

Continuing Project

Assessing & Mapping Regional Variation in Site Productivity

CAFS.19.75

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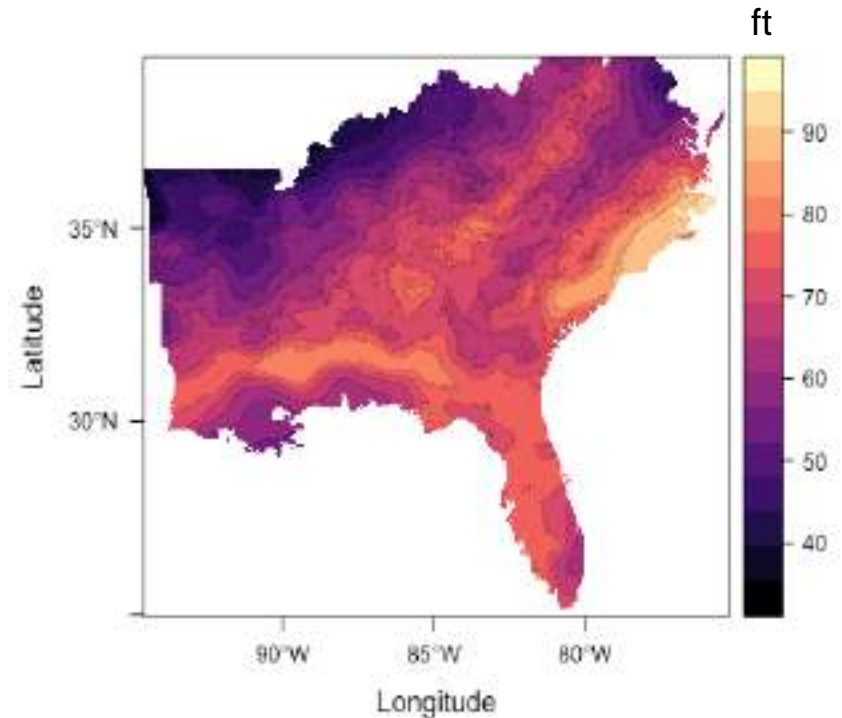
Presented by:

Rachel Cook and Cristian Montes

North Carolina State University and University of Georgia



What drives site productivity and how do we make predictions?



Objectives

1. Develop a consistent and biologically meaningful metric of potential site productivity
2. Relate soils, geology, and environmental variables to predict site productivity
3. Map across major forest regions



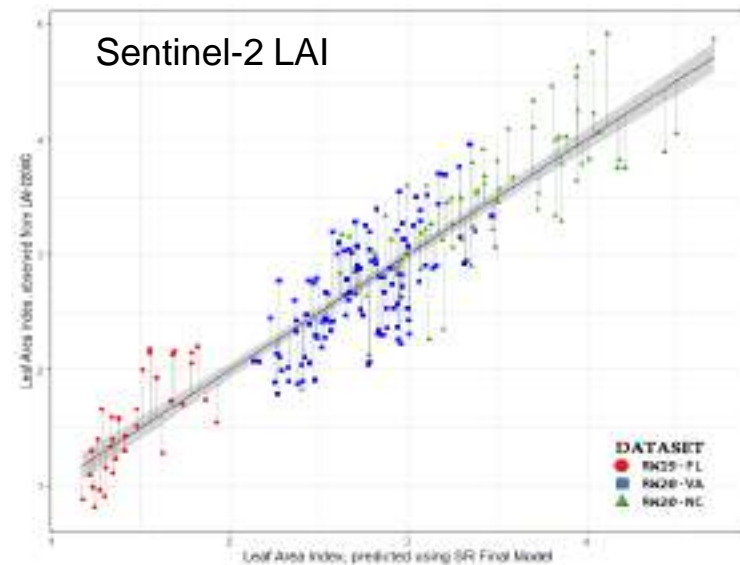
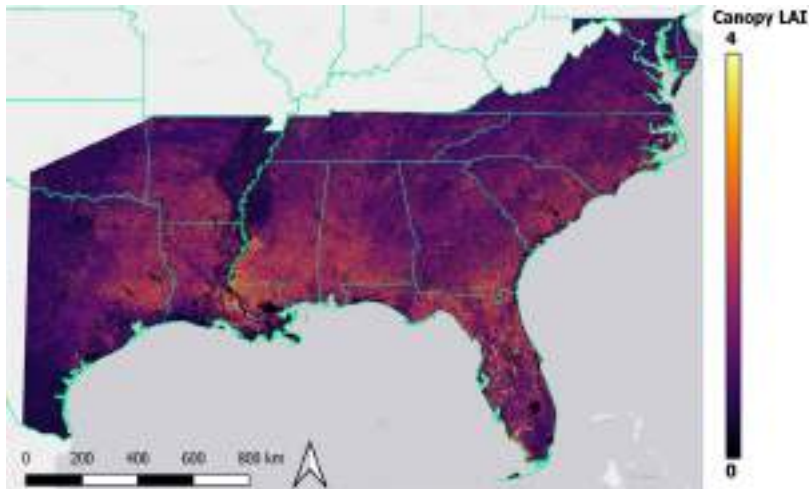
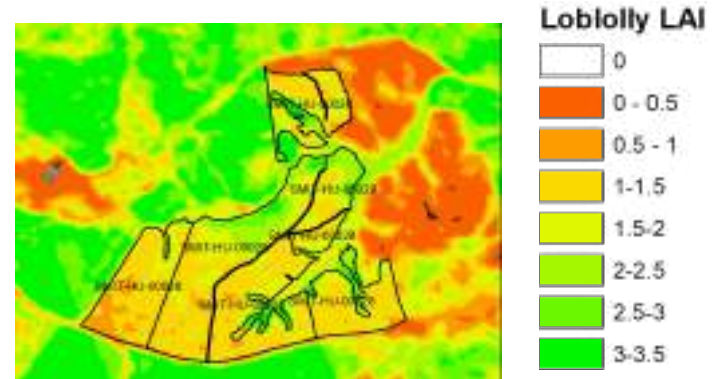
Experimental Plan

- Long-term measurements of stand conditions ✓
- High-resolution rasters of environmental factors ✓
- Spatially model soil characteristics that influence site productivity ✓
- Incorporate LAI and age of stands (almost ✓)



Quantifying site productivity

- What is site productivity exactly?
 - LAI
 - Site Index
 - Response to Fertilization:
 - Height
 - Basal area
 - Volume

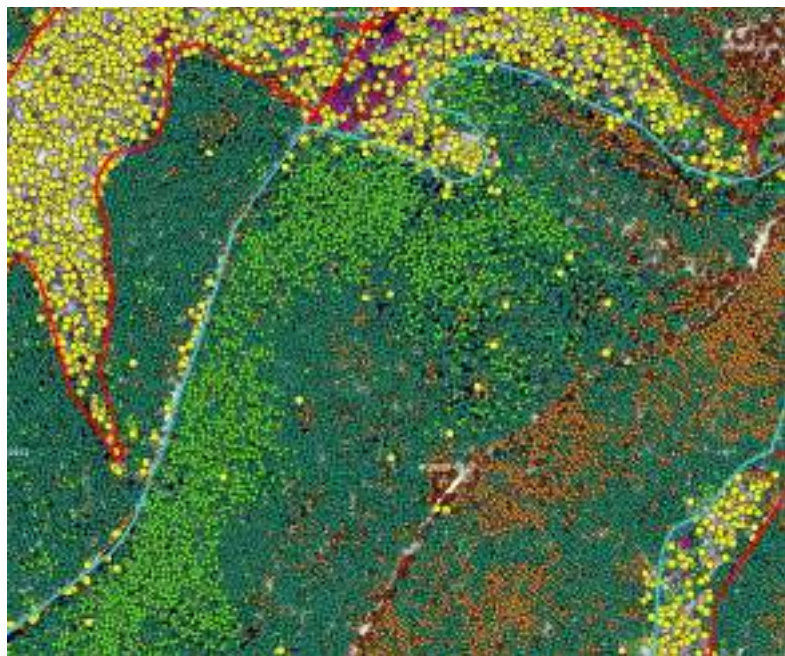


Cohrs et al., 2020. Sentinel-2 LAI Estimation for Pine Plantations in the SEUS. Remote Sensing



Site Index Mapping in Progress

- Operational cruise data and LiDAR to map SI ranges to soils



SI from LiDAR

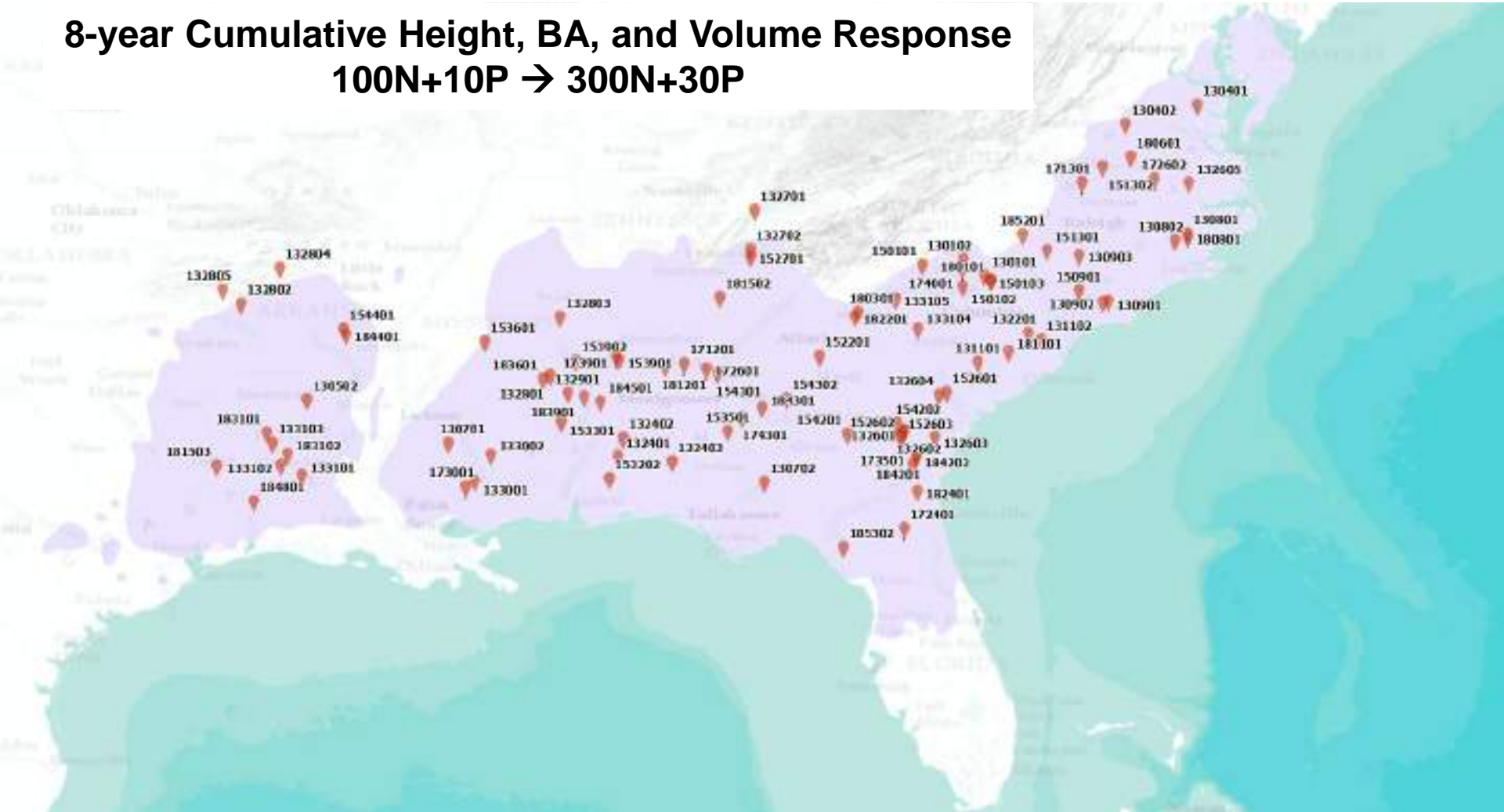


SI from x,y coordinates



Fertilizer Response Modeling

8-year Cumulative Height, BA, and Volume Response
100N+10P → 300N+30P



Soil & Climate Variables

<i>hydraulic</i>	water table depth		
	available water storage		
	potential wetland soil class		
	ponding frequency		
	hydric rating / hydrologic group		
	soil moisture subclass		
	drought tolerance		
runoff potential			
<i>physical</i>	depth to bedrock		
	soil thickness		
	soil organic carbon		
	root zone		
	soil loss to erosion/wind		
	particle size class		
	depth to B horizon		
	soil profile texture		
	cation exchange capacity		<i>chemical</i>
	CEC activity class		
	total exchangeable bases / hydrogen ions		
	relative pH		
	aluminum saturation		
	slope gradient		<i>other</i>
	N rate	from non-SSURGO sources	
	P rate		
	fertility rating		
	physiographic province		

Extracted from weather stations within 40 km of sites

Average minimum and maximum for whole-year & growing season

- **Temperatures**
- **Precipitation**
- **Vapor pressure deficit (VPD)**

- **Included**
 - long-term averages
 - first-year after fertilization
 - four years following fertilization

<i>Model</i>	<i># of predictor variables</i>
soils only	69
climate only	30
soils + climate	99



Model Performance

<i>Response variable</i>	<i>soils only</i>	<i>soils + climate</i>	<i>climate only</i>	<i>soils only</i>	<i>soils + climate</i>	<i>climate only</i>	<i>Response Variable Range (min value, max value)</i>
	<i>RMSE</i>	<i>RMSE</i>	<i>RMSE</i>	<i>R²</i>	<i>R²</i>	<i>R²</i>	
Cumulative height growth (m)	0.88	1.13	1.18	0.34	0.38	0.38	7.16 (1.70, 8.86)
Cumulative basal area growth (m ² ha ⁻¹)	2.66	3.23	5.20	0.39	0.41	0.21	18.02 (3.29, 21.31)
Cumulative volume growth (m ³ ha ⁻¹)	29.92	37.55	35.16	0.45	0.23	0.26	228.28 (33.08, 261.37)
Cumulative height growth response (m)	0.54	0.50	0.55	0.20	0.20	0.16	3.10 (0.002, 3.11)
Cumulative basal area growth response (m ² ha ⁻¹)	1.96	1.96	2.06	0.15	0.16	0.10	10.55 (0.06, 10.61)
Cumulative volume growth response (m ³ ha ⁻¹)	17.89	18.90	21.11	0.13	0.23	0.19	102.19 (0.51, 102.70)



conversion assist :

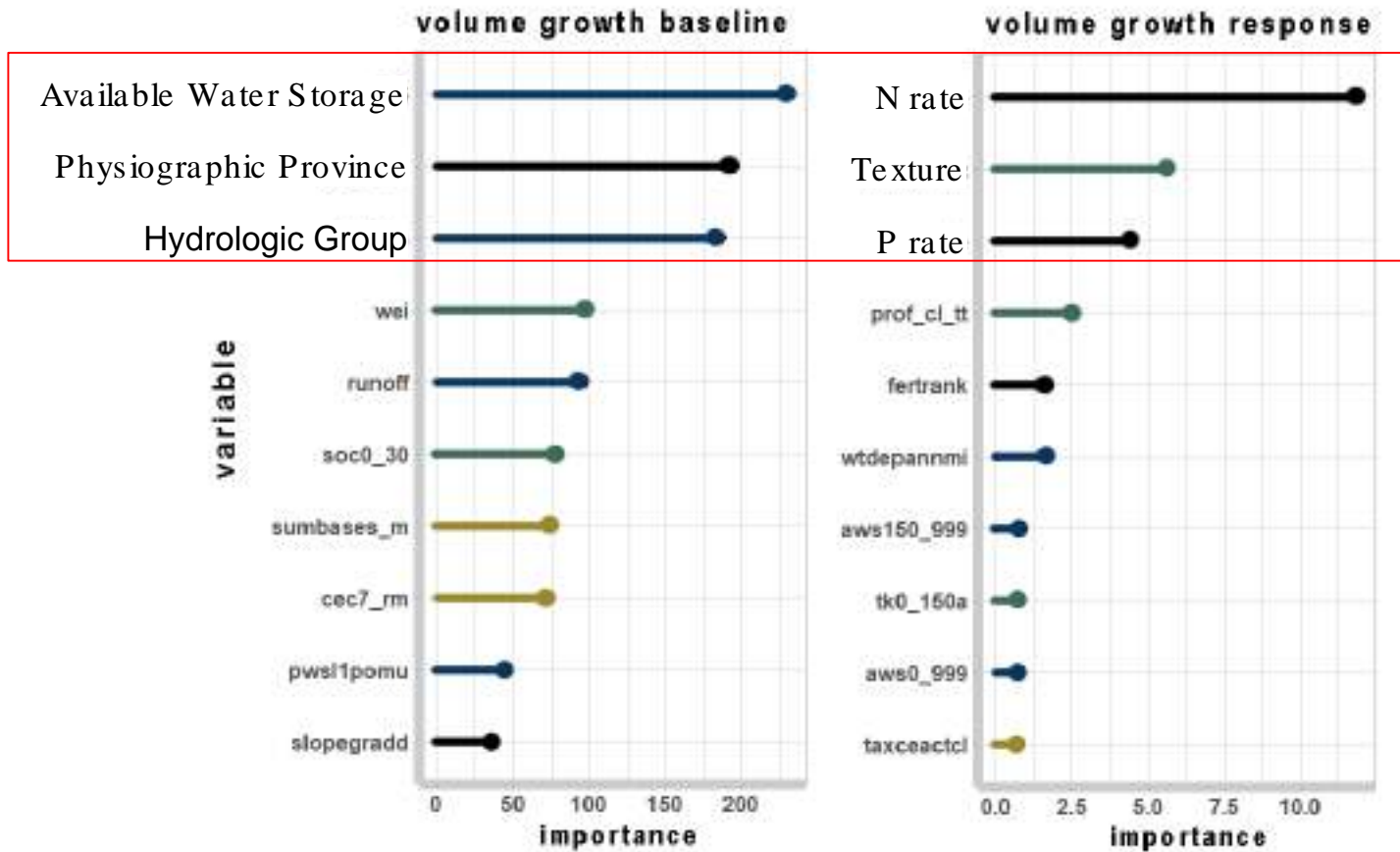
1 m is equal to 3.28 ft

1 m² ha⁻¹ is equal to 4.359 ft² ac⁻¹

1 m³ ha⁻¹ is equal to 14.3 ft³ ac⁻¹ or 0.676 tons ac⁻¹



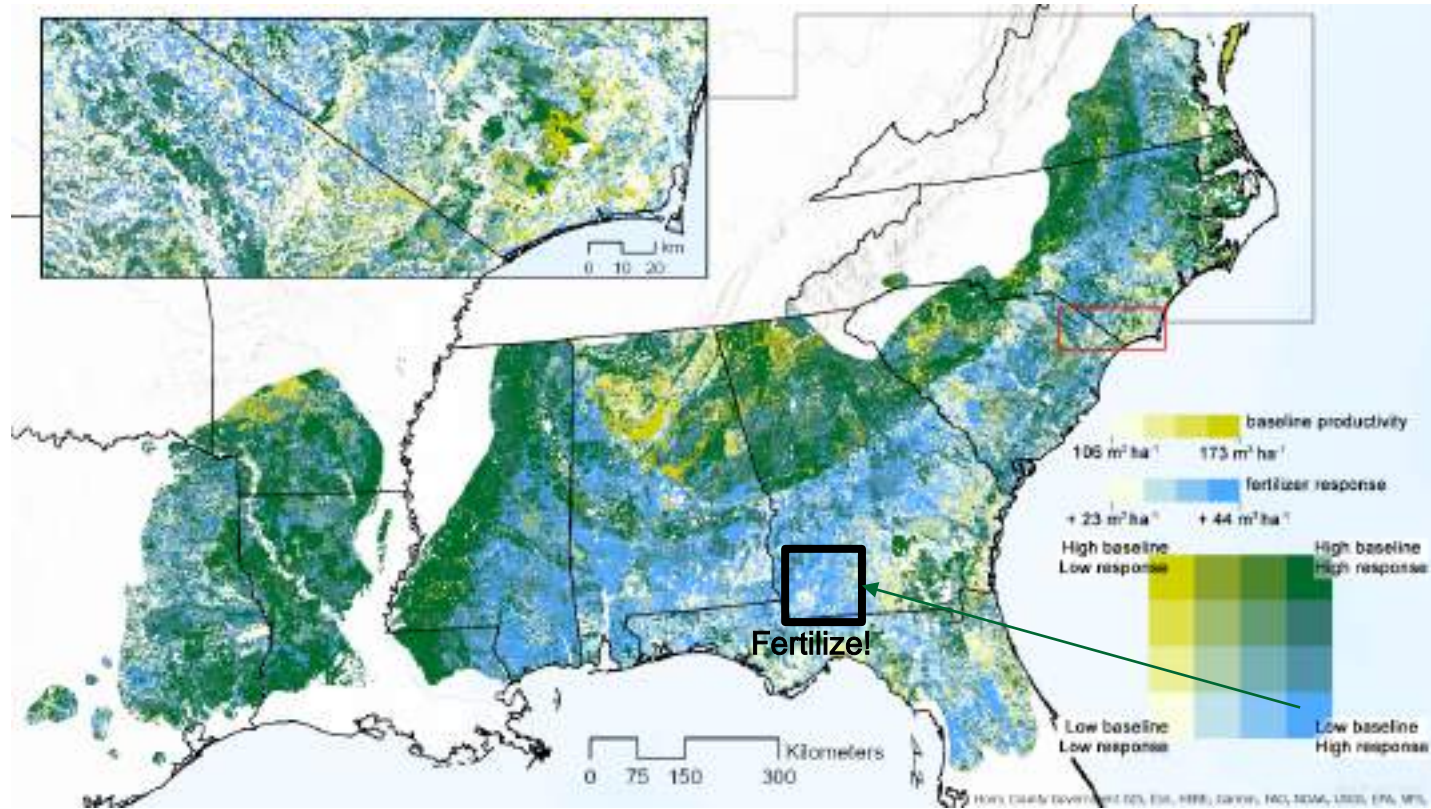
Variable Importance



hydraulic physical chemical other



Predictive maps



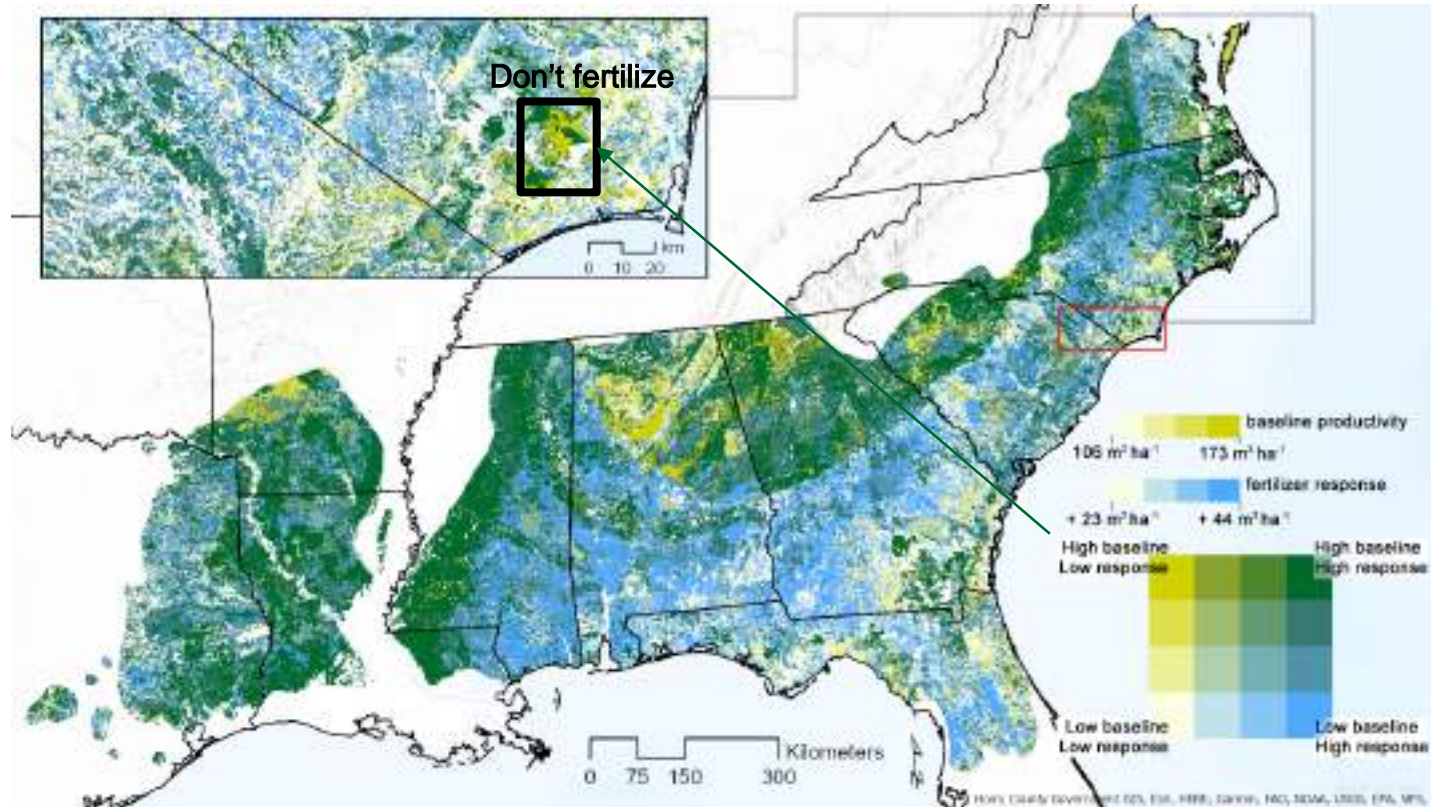
conversion assist :

1 m³ ha⁻¹ is equal to 14.3 ft³ ac⁻¹ or 0.676 tons

1 km is equal to 0.621 mi



Predictive maps



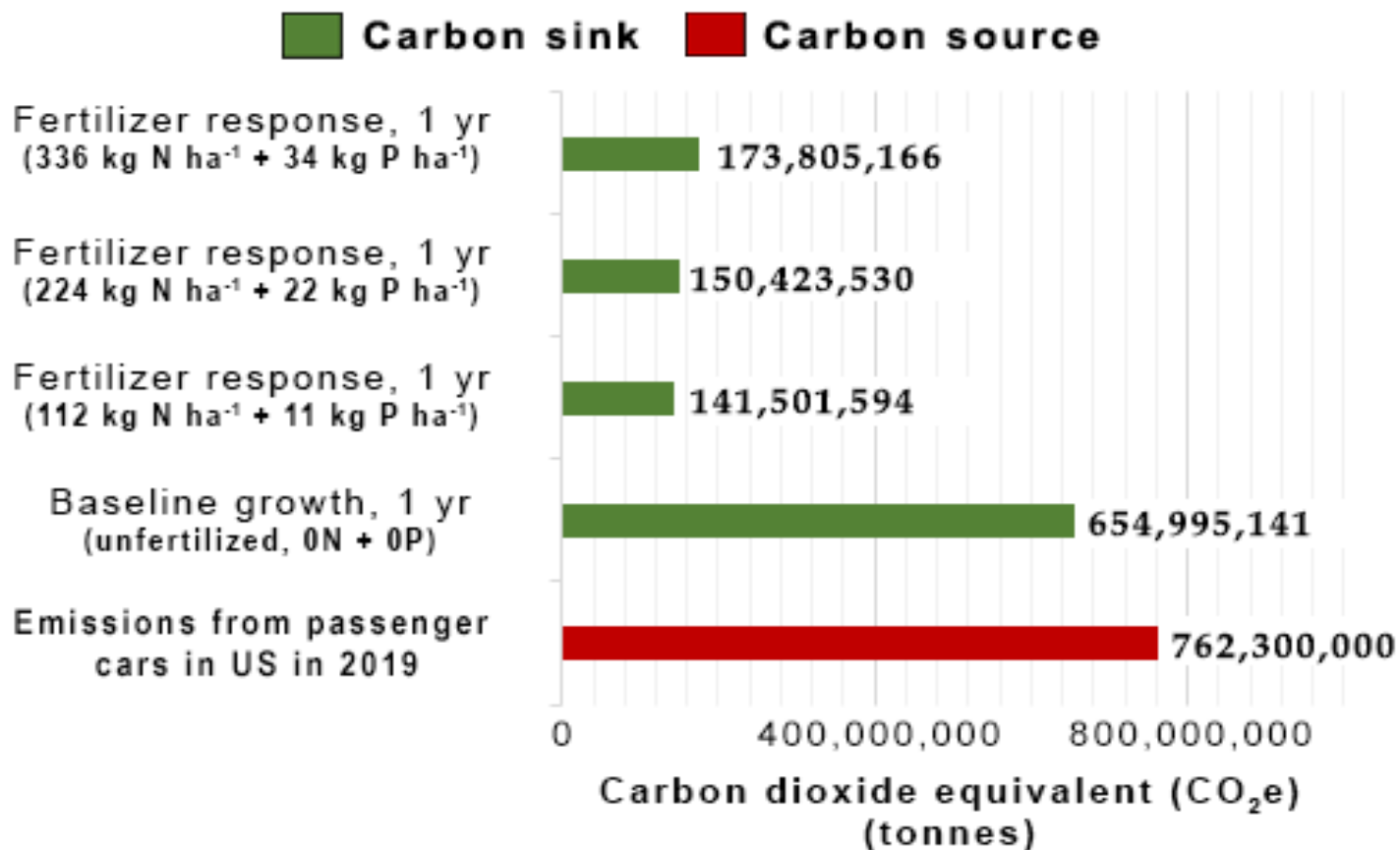
conversion assist :

1 m³ ha⁻¹ is equal to 14.3 ft³ ac⁻¹ or 0.676 tons

1 km is equal to 0.621 mi

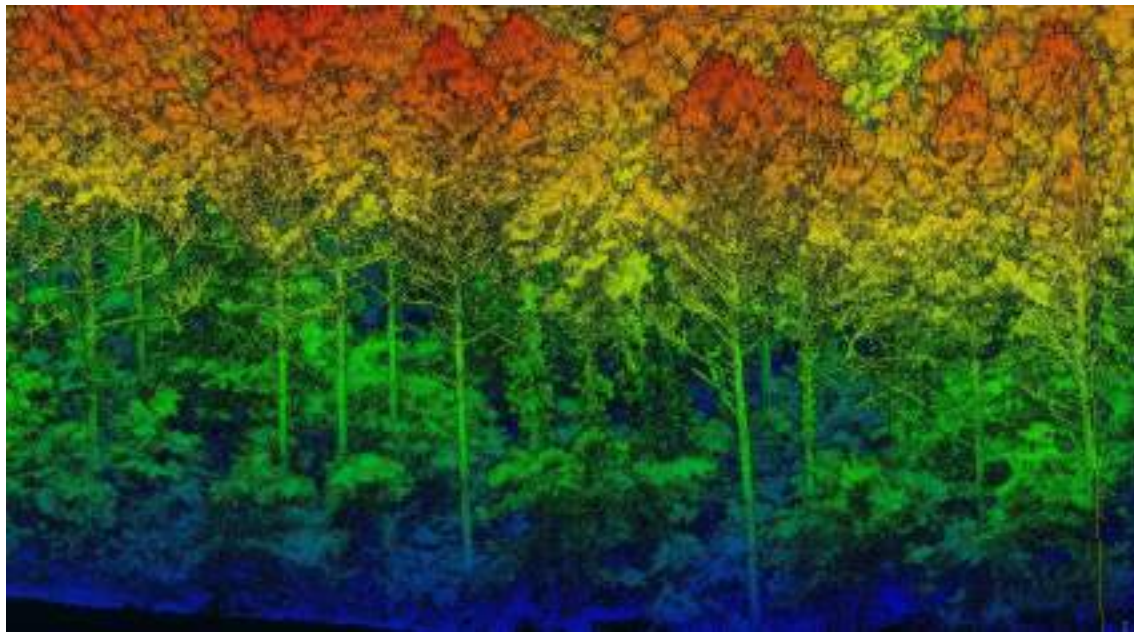


Potential Carbon Sequestration



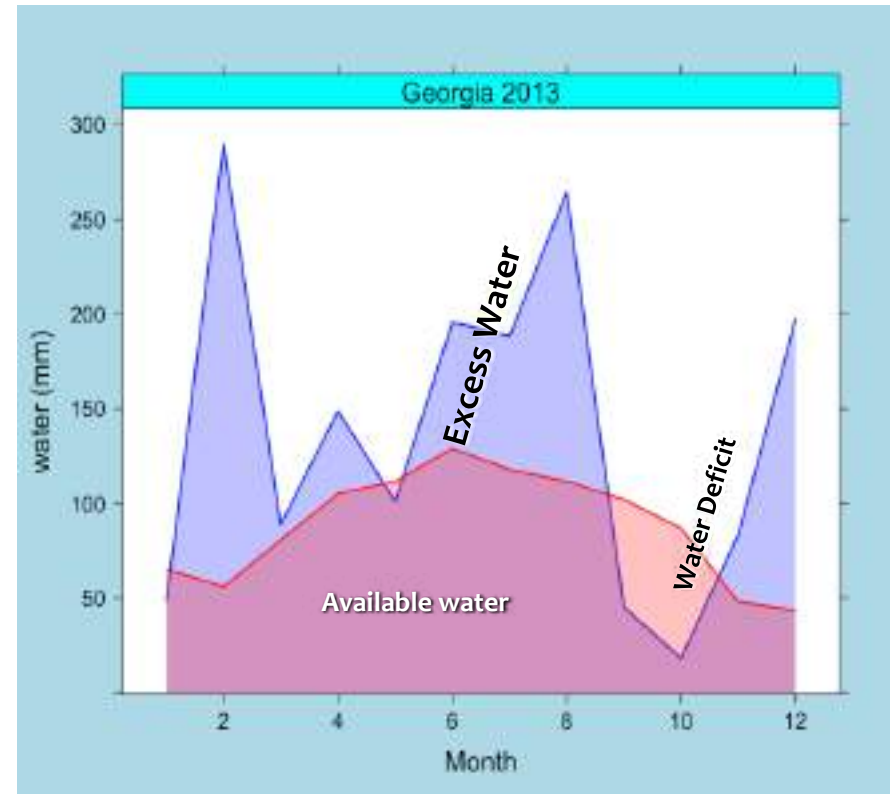
Deliverables

1. Methodology for quantifying site productivity
2. Dataset of variables for assessing regional variation in site productivity
3. Final model for relating site productivity metrics to environmental and edaphic variables

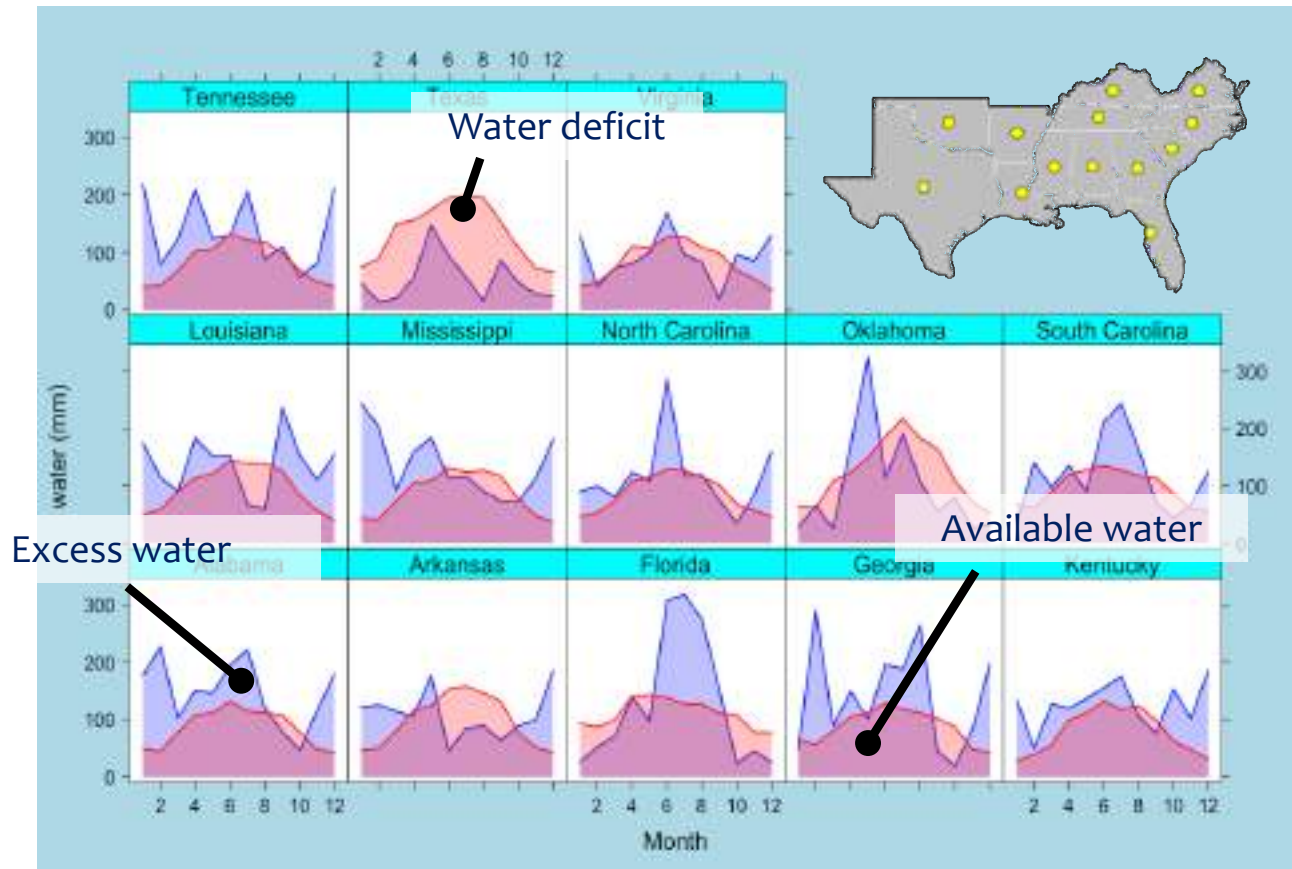


Some environment drivers of productivity

- The $\min(ET_0, RIAN)$ is a good proxy for photosynthesis.
- Lack of water reduces photosynthesis.
- Excess water reduces photosynthesis



We find enough variation on these biophysical variables all over the southeast US.



The **3** other strategies for base site index maps

Strategy

A

Model Stand Productivity including Climate and Soil Explicitly. Use the information from prediction equations to estimate site.

Strategy

B

Using Productivity estimates for individual sites (and their uncertainty), interpolate a map using environmental co-variables many techniques.

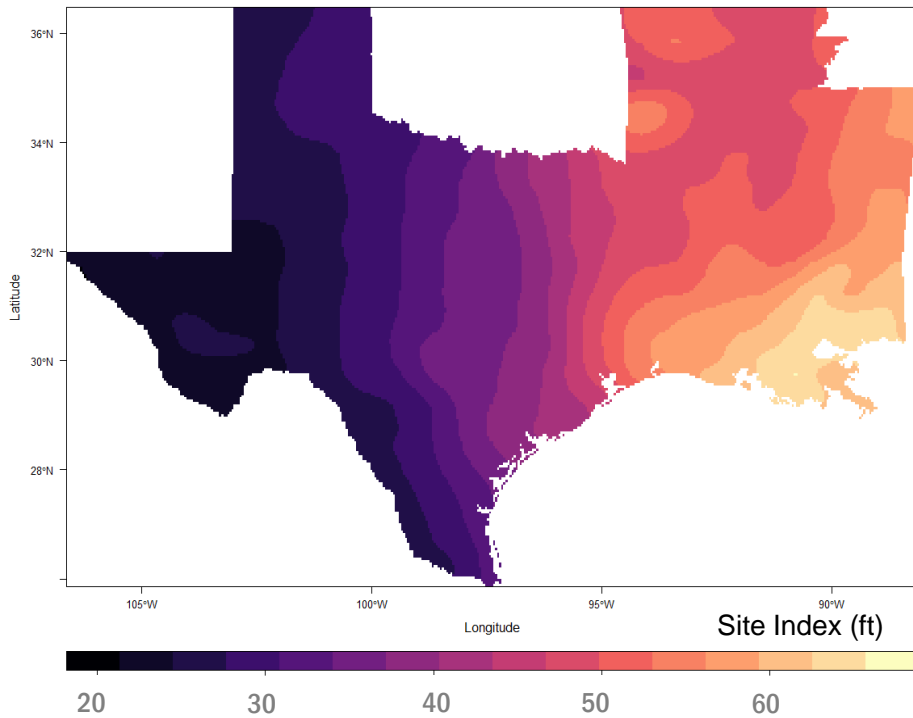
Strategy

C

Estimate growth parameters for different sites, interpolate those parameters and rely on existing stands to project forward.



Strategy A : Empirical function with auxiliary variables

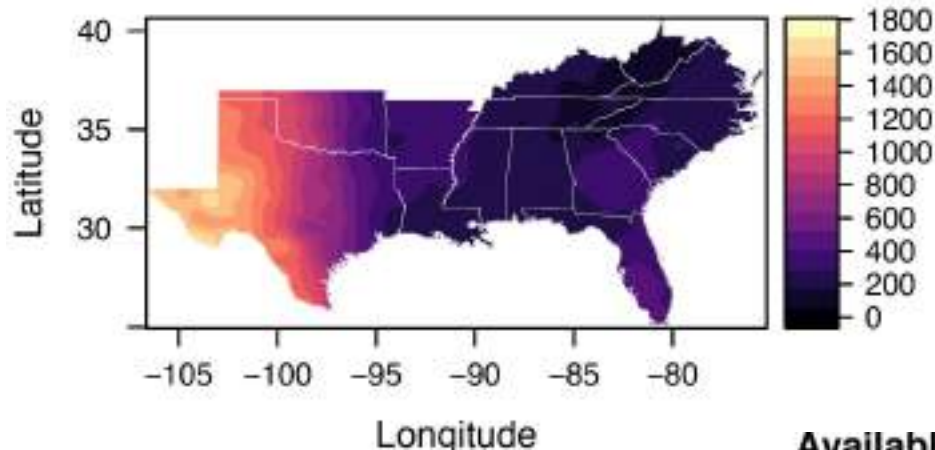


Base age invariant fit.
Long-term uncertainty accounted.
Climate errors accounted.
Multicollinearity accounted.

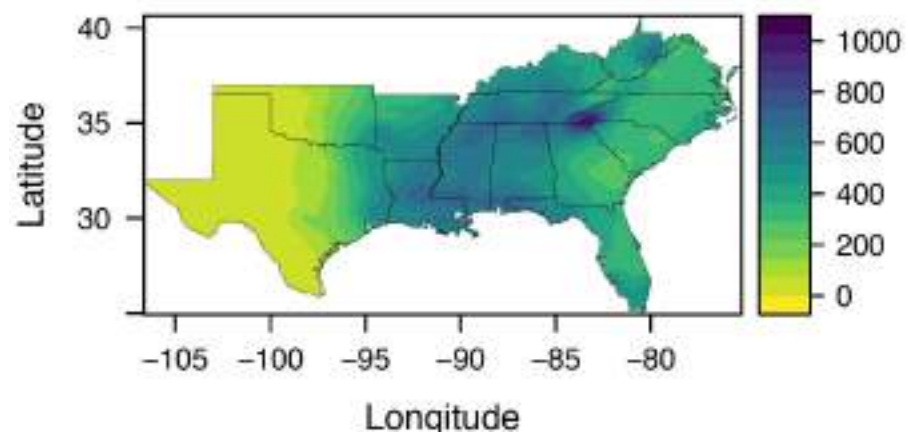




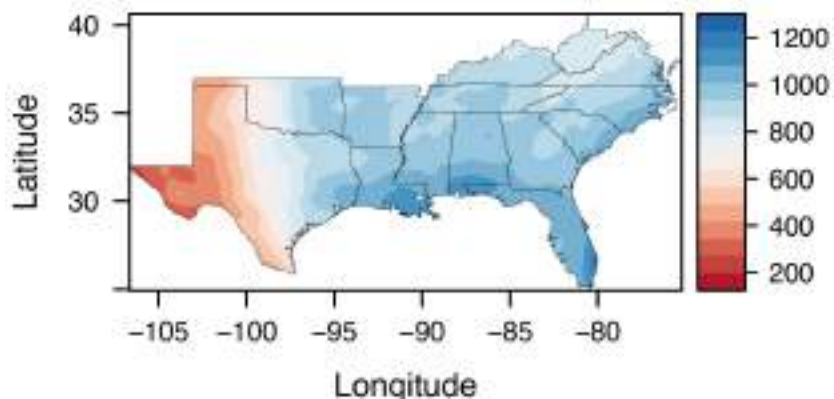
Water Deficit (mm)



Excess Water (mm)

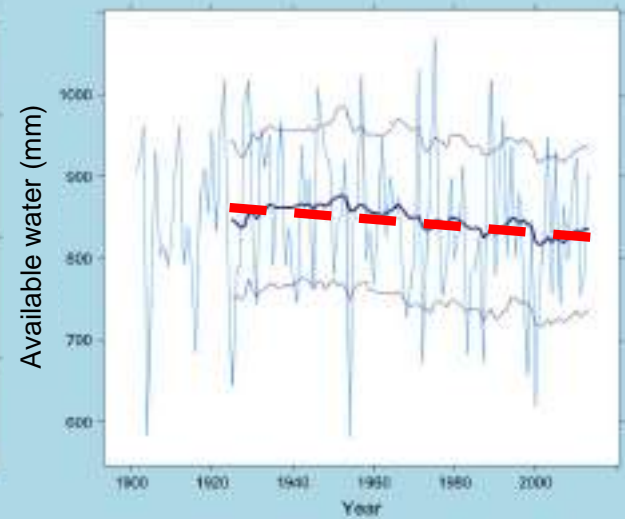
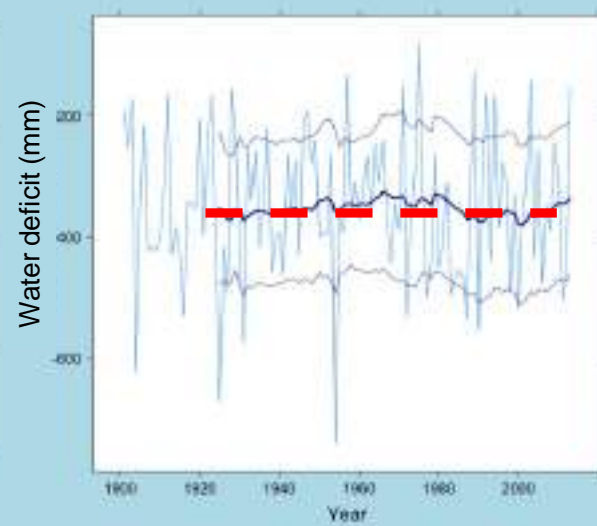
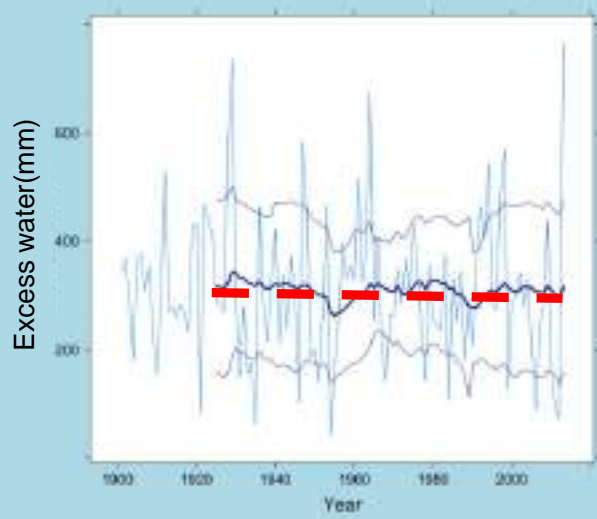


Available Water (mm)



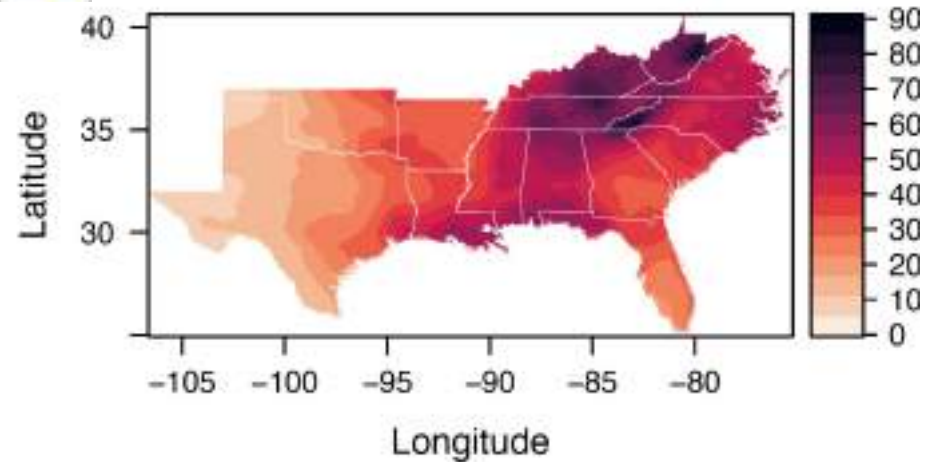


Indicators have stability over time, though with measurable error.

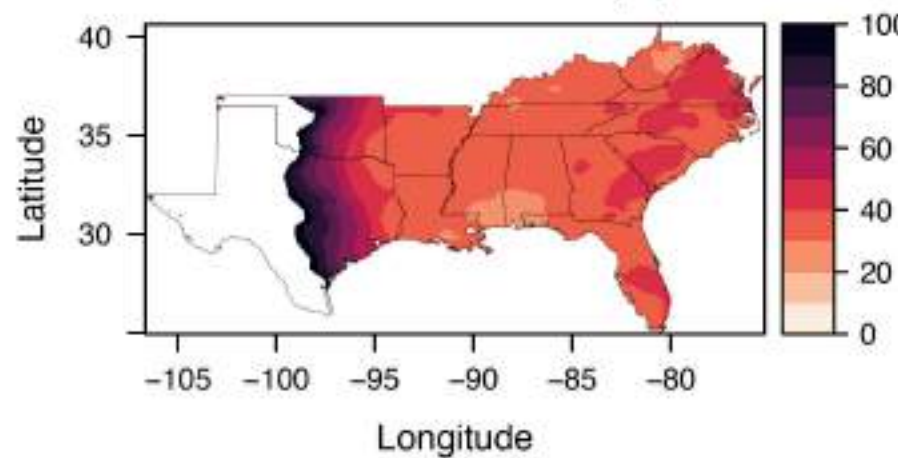




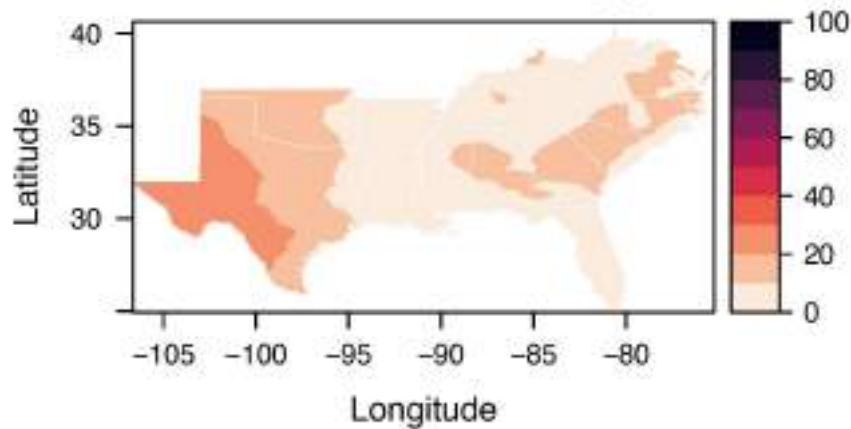
C.V. Water Deficit (%)



C.V. Excess Water (%)

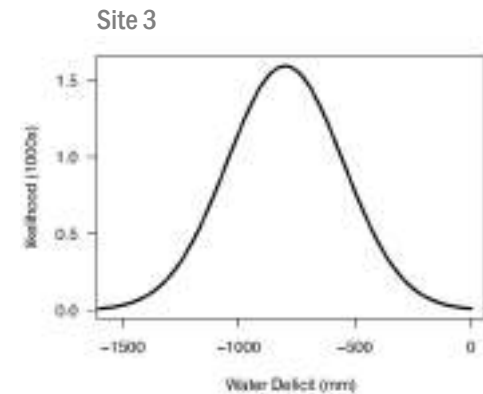
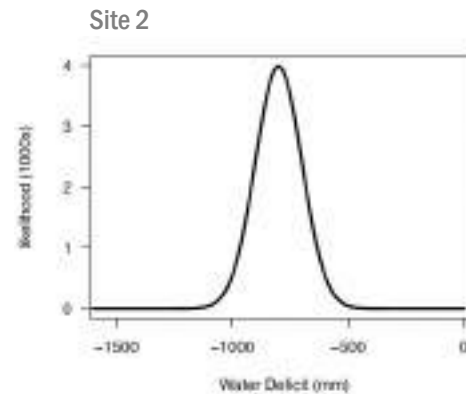
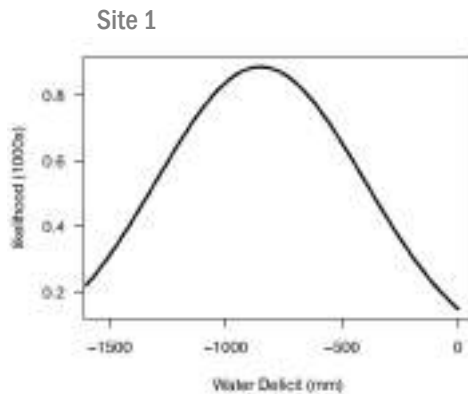


C.V. Available Water (%)



Environmental uncertainty varies by region, changing the weights we should give to each variable to avoid bias, we use latent variable approach to solve for each e.v.

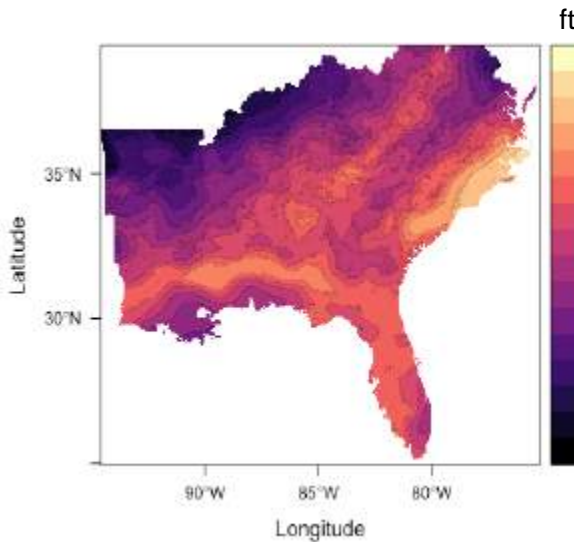
$$H_t = \beta_0 EW^{\beta_1} WD^{\beta_2} AW^{\beta_3} \frac{\beta_4}{t^{\beta_5}}$$



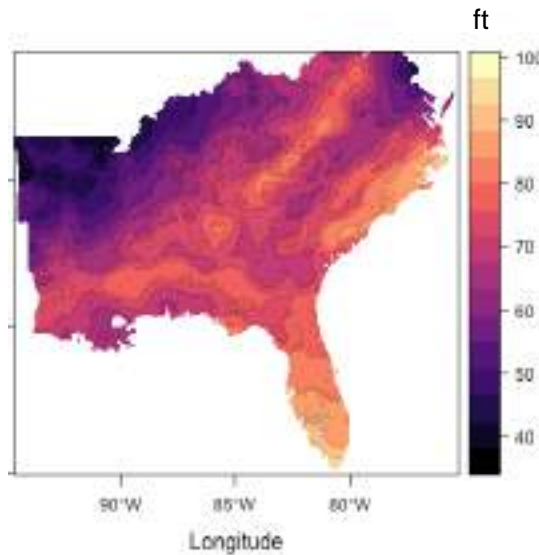
Strategy : Expected value interpolation method



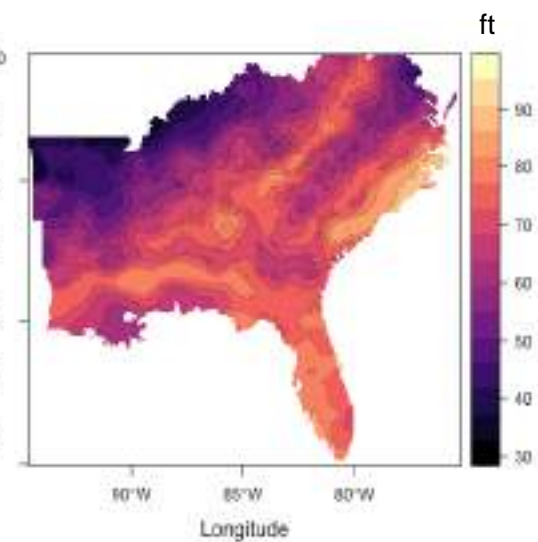
Chapman-Richards



Ludkvist Korf (Bailey-Clutter)



Hossfeld-IV



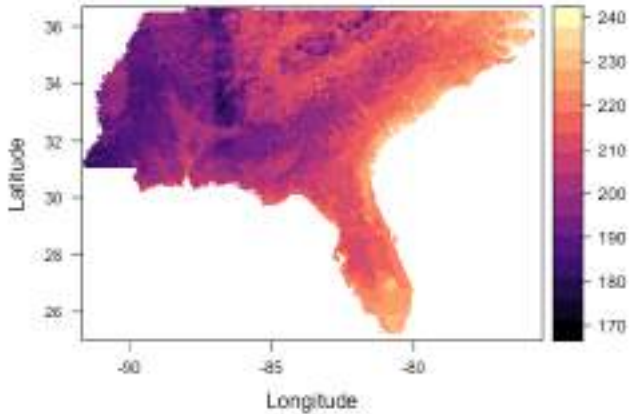
Local DH-Age fits.
Long-term uncertainty accounted.
Multicollinearity accounted.
80 % variation explained.



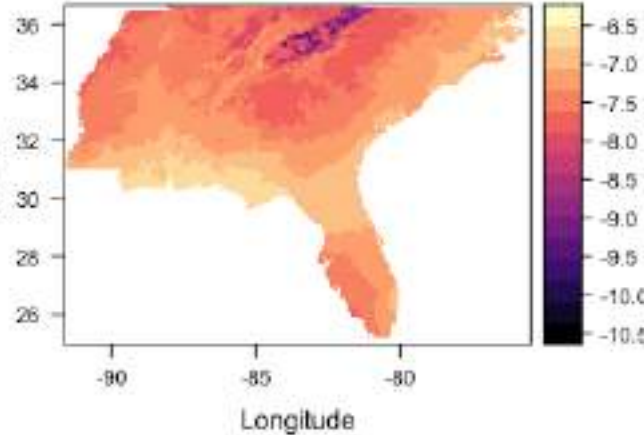
Strategy : Example multivariate parameter interpolation method using ML



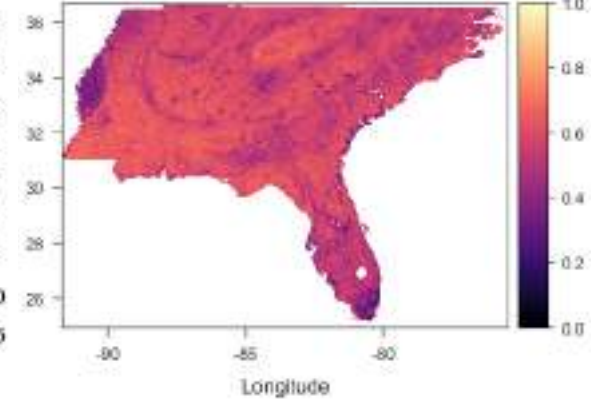
β_0



β_1



β_2



Local DH-Age fits.
Long-term uncertainty accounted.
Multicollinearity accounted.
Local inventory is important.
95% variability accounted.



Company Benefits

- Improved metrics for assessing site productivity
- Development of simplified soil classification system for forest management
- Incorporate LAI to enhance predictive response
- Improve confidence of response and therefore return on investment



Three-year Timeline - Updated

- ✓ Year 1 (2020): Data gathering and compilation of forest soil map units and available stand data
- ✓ Year 2-3 (2021-2022): Spatial modeling and model comparisons of site productivity and drivers

Year 4: Develop web-based interface of base and potential site productivity (additional funding from International Paper)

