



## Loblolly Pine Productivity Regional Simulations Under Changing Climate and CO<sub>2</sub> Concentrations

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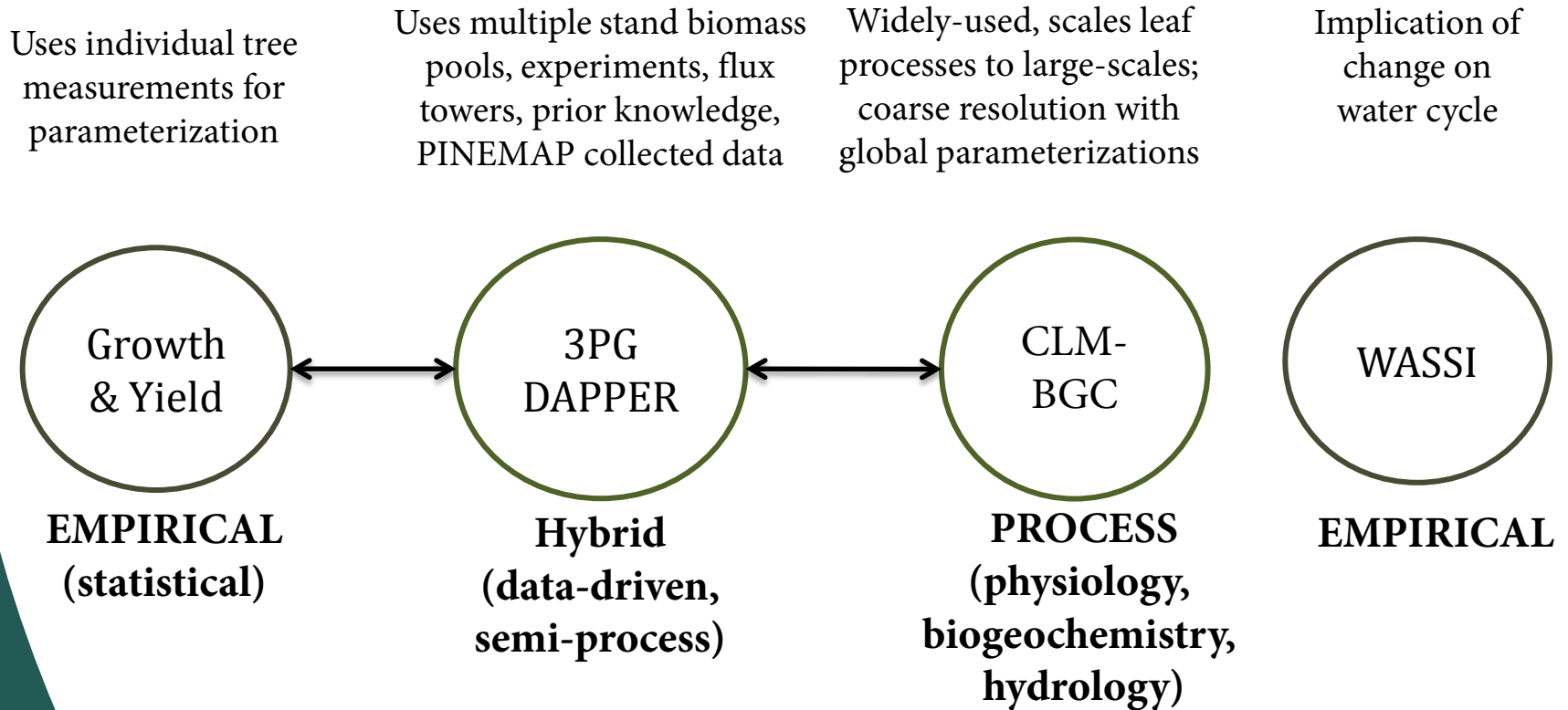
### 3-PG

Thomas, Wynne, Brooks, Ward, Thomas, Jerslid, Dinon-Aldridge, Sampson, Gonzalez, Seiler, Bracho-Garrillo, Bracho-Garrillo, Fox, Burkhart, Noormets, Albaugh, Teskey, Strahm



# Overview

**How are productivity, carbon storage, and water cycling going to change over the 21<sup>st</sup> century?**



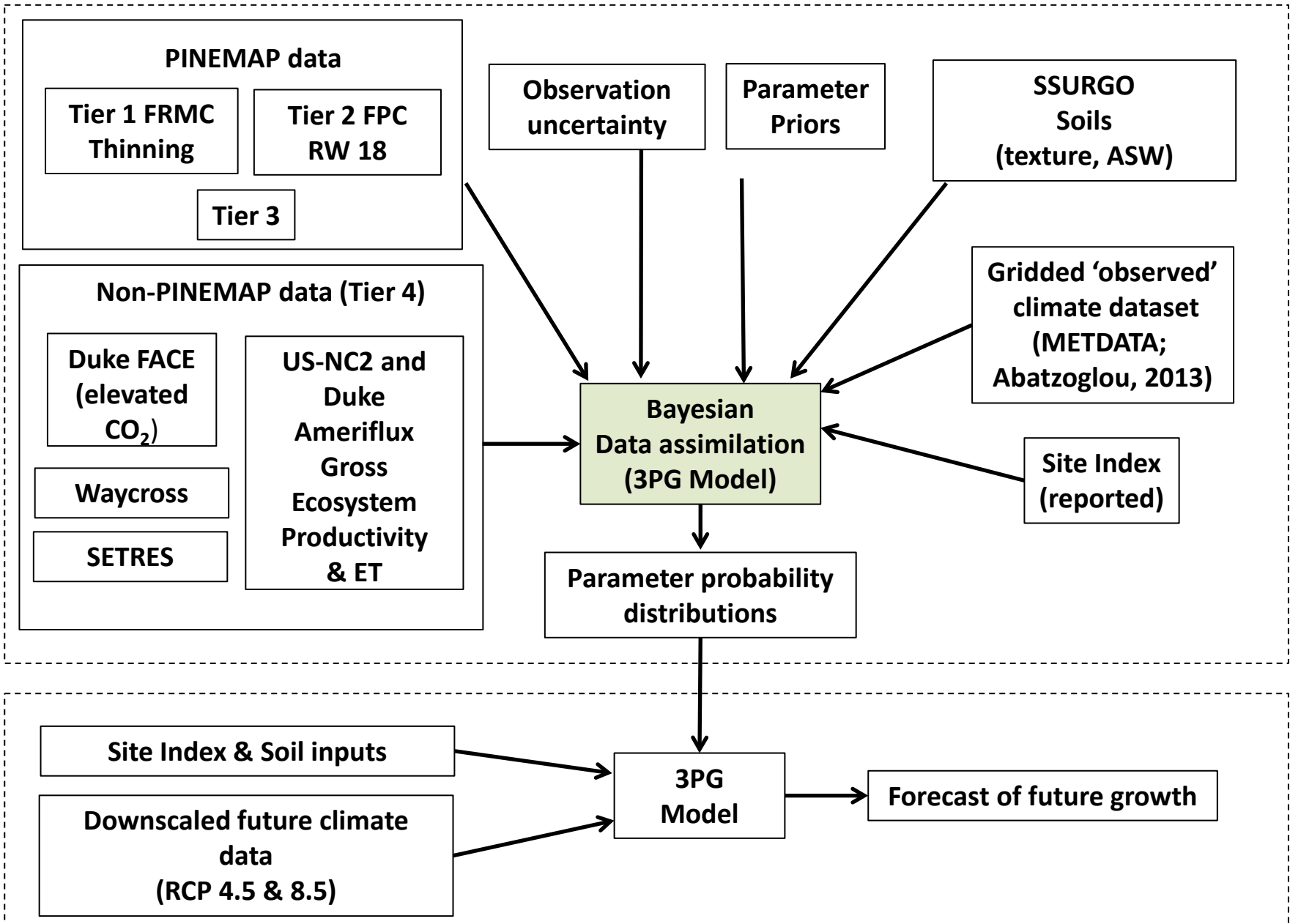


## 3-PG and data-assimilation

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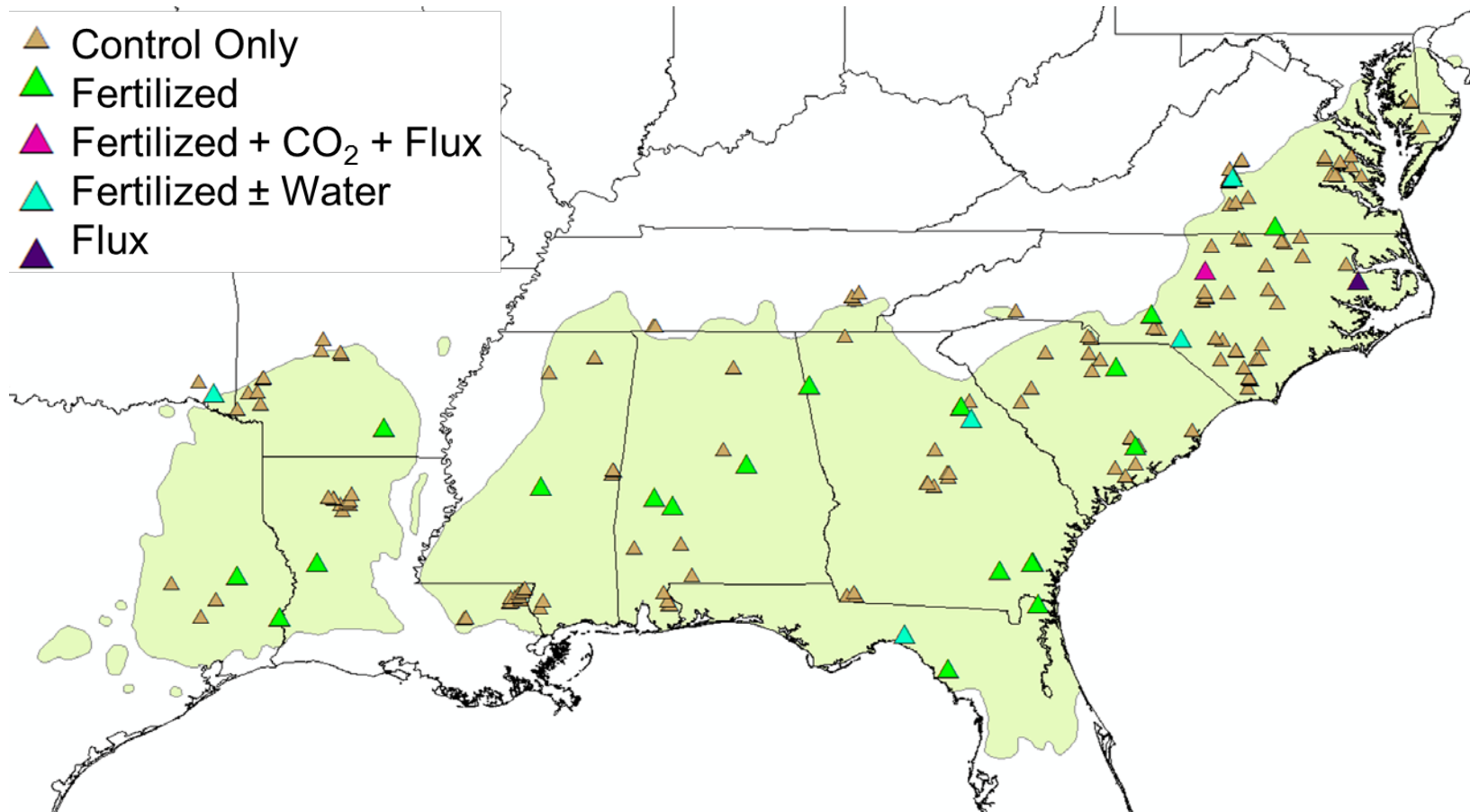
- Calibrate key parameters for regional, climate change research
- Develop uncertainty estimates in predictions
- Constrain belowground allocation to improve NPP and NEP estimates
- Synthesize research from PINEMAP project and other regional studies

# Data Assimilation of Pine Plantation Ecosystem Research (DAPPER) System



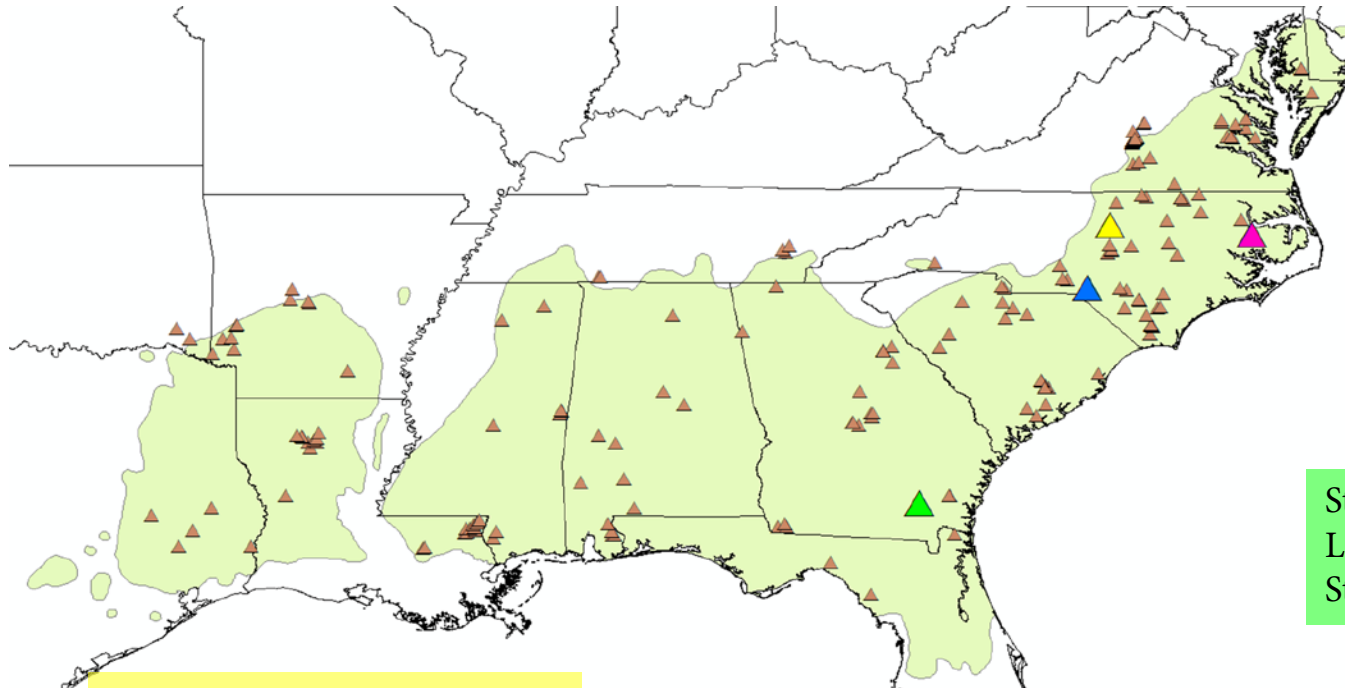


# Data: Empirical Treatments





# Data: Observation Streams



Stem Biomass\*  
Foliage Biomass\*  
Stem Count

Stem Biomass\*  
Leaf Area Index  
Stem Count

Stem Biomass\*  
Leaf Area Index  
Fine Root Biomass  
Coarse Root Biomass  
Stem Count  
Gross Ecosystem Production\*  
Evapotranspiration  
Foliage Production  
Fine Root Production  
Hardwood Biomass Pools\*

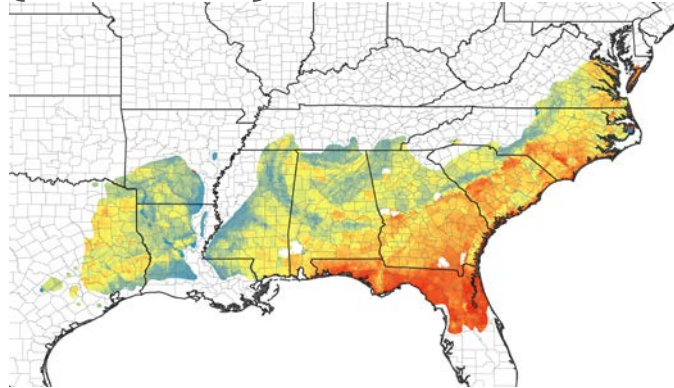
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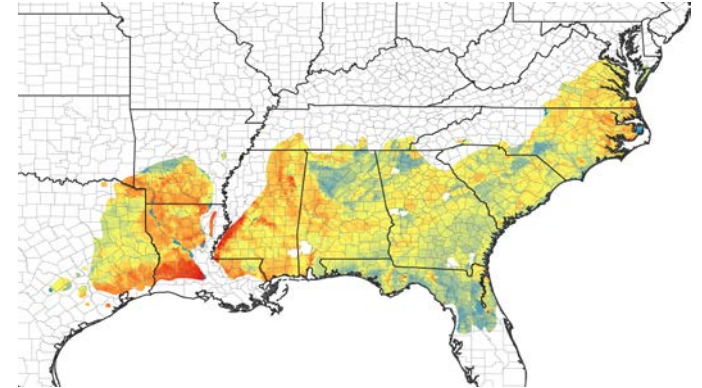


# Regional Data

- Soils (SSURGO)

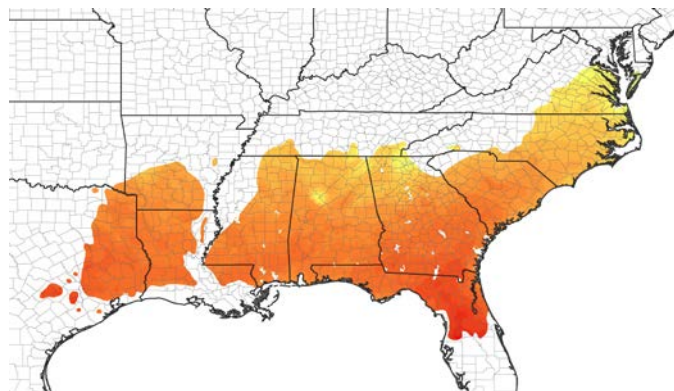


Percent Sand

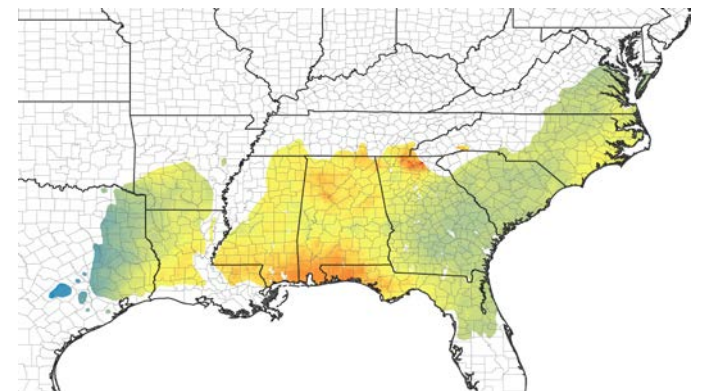


Available Soil Water

- Climate (MACA)



Temperature



Precipitation





# Key highlights from 3PG development

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- **Key philosophy: What functions in the model are supported by data through prior knowledge and/or data used in fitting?**
- A simple representation of understory hardwoods
  - Necessary to use flux tower ET and estimated GEP
- Separates fine roots and coarse root
  - Improves total NPP estimates
- Two cohort approach to simulating leaf biomass and phenology
- CO<sub>2</sub> enhancement of light-use efficiency
- Simplification of soil moisture influence on light-use efficiency
  - 4 hardcoded parameters -> 2 fitted parameters
- Simplification of influence of FR on root allocation



# Key highlights from data assimilation

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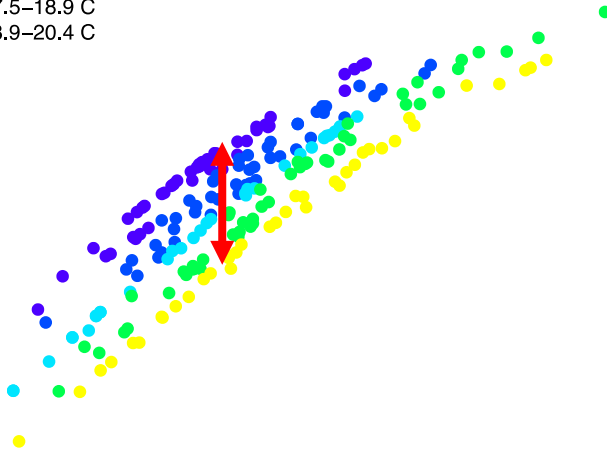
- Non-fertilized plots: FR is a function of site index and 1970-2015 mean annual temperature
  - Same SI = higher FR in colder regions
  - FR is relative to a plots 'potential' photosynthesis
- Fertilized plots: FR is not assumed to be 1 but is assumed to be equal to or greater than the control plot
- Assumes that LAI can never be greater than 6



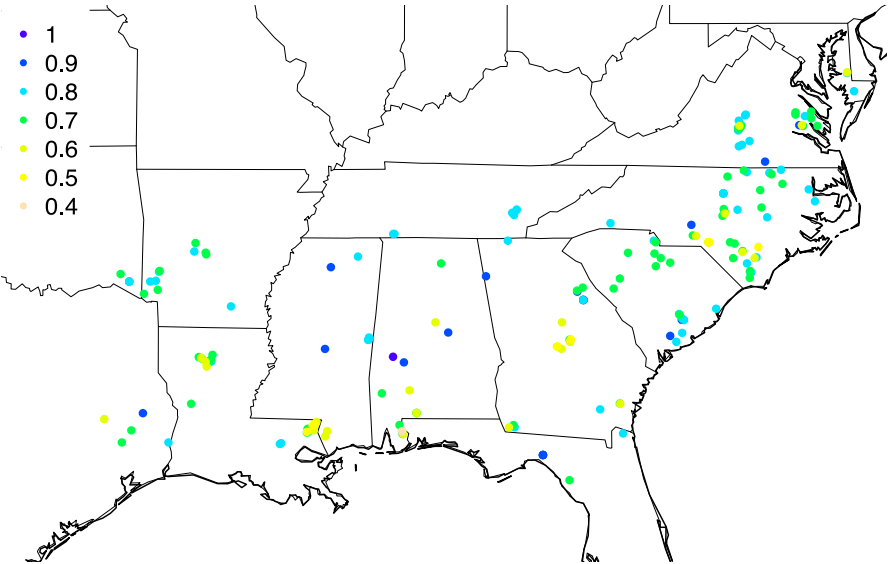
# Regionalization of FR

ean Annual Temperature)

- 8.6–14.3 C
- 14.3–16.5 C
- 16.5–17.5 C
- 17.5–18.9 C
- 18.9–20.4 C

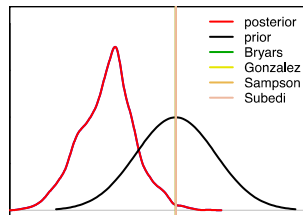
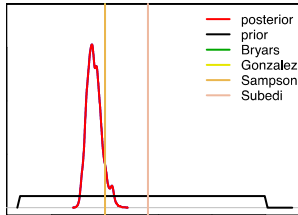


Same SI = high FR in colder regions



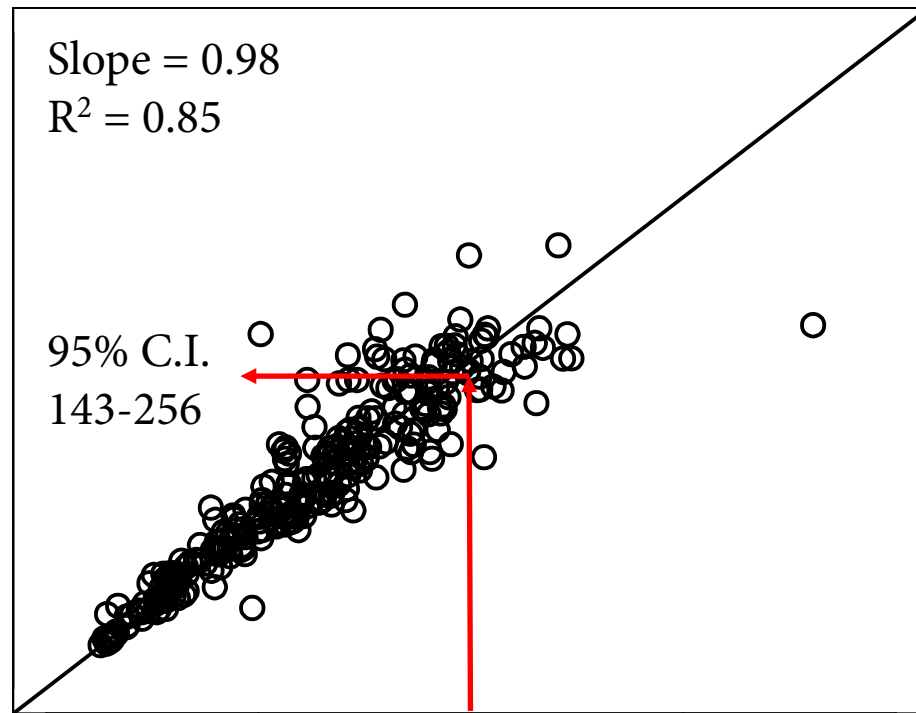


# Distributions of parameters



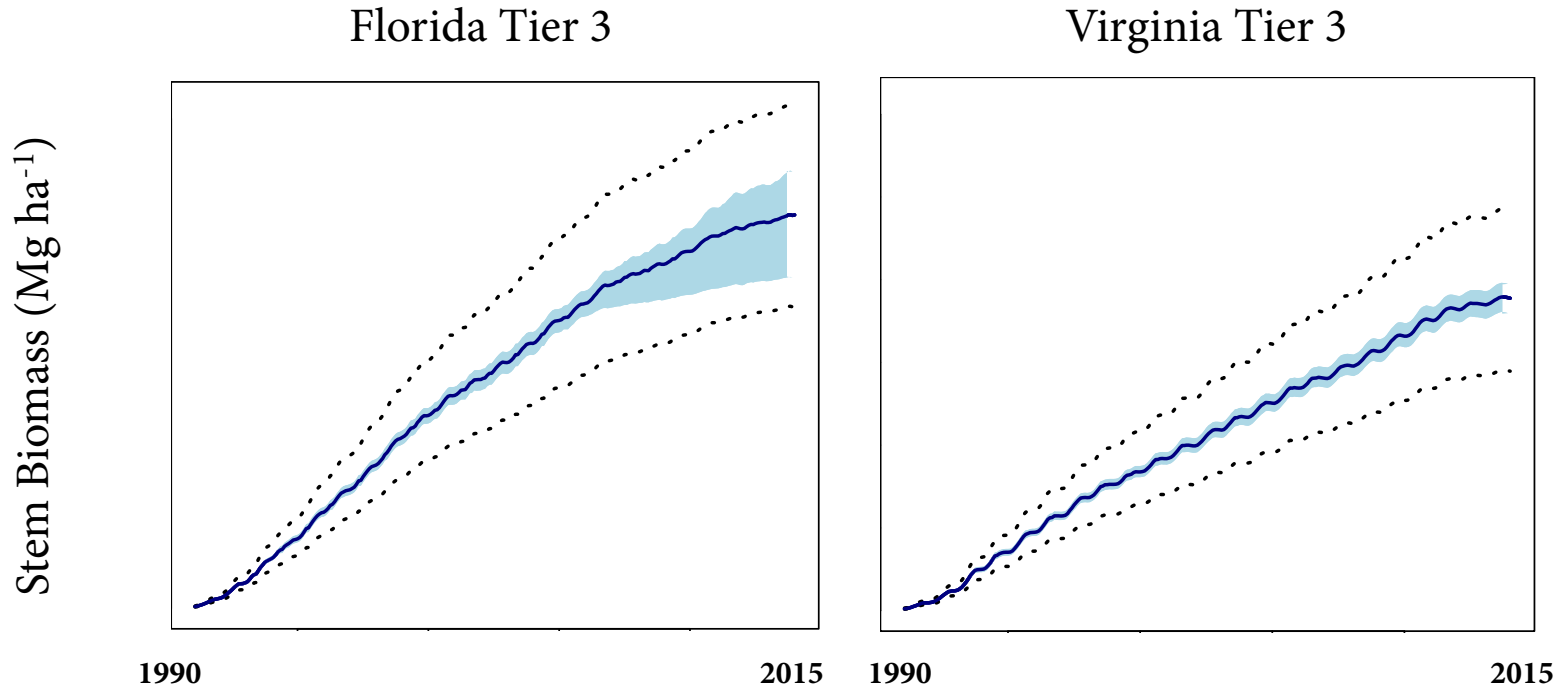


# Model fit





# Uncertainty estimation

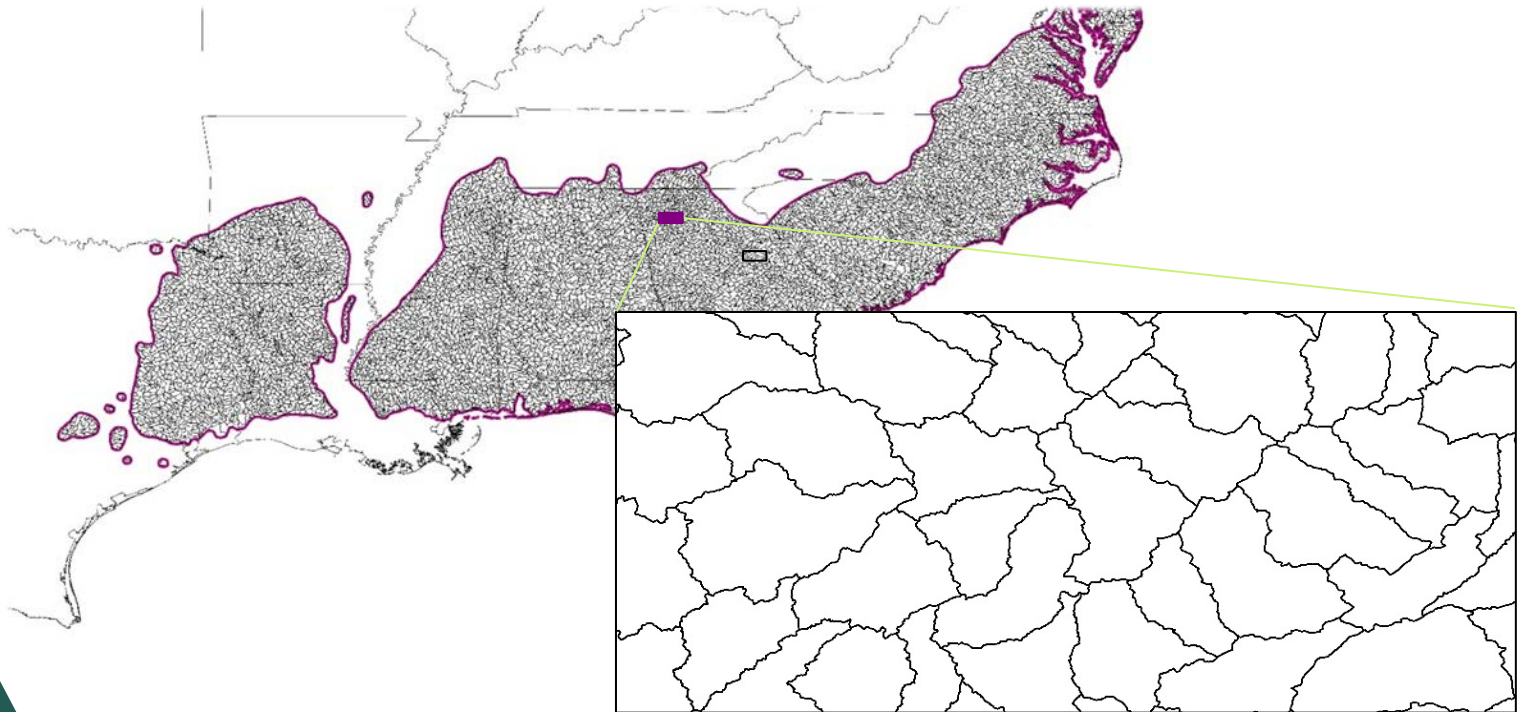


Dark line = median prediction  
Shaded = 95% C.I. on parameter uncertainty  
Dotted = 95% C.I. on total uncertainty

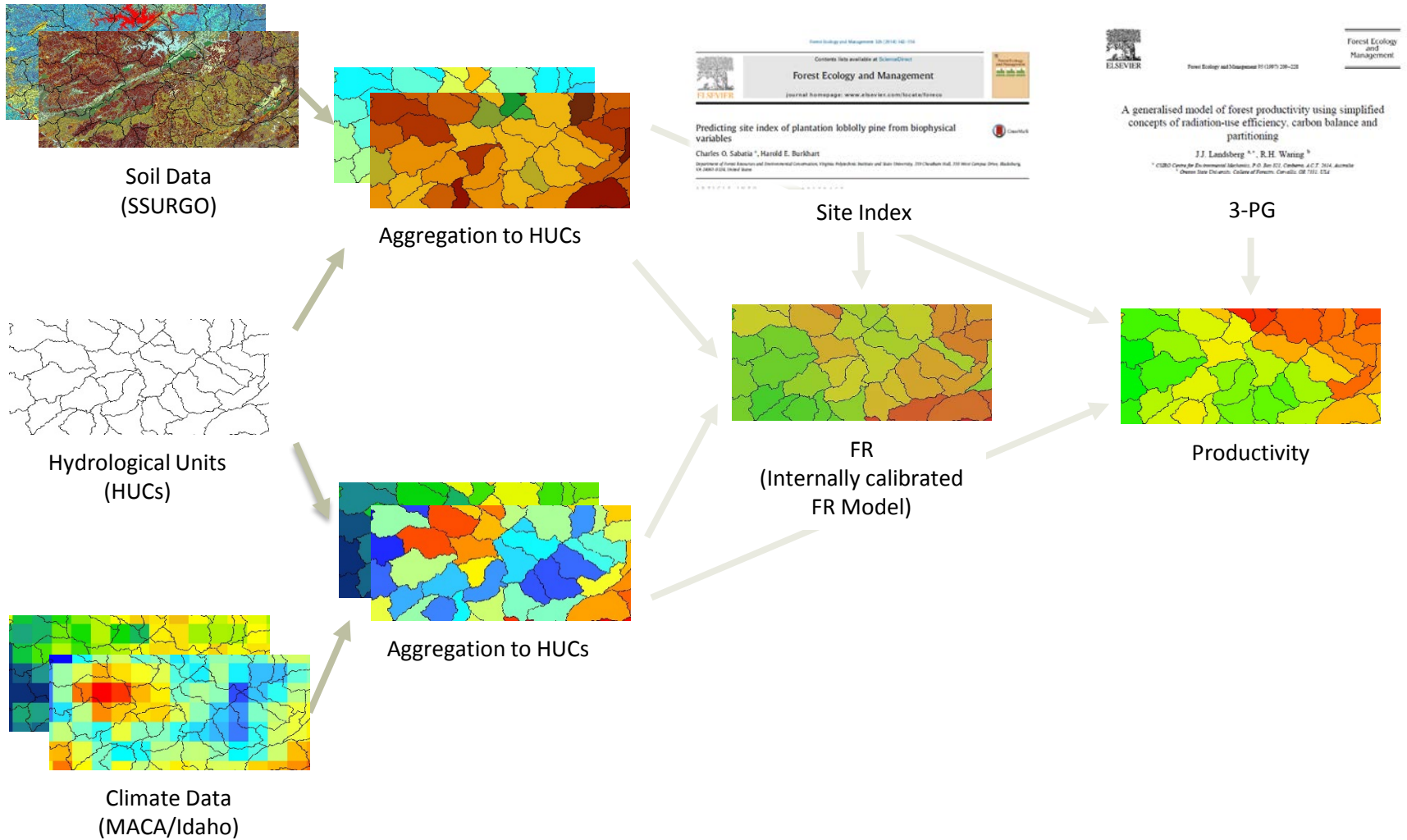


# Regional scaling

- Primary spatial unit is 12-digit hydrological unit code features (HUCs) from the USGS
  - Chosen to facilitate model intercomparison
  - Balances spatial scope with tractability
  - ~18000 HUCs across the PINEMAP region of interest
    - Median size: ~22000 acres

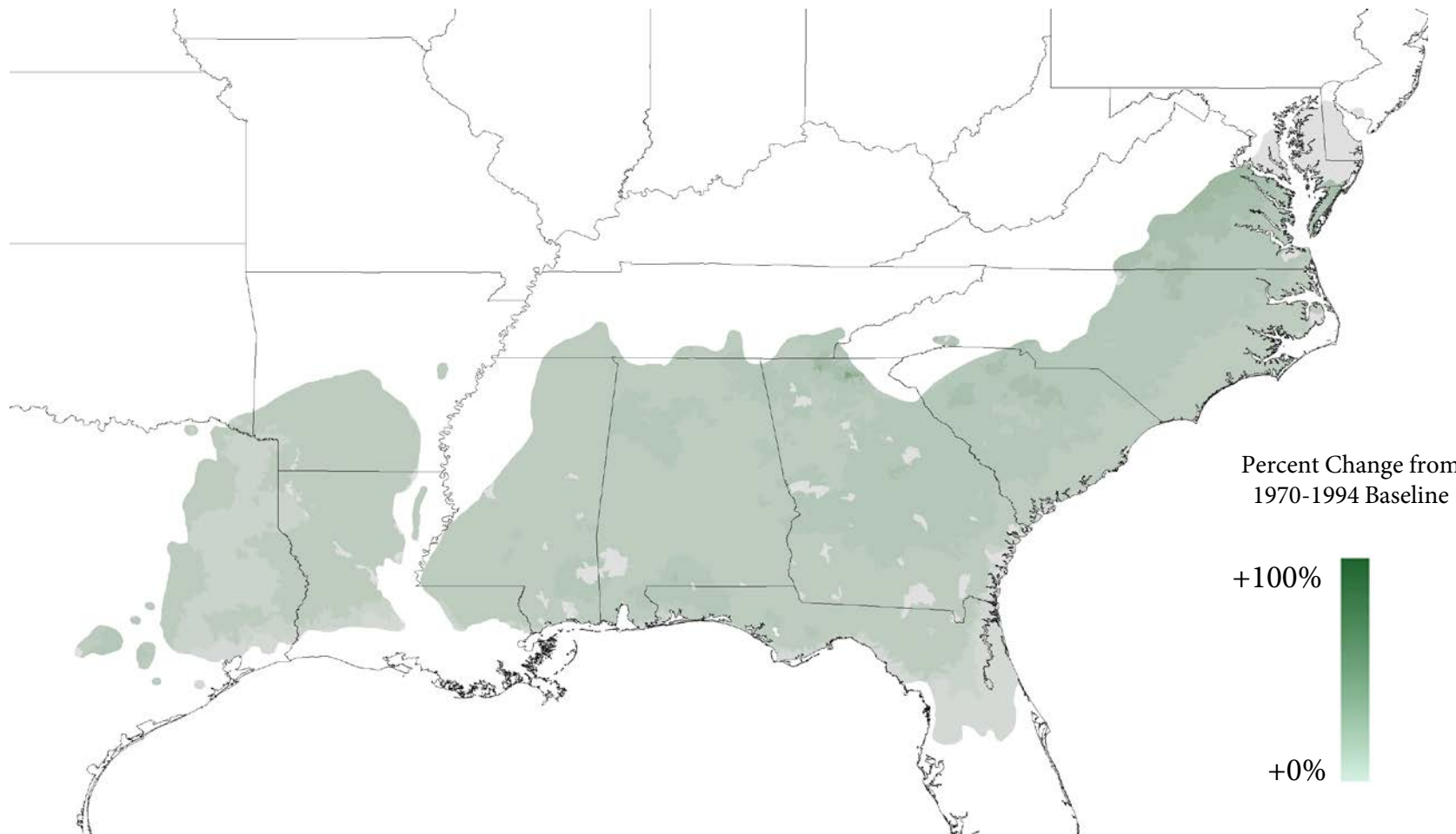


# Regionalization Process



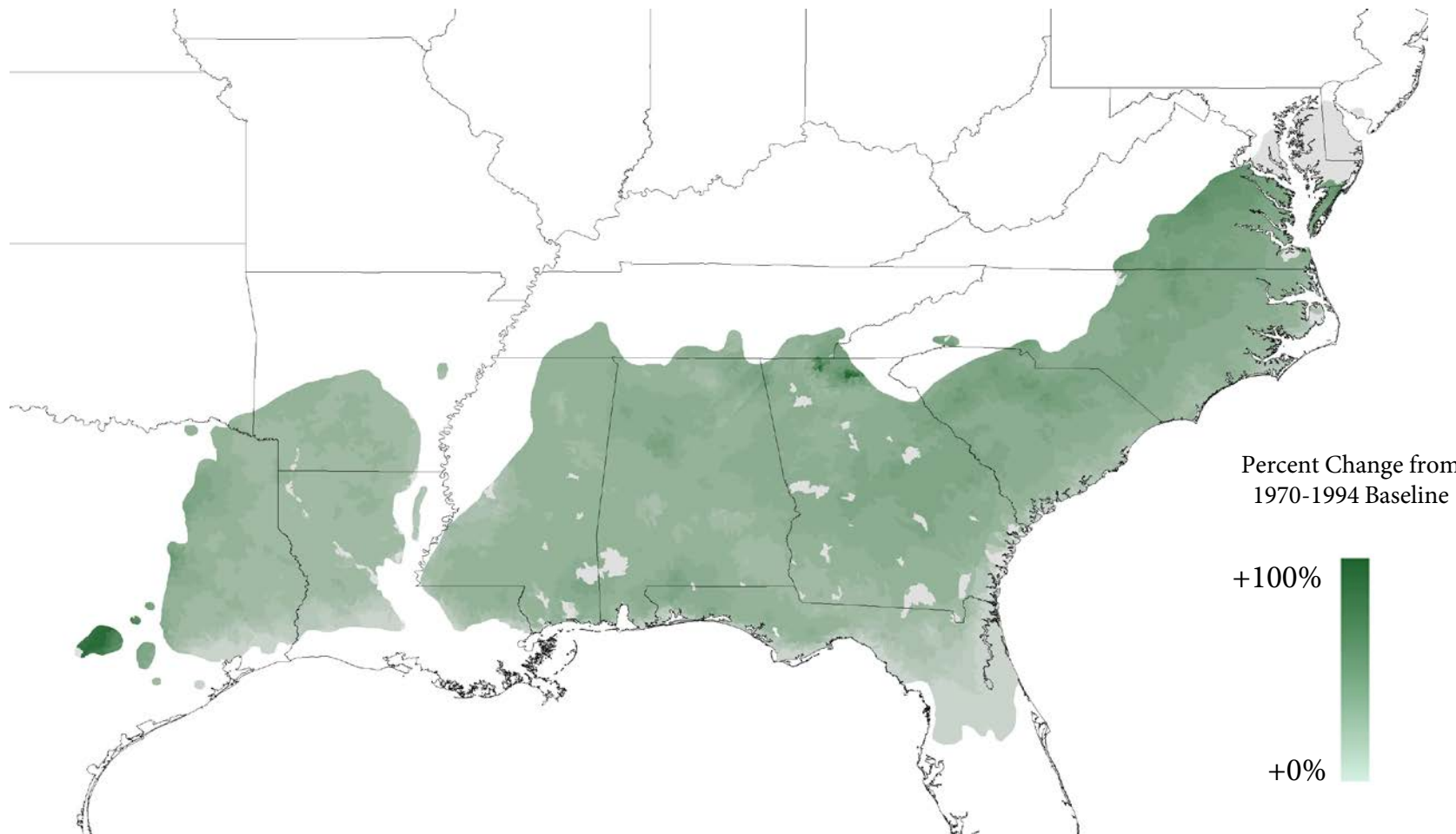


# Results: 1995-2019 Stem Biomass



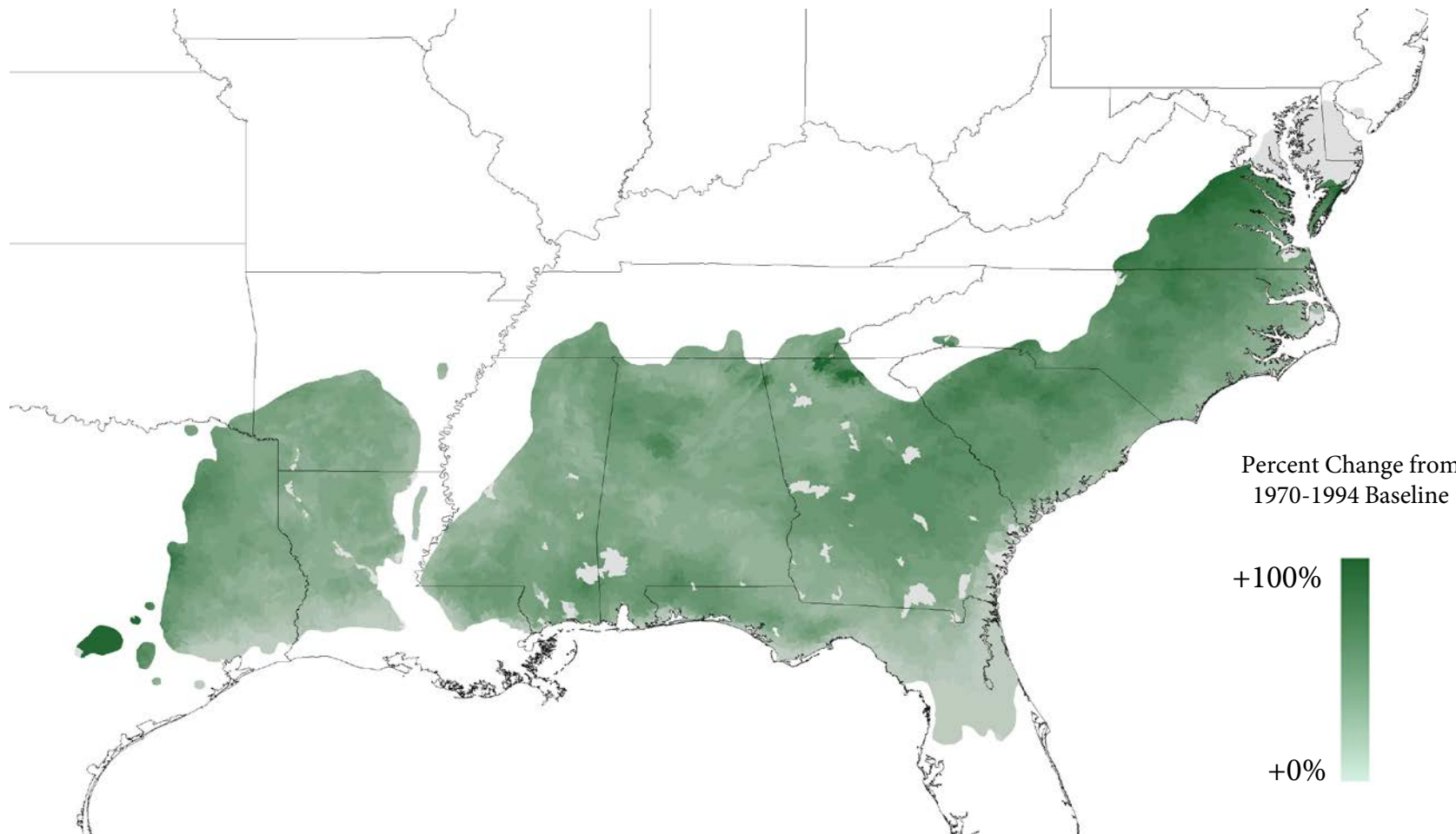


# Results: 2020-2044 Stem Biomass



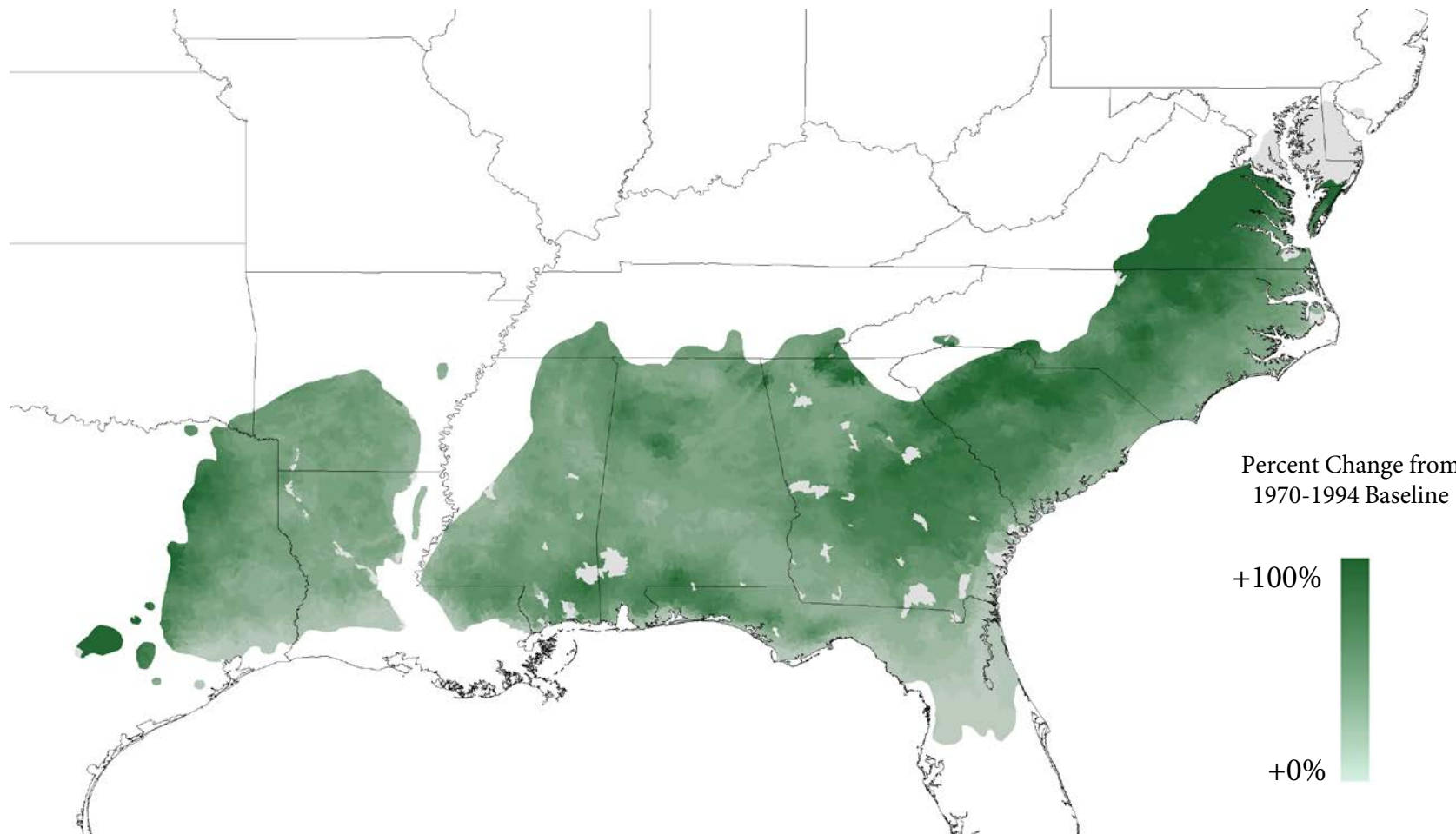


# Results: 2045-2069 Stem Biomass





# Results: 2070-2094 Stem Biomass





# Results: Regionwide

RCP 8.5 (business as usual)	1970-1994	1995-2019	2020-2044	2045-2069	2070-2094
<b>Stem Biomass</b> (Mg/ha)	155.3±35.2 (+0.0%)	175.9±35.9 (+13.3%)	204.1±35.8 (+31.4%)	223.1±33.3 (+43.7%)	235.3±31.7 (+51.5%)
<b>NEP</b> (Mg C/ha)	3.2±1.7 (+0.0)	5.0±2.0 (+2.5)	5.7±2.0 (+2.5)	6.8±2.2 (+3.6)	7.9±2.4 (+4.7)
RCP 4.5 (peak emissions ca. 2040)					
<b>Stem Biomass</b> (Mg/ha)	155.3±35.2 (+0.0%)	177.4±36.0 (+14.3%)	195.9±36.0 (+26.1%)	209.9±35.5 (+35.2%)	213.8±35.0 (+37.7%)
<b>NEP</b> (Mg C/ha)	3.2±1.7 (+0.0)	4.7±1.9 (+1.5)	5.6±2.1 (+2.4)	6.0±2.1 (+2.8)	6.0±2.1 (+2.8)



# Conclusions

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- Used multi-site, multi-experiment, multi-data streams for regional model parameterization
- 3-PG predicts substantial increases to loblolly pine productivity across the region
- 3-PG combined with an empirical Rh model predicts increases in ecosystem carbon storage (NEP)
- Response of productivity to climate change alone is neutral to negative but response to CO<sub>2</sub> is strongly positive



# Caveats

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- Only one climate model used so far
  - 19 others to be incorporated
  - Uncertainty has not been propagated at the regional scale
  
- NEP a function of NPP and Soil Respiration
  - Variability in  $R_s$  will impact NEP estimates