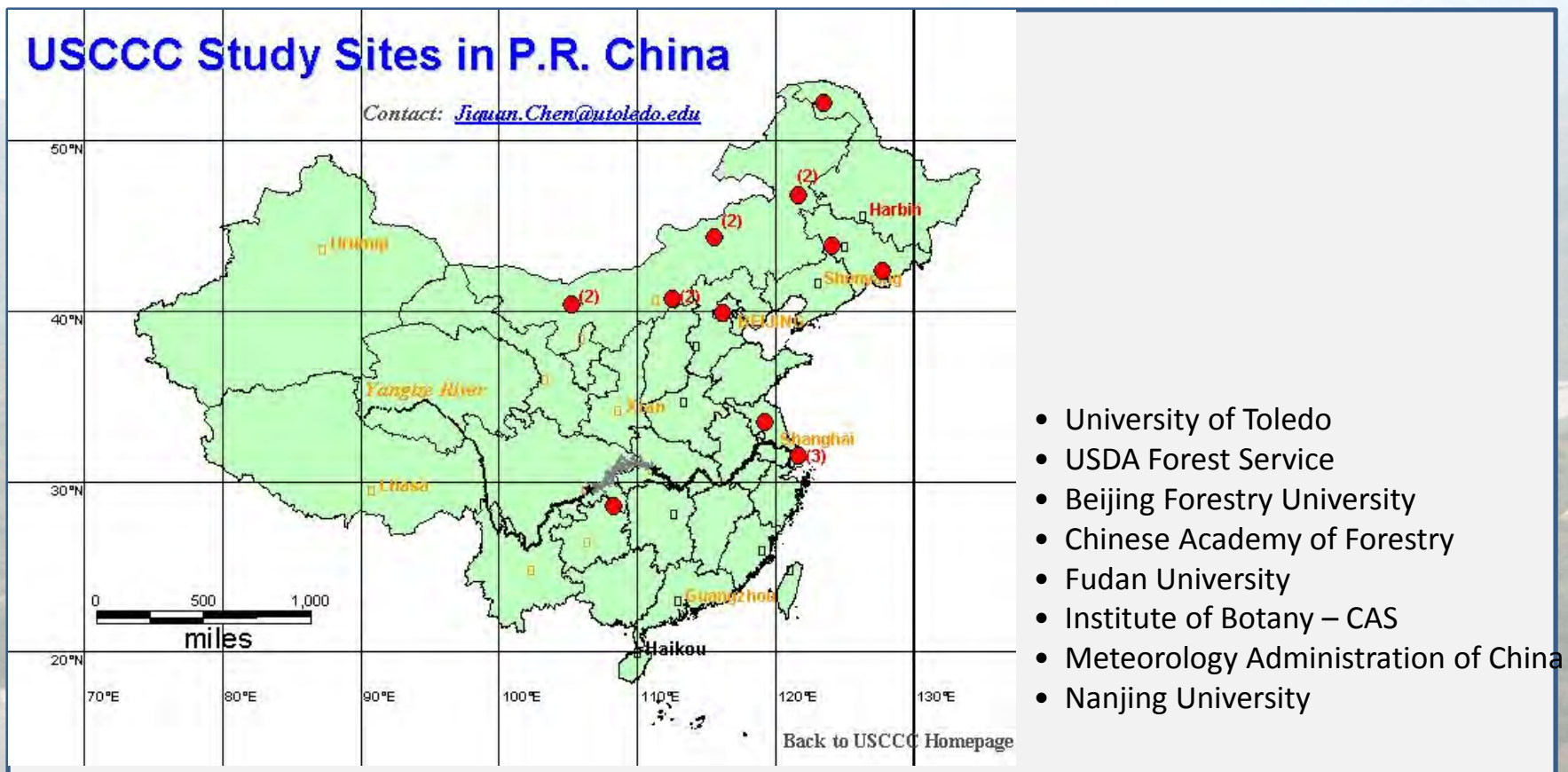


Key Collaborators & Objectives

- University of Toledo, Ohio – Landscape Ecology and Ecosystem Science Lab
- North Carolina State University
 - Fill an important gap in flux network
 - Contribute to the flux network
 - Utilize existing expertise and new funding opportunities
 - Model validation
- Northern Global Change Program - NASA Grant
 - Tie remote sensing & forest inventory data (spatially extensive, coarsely resolved) with site level data (spatially intensive, highly resolved)
 - Develop a consistent set of land-based protocols and measurements
 - Regional analysis of disturbance affect on flux rates
 - Develop models and decision support tools

Key Collaborators & Objectives (cont.)

- US China Carbon Consortium (USCCC)

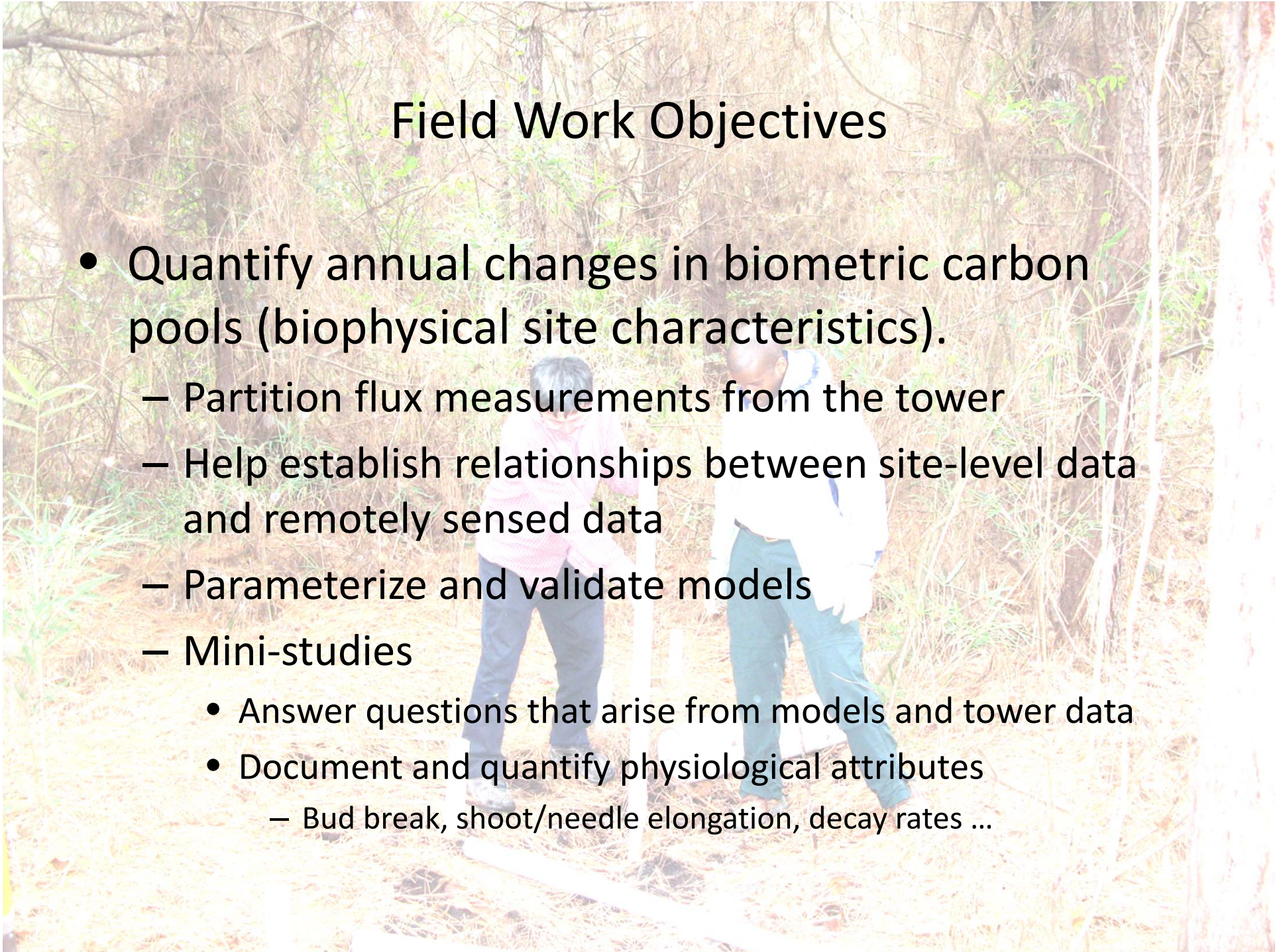


Objectives of USCCC

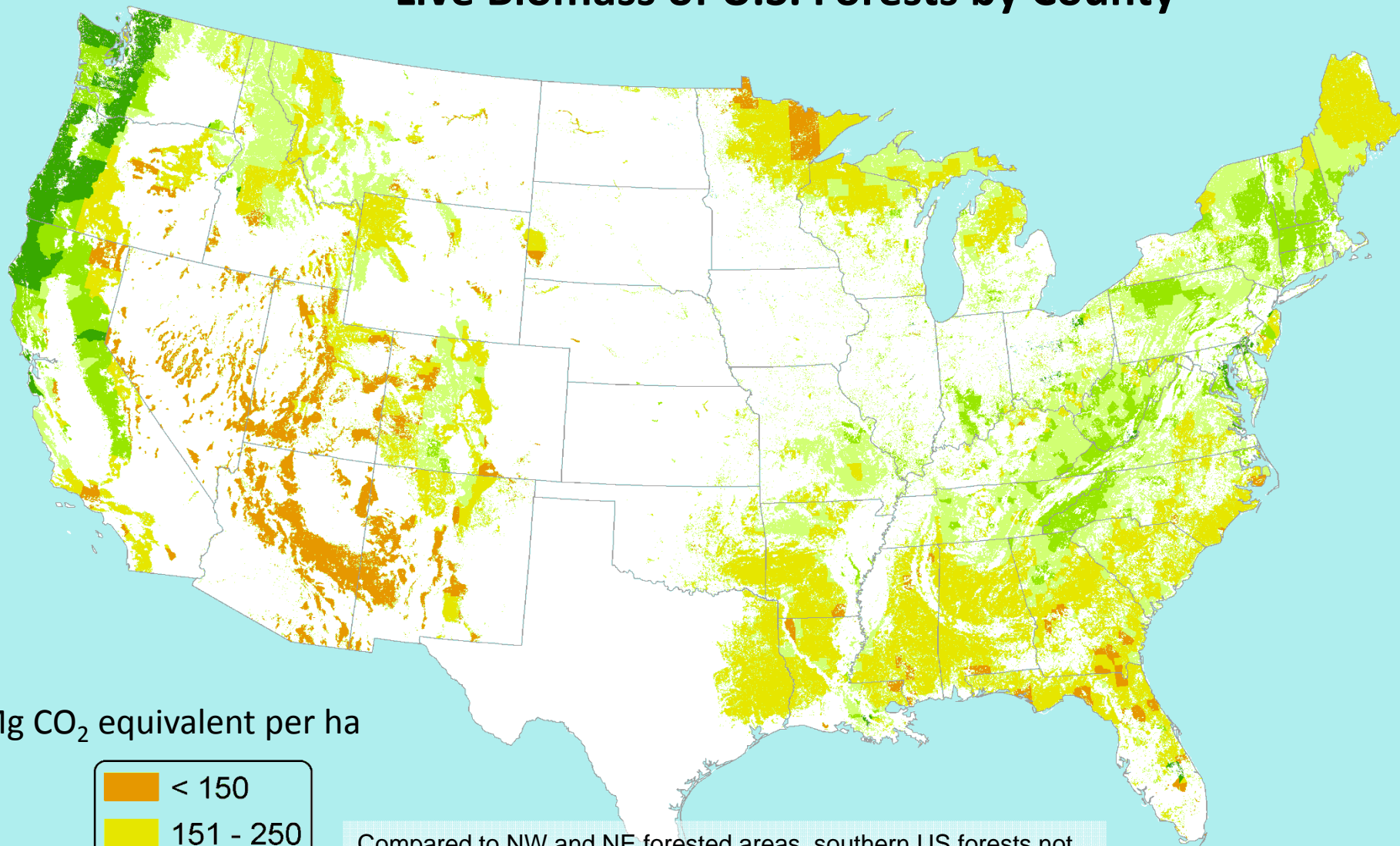
- To strengthen collaborative carbon and water cycling research between Chinese and US scientists
- To establish comparable methods for studying carbon and water cycles in China and the US
- To share databases from individual study sites to facilitate regional and continental scale assessments of carbon and water cycling
- To provide sampling and analysis support to USCCC members
- To serve as a base for acquiring additional carbon and water cycling research funding
- To collaborate on the development and publication of carbon and water research in international journals

Field Work Objectives

- Quantify annual changes in biometric carbon pools (biophysical site characteristics).
 - Partition flux measurements from the tower
 - Help establish relationships between site-level data and remotely sensed data
 - Parameterize and validate models
 - Mini-studies
 - Answer questions that arise from models and tower data
 - Document and quantify physiological attributes
 - Bud break, shoot/needle elongation, decay rates ...



Live Biomass of U.S. Forests by County



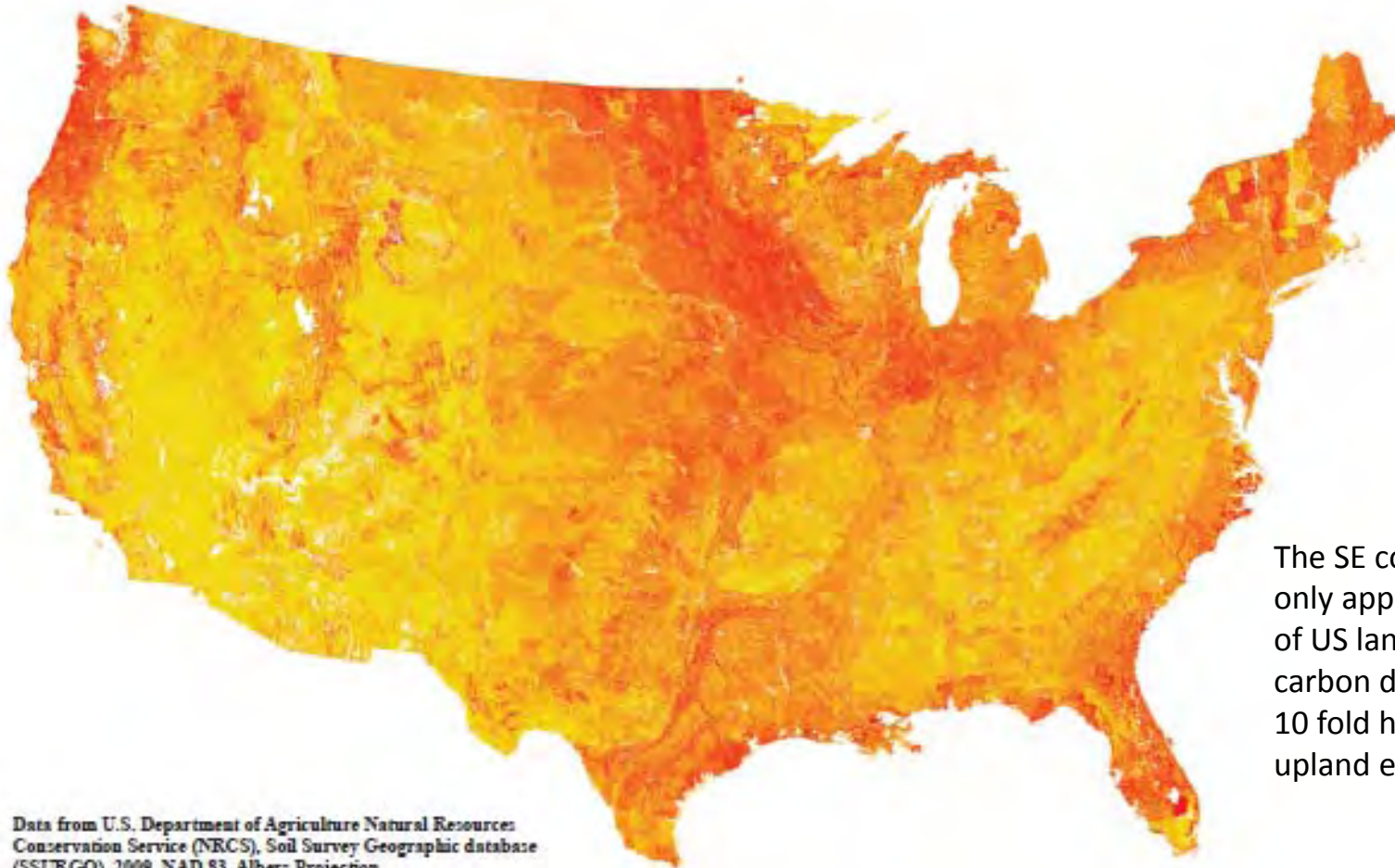
Mg CO₂ equivalent per ha

- < 150
- 151 - 250
- 251 - 337
- 338 - 500
- > 500

Compared to NW and NE forested areas, southern US forests not a large sink for aboveground carbon (on a per forested area basis, not land area).

Map From Linda Heath
USDA Forest Service, NRS

Soil Organic Carbon (kg/m²)



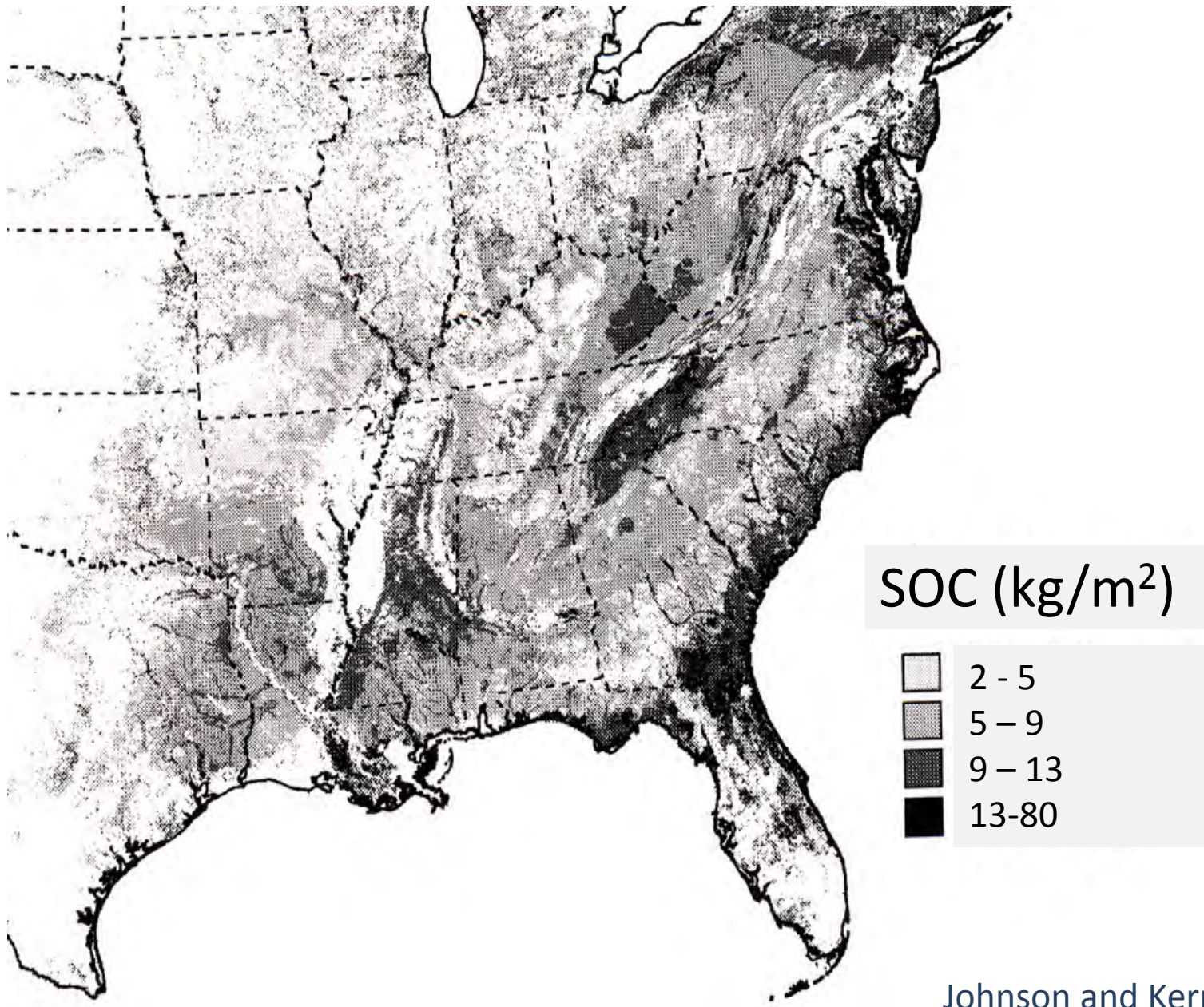
The SE coastal plain is only approximately 5% of US land area, but soil carbon density can be 10 fold higher than upland ecosystems

Data from U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), Soil Survey Geographic database (SSURGO), 2009, NAD 83, Albers Projection

EXPLANATION

Total soil organic carbon, in kilograms per square meter





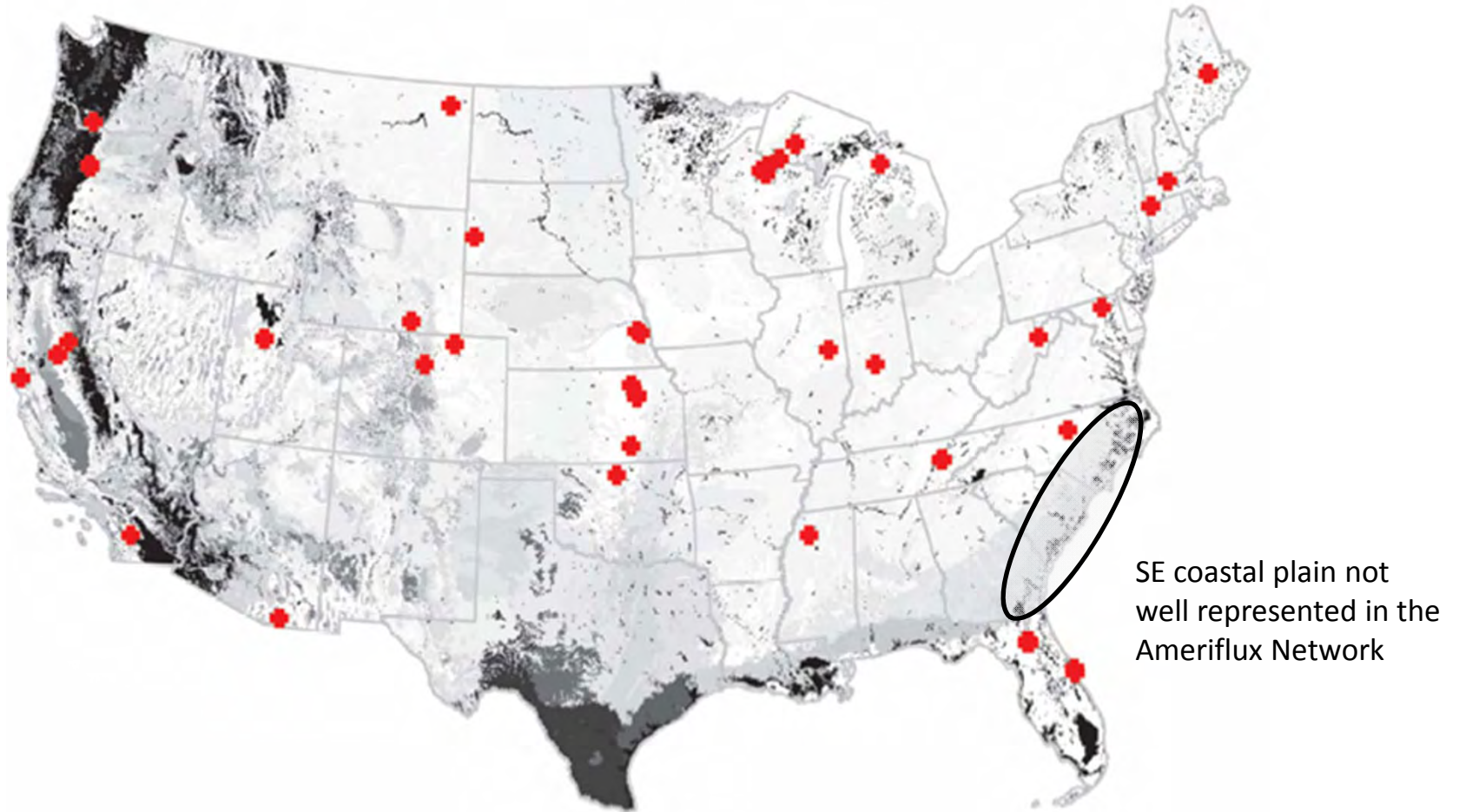
Johnson and Kern, 2003

Intensive Management, High Disturbance & Soil Carbon Loss



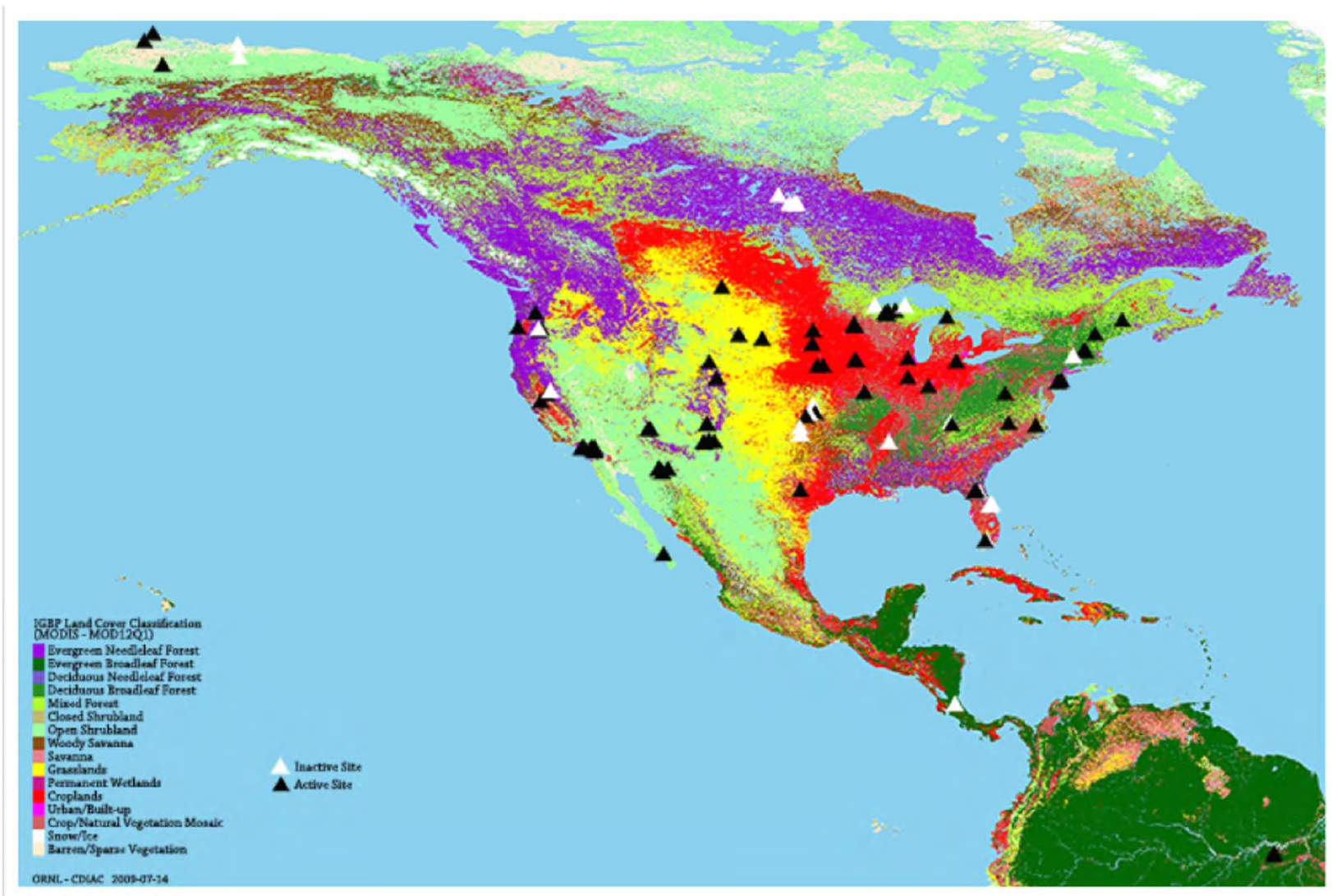
It is unknown how management practices affect long-term soil carbon sequestration and loss, especially when converting bottomland hardwoods to pine plantations

Ameriflux Sites, 2004

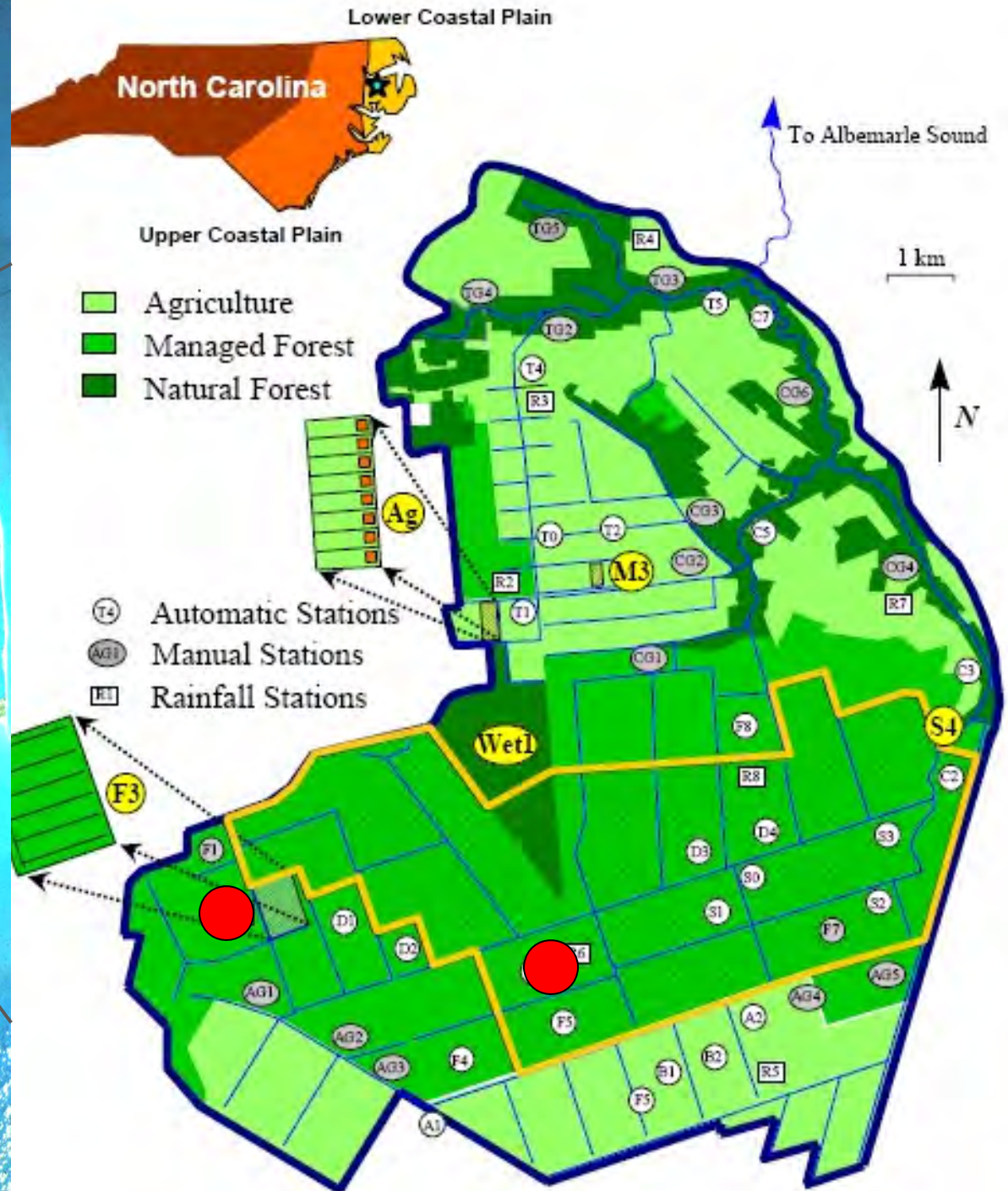


Map created by Bill Hargrove
USDA FS, SRS, EFETAC

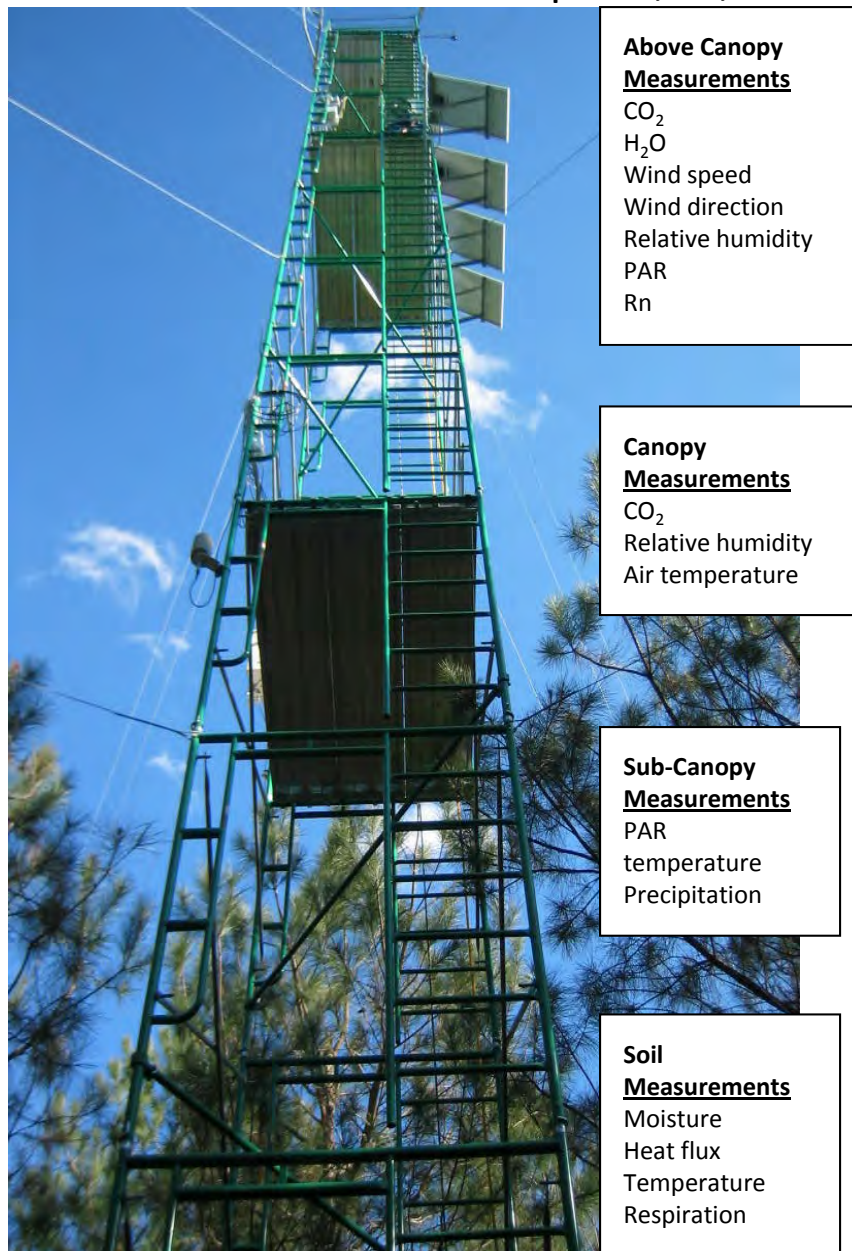
Ameriflux Sites, 2009



Research Sites in Weyerhaeuser's Parker Tract



Eddy-flux Tower – data from tower, along with biomass plots around the site are used to estimate annual carbon pools, ET, NEP and NPP



Core Data Loggers



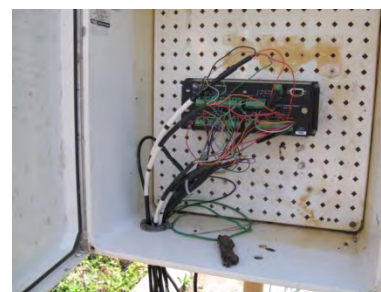
CR5000

Wind speed & direction
Atmospheric CO₂
Air T & RH
PAR
Radiation
Rainfall



CR10

CO₂ throughout the canopy



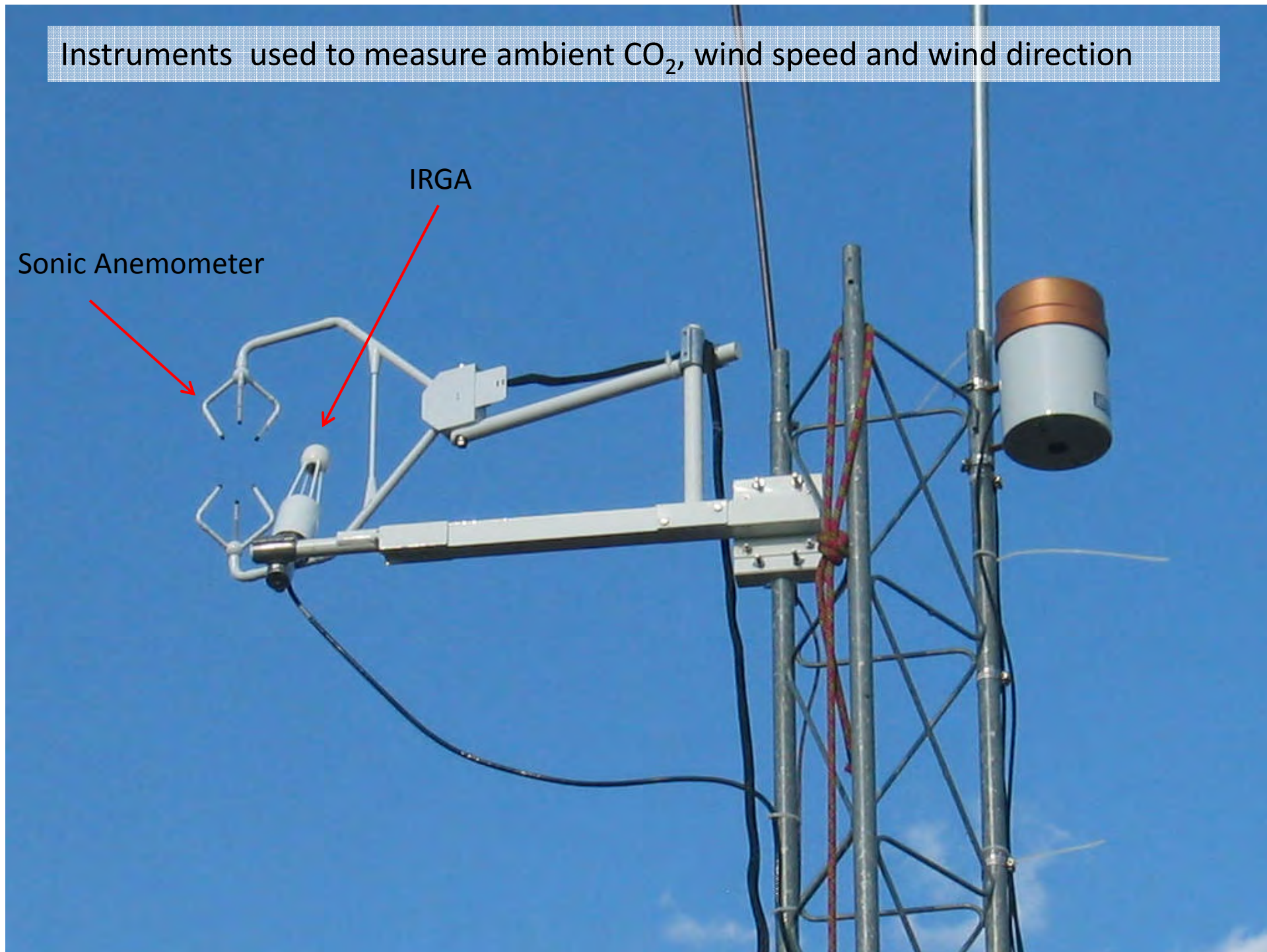
CR1000/CR23

Soil T
Soil moisture
VWC
Air T & RH
Soil heat flux

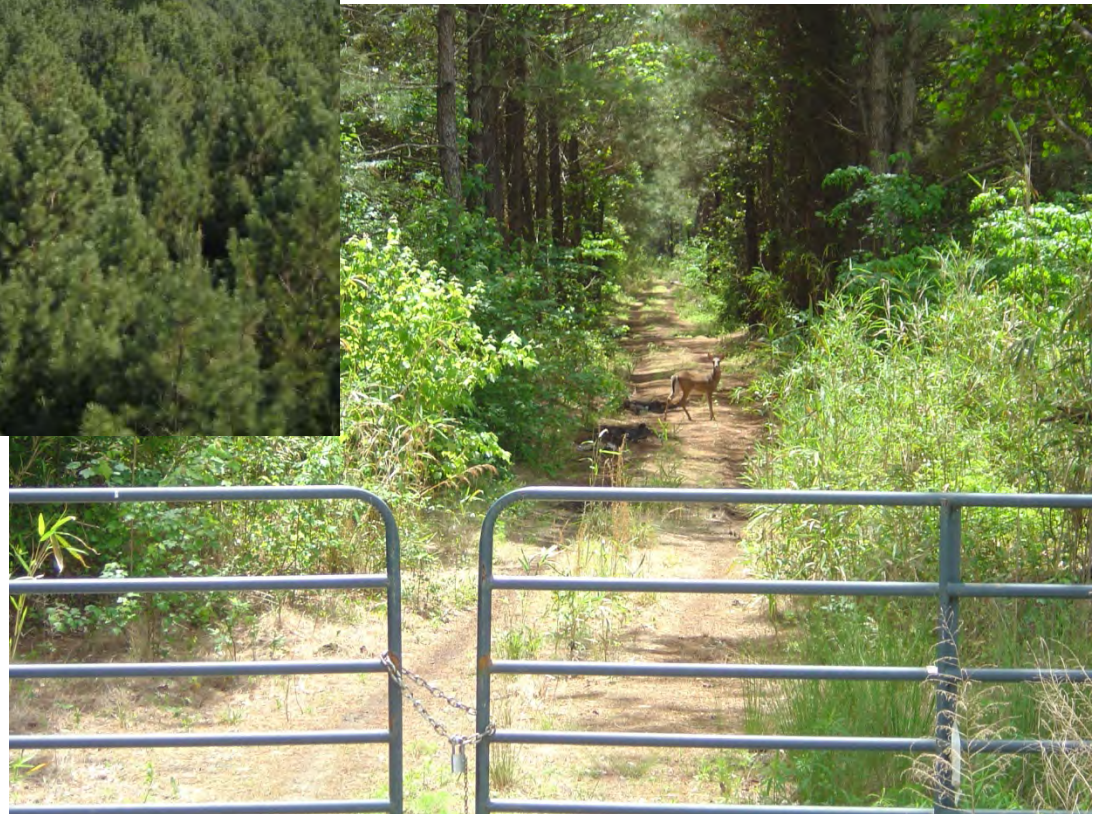
Instruments used to measure ambient CO₂, wind speed and wind direction

Sonic Anemometer

IRGA



18-Year Old Pine Plantation Before Thinning



19-Year Old Pine Plantation After Thinning



How will the thinning operation affect the site's carbon sequestration and water usage rates?

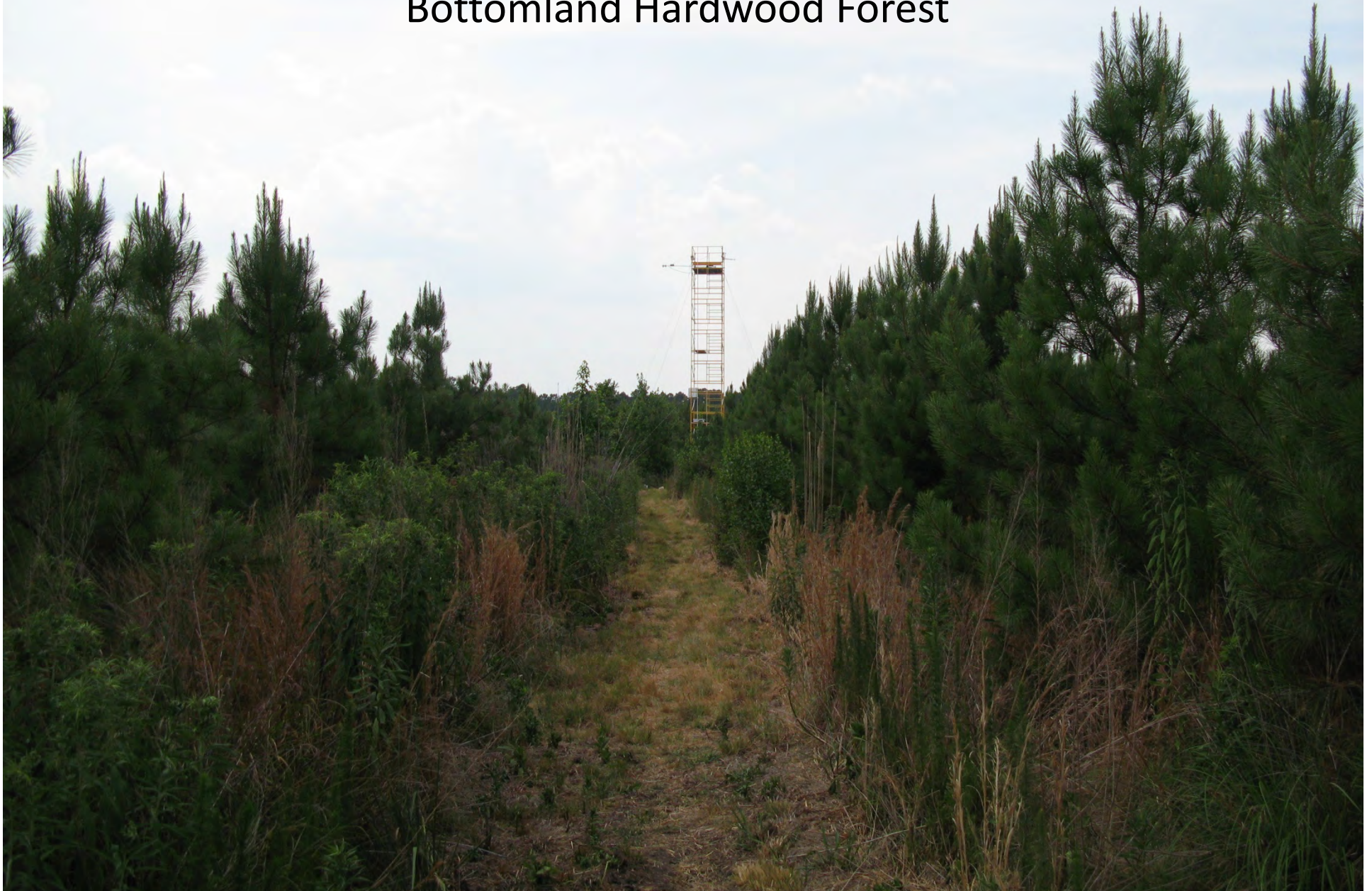
Bottomland Hardwoods Site One Year After Clear-cut Harvest, Ditching and Bedding



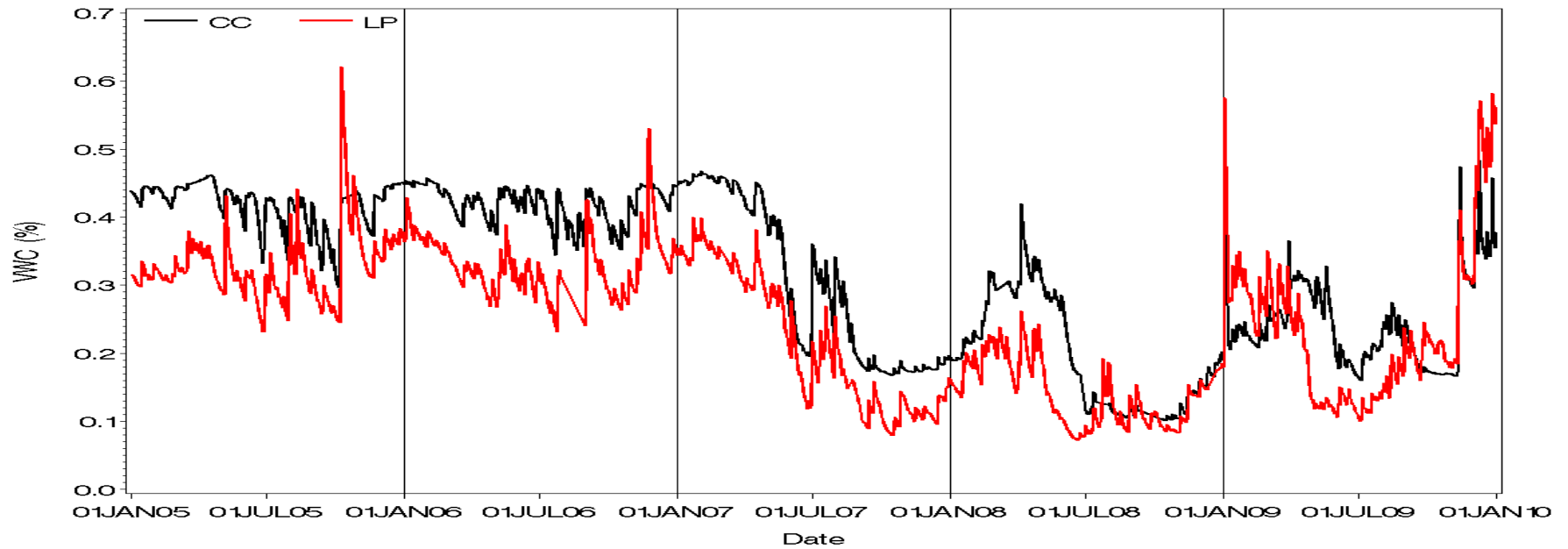
Loblolly Pine Plantation Two Years After Conversion From a Bottomland Hardwood Forest



Loblolly Pine Plantation Four Years After Conversion From a Bottomland Hardwood Forest

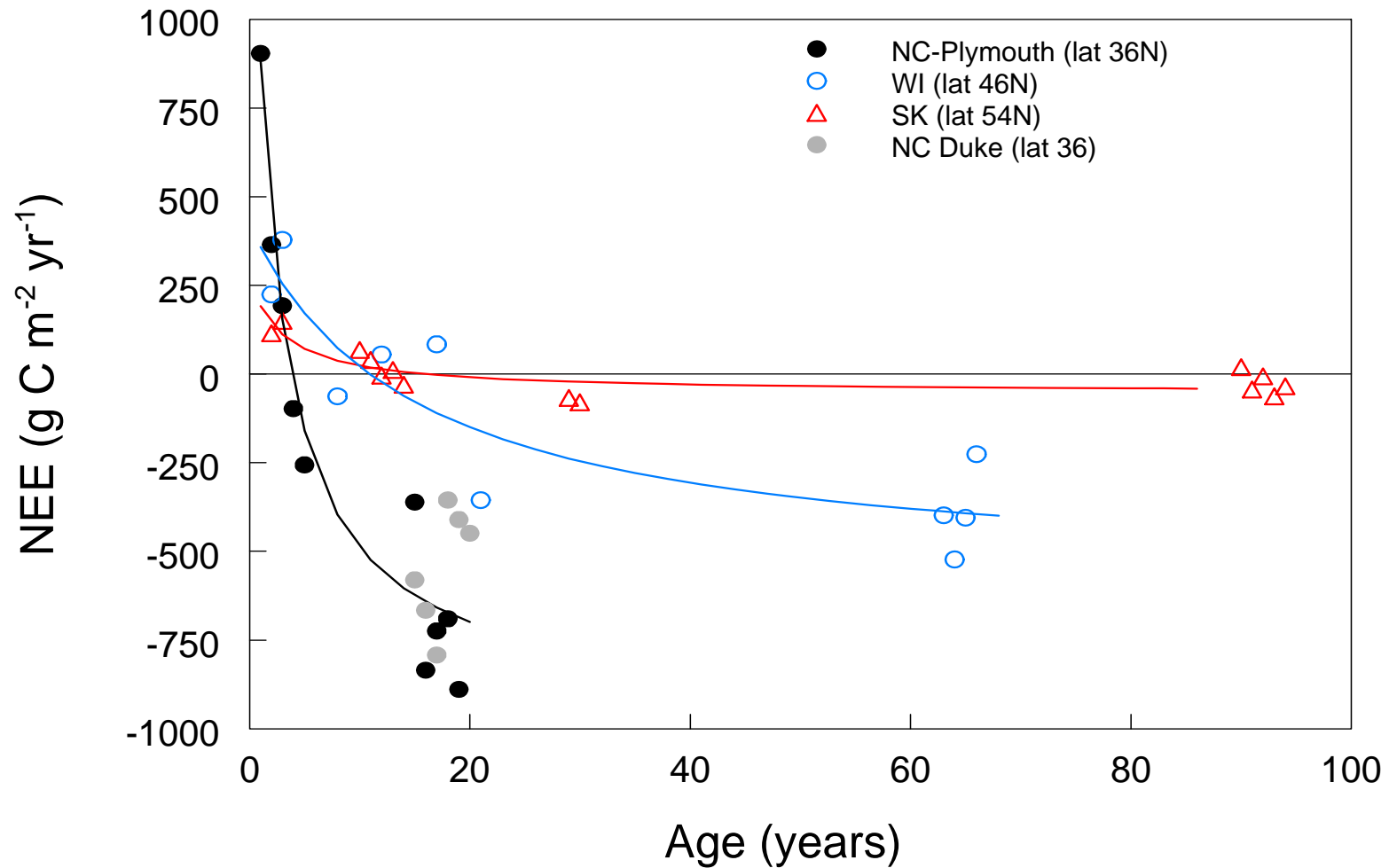


Climate Extremes



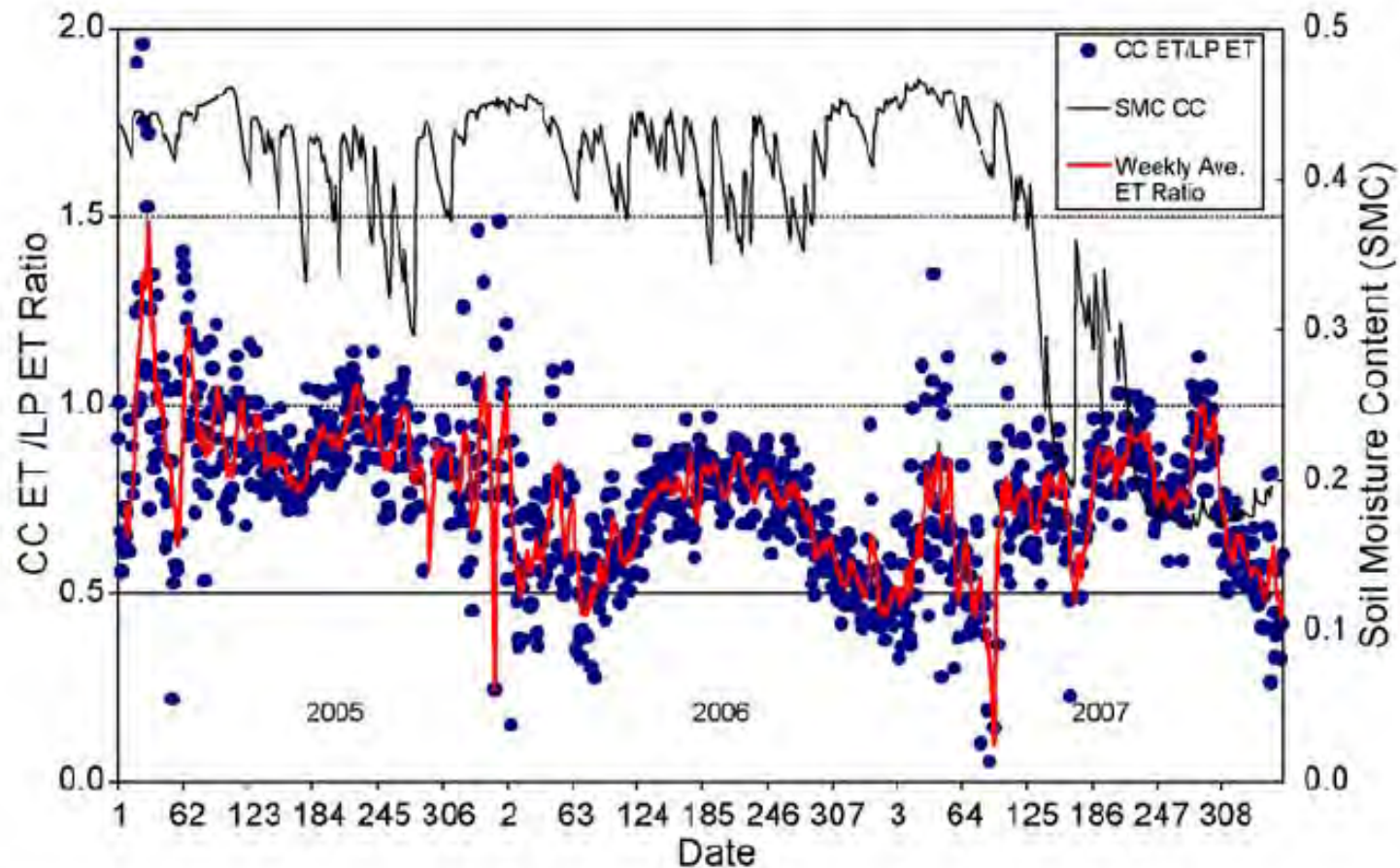
2007 and 2008 were two of the driest years on record

Net Ecosystem Exchange Across Ecosystems and Stands Age



The young pine site became a weak carbon sink four years after planting

Evapotranspiration Ratio Between the Two Sites



Evapotranspiration ratio suggests relative differences were more pronounced during the dormant season and dry periods

Summary - Carbon pools and fluxes

The CO₂ exchange rates are high, rivaling those in tropical forests, but similar to other commercially managed pine plantations.

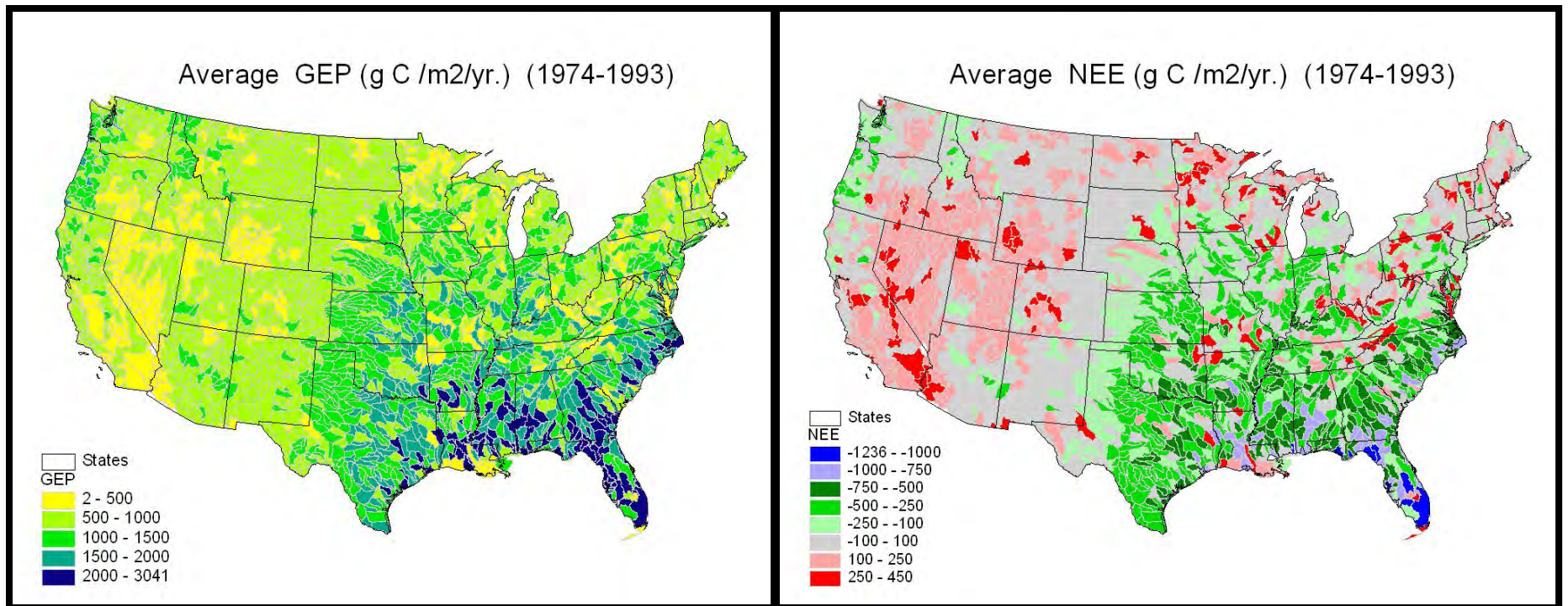
Post-disturbance carbon losses from logging residue and soil are substantial, but the source period is shorter than reported for more northern forests.

The contribution of soil to ecosystem respiration decreased from over 90% immediately following a harvest to about 55-60% by age 16.

The replenishment of soil carbon through litterfall in the older stand nearly equaled heterotrophic respiration in 2006, but was 7 and 30% lower in 2007 and 2005, respectively, highlighting the vulnerability of soil carbon stocks to decomposition.

Energy and water balance differences between the two site were most pronounced during dry years.

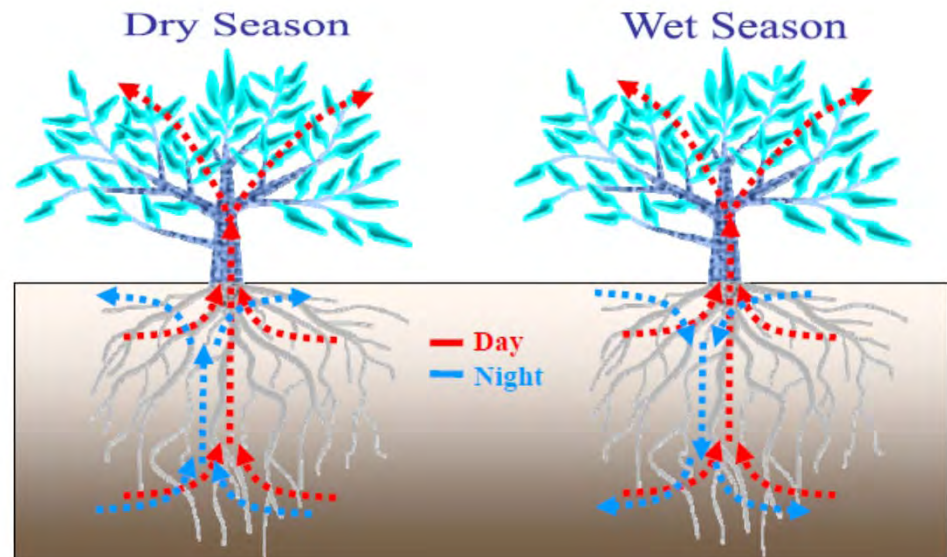
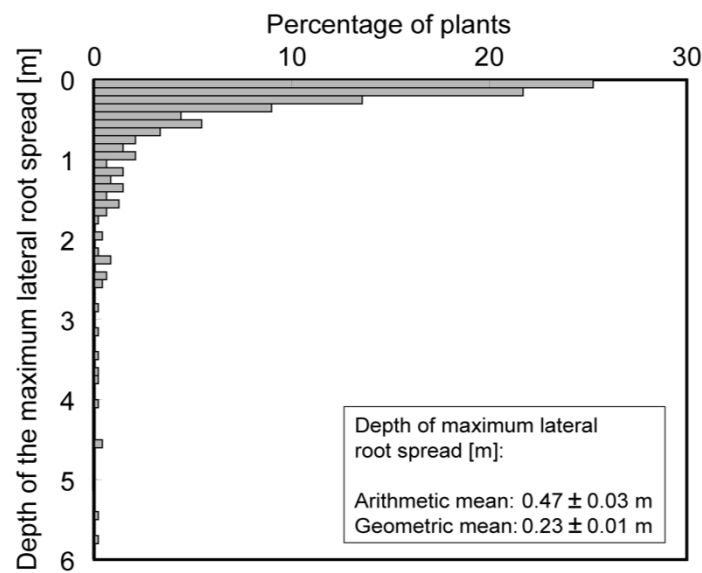
Modeling Continental Scale GPP and NEE with the WaSS-CB Model



Measuring Tree and Root Sapflow

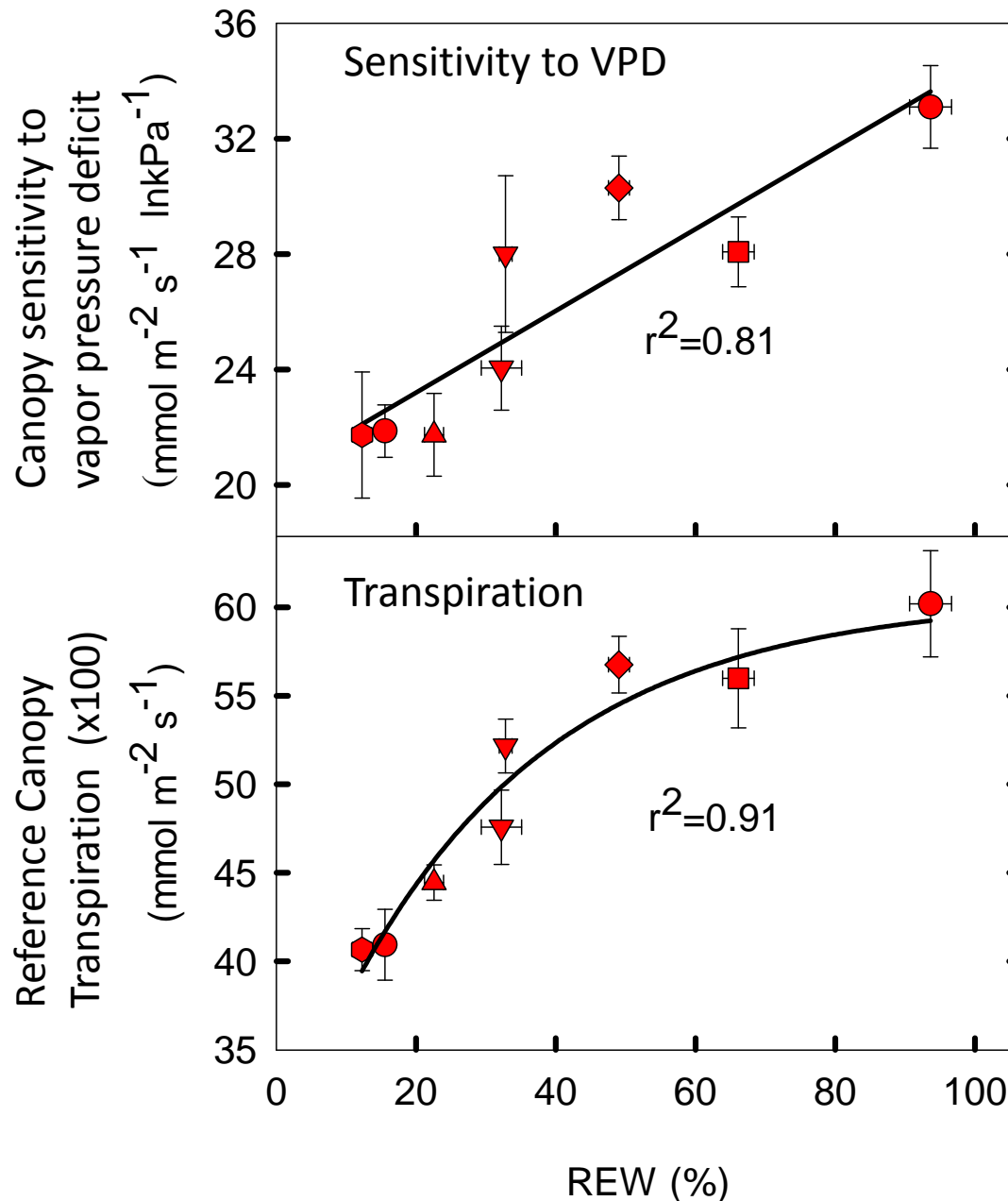


Ecosystem Response to Upper Soil Water Limitations, (the **ENIGMA OF ROOTS**)



Schematic description of hydraulic redistribution by roots

Sensitivity of Trees to a Changing Climate



The onset in reduction of canopy whole tree transpiration and its sensitivity to vapor pressure deficit (VPD) was tied to a decrease in soil water content below 50% relative extractable water (REW).

Climate models predict an increase in vapor pressure deficit with increasing temperature.

What this could mean:

- Reduced water and carbon assimilation
- Greater sensitivity to drought

Analyzing the Soil and Root Profiles to Help Understand Ecosystem Response to Upper Soil Water Limitations



Soil layer (cm)	Root profile (%)
0-30	49
30-60	32
60-100	19

Root area profile

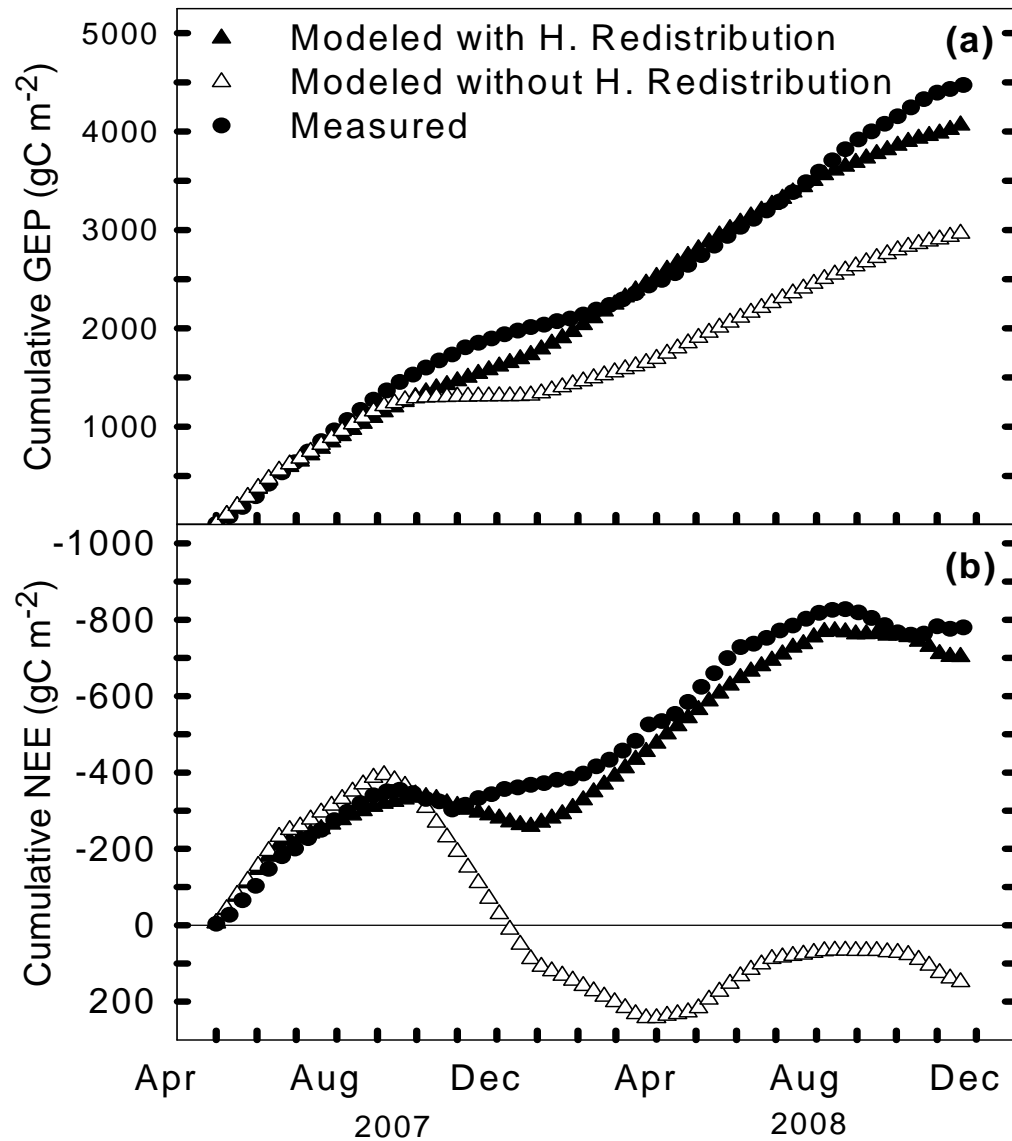
Root size class (mm)	Root area index (m ² /m ²)	Root area index (% of total)
0-2	8.6	79
1-2	1.4	13
2-5	0.85	8

Soil and Root Profiles

One cubic meter soil pits were excavated to characterize the soil profile, quantify coarse and fine root biomass, and soil and root carbon content.



Hydraulic Redistribution and Carbon Exchange



Effect of deep root functioning (Hydraulic Redistribution) on Carbon Exchange

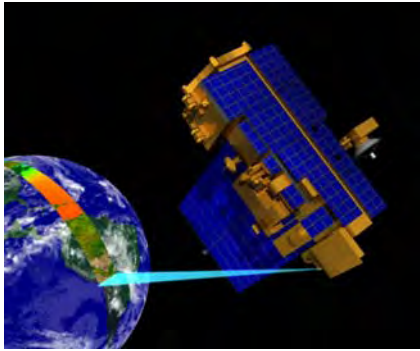
Deep root functioning plays an important role by maintaining forest ecosystems as significant carbon sink.

Without hydraulic redistribution the site would have been a source of CO₂ during drought. Hydraulic redistribution helped maintain GEP above ER

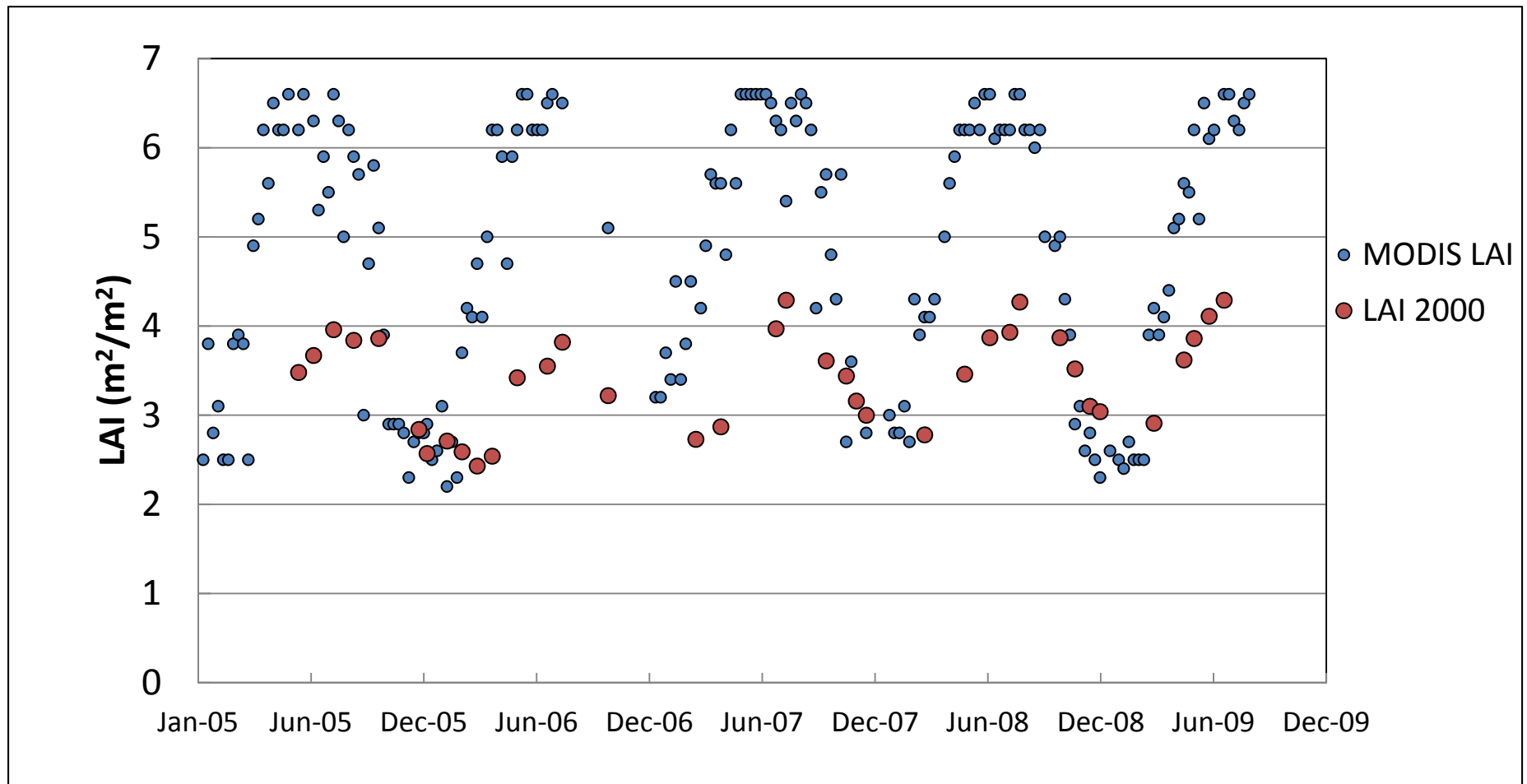


Next Step

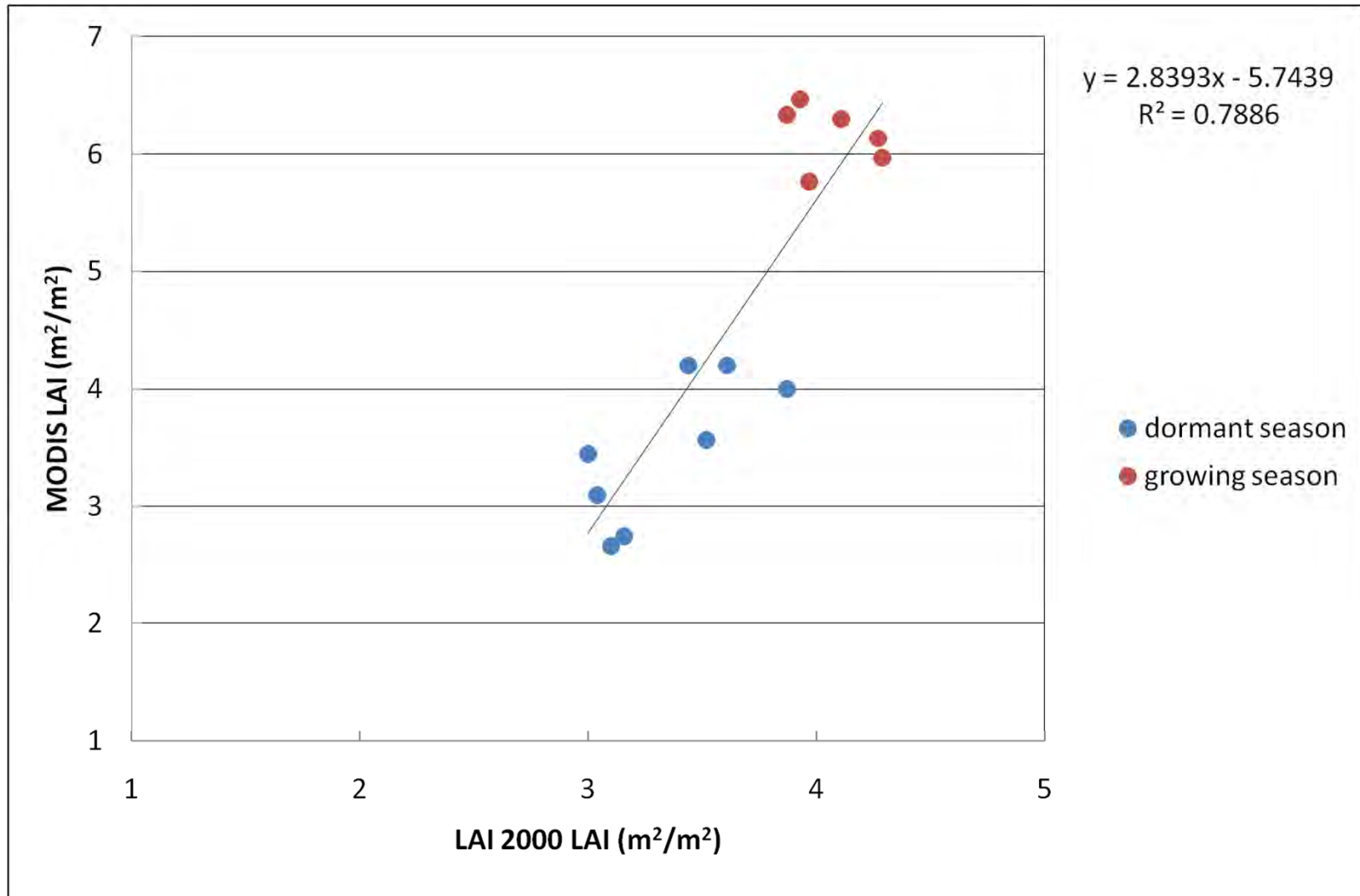
Assuming that the increase in transpiration of drought-stressed regions is affected by the seasonal cycles of temperature through changes in latent heat (Law et al. 2001; Sun et al. 2010), can we establish a direct link between plant root functioning and climate?



Comparing MODIS and LAI 2000 Estimates of Leaf Area Index



LAI 2000 vs. MODIS derived LAI During the Dormant and Growing Seasons



Thanks to the many people who have made this research successful!

