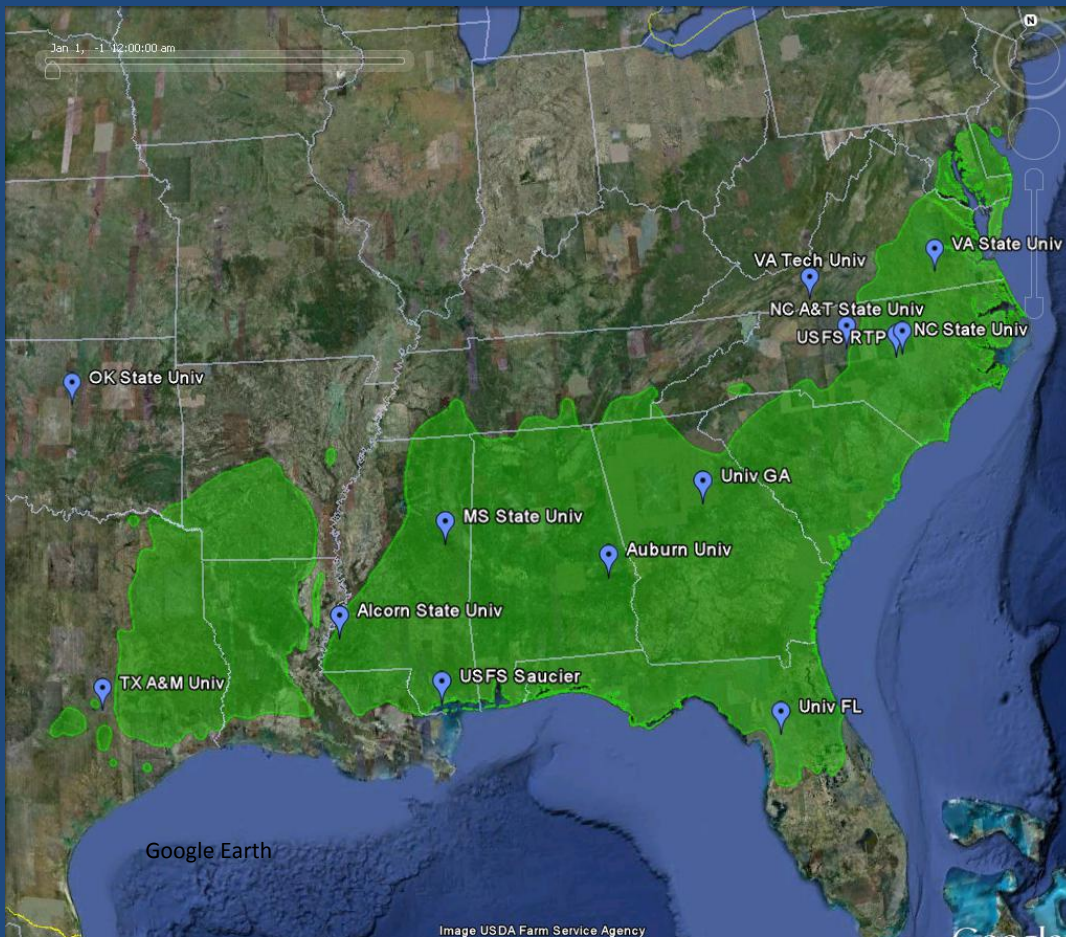


PINEMAP

Pine Integrated Network: Education, Mitigation and Adaptation Project *Mapping the future of pine management in a changing world*



USDA United States Department of Agriculture
National Institute of Food and Agriculture

Investing in Science | Securing Our Future

\$20,000,000 for 2011-2015

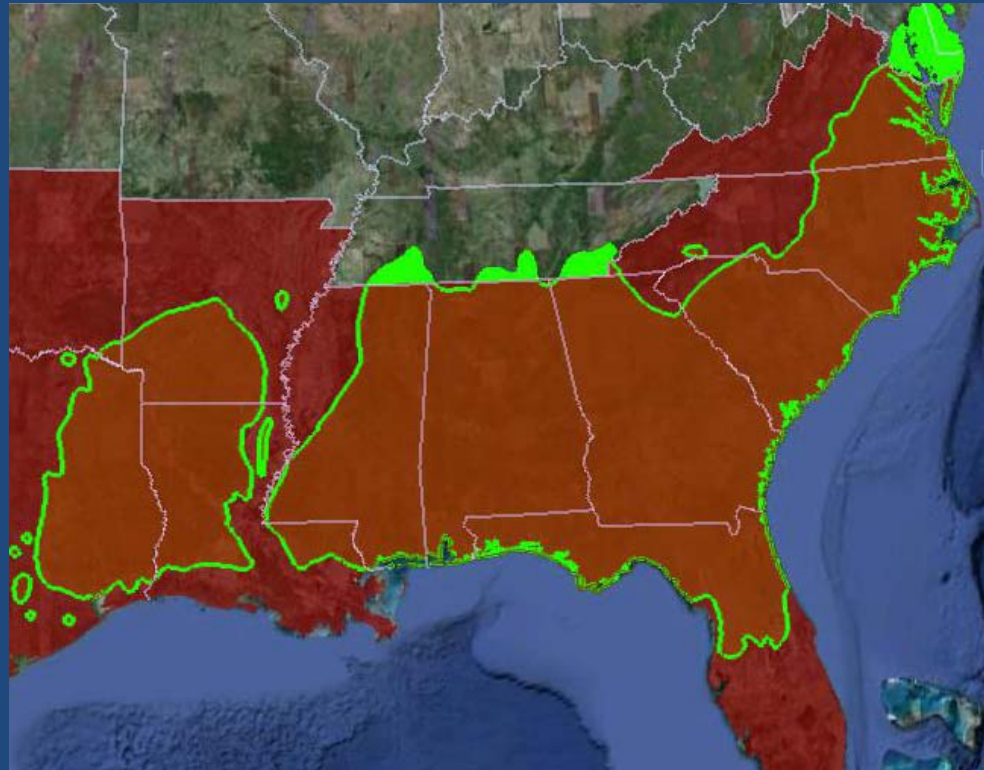
Aim 1

Webinar Presentation

- Introduction and Monitoring Network (Fox)
- Study to Manipulate Rainfall (Will)
- Work to estimate water use and ET using sapflow (Ward)
- Work to estimate Net Ecosystem Productivity (NEP) using soil CO₂ efflux (Vogel)

Scope

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



Overall Goals

To create, synthesize, and disseminate the knowledge that enables southern forest landowners:

- to harness pine forest productivity to mitigate atmospheric CO₂,
- 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.

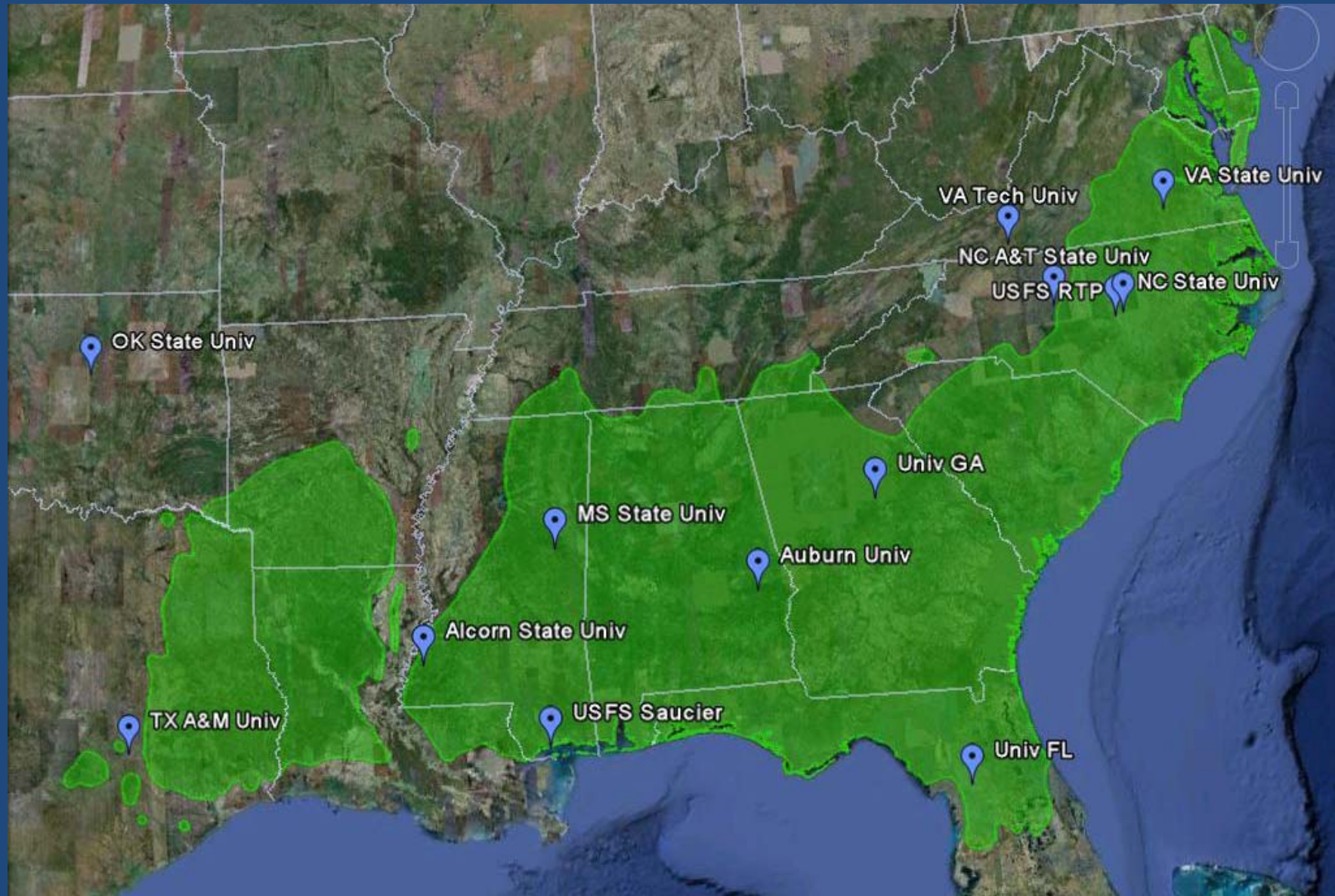
Long-Term Outcome of Program

Reduce the use of energy, nitrogen fertilizer, and water by 10% and increase carbon sequestration by 15% through resilient forest production systems under changing climate by 2030

Provide New Management Methods

- ***Mitigation*** – Reduce greenhouse gas emissions in forestry and maximize carbon sequestration
- ***Adaptation*** – Maximize resiliency and reduce impact of climate change on productivity of forest systems and reduce carbon, nitrogen and water footprints under changing climate
- ***Climate Education and Extension***- Increase number of scientists, educators and extension professionals with skills to address climate change in forestry

~51 Co-PIs at 12 Institutions



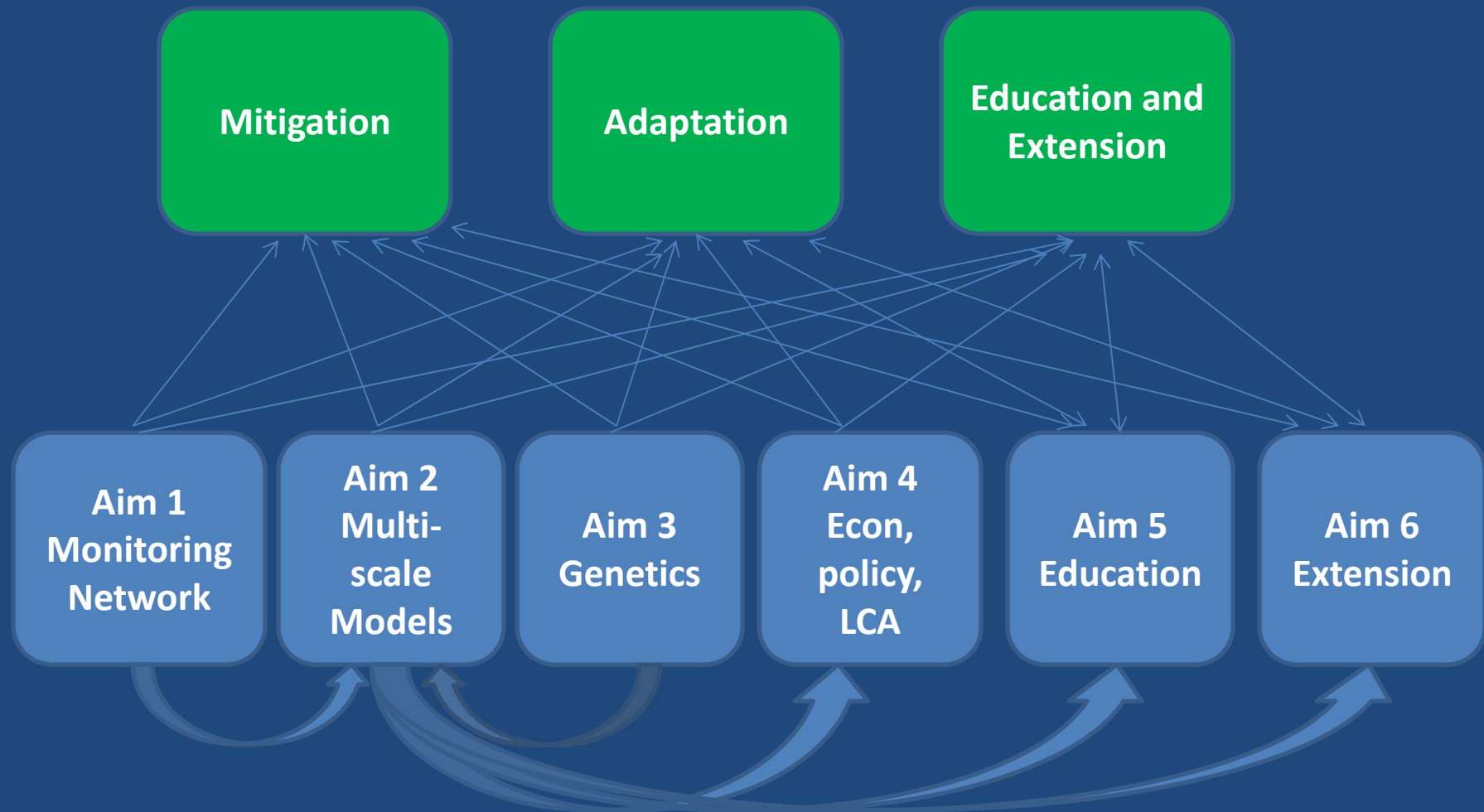
Project Structured Around 6 Aims

- **Aim 1** – Monitoring network establishment and measurement
- **Aim 2** – Multi-scale modeling
- **Aim 3** – Gene discovery and deployment guidelines
- **Aim 4** – Life cycle assessment; multi-scale policy and economic analysis; assessment of alternative management adoption
- **Aim 5** – Educational and training programs for stakeholders and students
- **Aim 6** – Extension program development and delivery

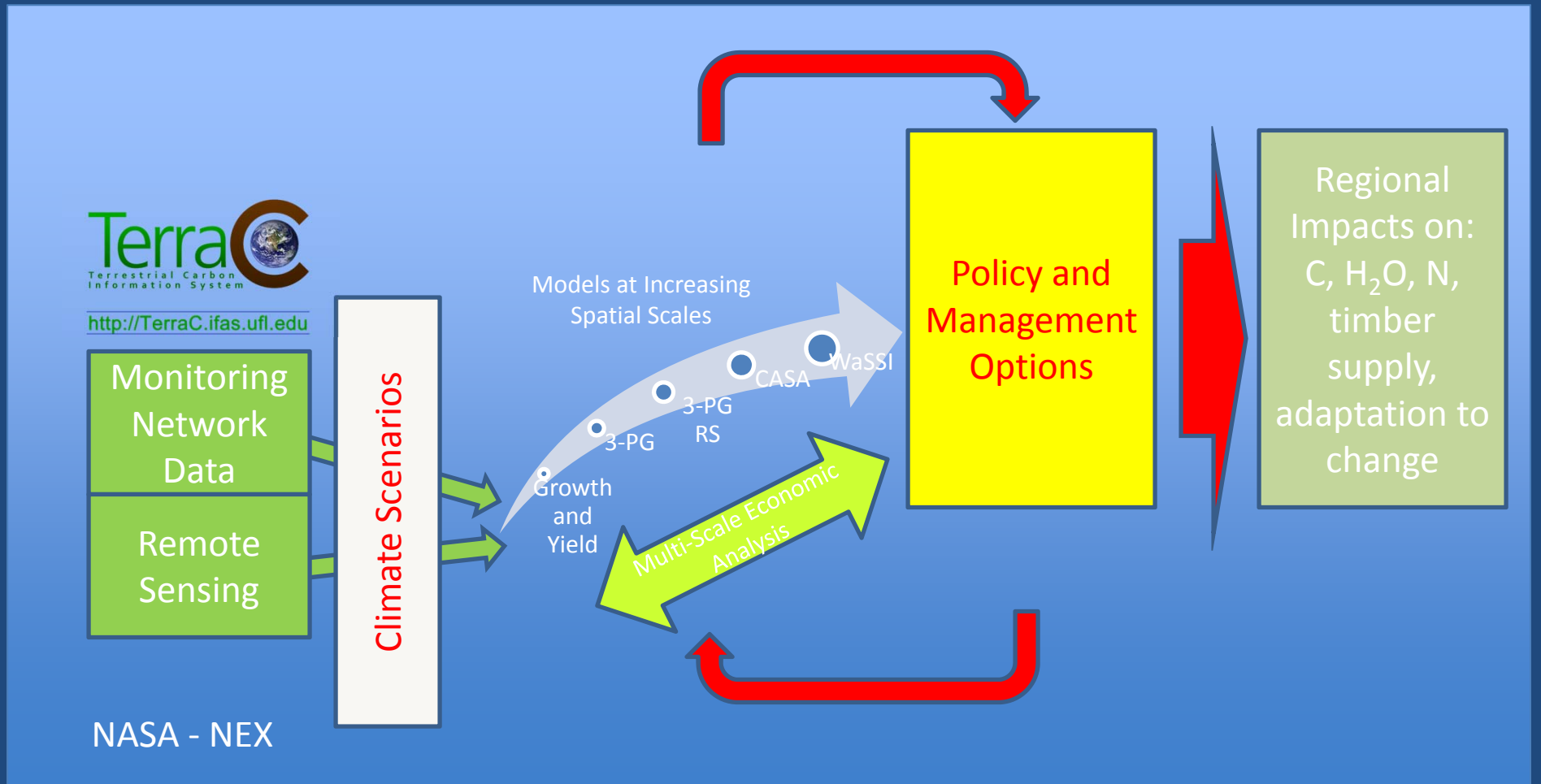
General Milestones Expected

- *Describe existing monitoring networks and how they will be used and/or supplemented to measure and monitor stores and fluxes of C, N, H₂O*
- *Develop standardized methodologies for estimating C, N, H₂O footprints*
 - *Feedbacks from human behavior and decisionmaking*
- *Establish current baselines for C fluxes and N, H₂O, energy use*
 - *Inventory existing production practices that impact C,N,H₂O, and determine links to current management practices*
- Develop suite of existing or novel approaches or management practices that leads to net decrease in footprints or increase in C sequestration, with focus on long-term sustainability
- Conduct comprehensive LCA
- Demonstrate adoption of approaches and reductions in footprints

Disciplinary Aims Contribute to Broader Integrated Project Goals



Models Assess Scenarios and Estimate Regional Impacts



Aim 1 – Silviculture and Field Ecology

- Establish a regionwide **three-tiered** monitoring network and develop standardized methods to quantify carbon, water, and nutrient storage and flux baselines and responses to climate and management.
 - Tier I – existing growth & yield monitoring sites measure regional variation in productivity (**500 existing sites**)
 - Tier II - existing silvicultural experiments plus AmeriFlux eddy covariance stations measure effects of management **factors on carbon, nutrient, and water cycles (~140 existing sites)**
 - Tier III – “rainfall-exclusion” treatments in factorial design with silvicultural treatments to measure response to changes in water and nutrient availability (**4 new sites**)

University – forest industry research cooperatives participating in this project

Research Cooperative	Host University (year founded)	# Members
Cooperative Forest Genetics Research Program	University of Florida (1953)	8
Cooperative Tree Improvement Program	North Carolina State University (1955)	25
Forest Biology Research Cooperative	University of Florida (1996)	8
Forest Modeling Research Cooperative	Virginia Polytechnic Institute and State Univ. (1979)	21
Forest Productivity Cooperative	Virginia Polytechnic Institute and State Univ. / NC State Univ. (1969)	55
Plantation Management Research Cooperative	University of Georgia (1975)	17
Southern Forest Resource Assessment Consortium	North Carolina State University (1994)	22
Western Gulf Forest Tree Improvement Program	Texas A&M Univ. / Texas Forest Service (1969)	13

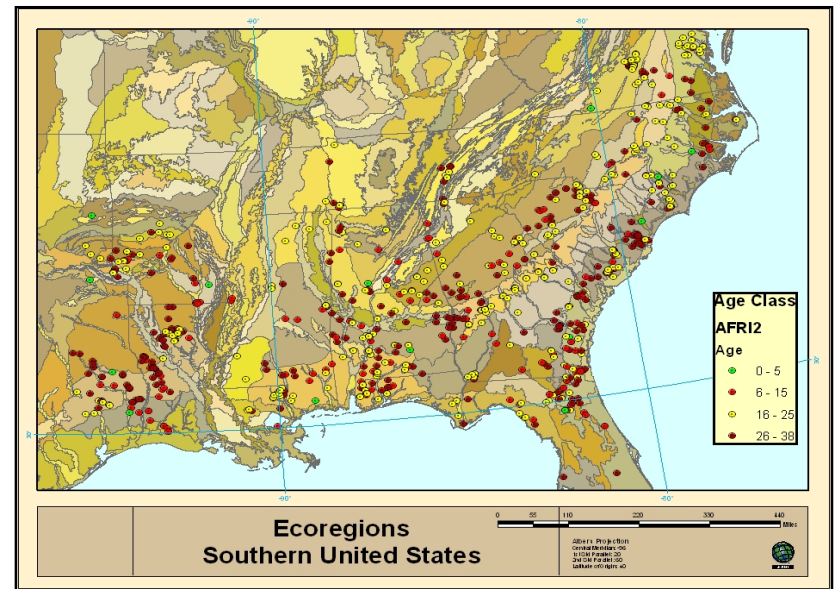
Tier I Studies

- Data from ~500 of the existing of existing growth and yield plots across the region will be used to
 - Characterize climate and geographic effects on tree productivity
 - Validate models
 - Improve growth and yield models



Tier II Studies

- >100 sites chosen from existing replicated experiments
- Measure inventory, C & N pools, soil GHG fluxes and key ecophysiological model parameters
- How do above- and below-ground C and N pools and fluxes, and key ecophysiological modeling parameters, vary with climate, soils, stand development, and management factors?
- Parameterization, verification and validation of growth and yield and carbon models

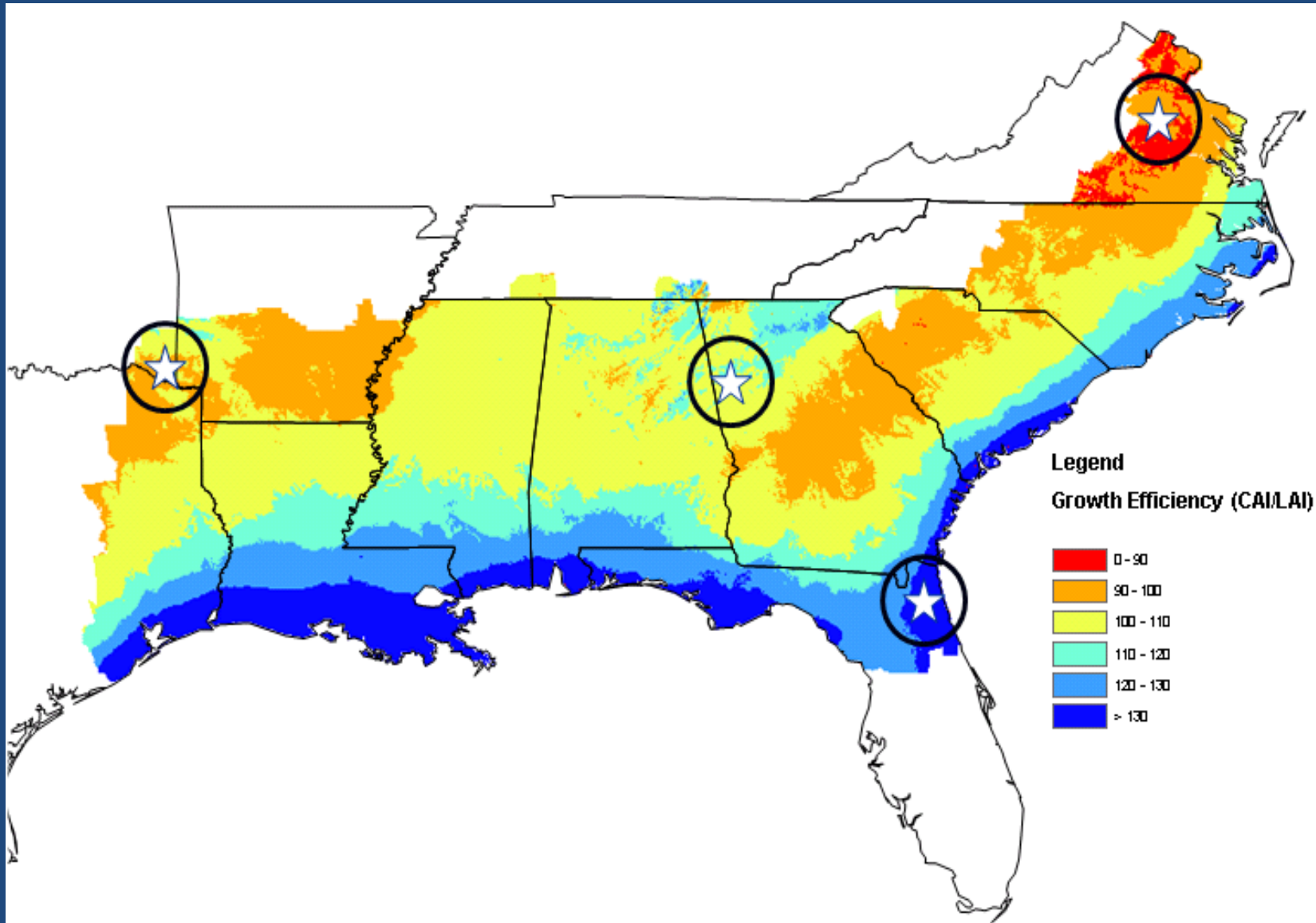


Tier III Studies

- 4 sites chosen to represent contrasts in climate and potential productivity across the full loblolly pine range
- Impose factorial combination of fertilization (control and “optimum”) and precipitation (rainfed and ~ 30% reduction)
- Same measurements as Tier II, plus intensive C, N and H₂O ecophysiology
- Questions same as Tier II, plus extension of parameter space to climatic conditions likely not experienced within the historic loblolly pine range
- Verification and validation of growth and yield, carbon, and water models



Approximate Tier III Locations



Stands

- Stands at or near crown closure
- Orchard mix of genetics appropriate for region
- Planting year
 - Oklahoma, 2008
 - Virginia, 2003
 - Georgia, 2006
 - Florida, 2004

Treatments

- Factorial combination of rainfall reduction and fertilization
- N = 4 at each site
- Gross plot size ~ 0.40 acres,
- Measurement plot size ~ 0.10 acres

Fertilizer

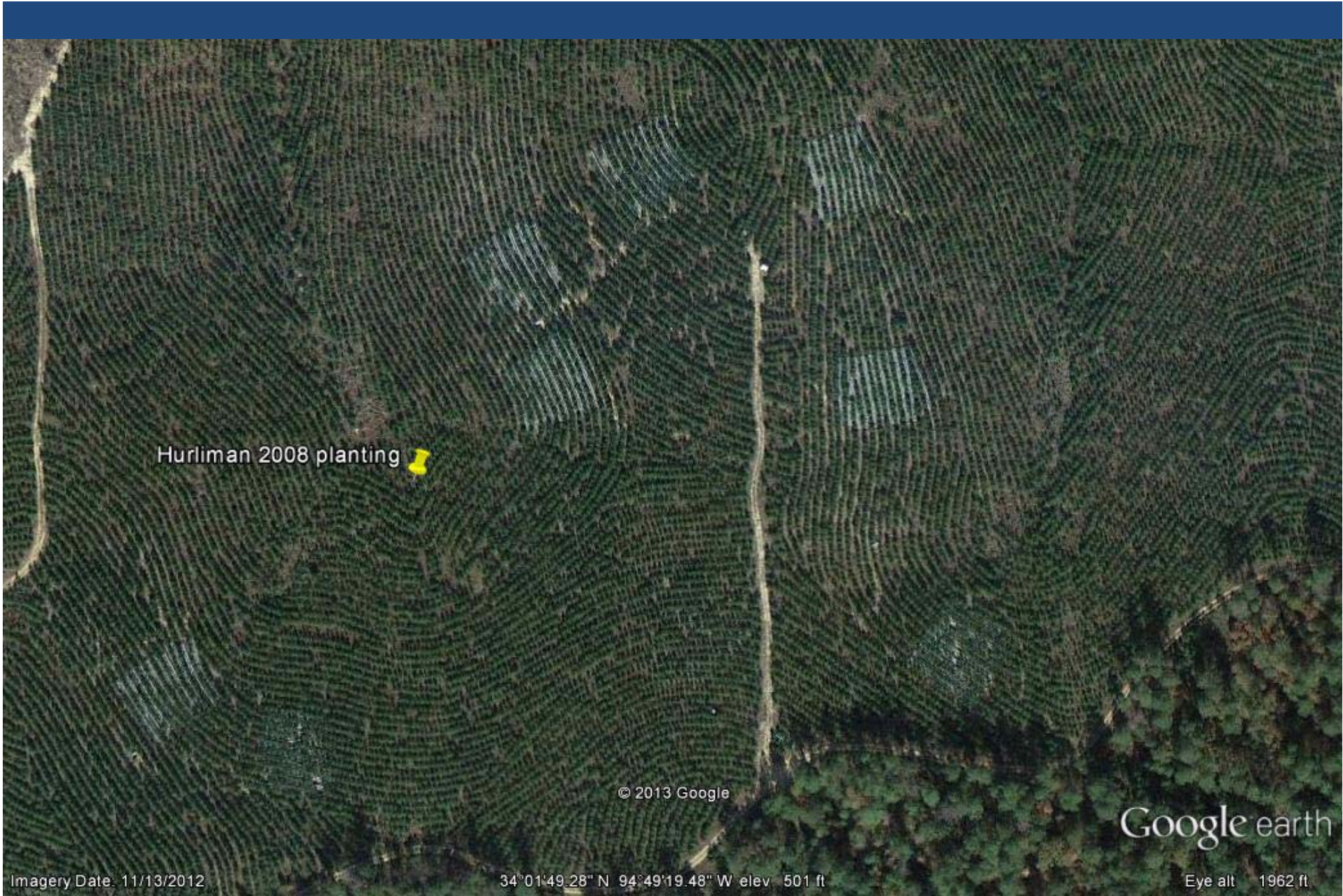
- 200 lbs/ac N
 - 386 lbs/ac urea
 - 125 lbs/ac DAP
- 25lbs/ac P
 - 125 lbs/ac DAP
- 50 lbs/ac K
- Micronutrients (full suite)
 - 1 lb/ac elemental B




Water reduction

- Reduce throughfall by 30%
- Avoid excessive trough widths
- Move excess water away off plots





Hurliman 2008 planting 

© 2013 Google

Google earth

Imagery Date: 11/13/2012

34°01'49.28" N 94°49'19.48" W elev 501 ft

Eye alt 1962 ft

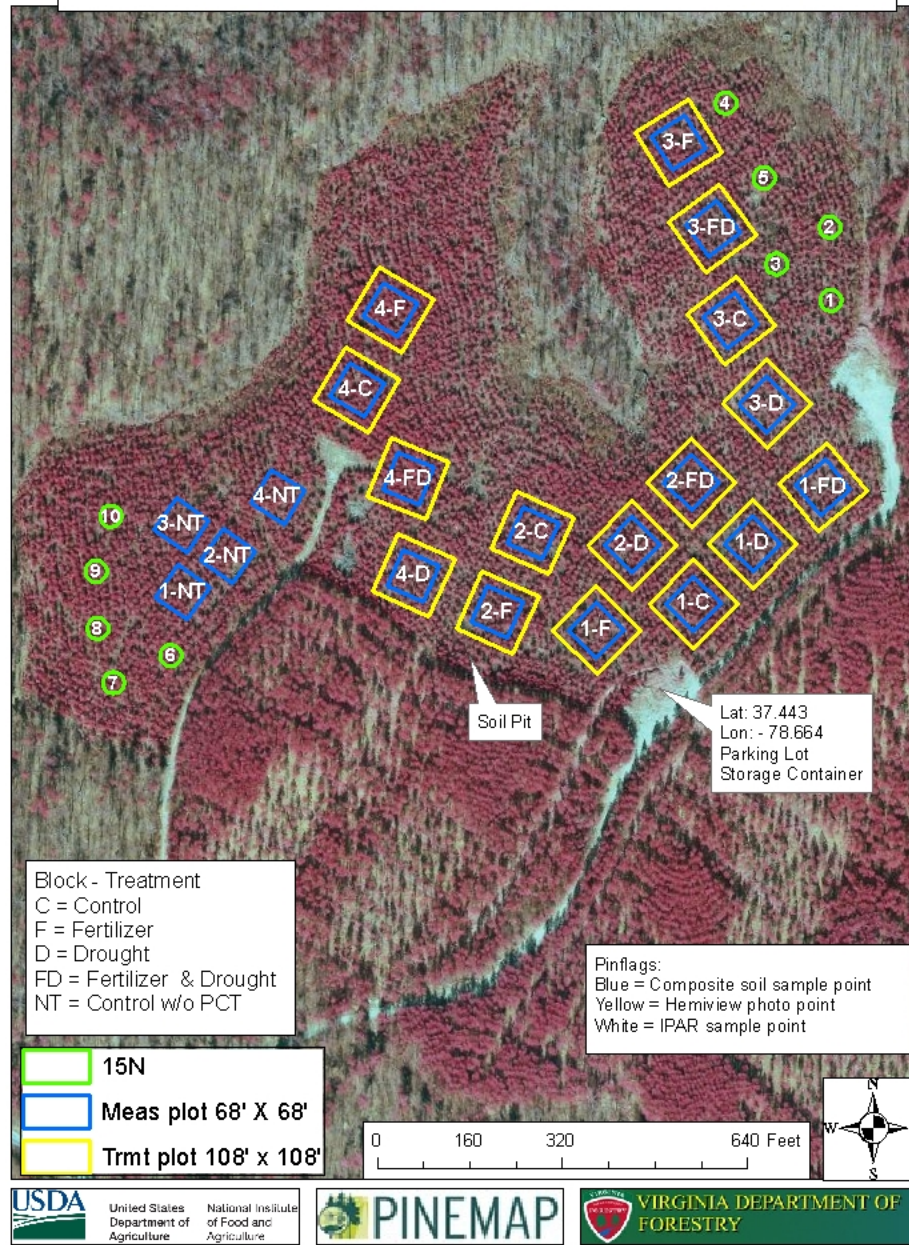


Google earth





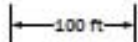
Virginia PINEMAP Throughfall by Fertilization Experiment





PINEMAP UGA/AU Tier III

Taliaferro Co, GA

Scale:  100 ft

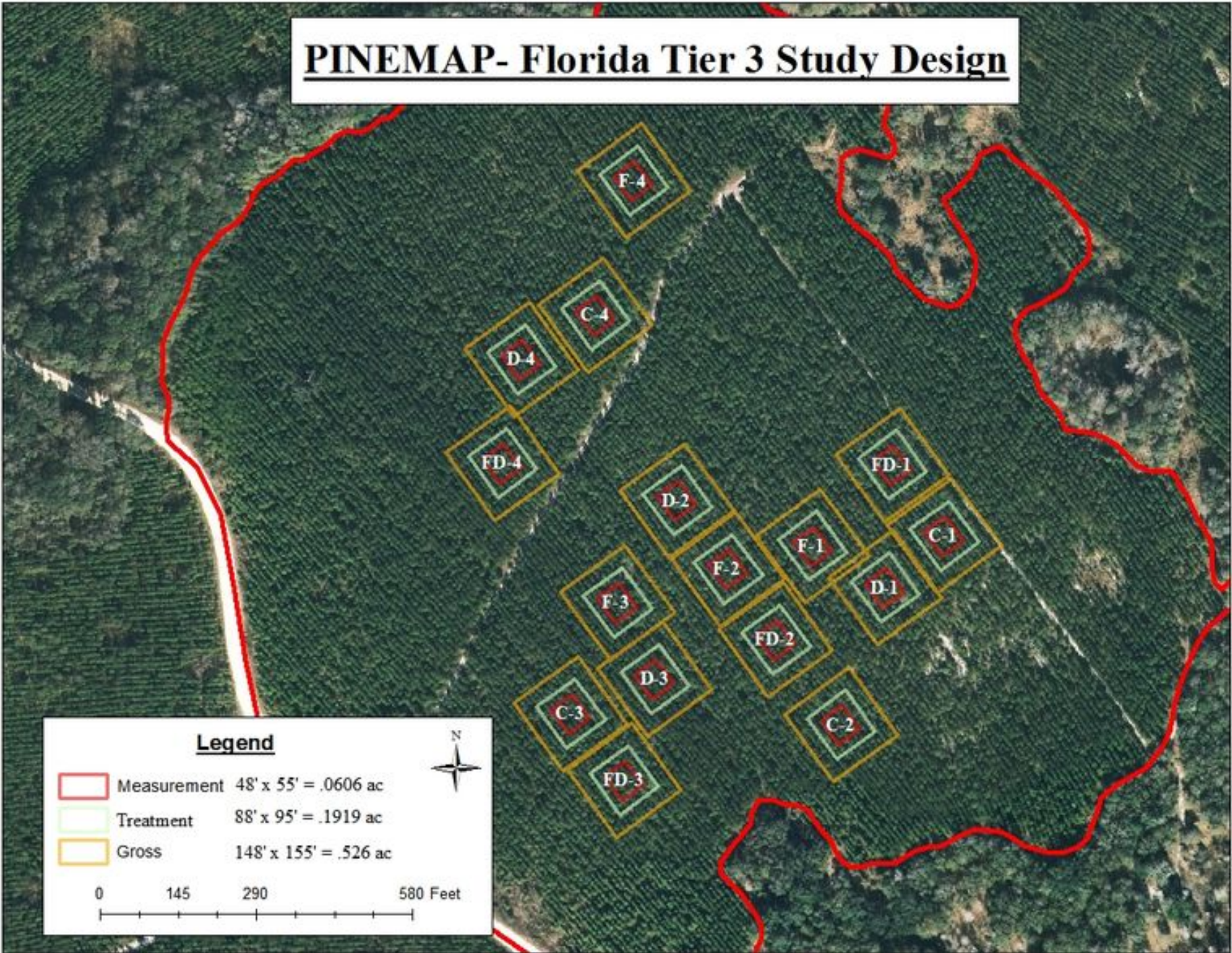
Treatment Plots 92' W x 112' L

Map date 2/10/12





PINEMAP- Florida Tier 3 Study Design





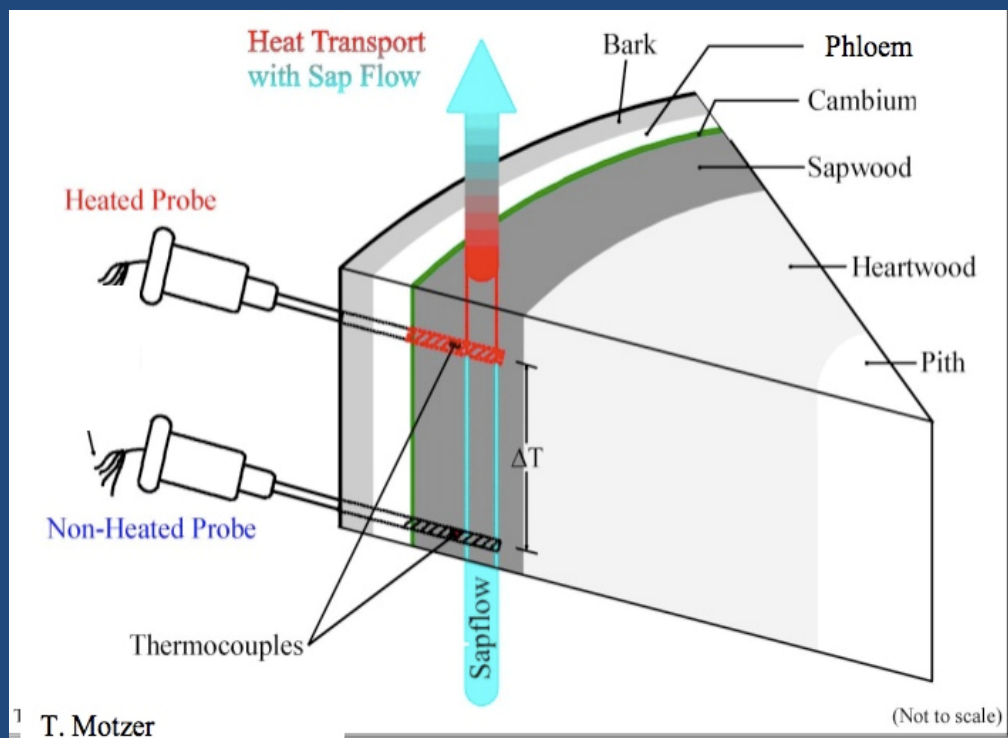
Current status

- Installation of all sites complete
- Data are being gathered
- Disease and insect?
- Snow



Sap Flux Density (J_s) Data

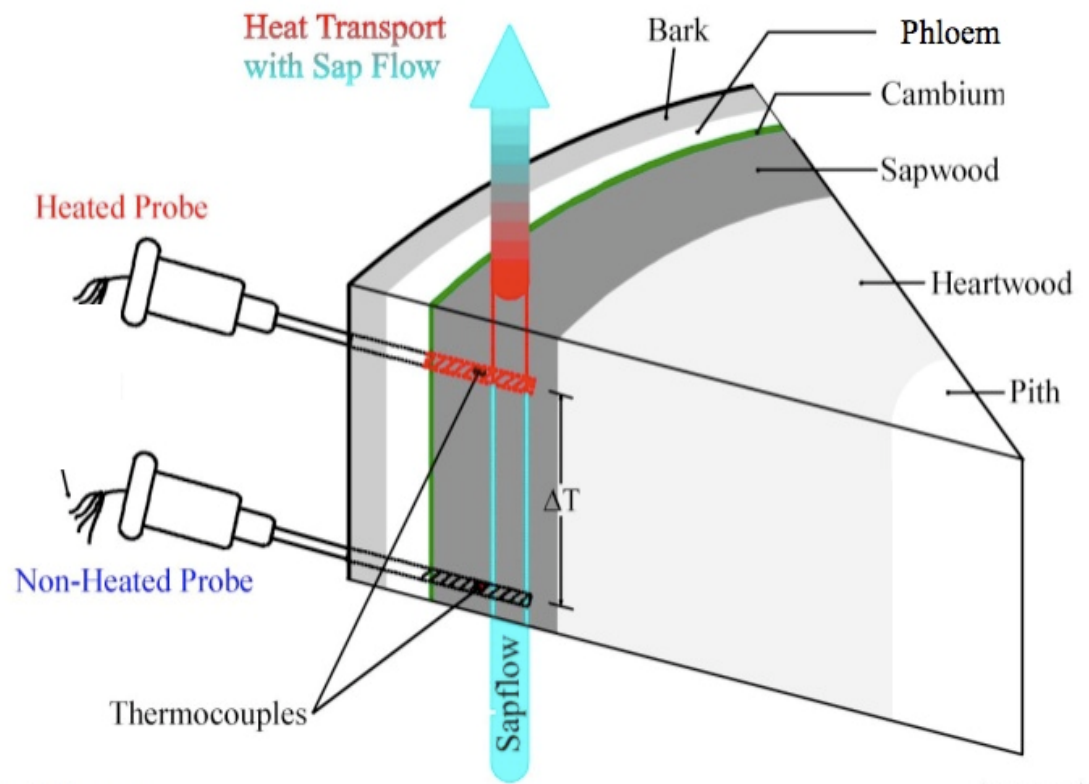
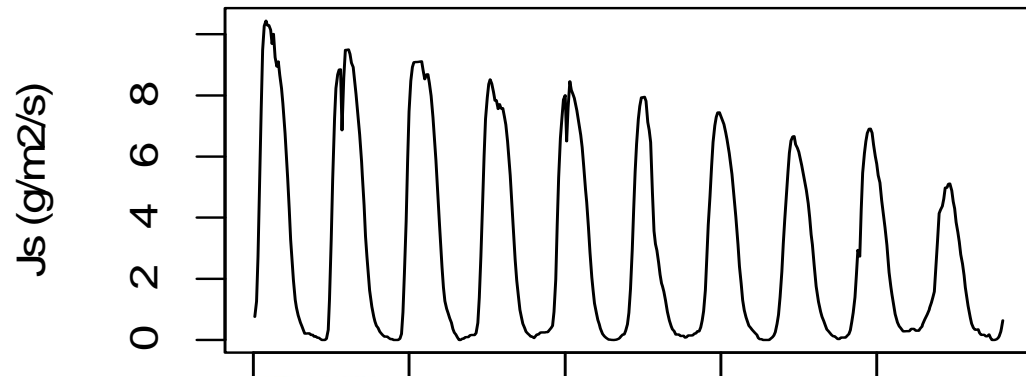
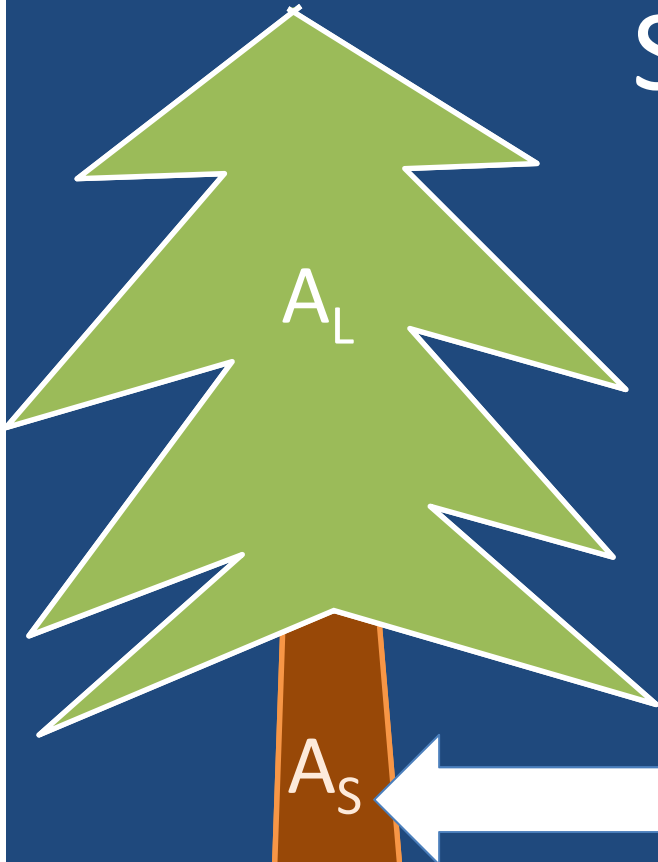
- Estimates water transport in outer sapwood of tree from dissipation of heat.
- Sensor is 20 mm in length, installed in outermost sapwood.
- Largest power consumption of sensors deployed at Tier 3 sites.



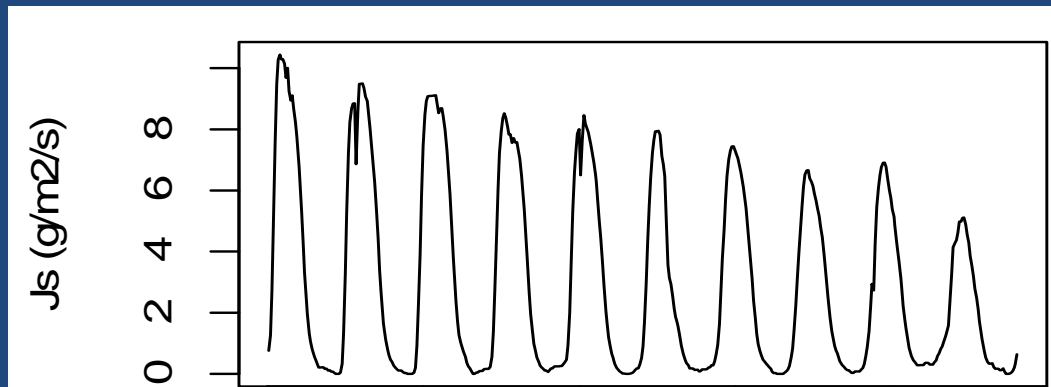
¹ T. Motzer

- Tier 3 Sites: Fertilization x Drought
- 4 Blocks x 4 Treatment Plots
 - 5 Sensors per Plot
 - 30 minute averages
 - Micrometeorological Covariates

Sap Flux Density (J_s) Data



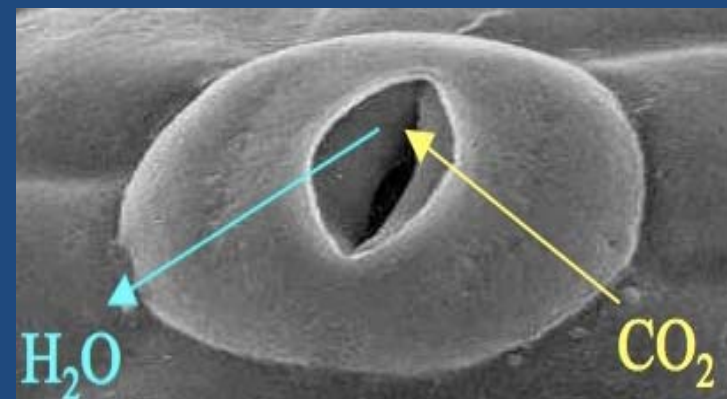
Sap Flux Density (J_s) Data



What are the quantities of interest and what do we need to know to estimate them from J_s of the outer sapwood?

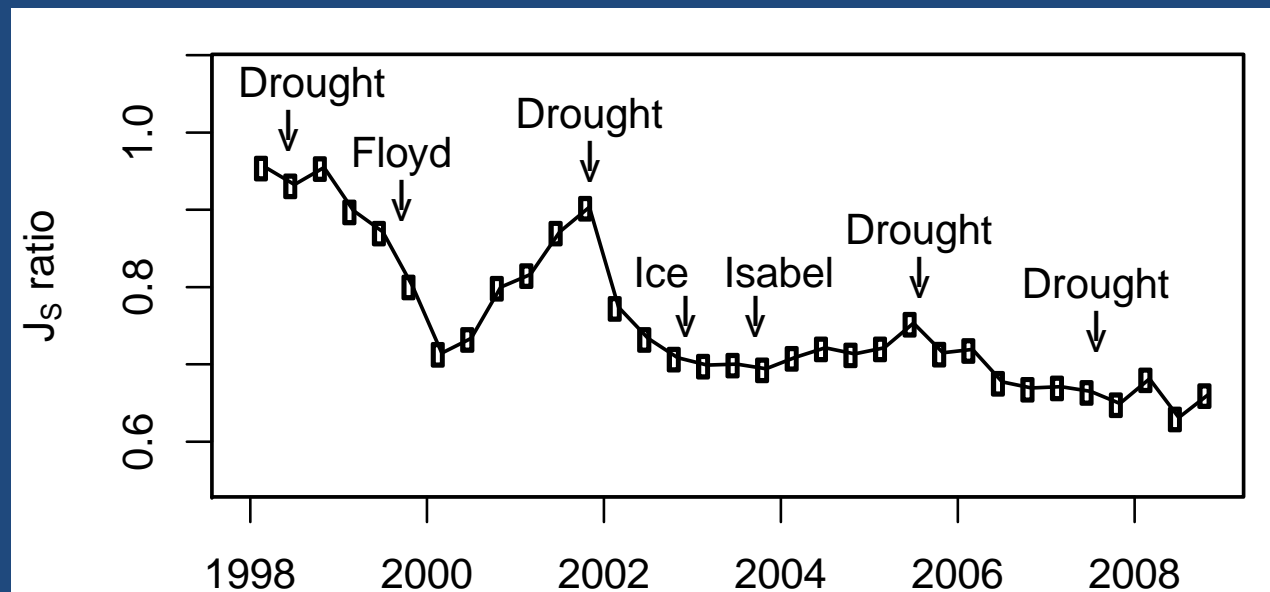
Transpiration is of interest in evaluating the effect of drought treatments. For this, we need estimates of the sap wood area of the stand, as well as the ratio of mean J_s to outer J_s .

Stomatal Conductance is a possible proximate explanation for decreased growth in drought plots, as well as for models such as 3PG. For this we need plot leaf area and site micrometeorological data.



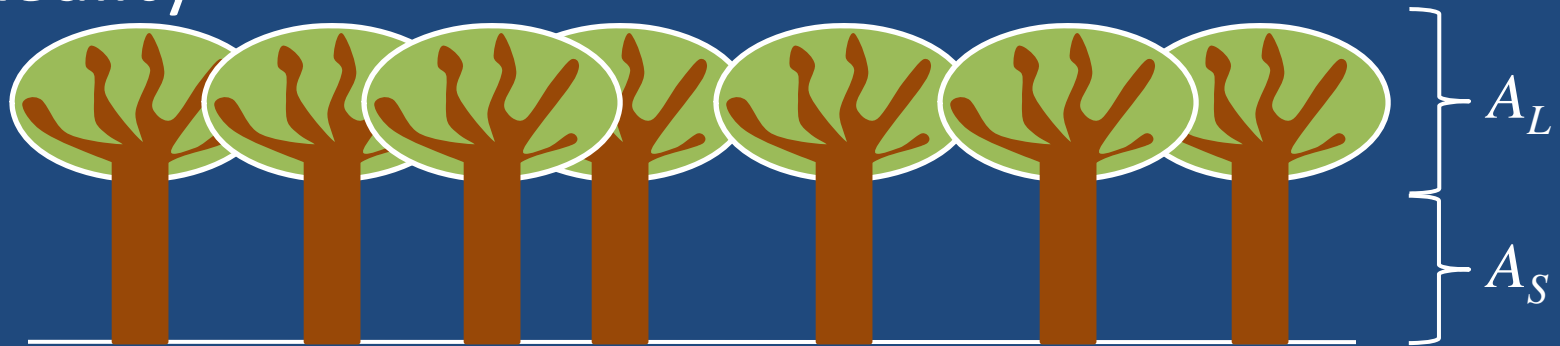
Estimating Transpiration

To estimate transpiration, we need plot sapwood area. To estimate from diameter surveys we need estimates of bark thickness. We also need an estimate of the ratio of mean J_s to outer J_s from another study. One example would be the Duke FACE study, for which the ratio was estimated for 11 years.



Big-Leaf Conductance Model

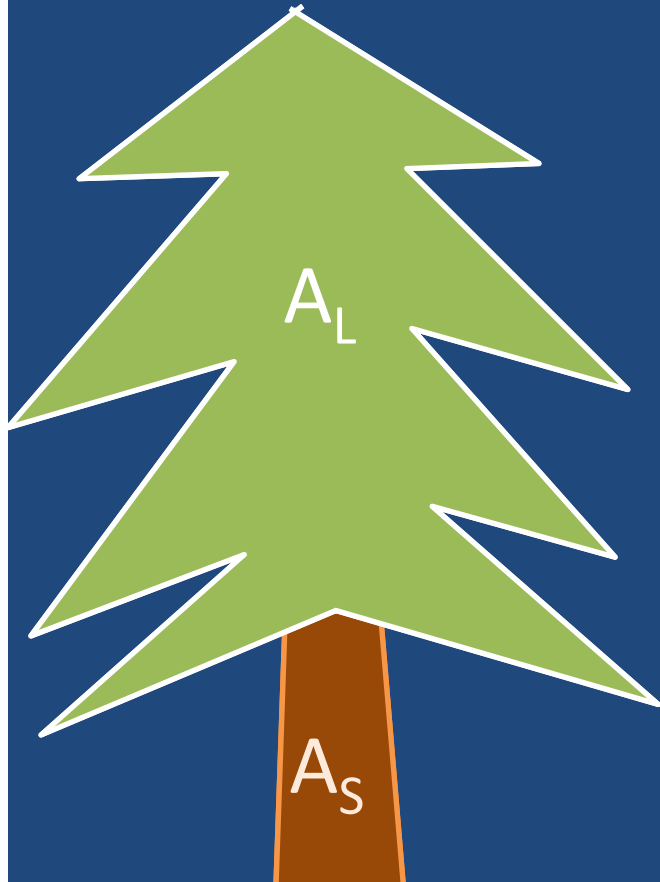
- Reality



- Model

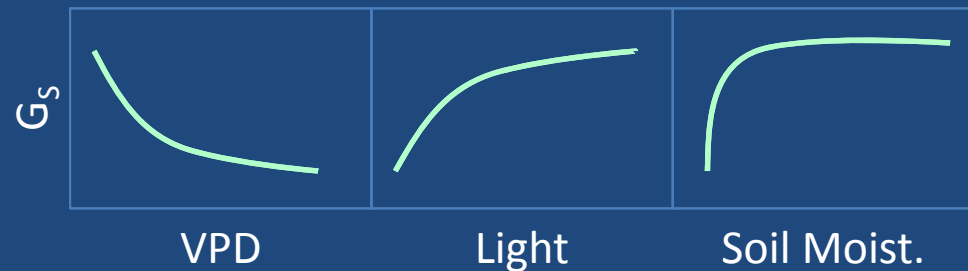


Calculation of Stomatal Conductance (G_s)

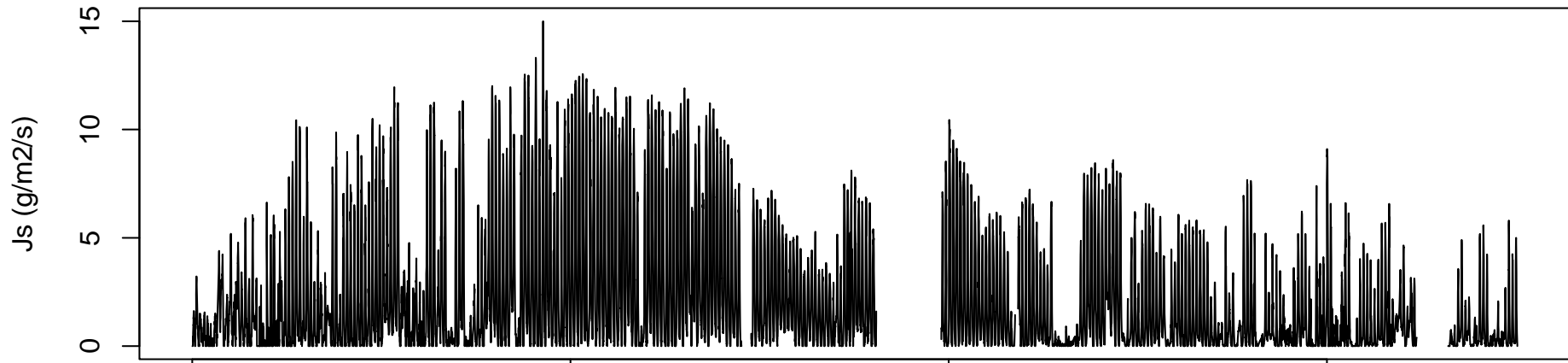


$$G_s \approx J_s \frac{A_s}{A_L} \frac{c}{VPD}$$

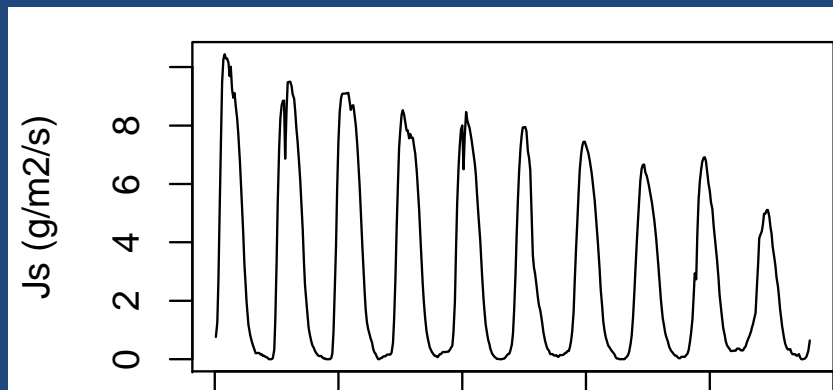
Response of G_s to Environmental Drivers



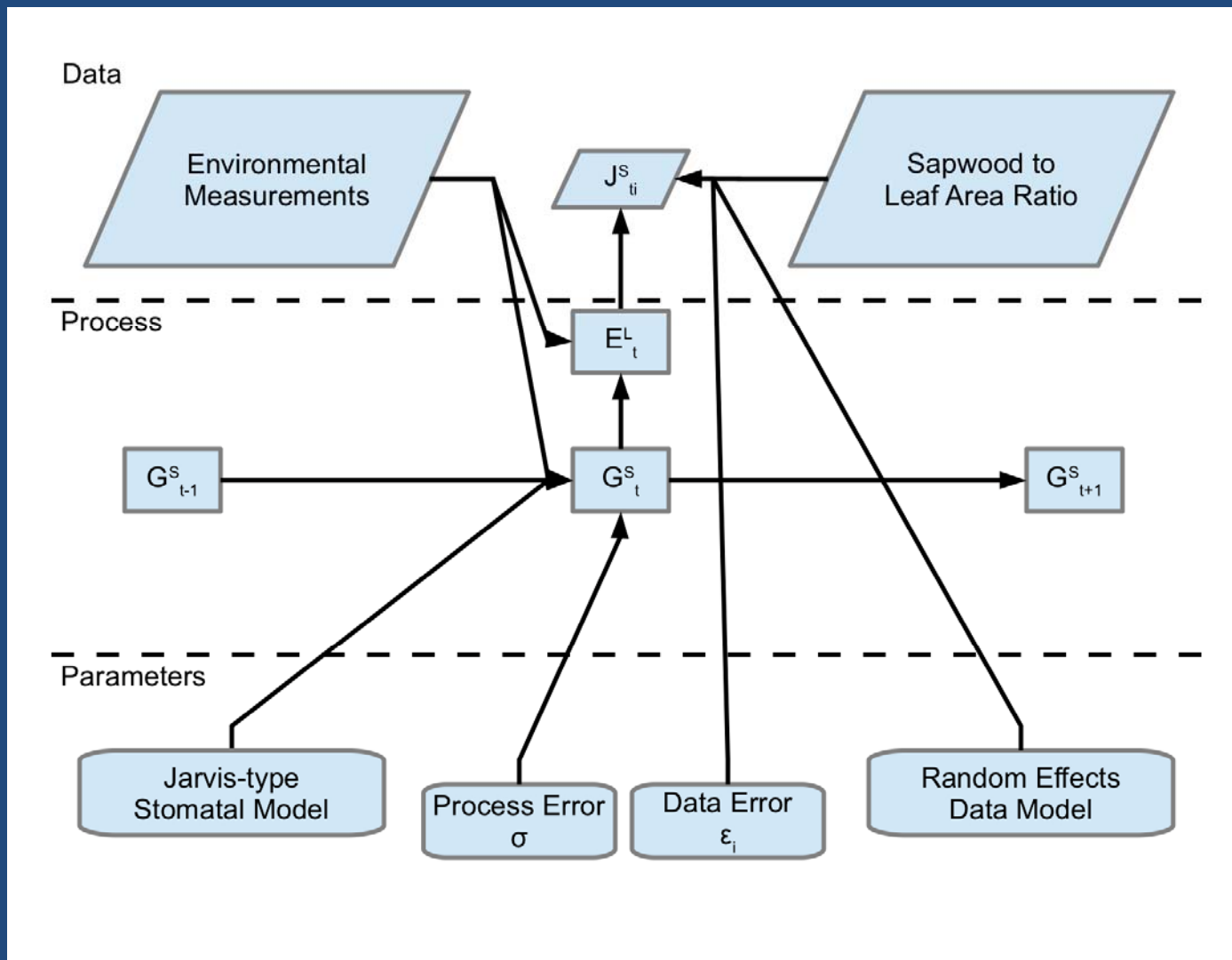
Sap Flux Density (J_s) Data



How does one account for non-random missing data in a small number of sensors, each with different mean J_s to scale plot level transpiration? How do we fit responses of G_s to co-varying environment drivers?



Bayesian State Space Model of G_s



**Concepts and terminology in
carbon cycling research:**

**Why measure Heterotrophic
Respiration?**

How do ecologists describe the Gain and Loss of Ecosystem Carbon?

- How this process is described is dependent on both time scale and spatial scale
- The description varies depending on how many factors are included in the estimate

Net ecosystem production (NEP)

Woodwell and Whittaker's (1968) definitions of NEP:

(A) The difference between ecosystem-level photosynthetic gain of $\text{CO}_2\text{-C}$ (gross primary production, or GPP) and ecosystem (plant, animal, and microbial) respiratory loss of $\text{CO}_2\text{-C}$ (ecosystem respiration, or ER)

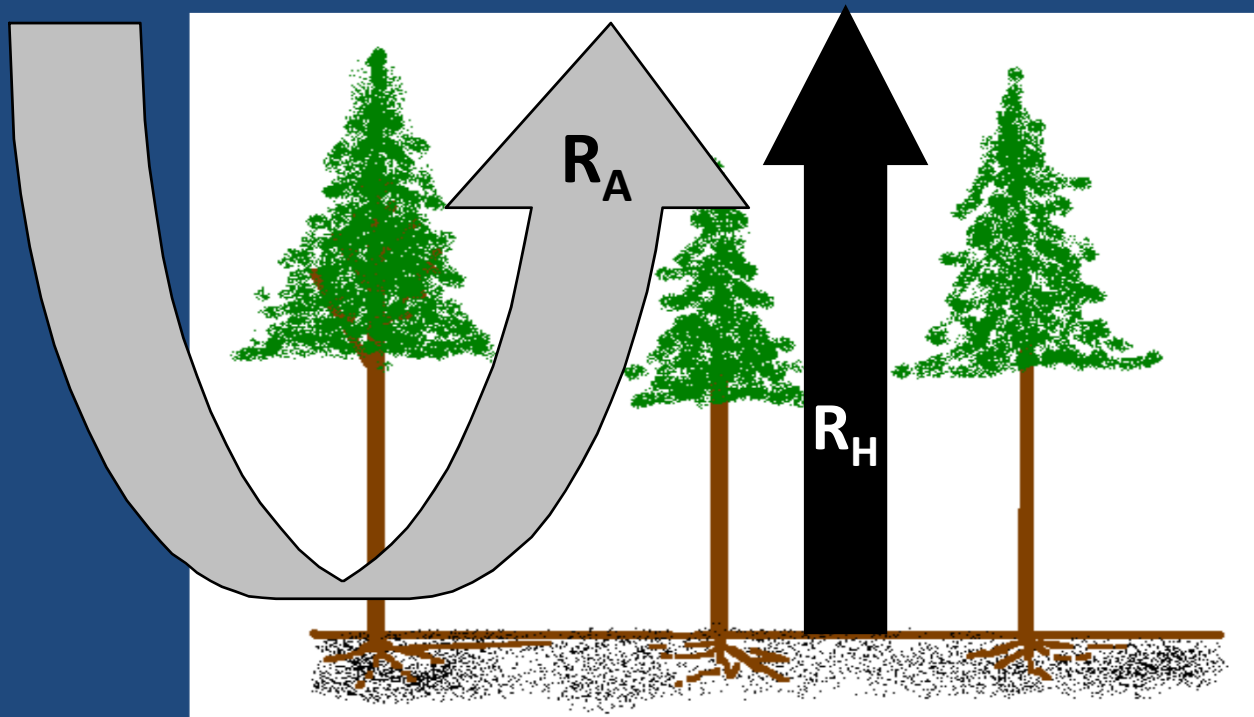
(B) The net rate of C accumulation in ecosystems.

The First Definition of W. and W. 1968

$$\text{NEP} = \text{GPP} - \text{ER}$$

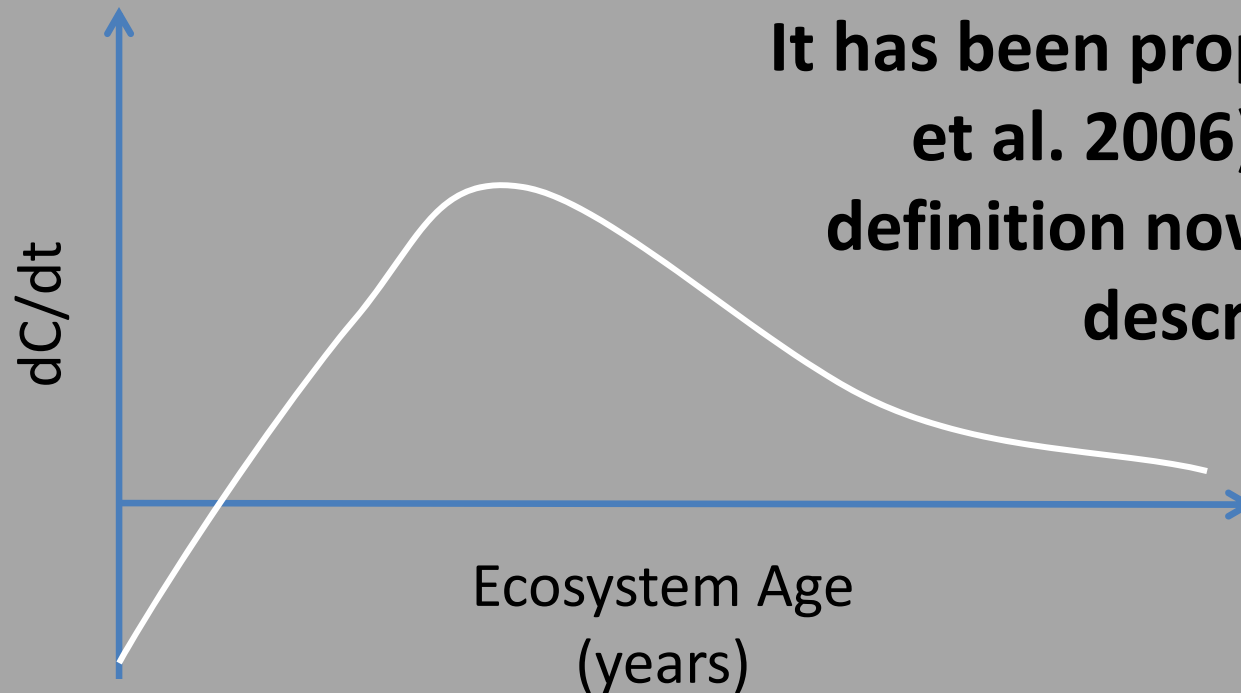
Ecosystem Respiration (ER)

GPP



Focused on
 CO_2
exchange

The Second Definition of W. and W. (1968)



It has been proposed (Chapin et al. 2006) that this definition now be used to describe:

Net Ecosystem Carbon Balance (NECB) =

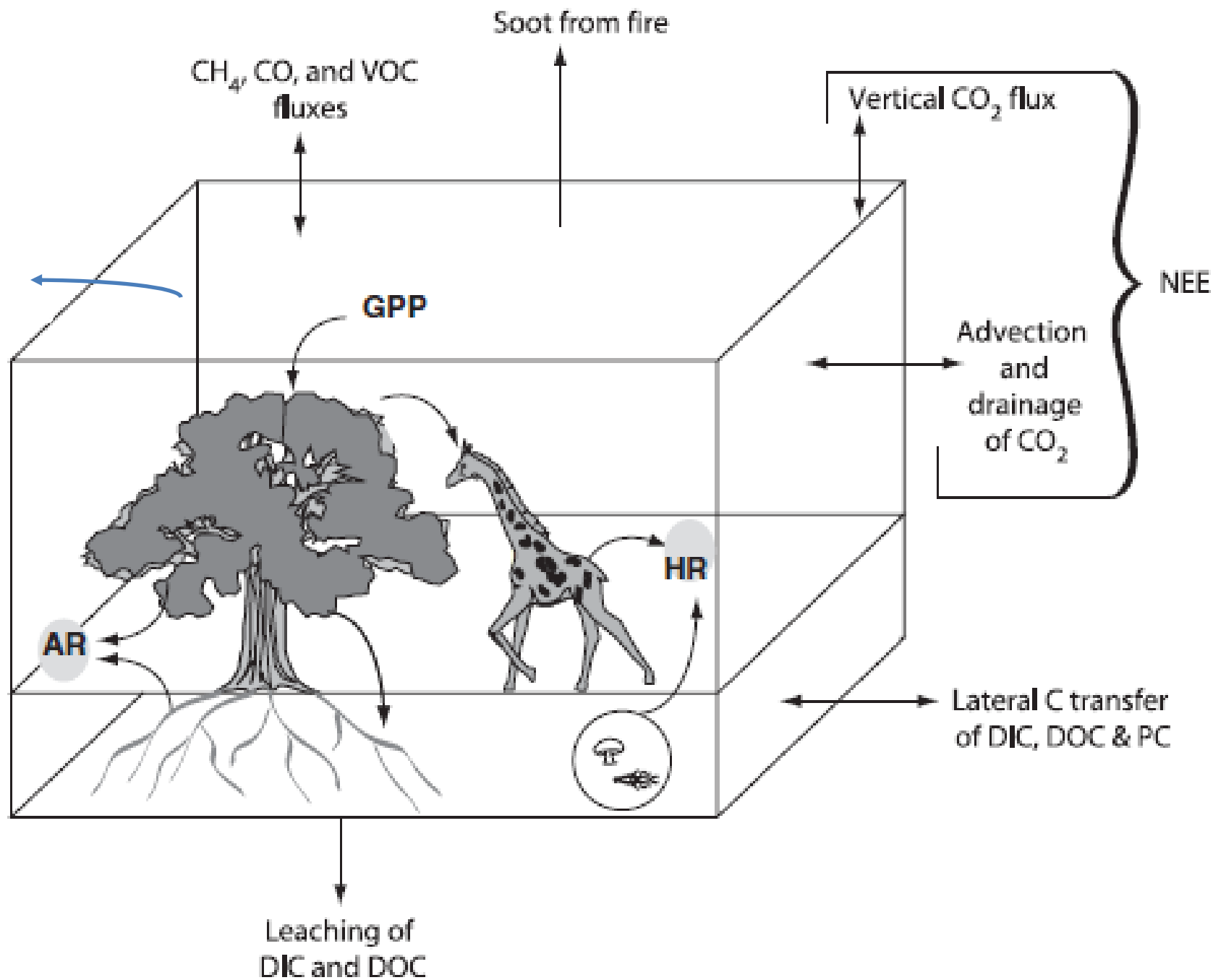
$$\text{NEP}_{\text{CO}_2} + F_{\text{CH}_4} + F_{\text{DOC}} + F_{\text{DIC}} \\ + F_{\text{VOC}} + F_{\text{PM}}$$

Why? Because the smaller fluxes integrated over long timescales (10^2 to 10^9 years) can be very important to terrestrial or atmospheric carbon balance and chemistry

$$\text{Net Ecosystem Carbon Balance (NECB)} = \text{NEP}_{\text{CO}_2} + F_{\text{CH}_4} + F_{\text{DOC}} + F_{\text{DIC}} + F_{\text{VOC}} + F_{\text{PM}}$$

One caveat, Atmospheric Scientists use the term Net Ecosystem Exchange (NEE)

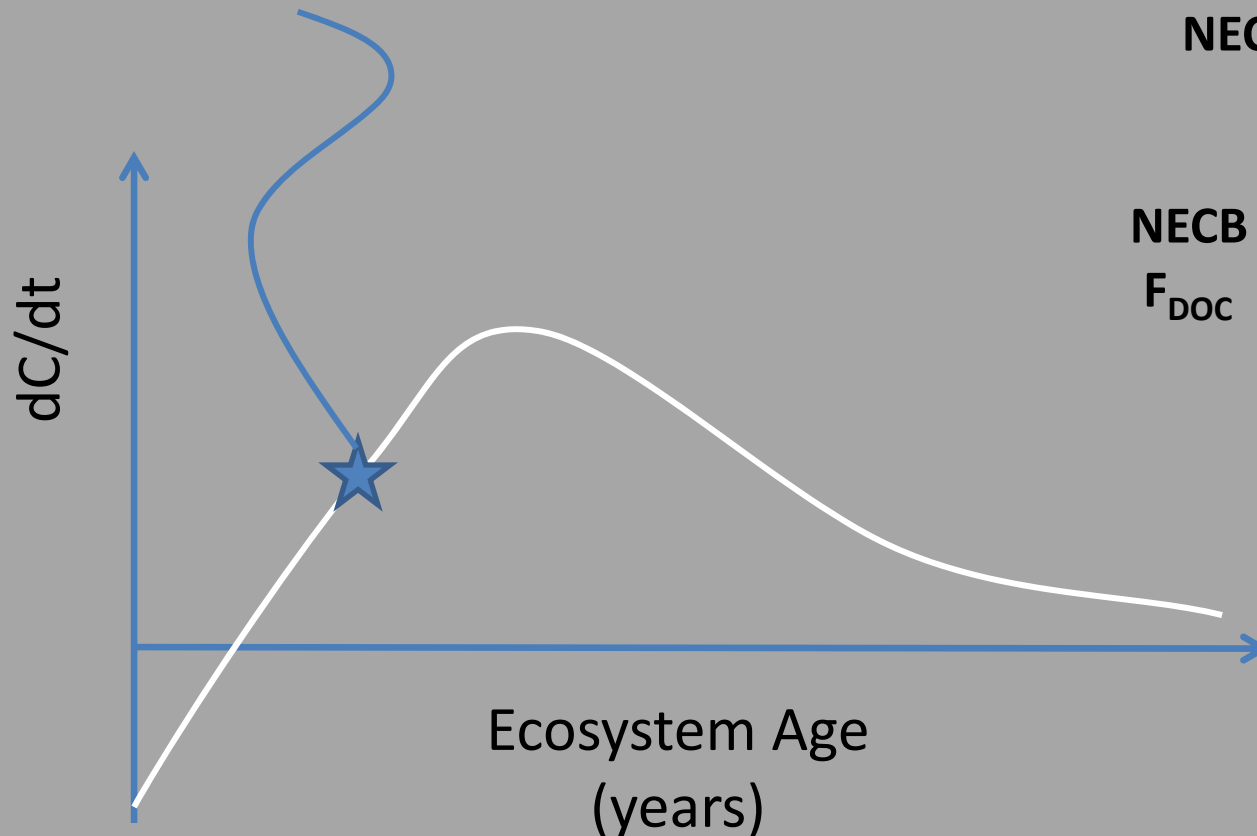
$$\text{NEP}_{\text{CO}_2} = -\text{NEE}_{\text{CO}_2}$$



NEP vs NECB

Consider one time point and GPP and ER are overwhelmingly important (NEP)

Consider the whole chronosequence and NECB is important concept



$$\text{NECB} = -\text{NEE}_{\text{CO}_2} + F_{\text{CH}_4} + F_{\text{DOC}} + F_{\text{DIC}} + F_{\text{VOC}} + F_{\text{PM}} + F_{\text{FP}}$$

For PINEMAP use the NEP concept, but we are not estimating GPP. So how do we get NEP?

Net Primary Production (NPP) = GPP – Ra

NPP is plant C gain or growth

NEP = NPP + Ra – ER

ER = Ra + Rh

So NEP = NPP + ~~Ra~~ – ~~Ra~~ – Rh

Thus,

NEP = NPP - Rh

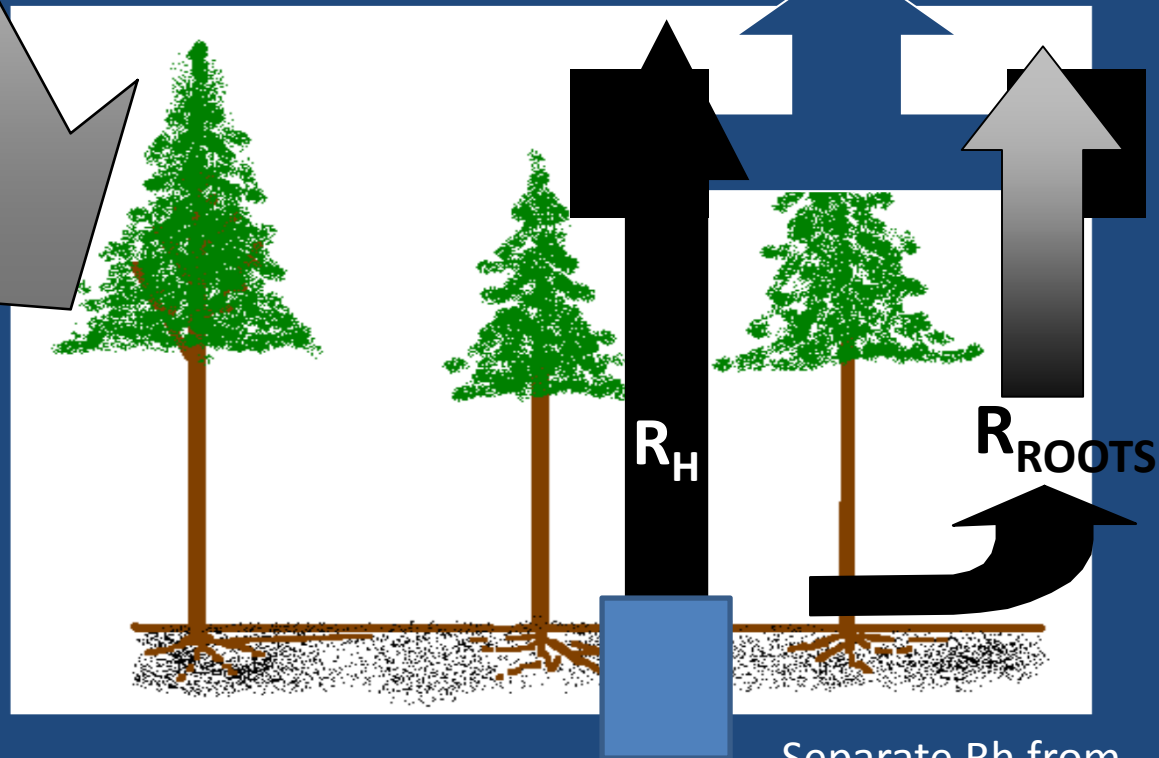
Most Rh generally comes from microbial decomposition of organic matter
(not from giraffes (animals))

The Annual Carbon Budget

NPP

$$R_{\text{ROOTS}} = \text{SCE} - R_h$$

Soil CO₂ efflux (SCE)



Separate R_h from
 R_{ROOTS} with barriers

PINEMAP's Approach: Estimate NPP- Rh under many treatments

