# Regional Model First Results and Intercomparisons

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United States Department of Agriculture
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# Overview

- Background
- Models
- Inputs
- Results
- Caveats
- Conclusions

# Background

- The modeling integrated platform directly addresses the following PINEMAP outcome themes

Increased carbon (C) sequestration from silvicultural and genetic enhancement of productivity and efficiency of fertilizer use, and resilience to climate variability and disturbance.

A more robust and resilient forest-based economy in the Southeast U.S.

Engaged and literate public with the capacity to make informed, practical decisions related to climate, forest ecosystems, and forest management.

Enhanced connections between corporate and noncorporate forest landowners and forestry and climate researchers and education and outreach professionals.

# Background

- In particular, the modeling platform is tasked with quantifying estimated changes in loblolly productivity based on an ensemble of models that regard productivity from different perspectives

- The multiple-model approach allows for more robust understanding of the changes predicted because the error and biases from any given model are counterbalanced by the others

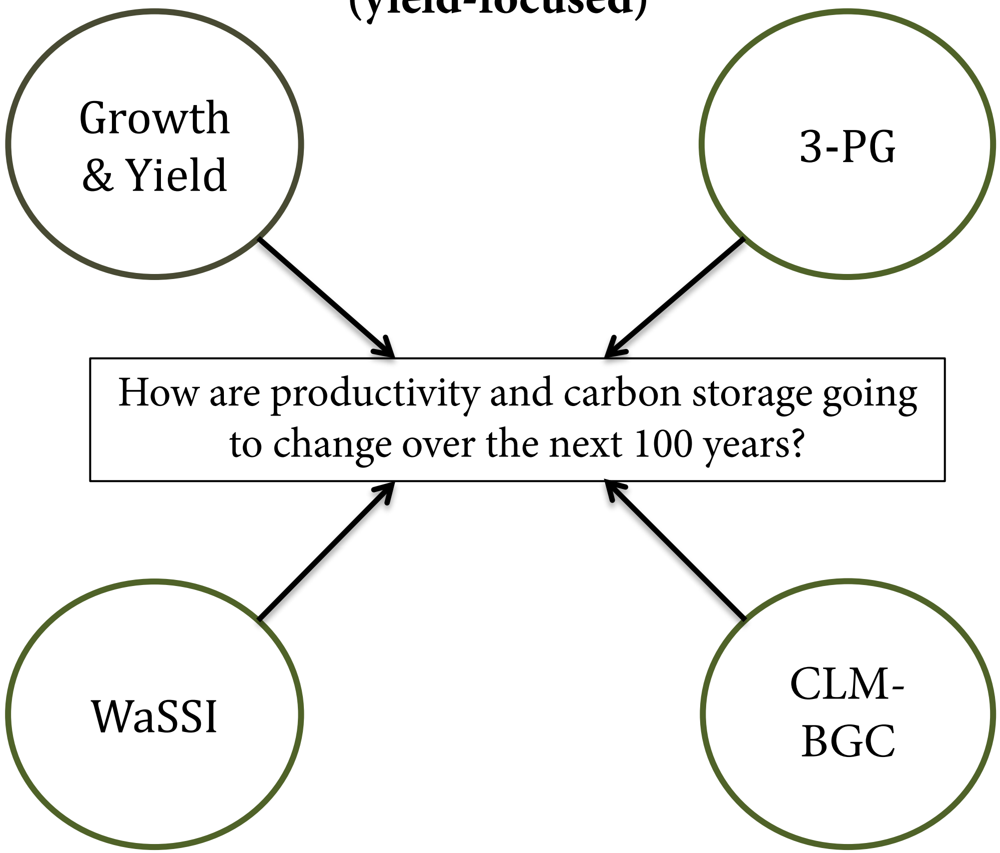
# The PINEMAP Modeling Family

**STAND**
**(yield-focused)**

Uses individual tree measurements for parameterization

Hybrid between a process and empirical model

**EMPIRICAL**
**(data-driven)**




**PROCESS**
**(physiological)**

Uses eddy-covariance data for parameterization; focus on fluxes

Scales leaf processes to large-scales; Coarse resolution with global parameterizations

**BIOGEOCHEMICAL**
**(carbon-focused)**

# Inputs

- Input data quality is crucial to the success of the modeling platform
  - There is an ongoing effort to ensure best available/computable data are used for inputs
    - Biophysical variables
      - Aggregation and handling of missing data
        - » Imputation
    - Physiological parameters and *in situ* measurements
      - Broad range of measurements drawn from the entire region
        - » Co-op data
- For best model comparability, input data was drawn from the same (or related) sources whenever possible

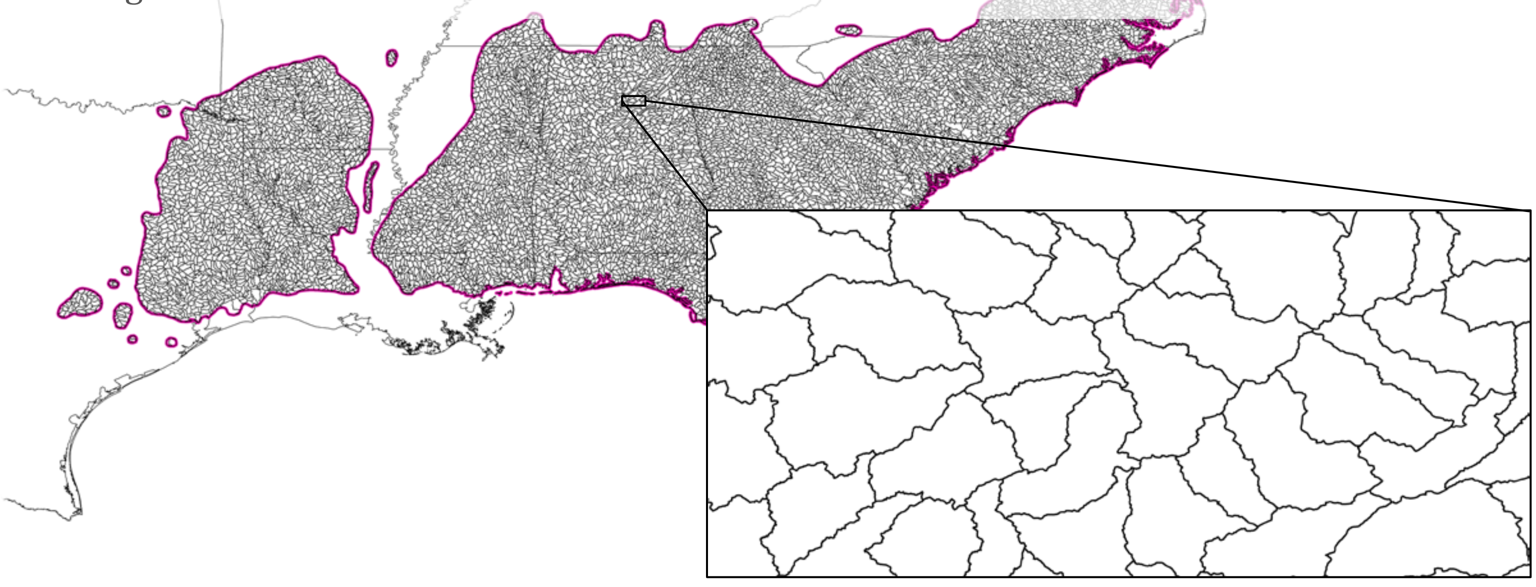
# Inputs

- In order to make baseline regional runs of the models, we needed data that are broad in coverage yet fine enough to produce meaningful results

| | 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 |

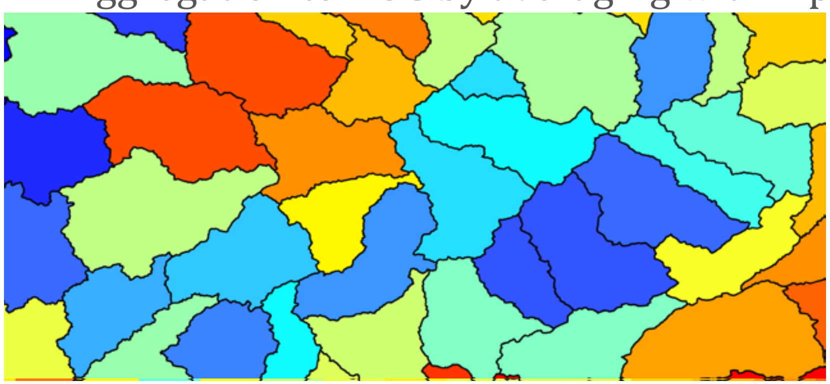
# Inputs: HUCs

- 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

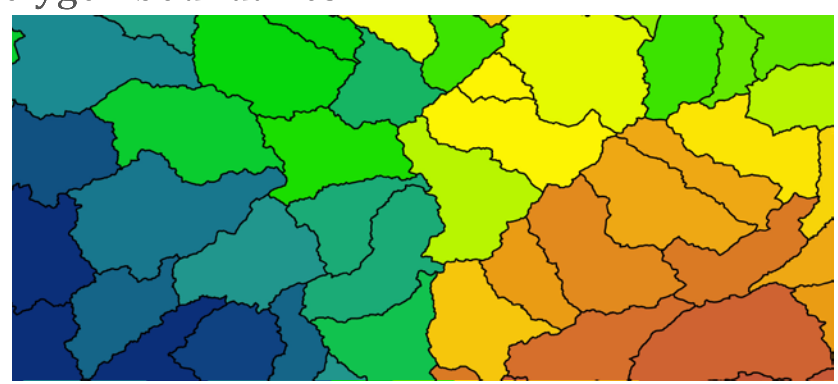


# Inputs: Climate

- MACA climate data
  - 1/16 x 1/16 degree spatial resolution
  - Daily temporal resolution
  - 20 different climate models
    - Derived from the same kinds of global climate 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



Temperature
(Mean, 2005, Celsius)
28.5 30.5



Precipitation
(Total, 2005, mm)
1070 1270

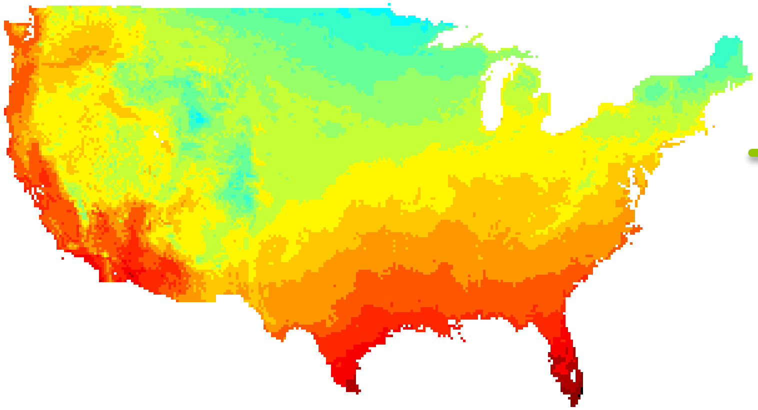
# Inputs: Climate

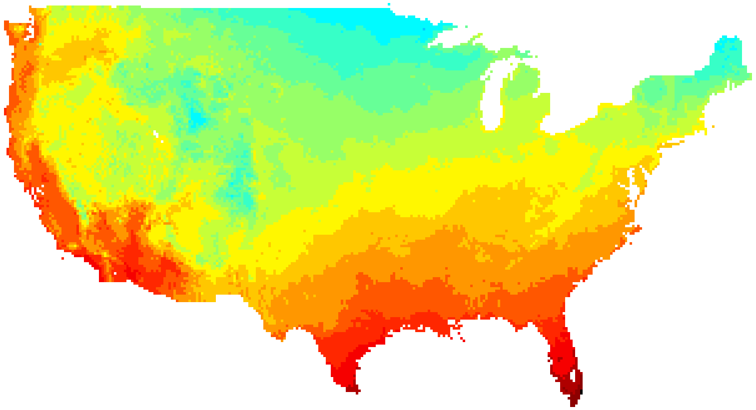
- Temporal aggregation depended on model requirements (MACA has daily resolution)
  - WaSSI
    - Monthly time step from 1950-2100
    - Mean temperature, total precipitation
  - 3-PG
    - Monthly time step from 1950-2100
    - Min/max temperature, total precipitation, average insolation, total frost 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

# Inputs: Climate

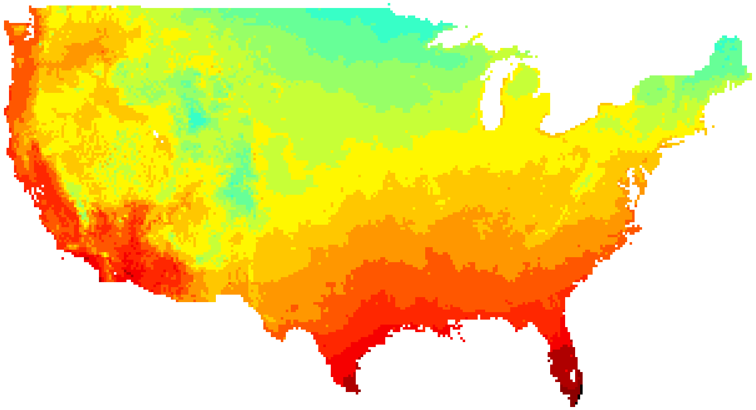
- **Example:** variation in temperature estimates

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

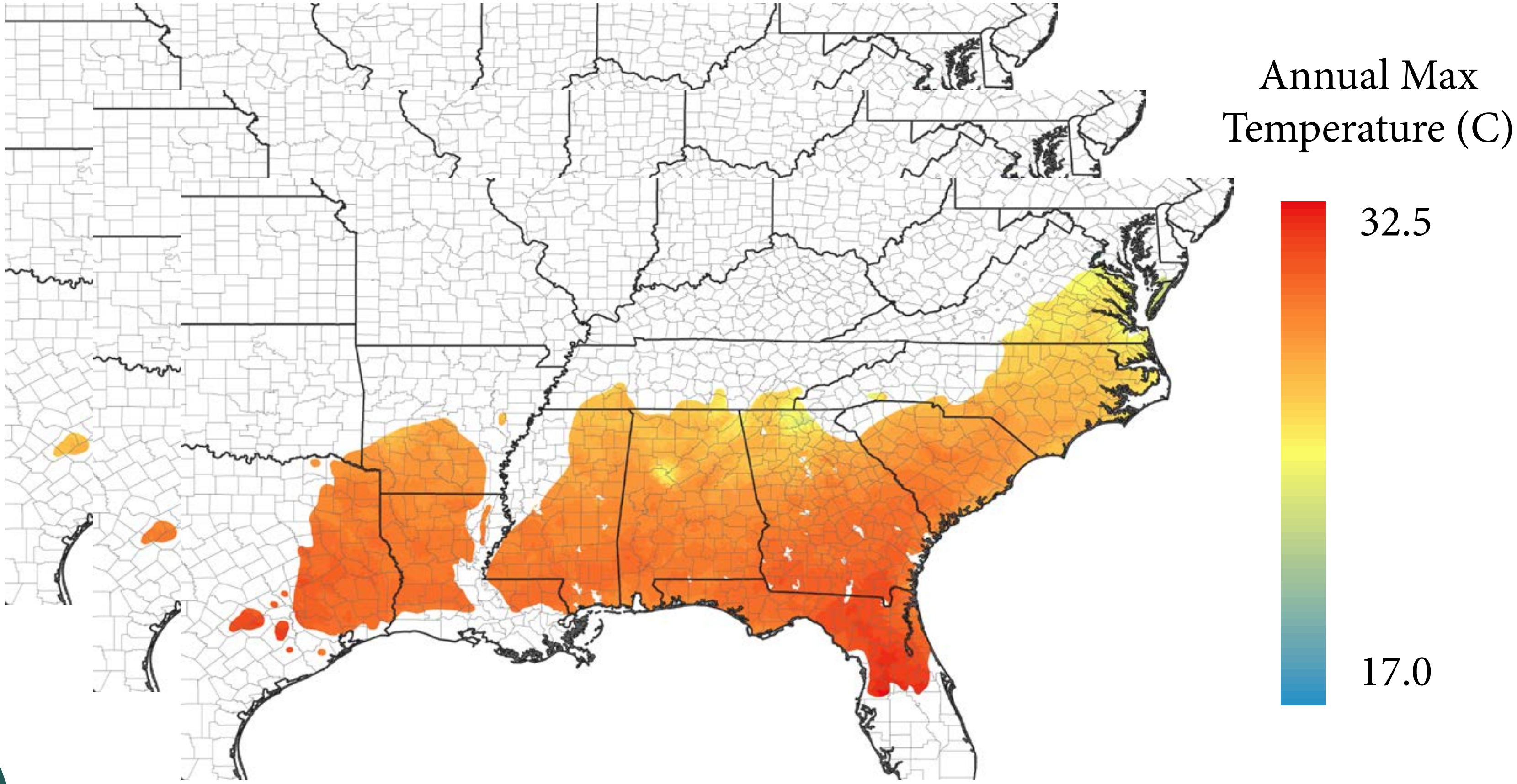




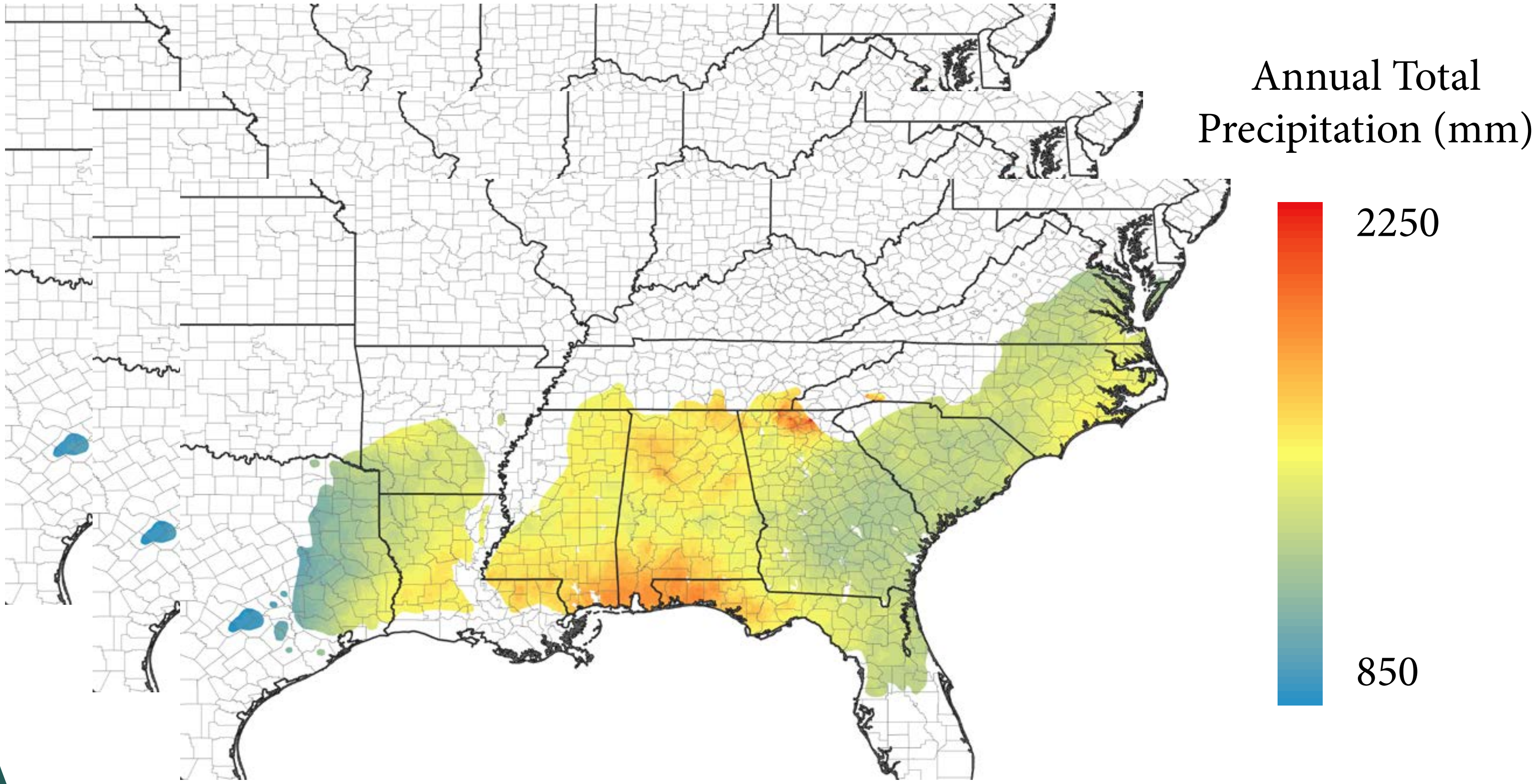
Mean +/- 1 standard deviation of differences across all 20 models + historical



# Inputs: Climate

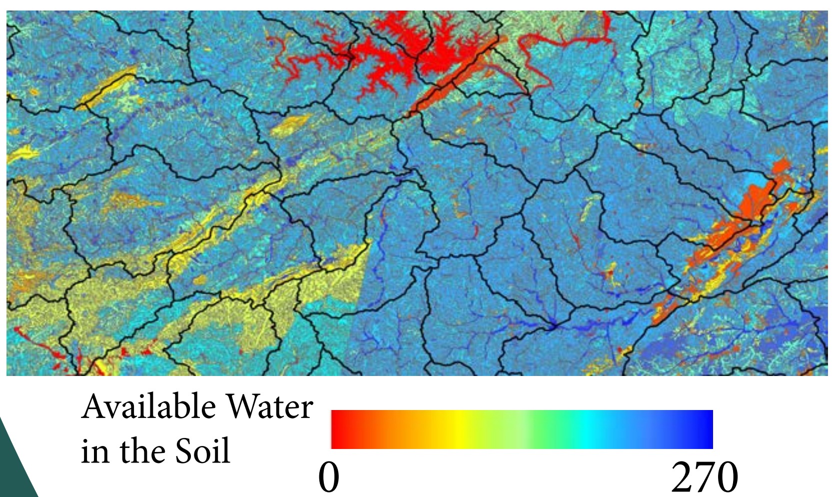


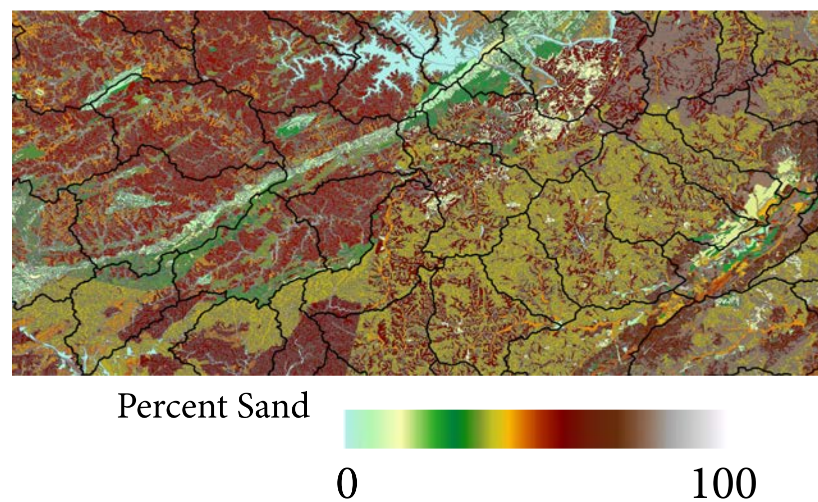
# Inputs: Climate



# Inputs: Soil

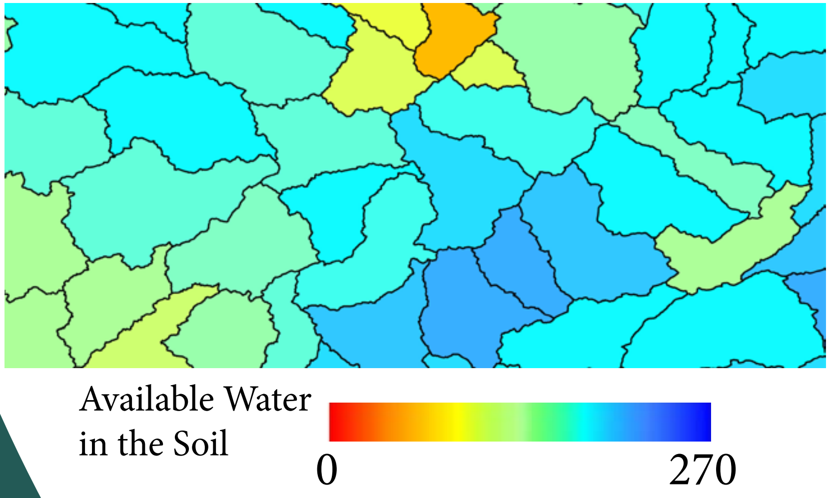
- USGS Soil Survey data (SSURGO), 2013 edition
- Soil variables were treated as constant over time
  - Common variables between G&Y and 3-PG
    - Available water storage (AWS)
    - Texture variables
      - Percent clay, sand, and silt

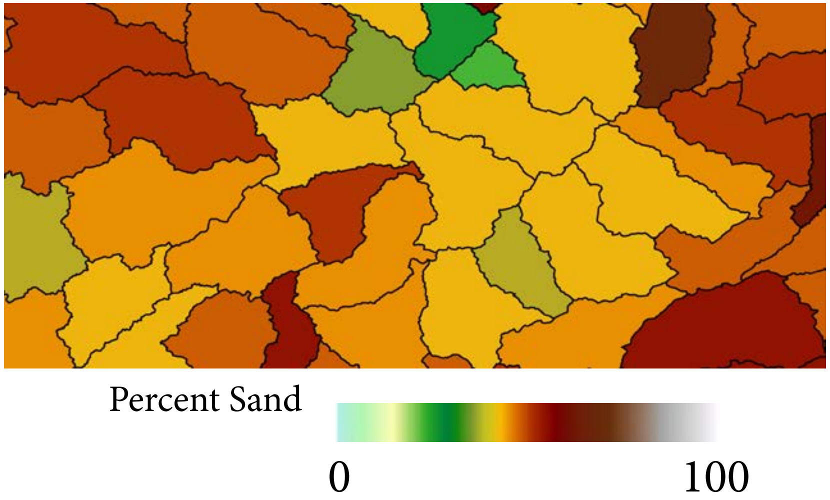


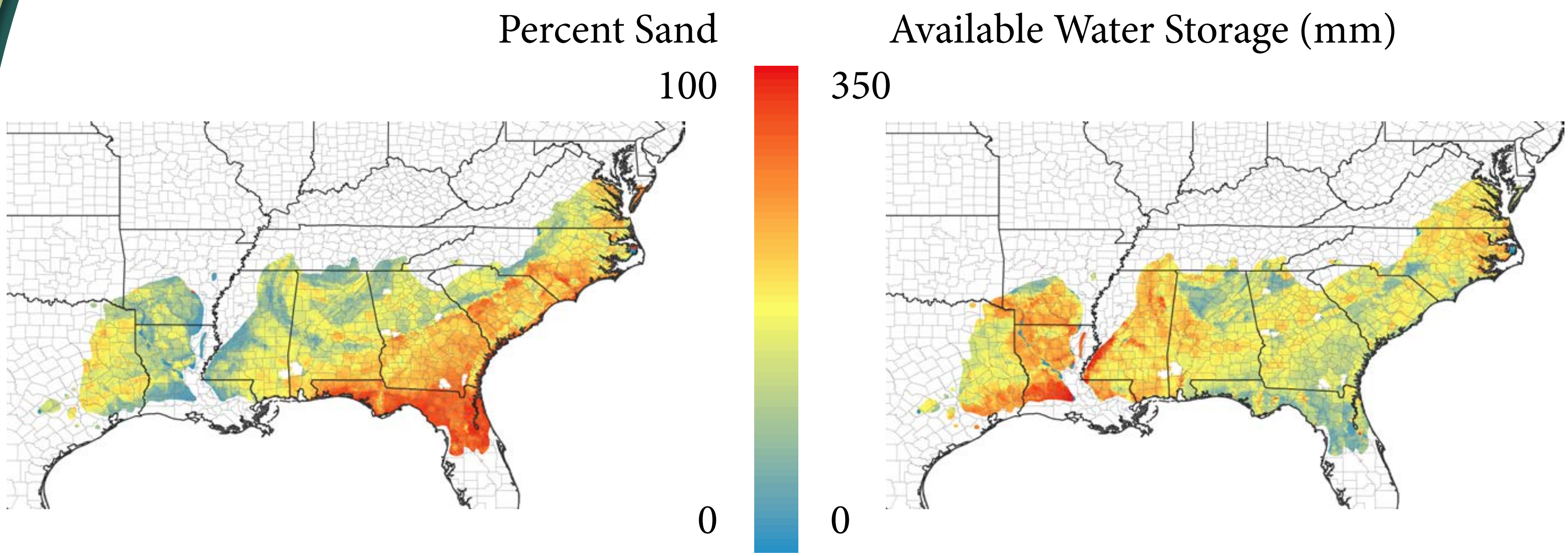
# Inputs: Soil

- Values for each HUC were obtained by area-weighted averaging of the mapunit features contained in that HUC
  - Available water storage was taken from the "muaggatt" table and joined directly to mapunit polygon features
  - Soil texture component polygon features were aggregated at the component level by thickness-weighted averaging through the horizons, then by component-proportion-weighted averaging to mapunit polygon features
  - Areas classified as "Very Poorly Drained" were excluded from aggregation, and proportion of such areas per HUC was recorded



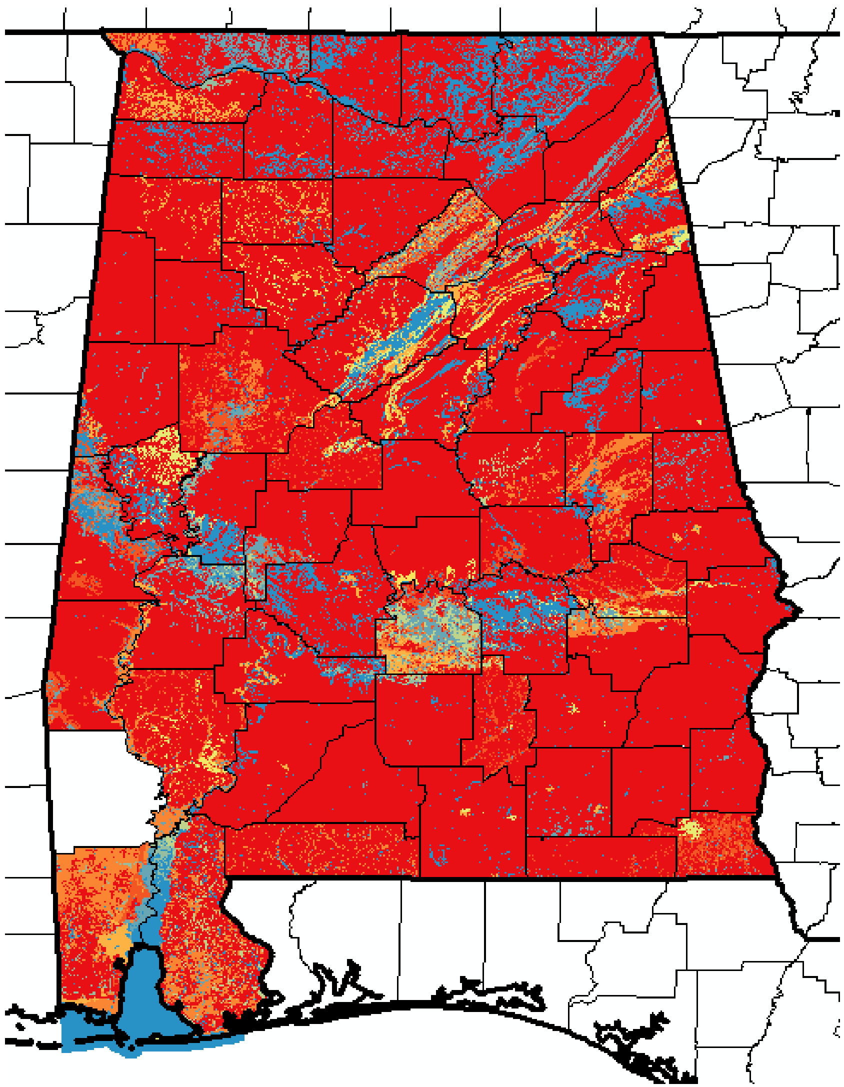



# Inputs: Soil

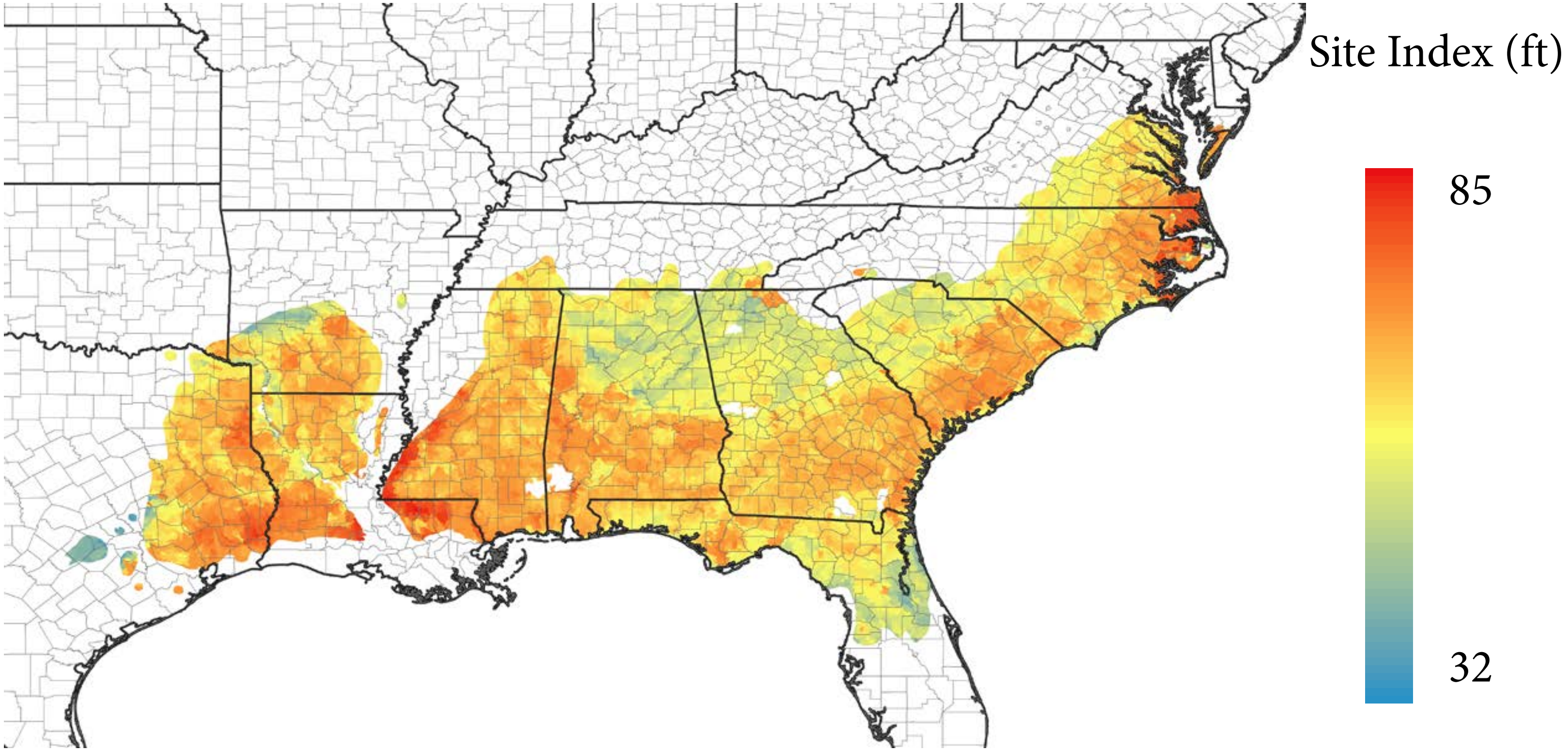


# Inputs: Site Index

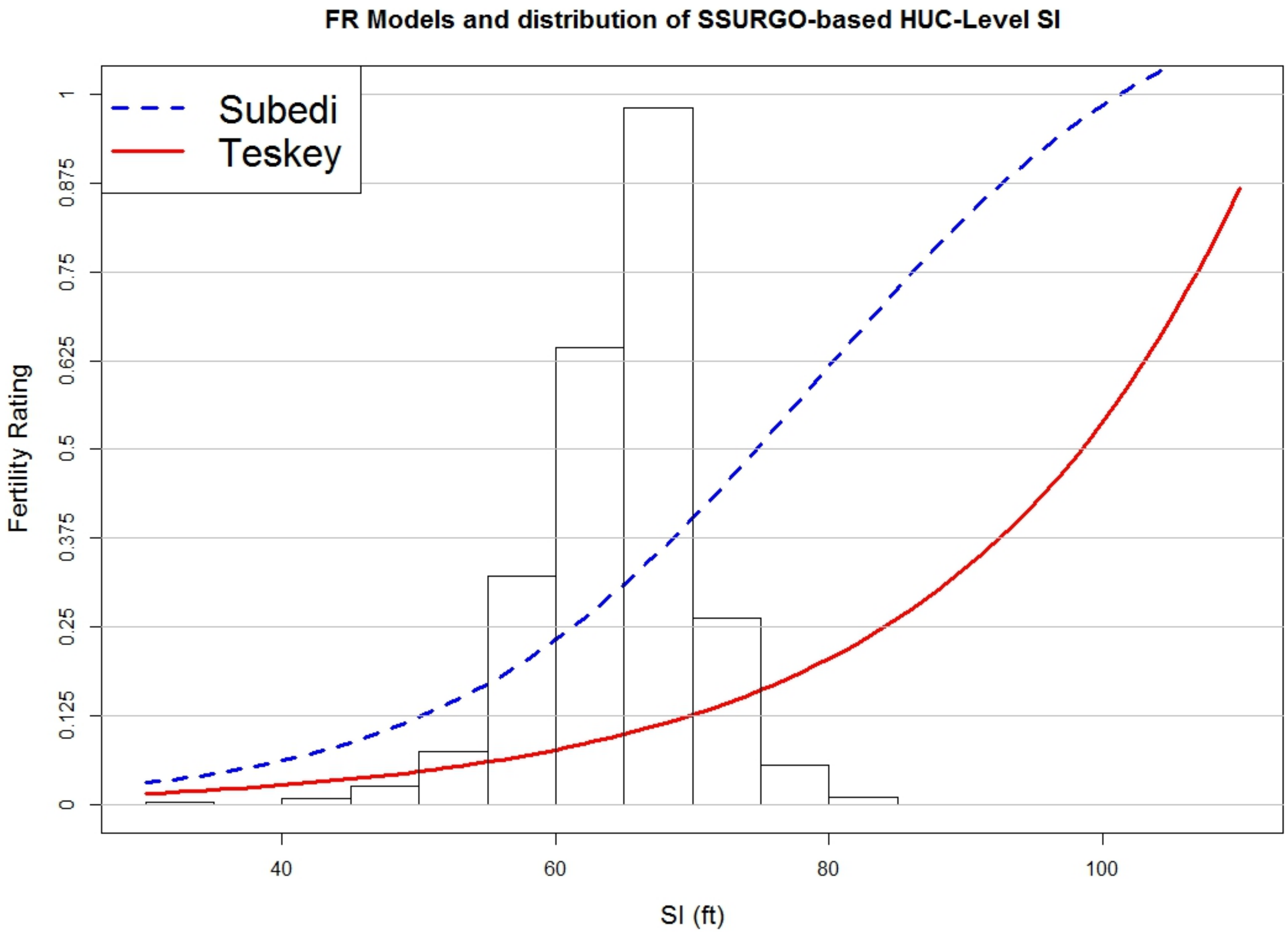
- Site index derived from the “coforprod” table of SSURGO
  - Links to the “component” table (sub-mapunit)
  - Measured values of site index from the mid-1900’s
    - Coile and Schumacher, 1953
  - A sizable proportion (~15%) of the components had no recorded site index data for loblolly pine
    - Imputation was done by computing mean site index by soil series (component name) from available data and using those values for components with no recorded data
    - Further refinement is pending…



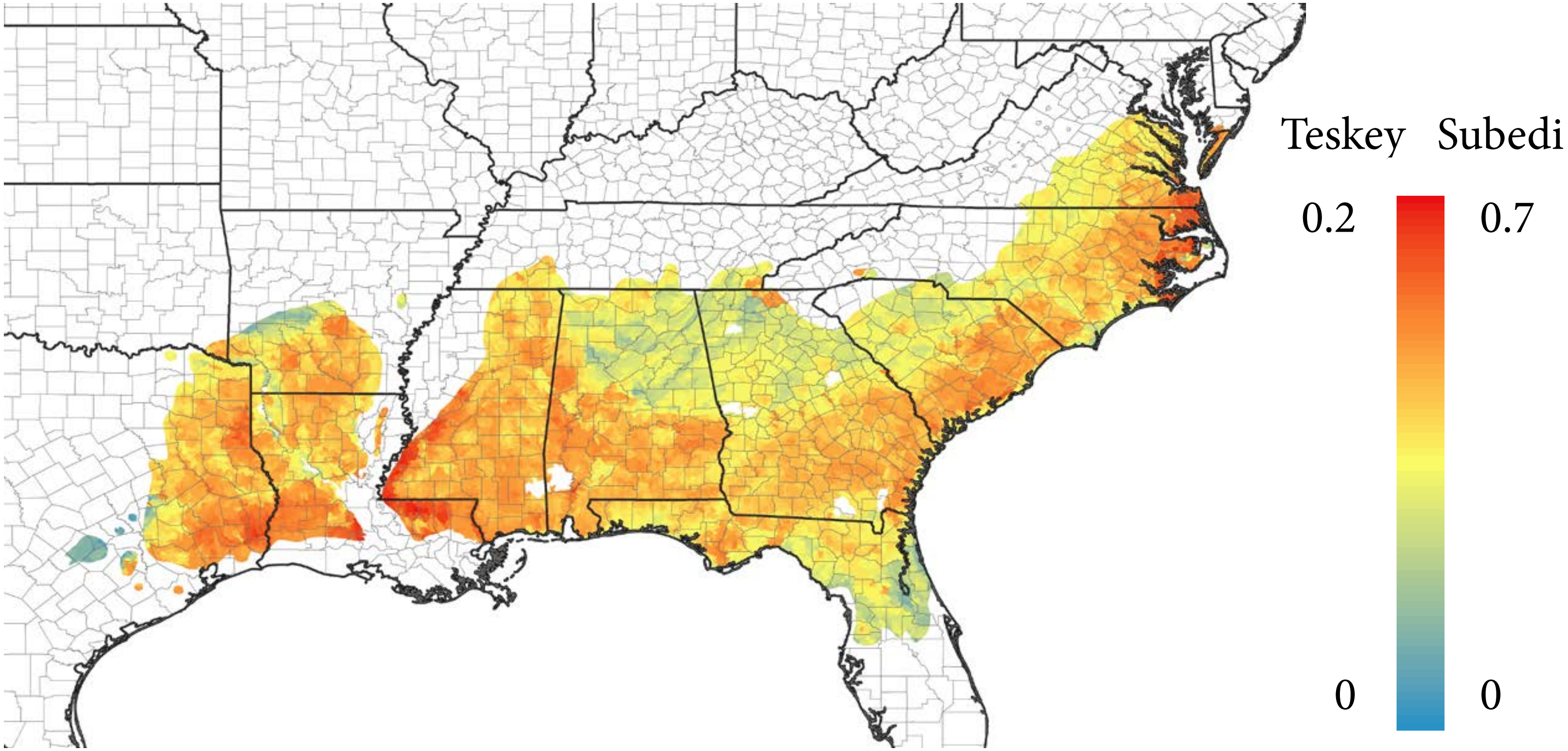
# Inputs: Site Index



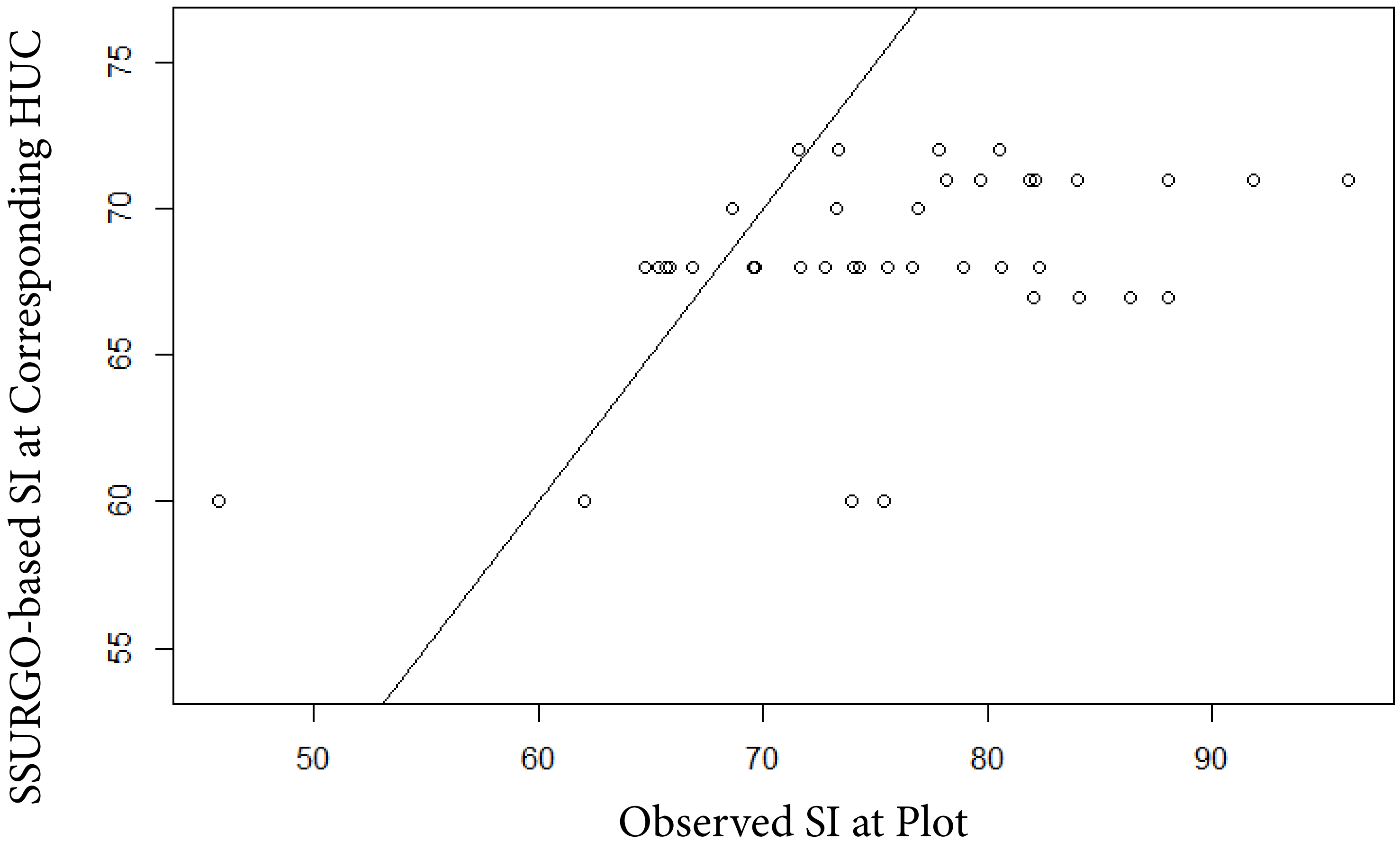
# Matching FR Models with Regional SI



# Fertility Rating



# Plot-level SI against SSURGO SI



# Results

- Preliminary results are in for one of the twenty climate models (CCSM-4)

| | Units | 3-PG | G&Y | WaSSI | CLM |
|---|---|---|---|---|---|
| Gross Primary Productivity (GPP) | MgC/ha/year | | | | |
| Net Ecosystem Productivity (NEP) | MgC/ha/year | | | | |
| Net Primary Productivity (NPP) | MgC/ha/year | | | | |
| Wood Carbon Above Ground (CAG) | MgC/ha | | | | |
| Volume Outside Bark (VOB) | $m^3$/ha | | | | |
| Leaf Area Index (LAI) | -- | | | | |
| Evapotranspiration (ET) | mm | | | | |

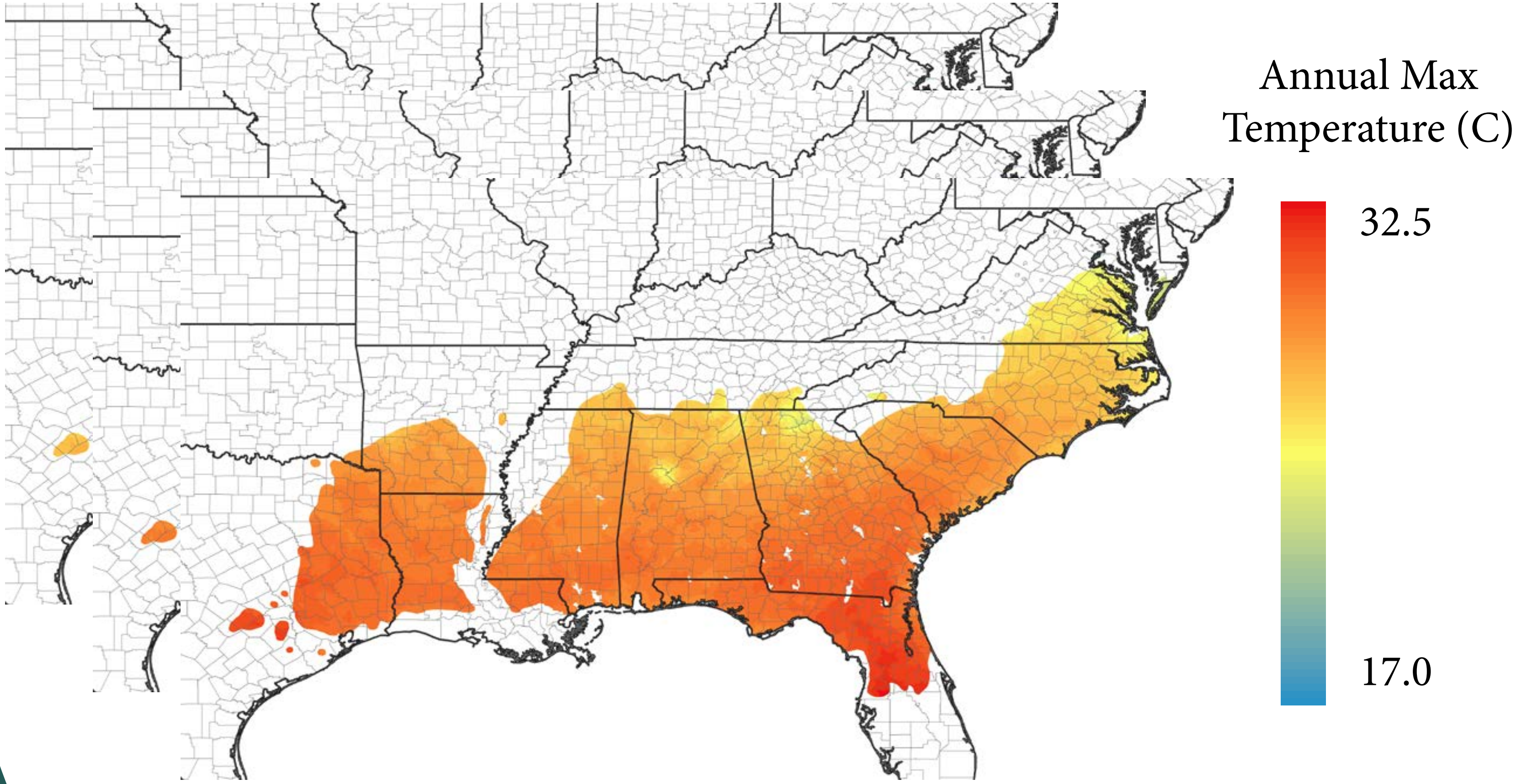
# Results

- 3-PG (Two variants from a field of candidates)
  - Flavor A (3A): Bryars/Teskey model structure, Teskey parameter set, Teskey SI-FR model
  - Flavor C (3C): Landsberg/Sands model structure, Sampson parameter set, Subedi SI-FR model
- G&Y (GY)
- WaSSI (W)
- CLM (With and without the $CO_2$ fertilization effect)
  - Climate drivers only (C)
  - Climate and CO2 fertilization drivers (C2)

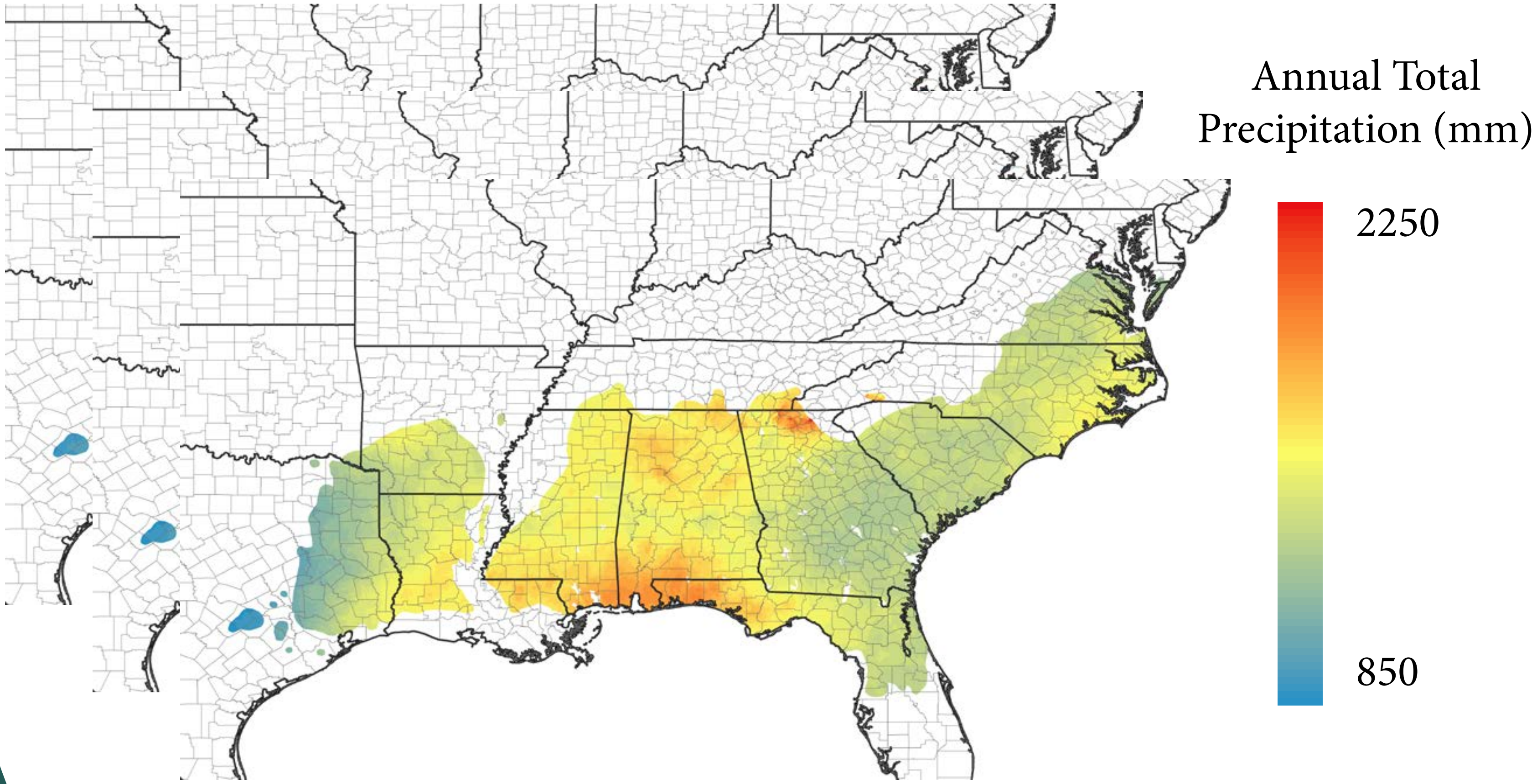
# Results

- Models were run on 25-year time slices where possible
  - 1971-1995, 1996-2020, etc.
    - G&Y starts at 1980 due to data availability
  - Values were taken at the end of the rotation for G&Y, 3-PG, and CLM
    - CLM uses a difference between year 25 and year 1
    - Mean value across the time slice was used for WaSSI outputs
- Both the RCP 8.5 (business as usual) and RCP 4.5 (no further emissions) scenarios of climate change were used when available

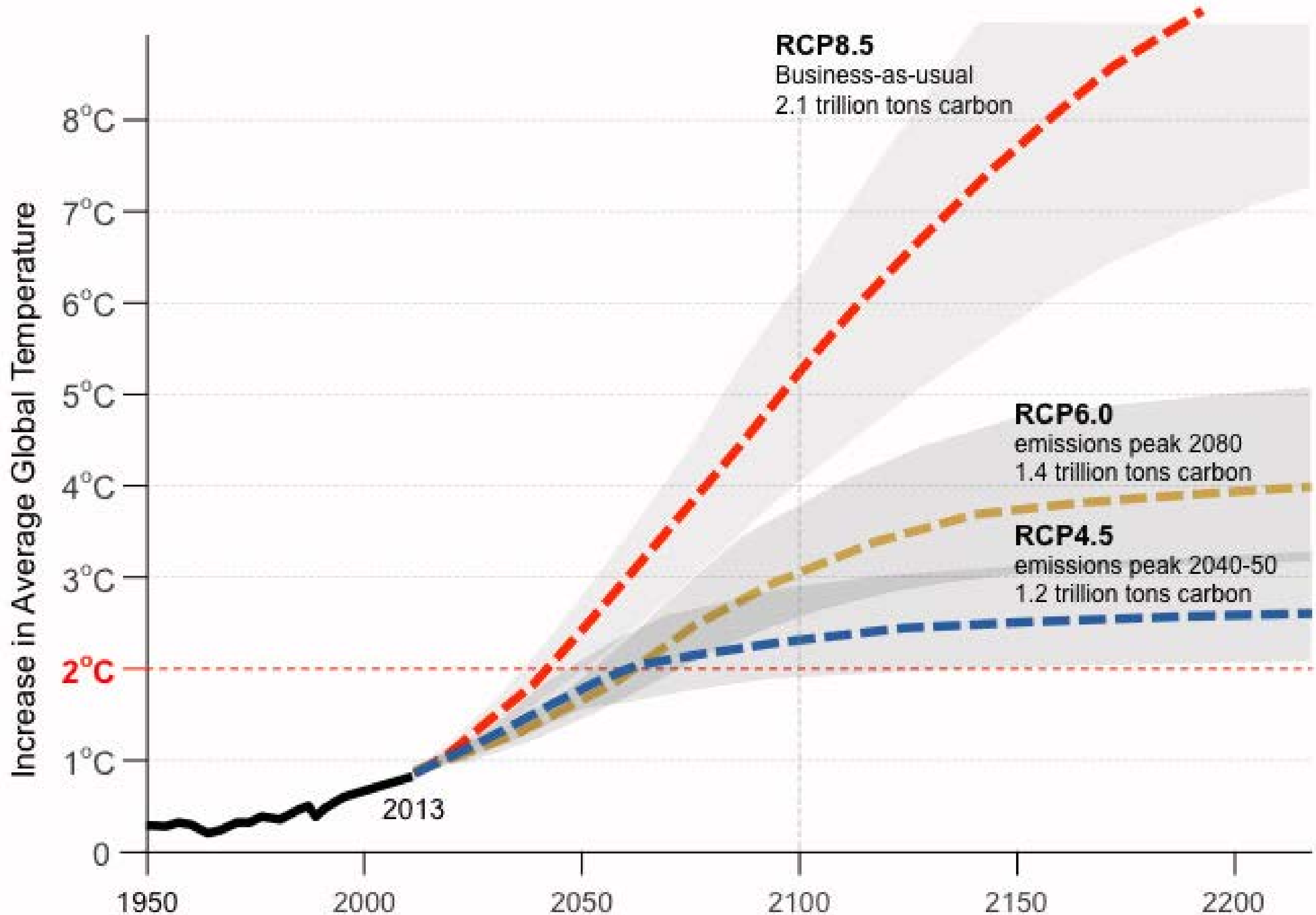
# Inputs: Climate



# Inputs: Climate



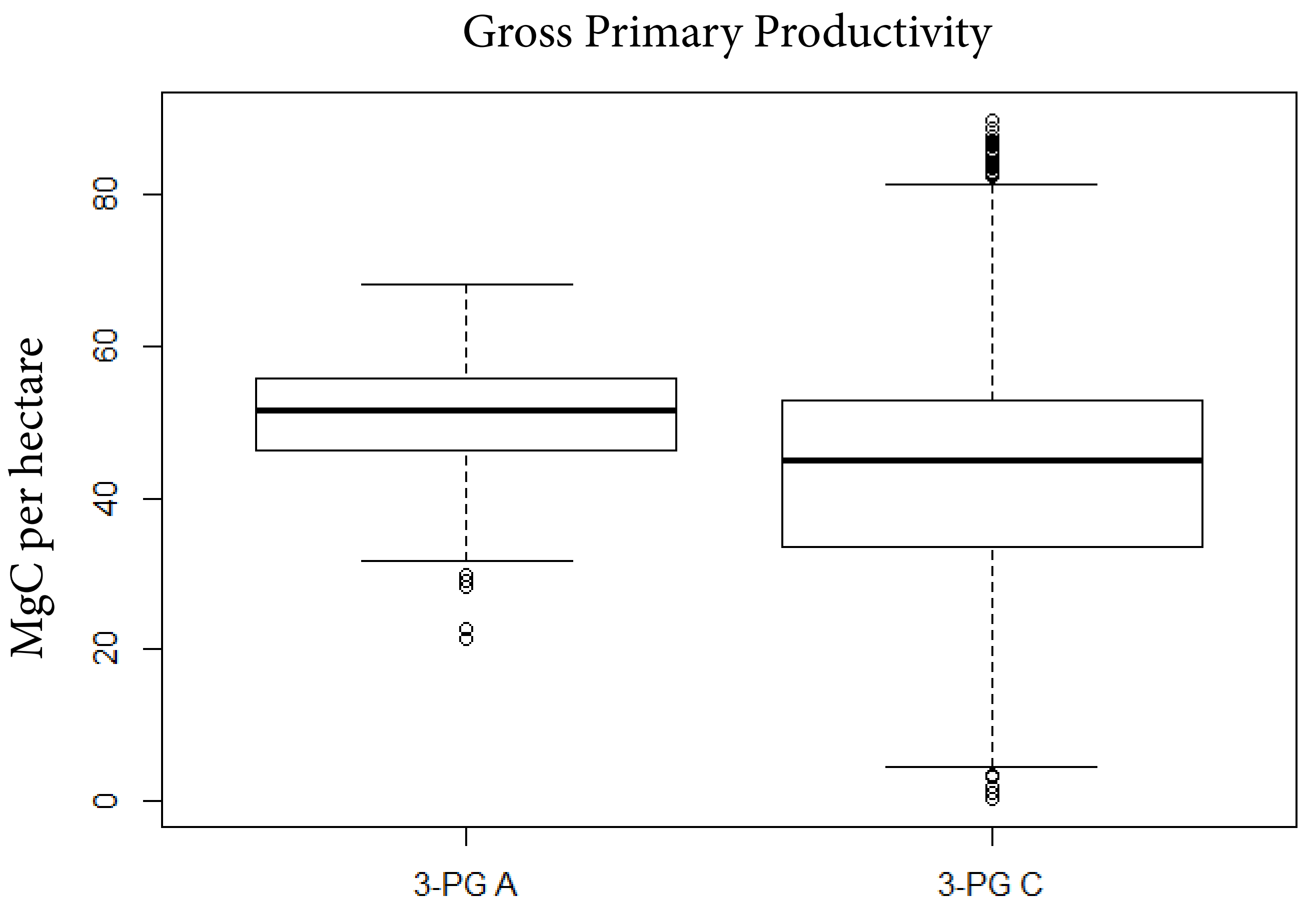
# Carbon Dioxide




**Global Temperature Projections for various RCP Scenarios**

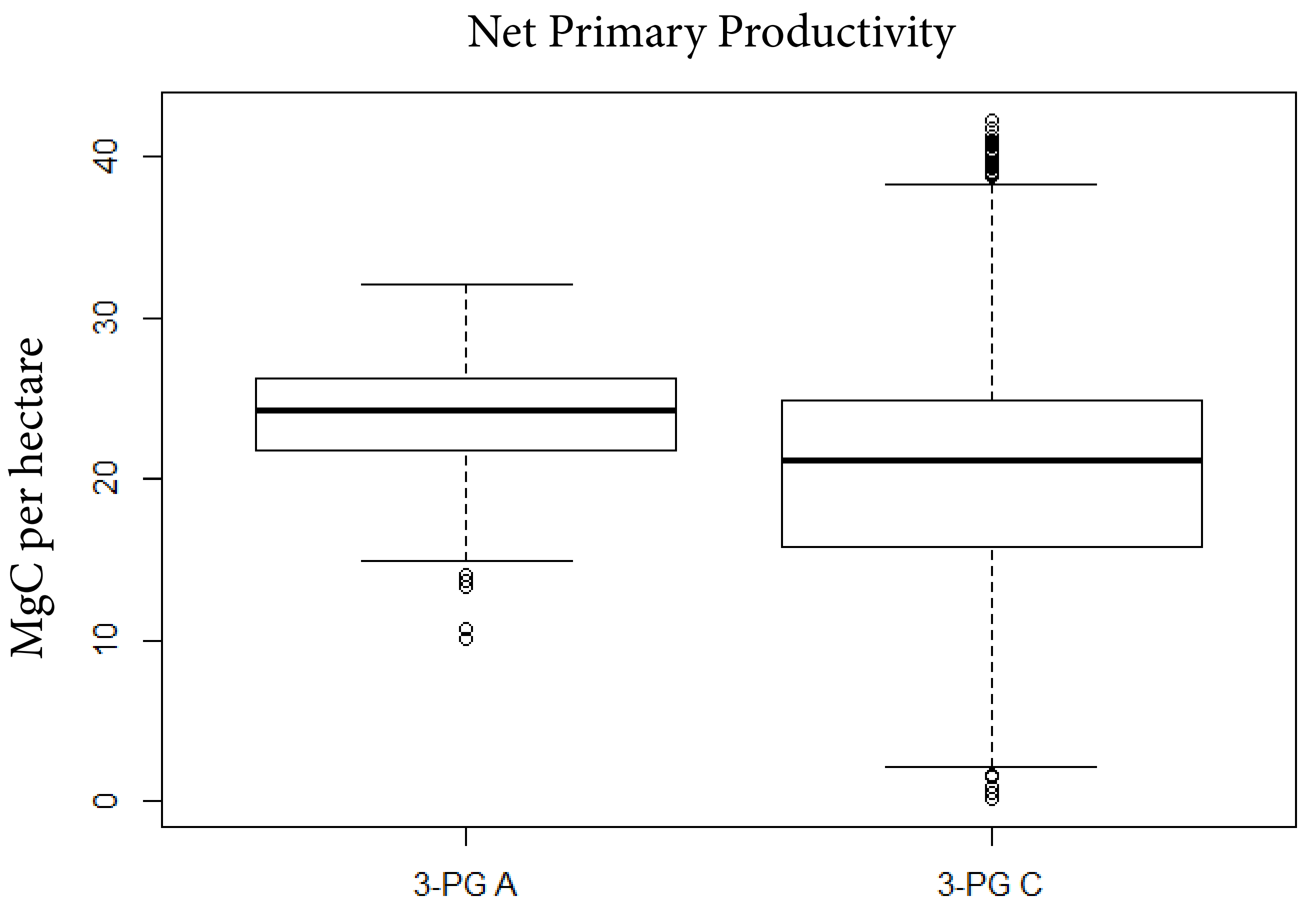
Source: Architecture 2030; Adapted from IPCC Fifth Assessment Report, 2013
Representative Concentration Pathways (RCP), temperature projections for SRES scenarios and the RCPs.

# 3-PG Flavor Comparisons (GPP)



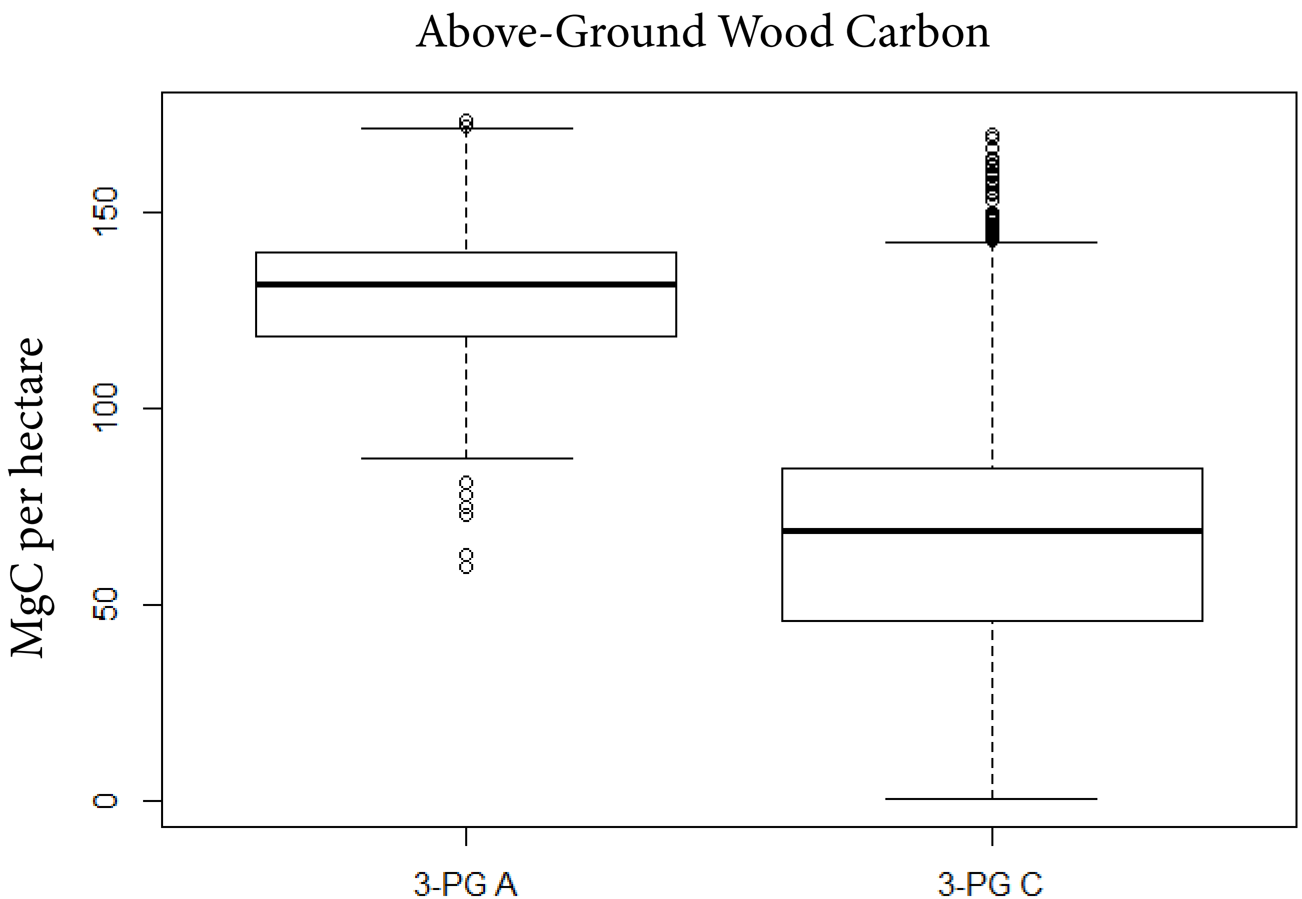

| 1 MgC/ha | ~ 0.446 tonsC/acre |
|---|---|
| | = 100 $gC/m^2$ |

# 3-PG Flavor Comparisons (NPP)



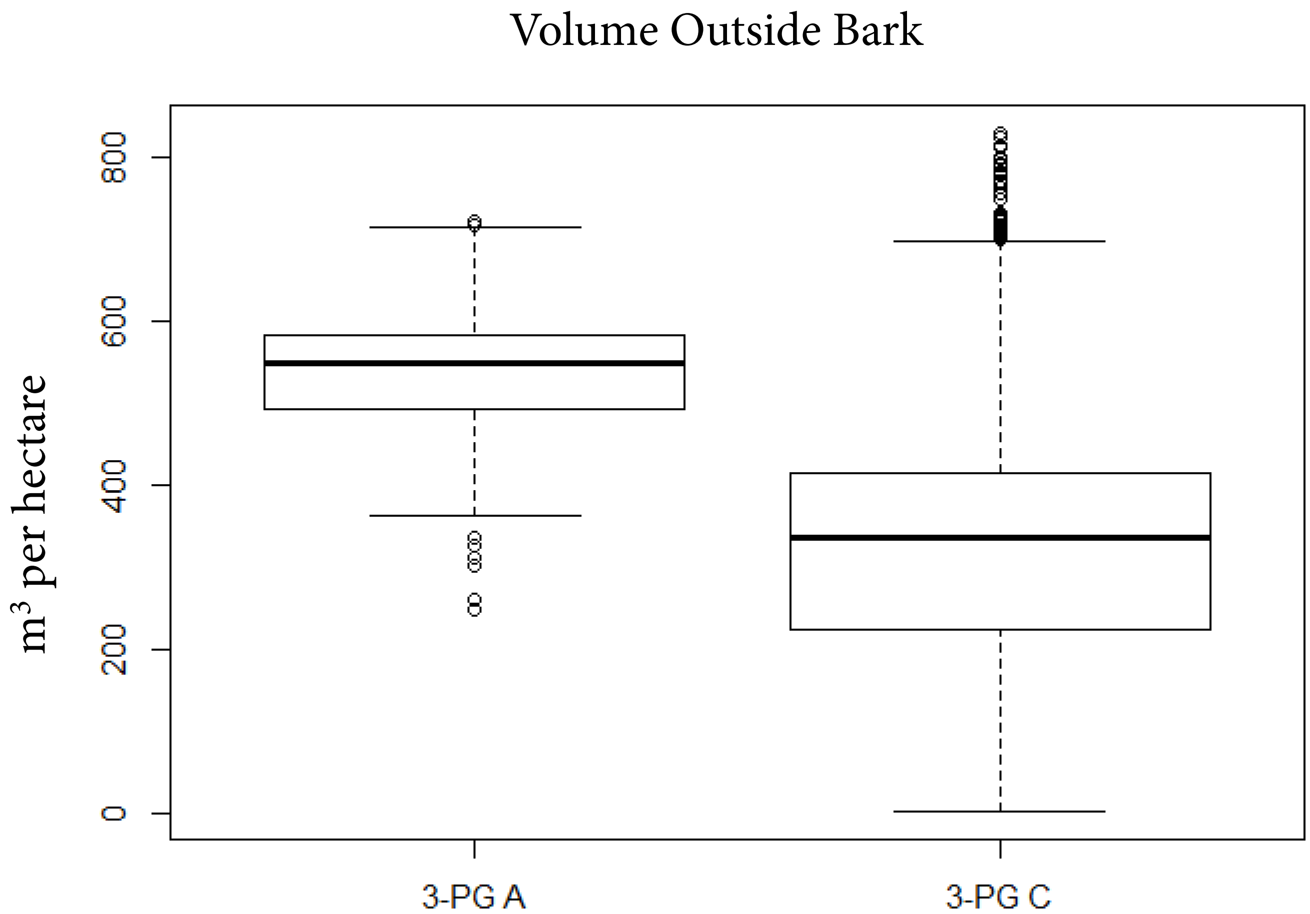

1 MgC/ha ~ 0.446 tonsC/acre
= 100 $gC/m^2$

# 3-PG Flavor Comparisons (CAG)



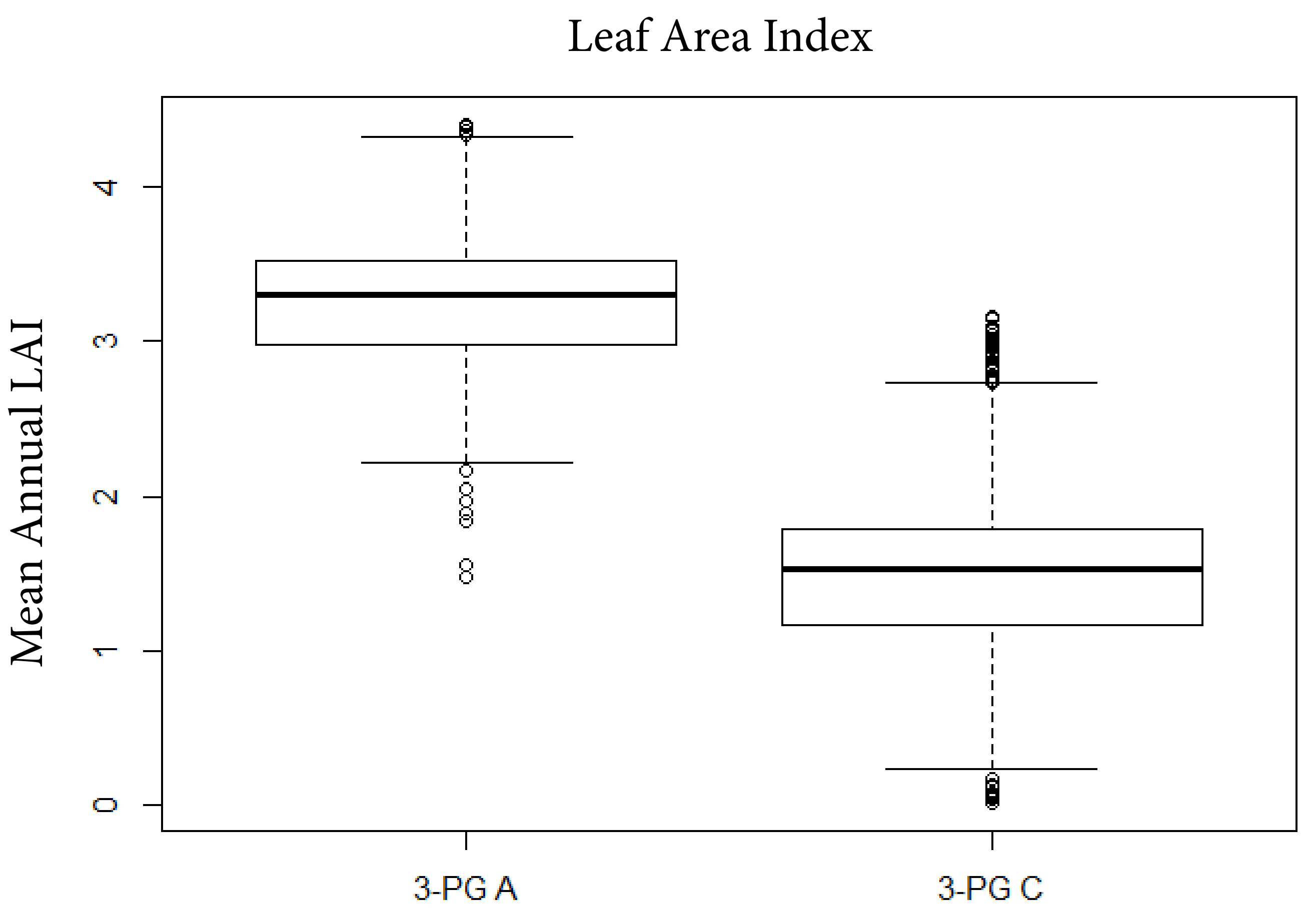

1 MgC/ha ~ 0.446 tonsC/acre
= 100 $gC/m^2$

# 3-PG Flavor Comparisons (VOB)

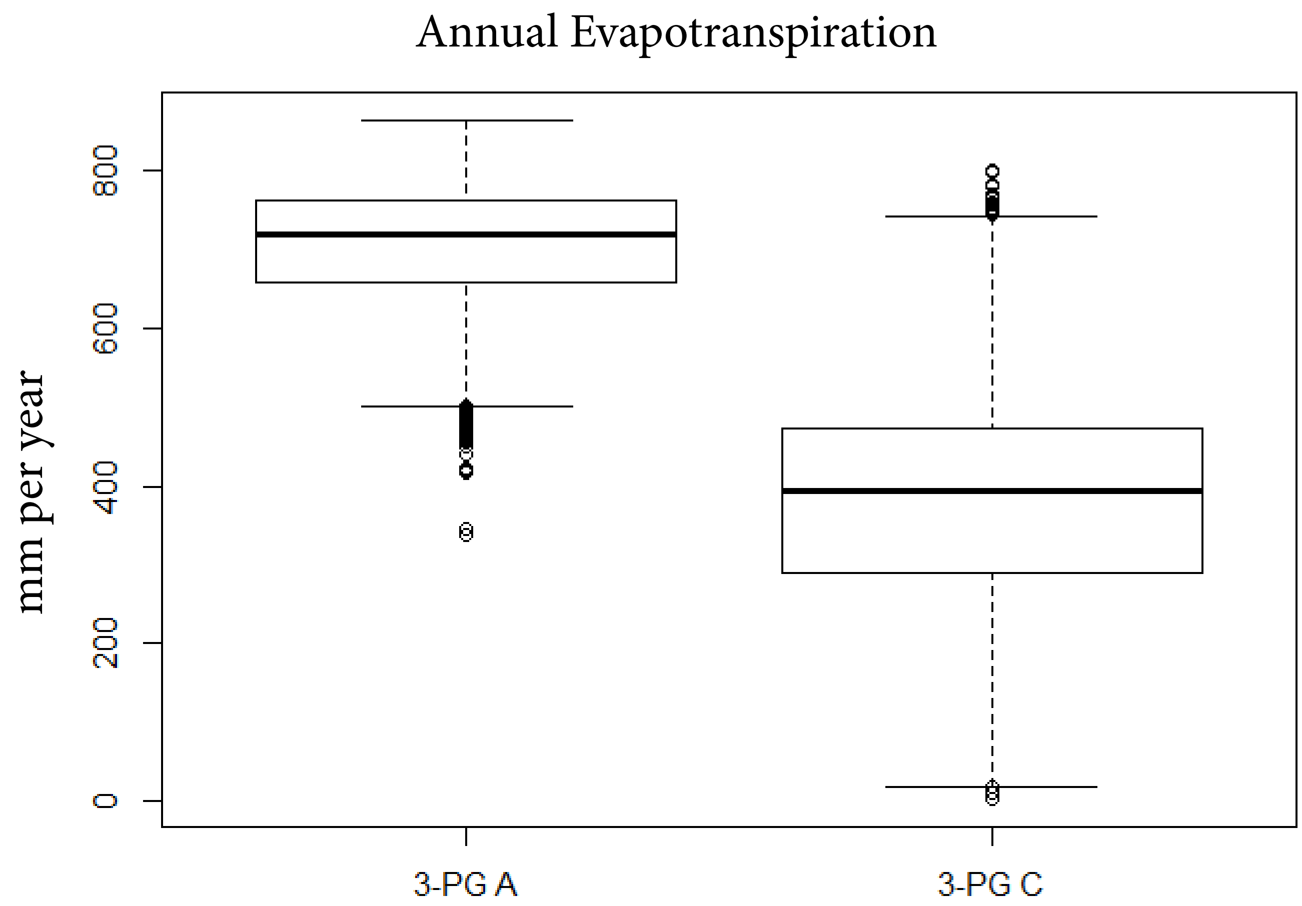



1 m$^3$/ha ~ 14.29 ft$^3$/acre

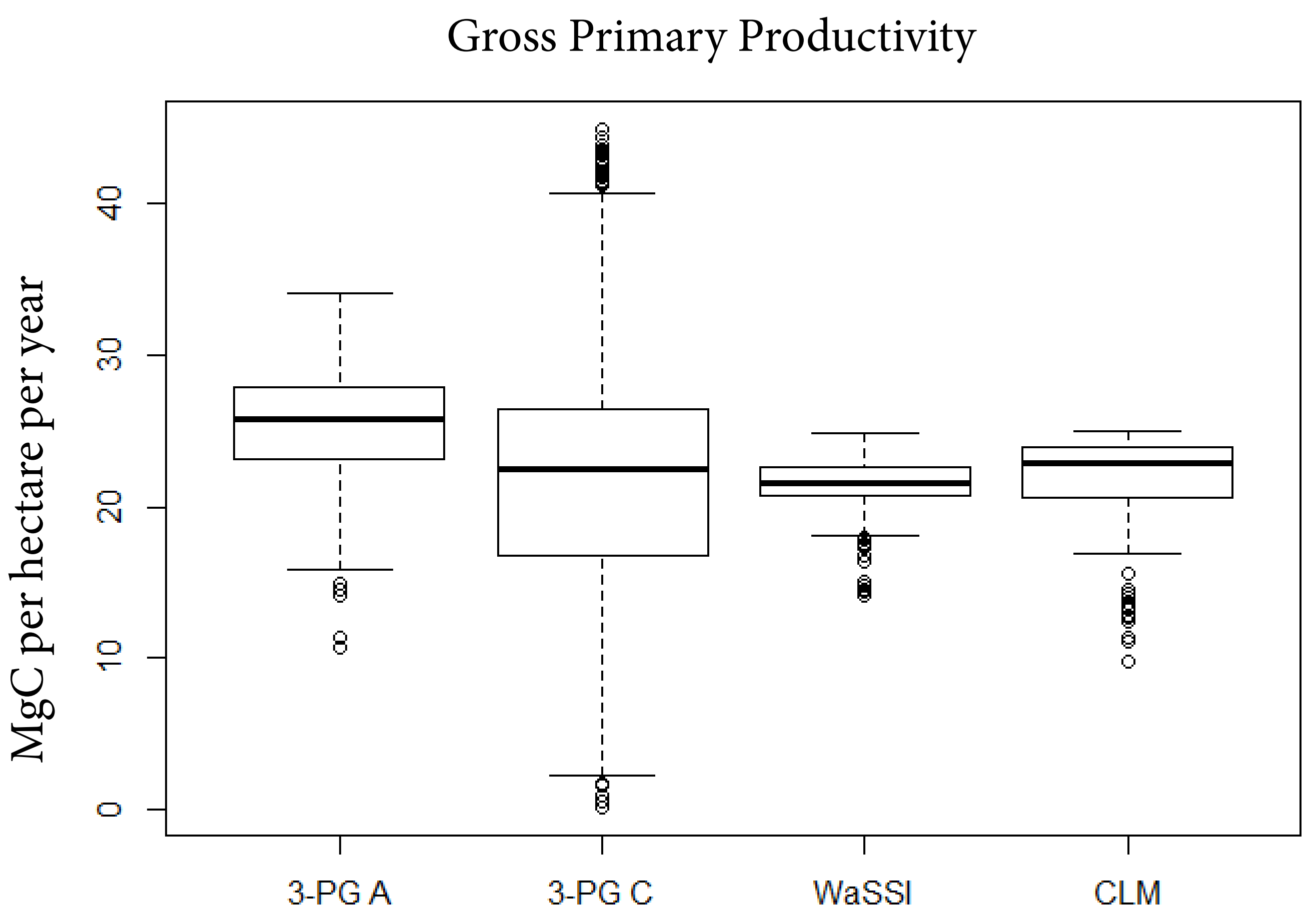
# 3-PG Flavor Comparisons (LAI)



# 3-PG Flavor Comparisons (ET)

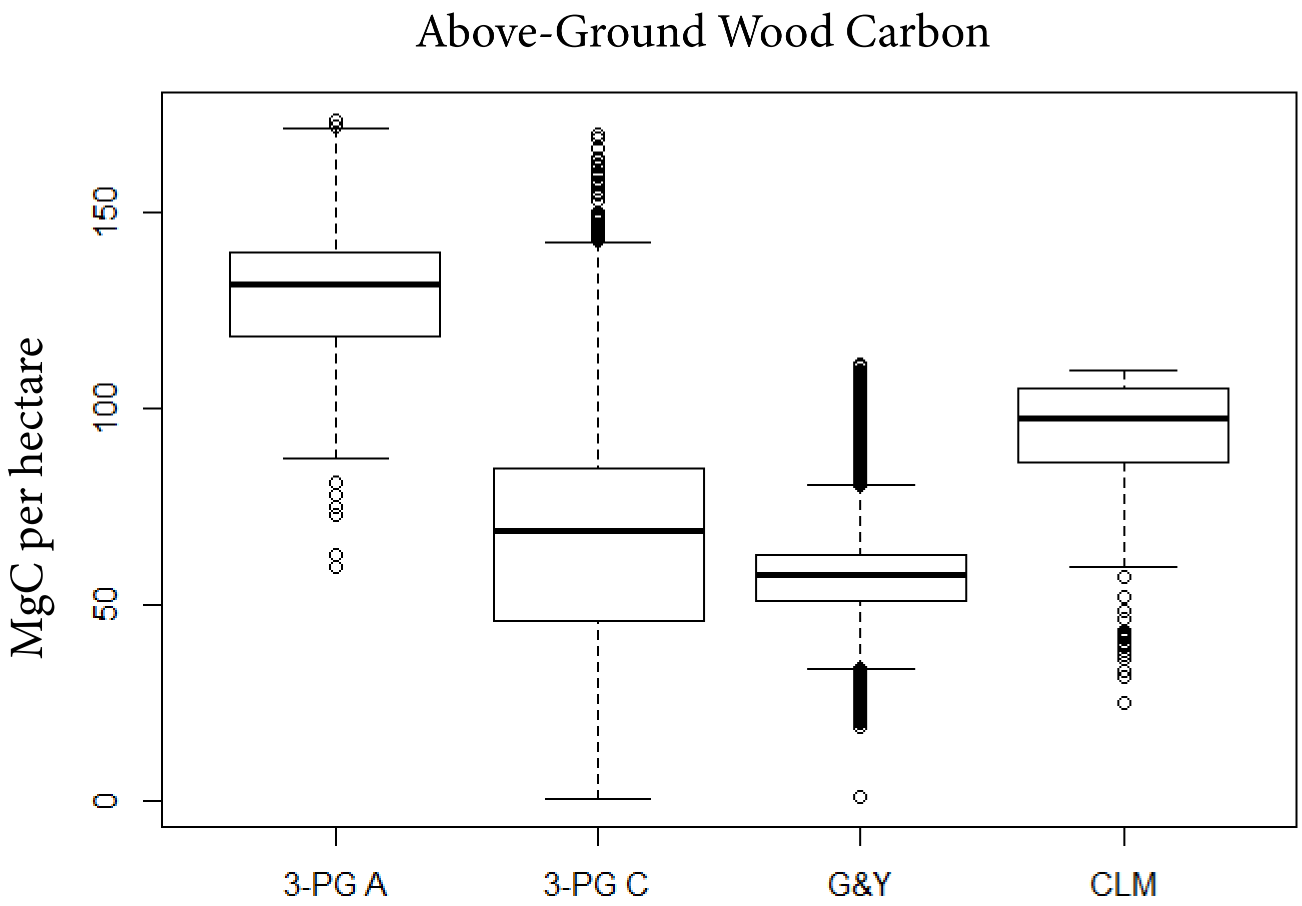


# Model Intercomparison (Baseline)



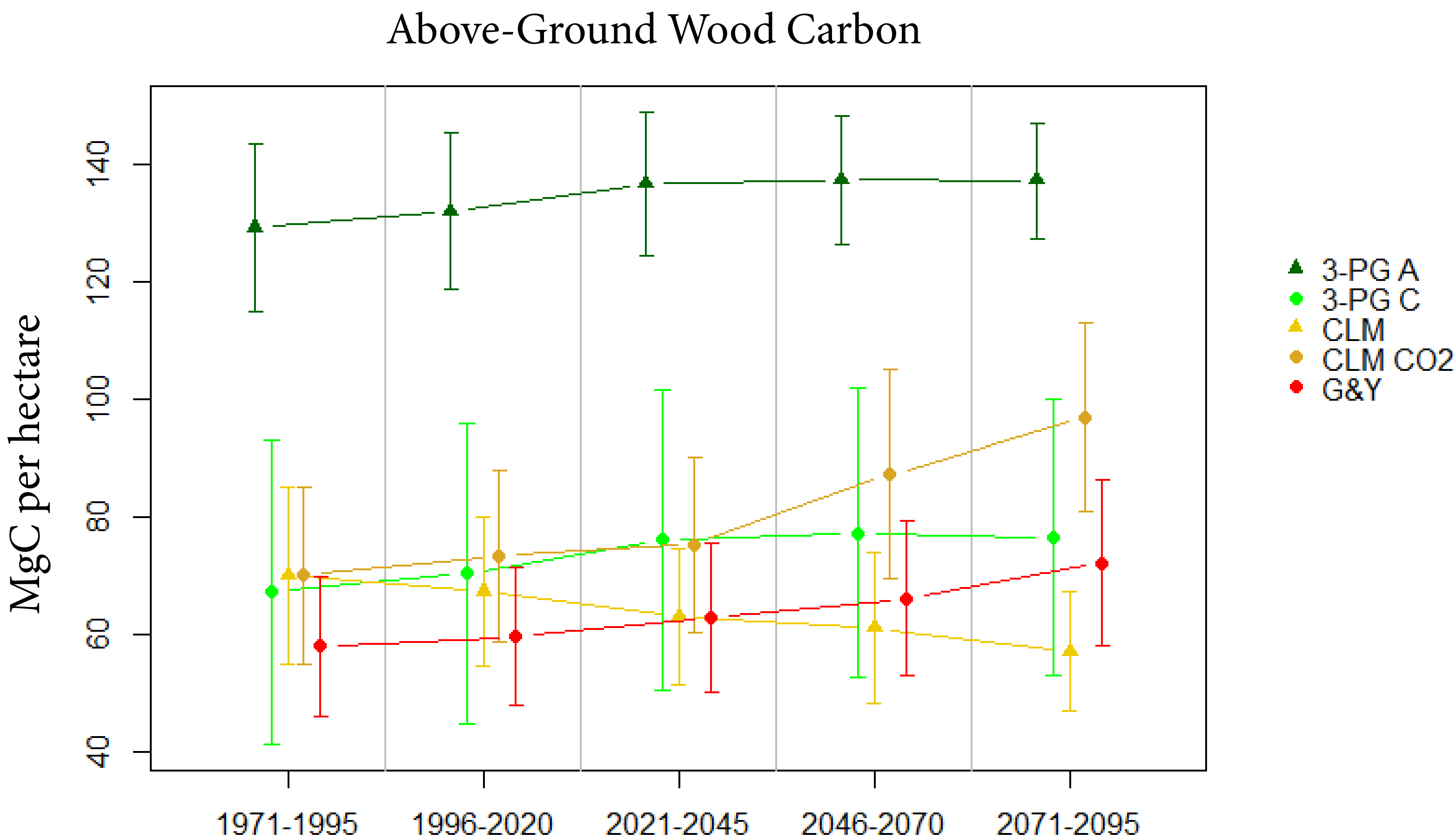

| | |
|---|---|
| 1 MgC/ha | ~ 0.446 tonsC/acre |
| | ~ 100 gC/m$^2$ |

# Model Intercomparison (Baseline)



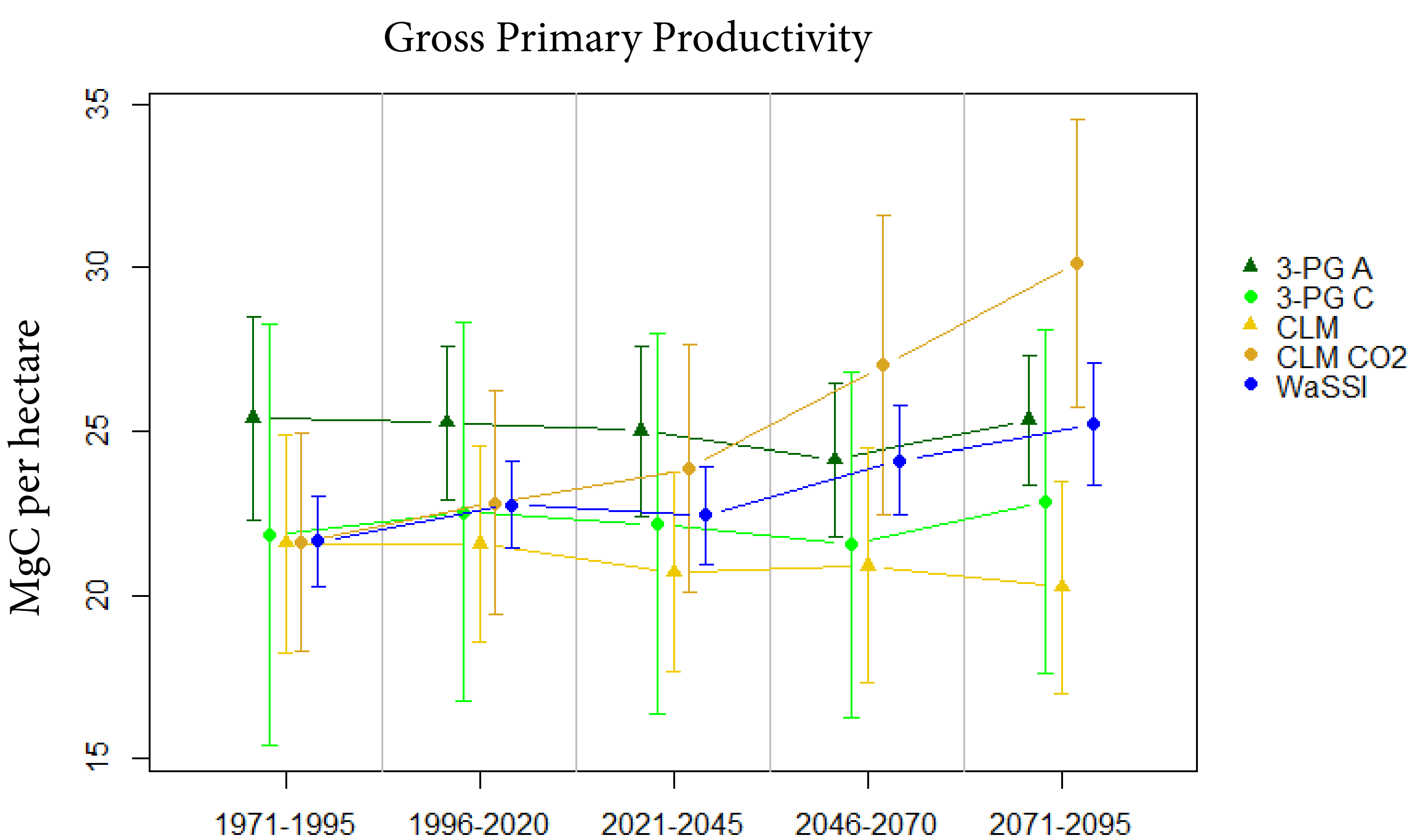

1 MgC/ha ~ 0.446 tonsC/acre
= 100 $gC/m^2$

# Comparing Models through time (RCP 8.5)



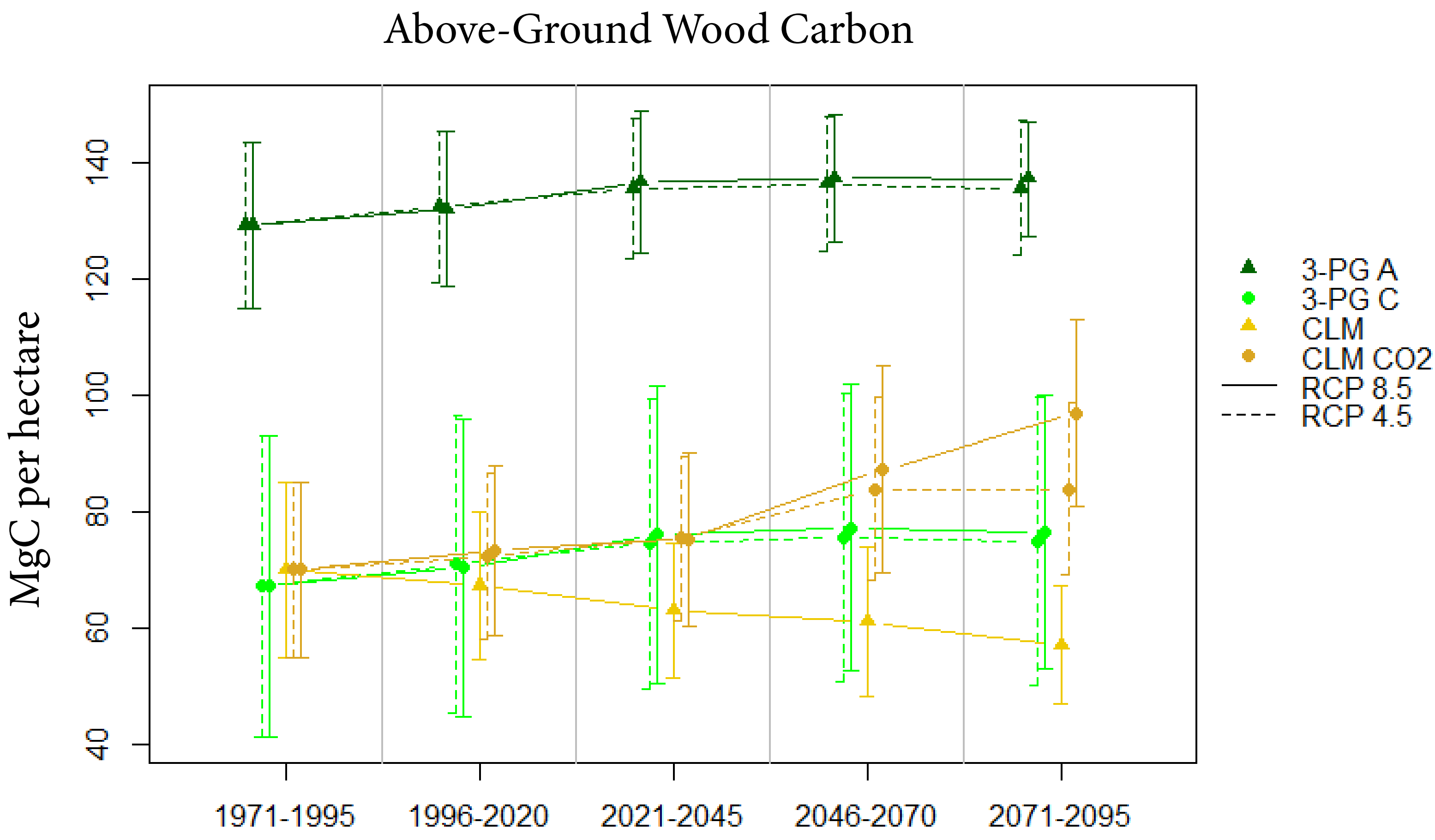

| | |
|---|---|
| 1 MgC/ha | ~ 0.446 tonsC/acre |
| | = 100 $gC/m^2$ |

# Model Variation through Time




1 MgC/ha ~ 0.446 tonsC/acre
= 100 $gC/m^2$

# Effect of Scenario

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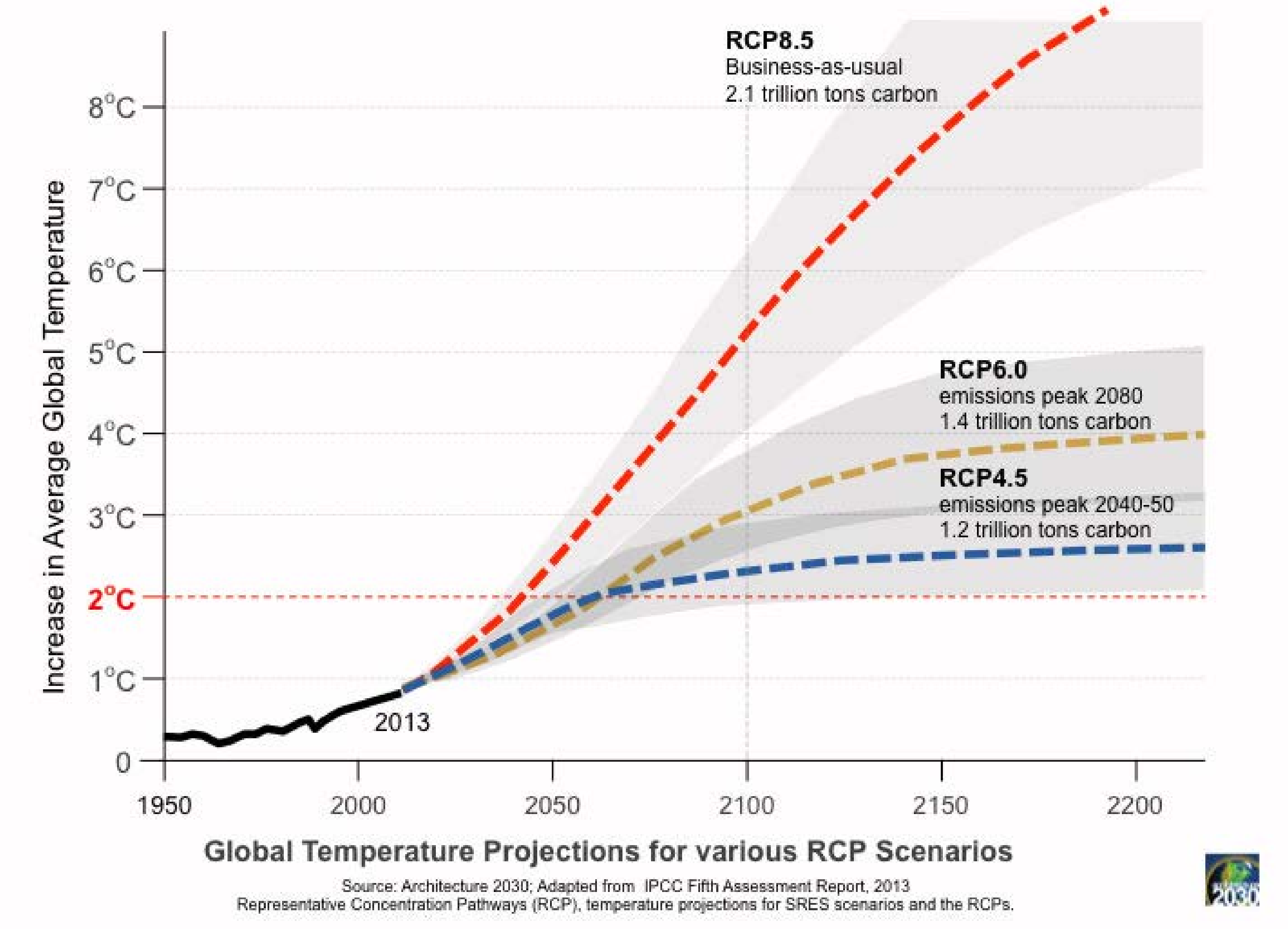
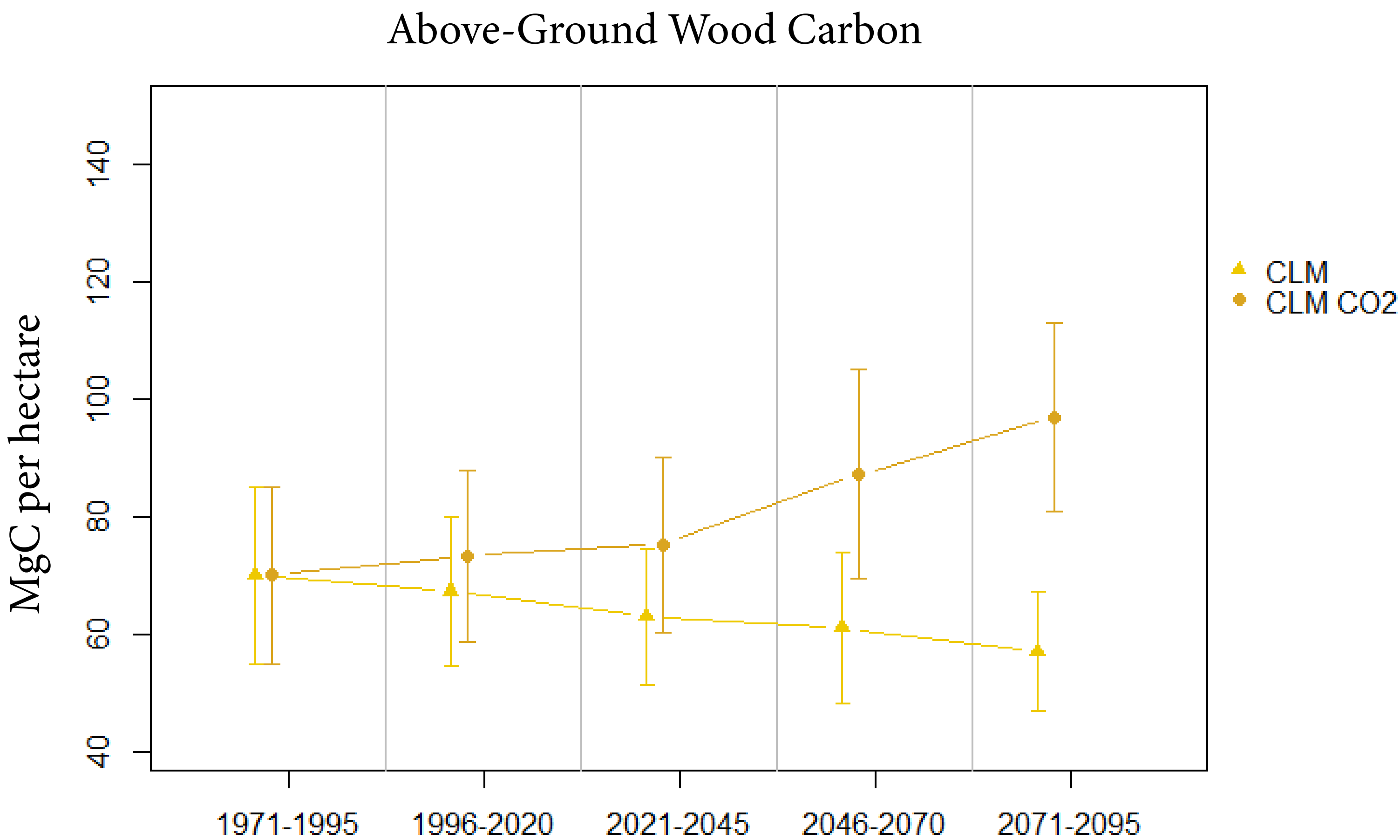
= 100 $gC/m^2$

# Carbon Dioxide

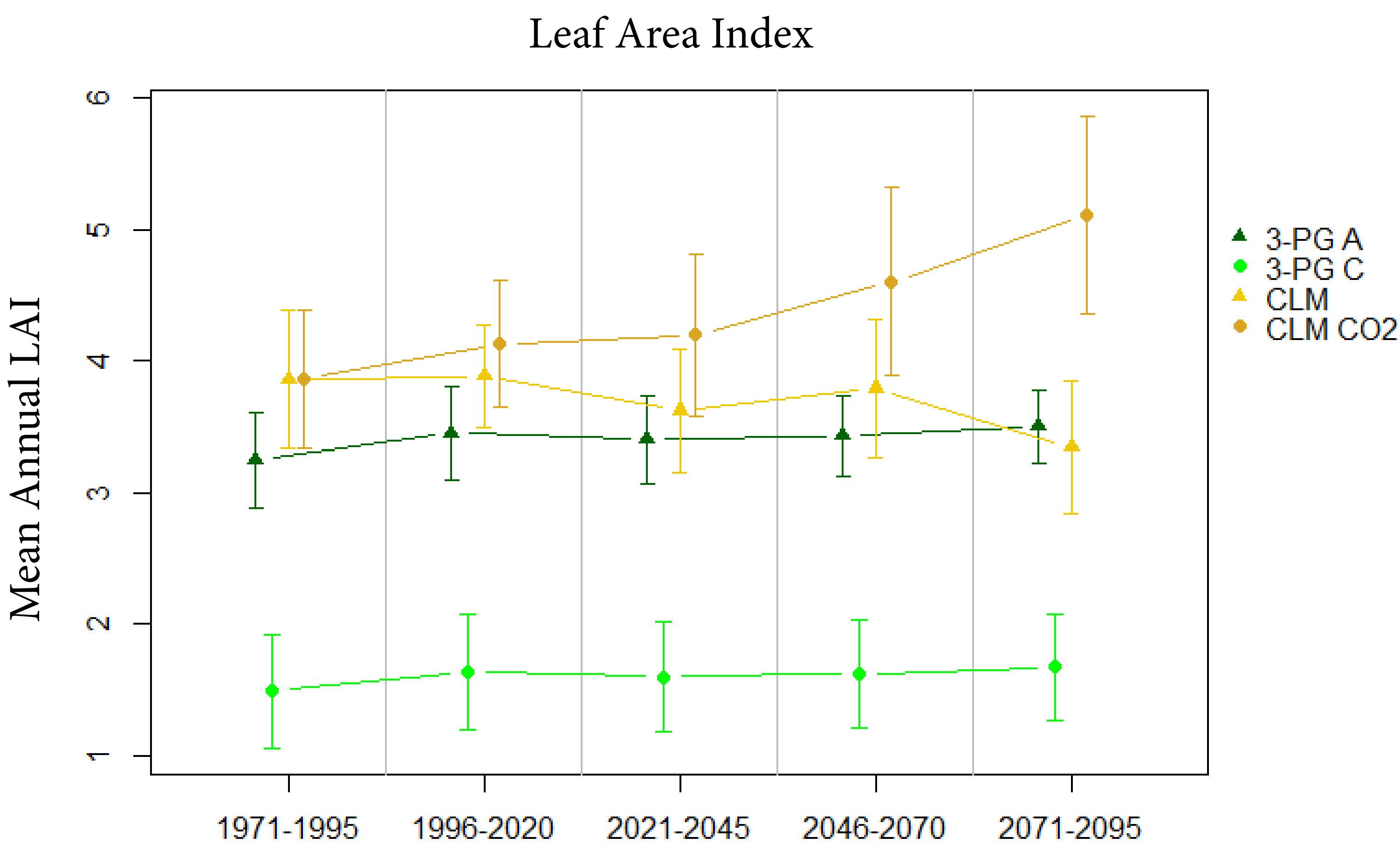


# Effect of $CO_2$ Fertilization

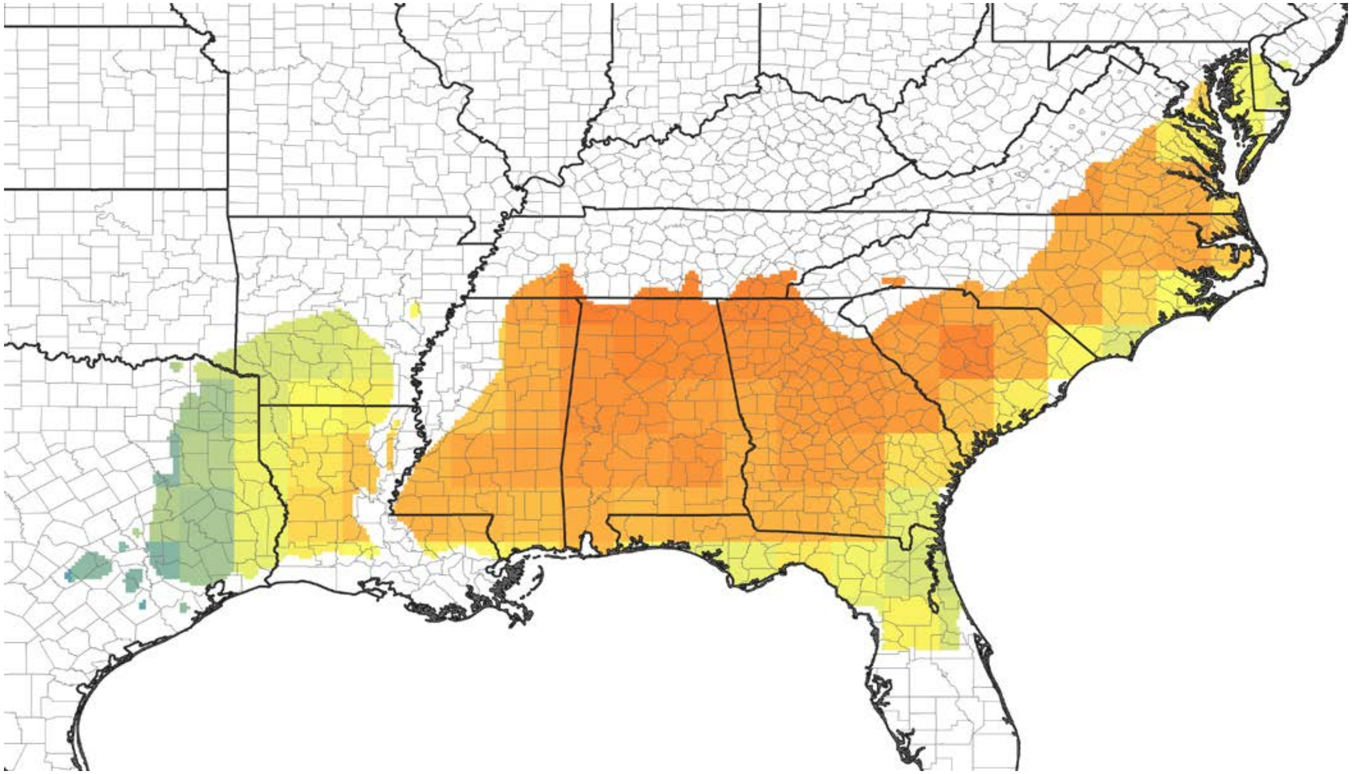



1 MgC/ha ~ 0.446 tonsC/acre
= 100 $gC/m^2$

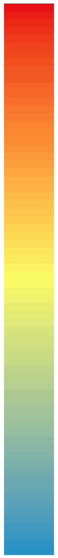
# LAI Differences due to Parameters



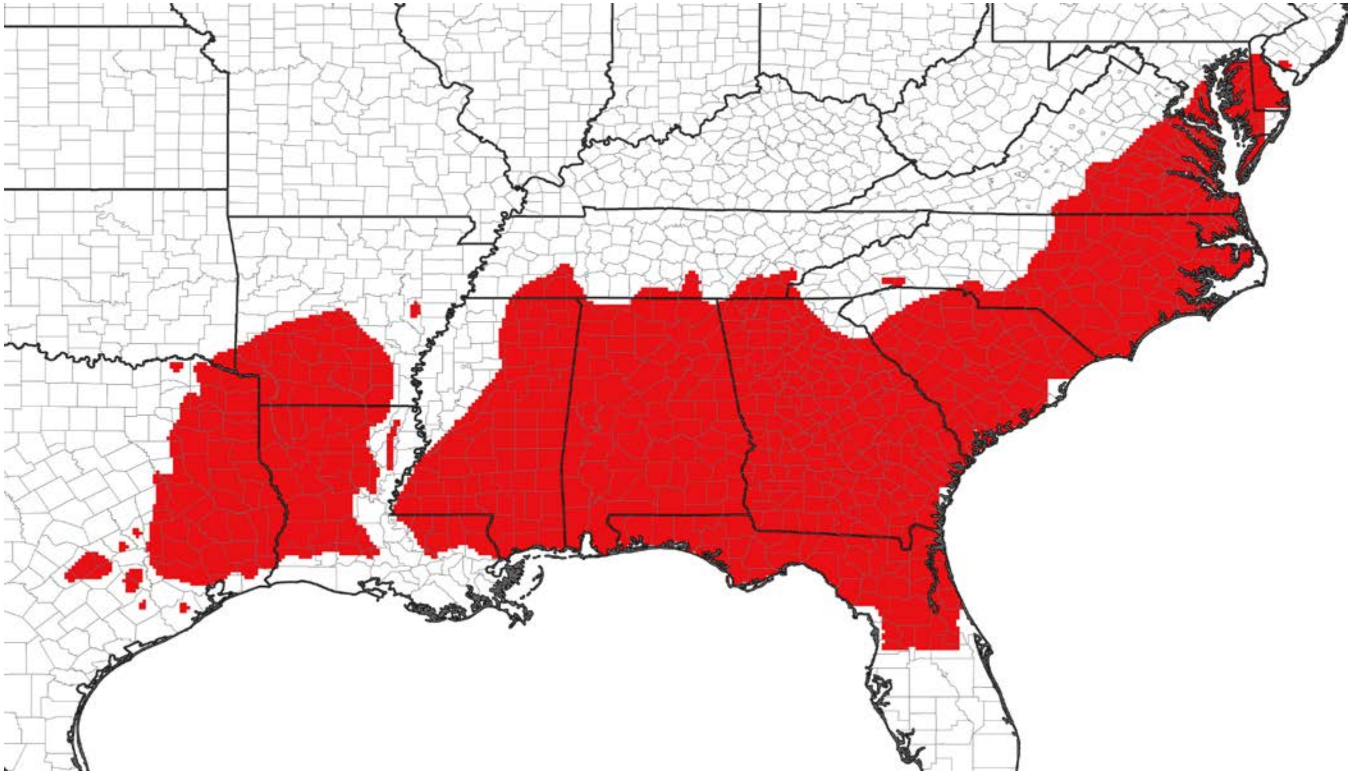
# Evapotranspiration



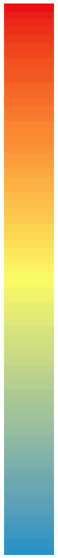
- 3-PG A
- 3-PG C
- WaSSI
- CLM
- CLM $CO_2$



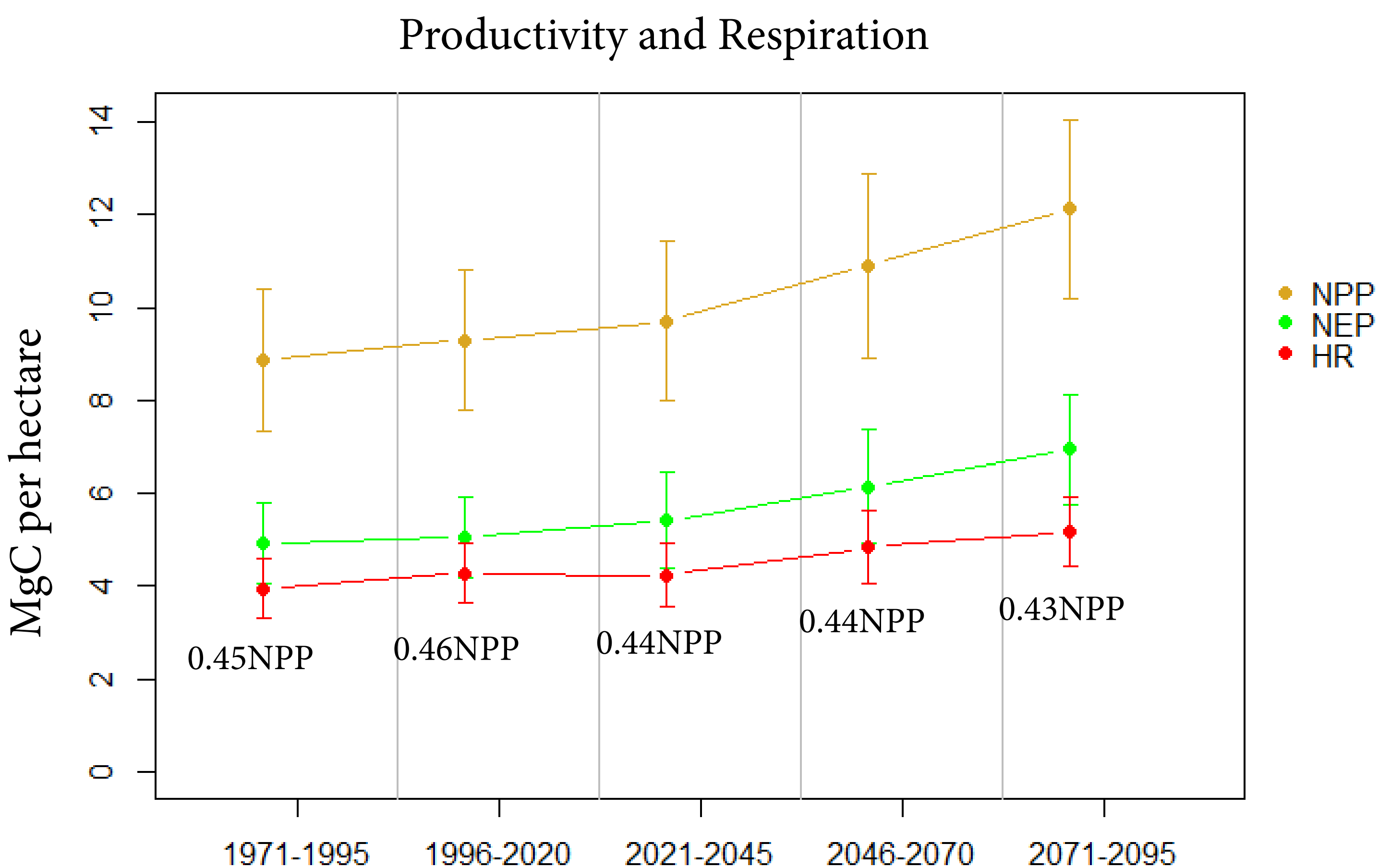
# Wood Carbon Above Ground



- 3-PG A
- 3-PG C
- G&Y
- CLM
- CLM $CO_2$



# NPP, HR, and NEP




| | |
|---|---|
| 1 MgC/ha | ~ 0.446 tonsC/acre |
| | = 100 $gC/m^2$ |

# Caveats

- The results presented today are for the baseline scenario
  - No silviculture or improved genetics
  - To date, only CLM was explicitly run with a $CO_2$ fertilization effect
- Today's results are based on only one climate model (CCSM-4)
  - 20 such models available
  - Ensemble approach allows for us to find the most consistent predictions from model to model
    - Both in a climate model context and a productivity model context

# Conclusions

- The ultimate goal of the modeling integrated platform is to understand the interaction of a changing environment with loblolly pine productivity
  - Communication of this understanding is key
    - Decision support systems
    - Other outreach venues

- The regional modeling effort allows us to assess the likely effects of climate on productivity by using today's measurements and knowledge base to make predictions
  - By using multiple models, we account for many of the biases and errors from individual models
  - Initial regional comparisons inform further refinement of models

# Thank you very much!

- Are there any questions or comments?