Predicting climate change impacts on southern pines productivity in SE United States using physiological process based model 3-PG

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Outline

1. Southern forests in SE United States
2. 3-PG Model
3. Model Calibration for *Pinus elliottii* (slash pine)
4. Model Validation
5. Case Study

   Climate Change Impacts on Productivity of Slash Pine Stands

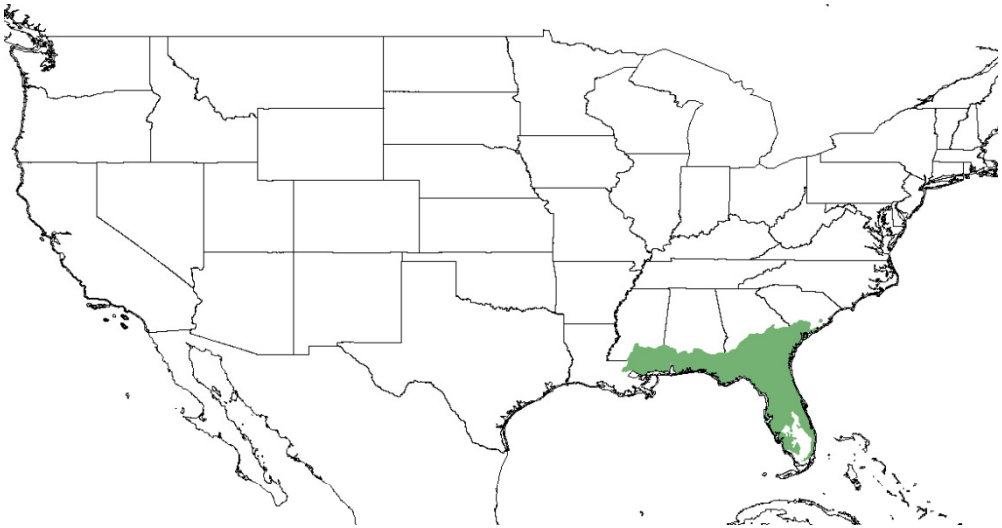
Background

- **Forests have multiple goods and services: wild-life, water, soil, C seq,… wood.**
- **In SE United States : 60% of landscape if forested including 28 million ha of southern pines.**
- **SE U.S. produces 58% of the total U.S. timber harvest and 18% of the global supply of roundwood (more than any other country).**
- **SE pine forests contain 1/3 of the contiguous U.S. forest C and can sequester 23% of regional GHG emissions.**
- **Most important southern pine species: *Pinus taeda* (loblolly pine), *Pinus elliottii* (slash pine) and *Pinus palustris* (longleaf pine).**

Background

Slash Pine (*Pinus elliottii* Engelm.)





- **Medium-Long-Lived.**
- **Fast-growing**
- **Important commercial species in SE United States**
- **Objectives: Pulpwood and sawtimber production**
- **Area of timberland: 4.2 million ha**

http://www.forestryimages.org

3-PG (Landsberg and Waring, 1997)

Tree growth model based on :

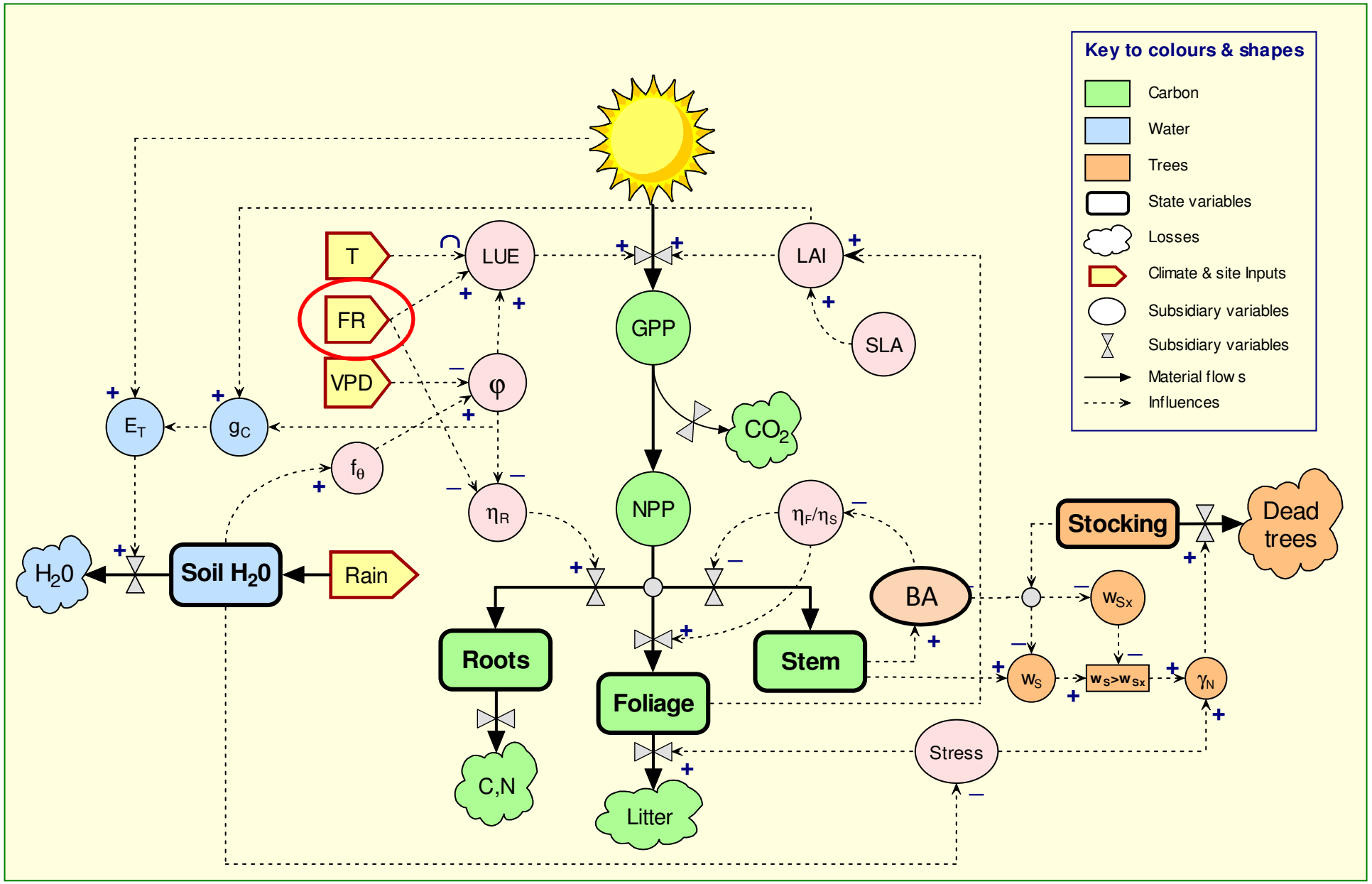
Physiological **P**rinciples that

Predict **G**rowth

Forest Production :

- **Light Interception**
- **Carbon Acquisition**
- **Carbon Allocation**

3-PG Model



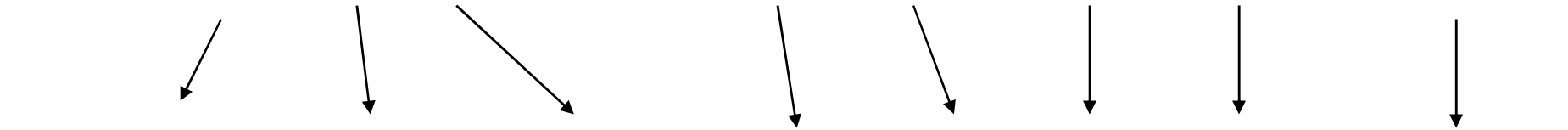
Landsberg and Waring 1997

3-PG Model

$$NPP = Q_0 * \left(1 - e^{-k * LAI}\right) * \alpha_C * R$$

All modifiers affect canopy production:

$$\alpha_C = f_T f_F f_N \min\{f_D, f_\theta\} f_{age} f_{C\alpha} \alpha_{Cx}$$

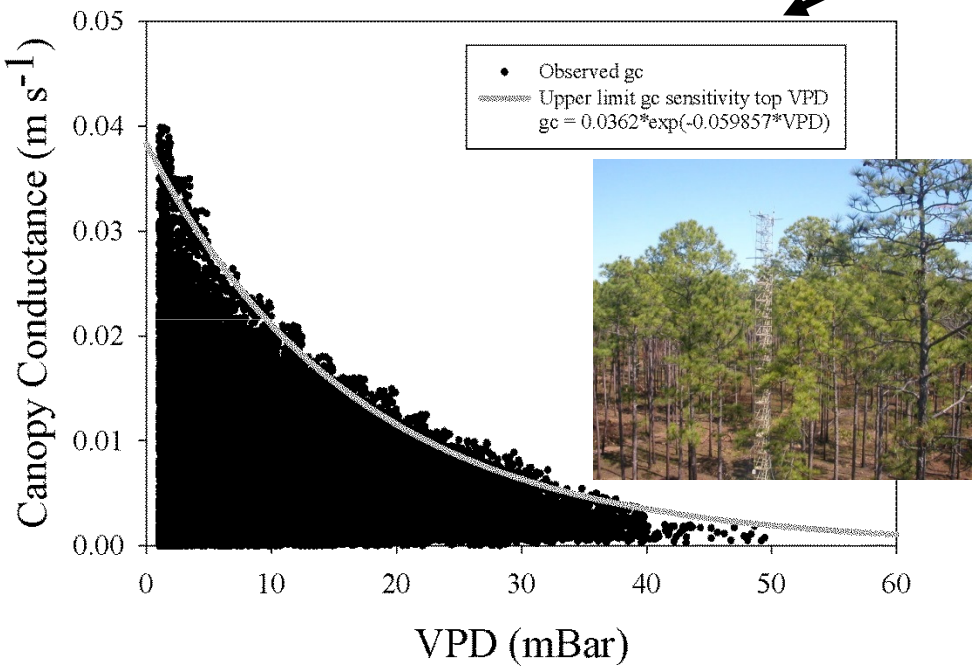


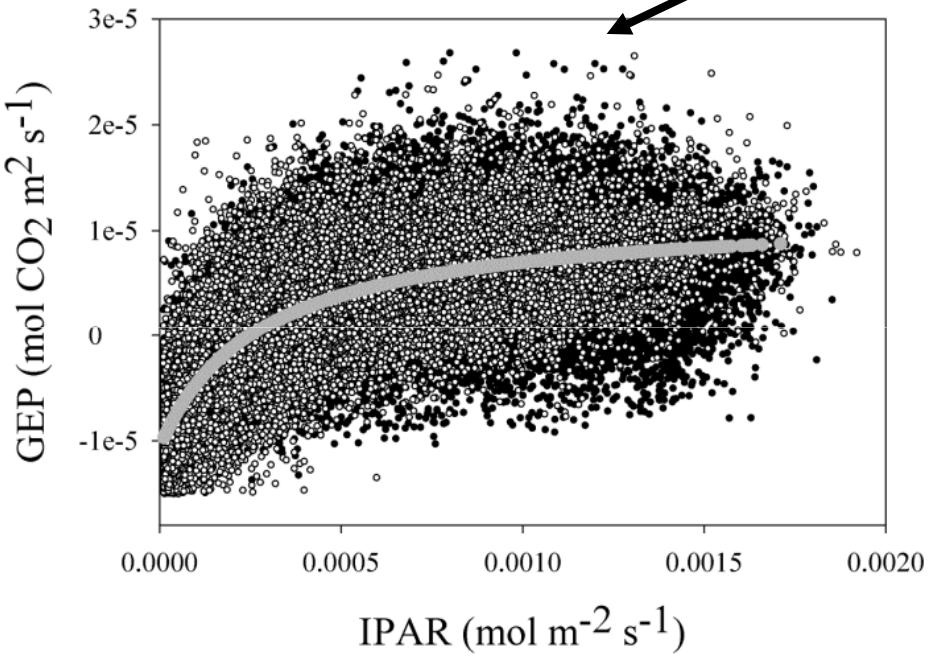
$$(0 \leq f_i \leq 1)$$

3-PG Model

Parameterization for Slash Pine

$$\alpha_C = f_T f_F f_N \min\{f_D, f_\theta\} f_{age} f_{C\alpha} \alpha_{Cx}$$





Canopy Quantum Yield = 0.056 mol CO_2 / mol PAR

$$f_D(D) = e^{-k_D D}$$

where

D = current VPD

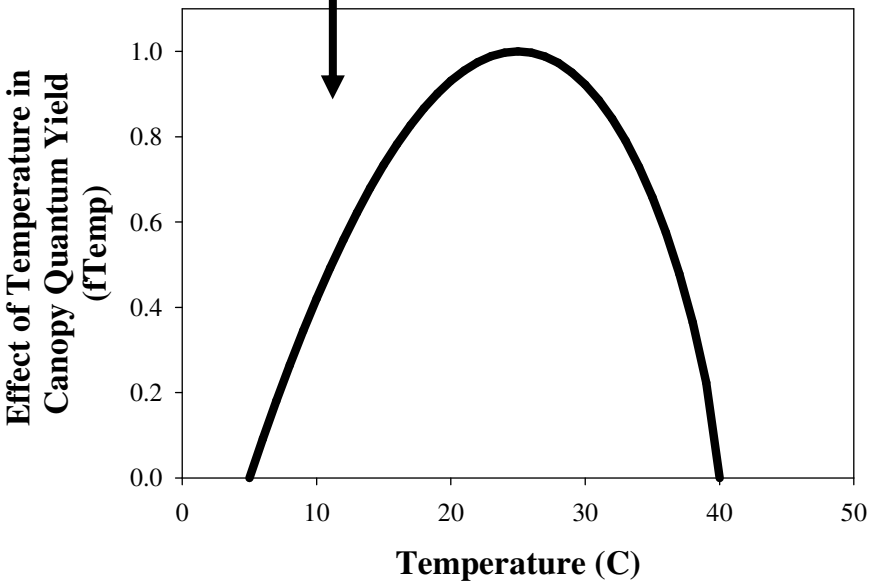
k_D = strength of VPD response

Gonzalez-Benecke et al. 2014

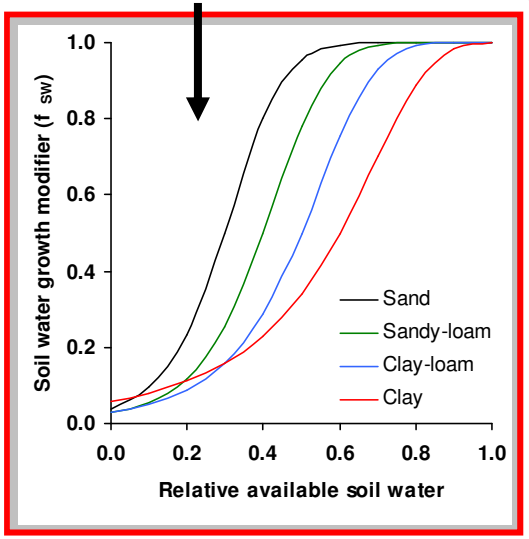
3-PG Model

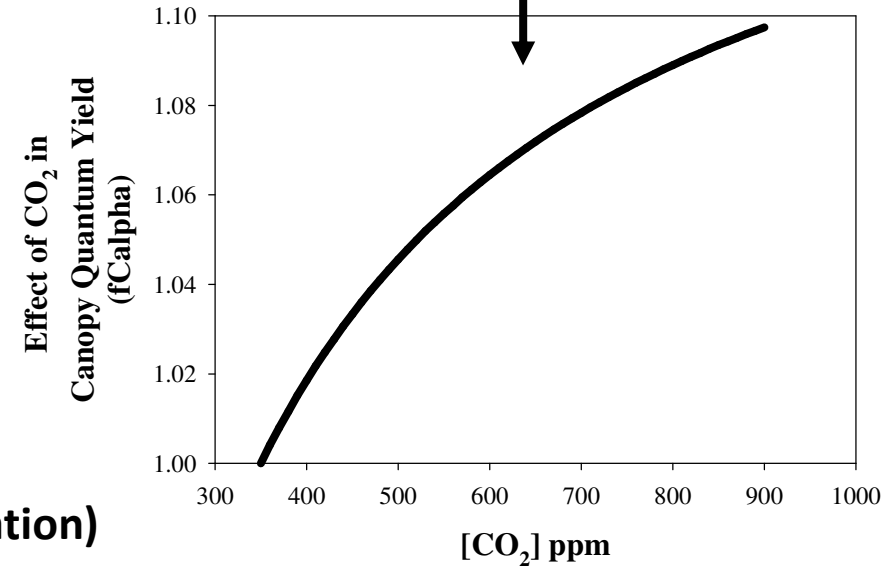
Parameterization for Slash Pine

$$\alpha_C = f_T f_F f_N \min\{f_D, f_\theta\} f_{age} f_{C\alpha} \alpha_{Cx}$$



Teskey et al. 1994

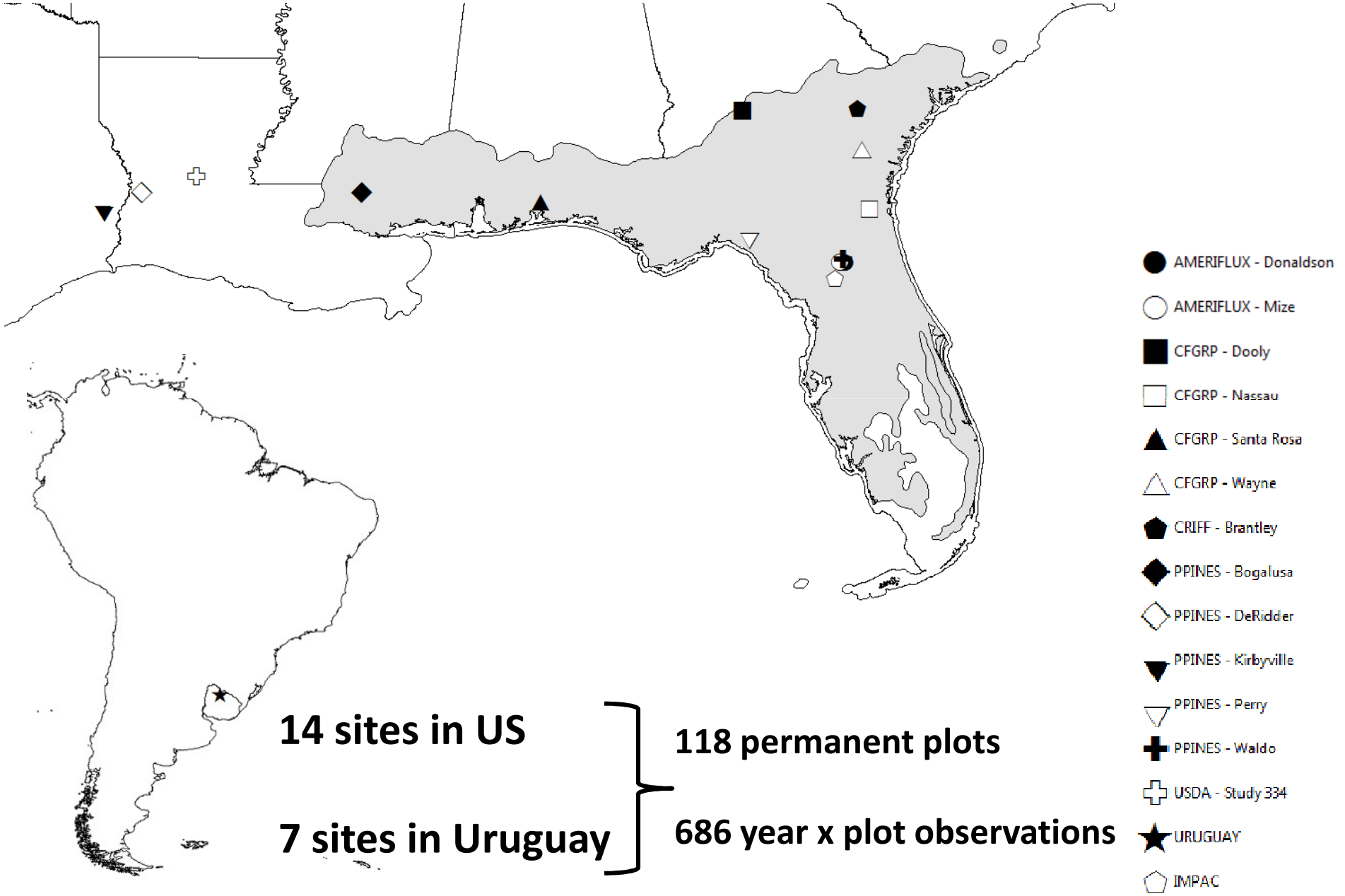




Teskey et al. (in preparation)

Results

Validation Sites



14 sites in US

7 sites in Uruguay

118 permanent plots

686 year x plot observations

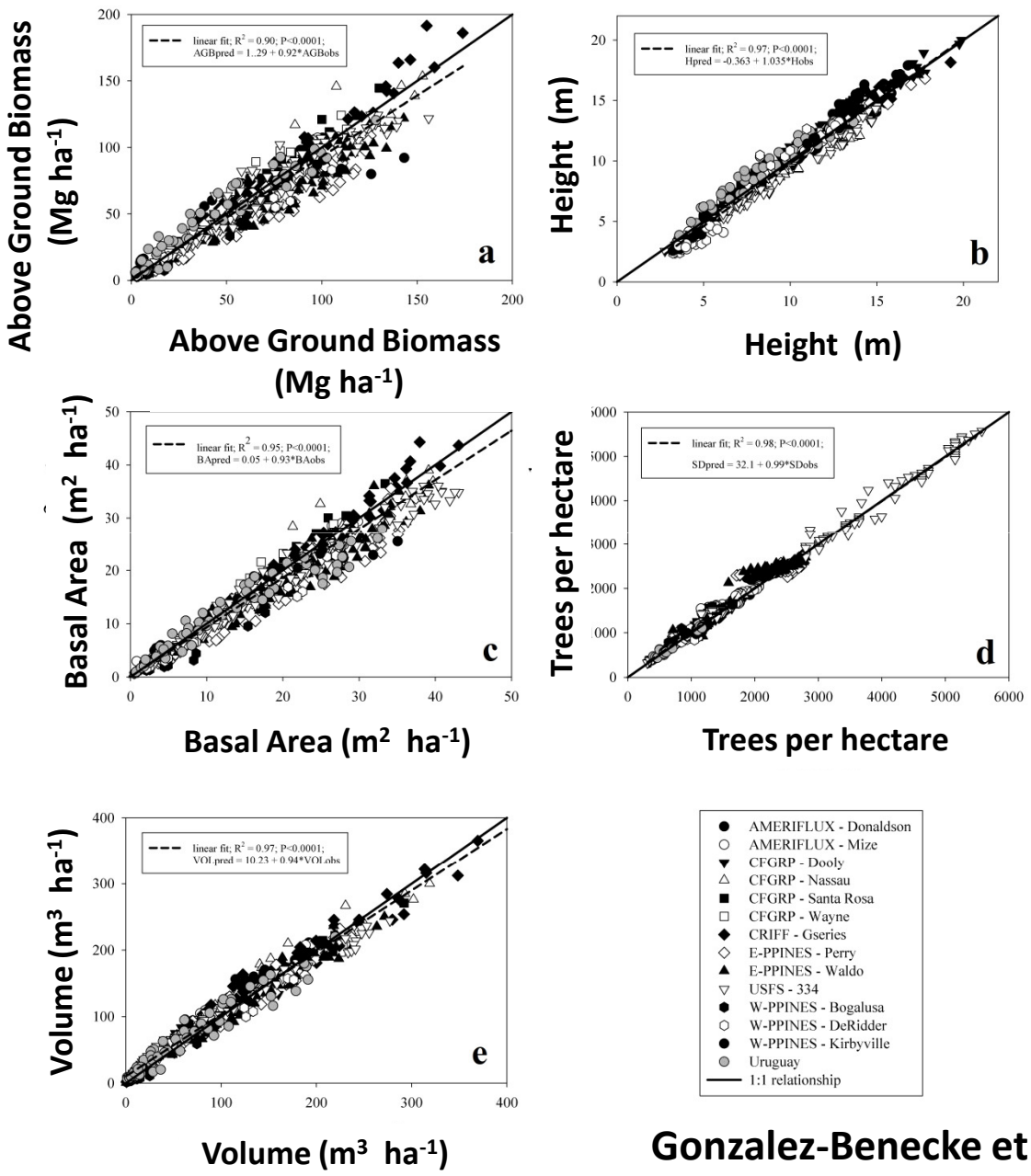
Results

Validation

X=observed

Y=predicted

Variable	Bias (%)	R^2
AGB (Mg/ha)	-5.3	0.89
BA (m^2/ha)	-6.9	0.93
Height (m)	0.4	0.96
Nha (ha^{-1})	0.8	0.98
VOB (m^3/ha)	4.1	0.97



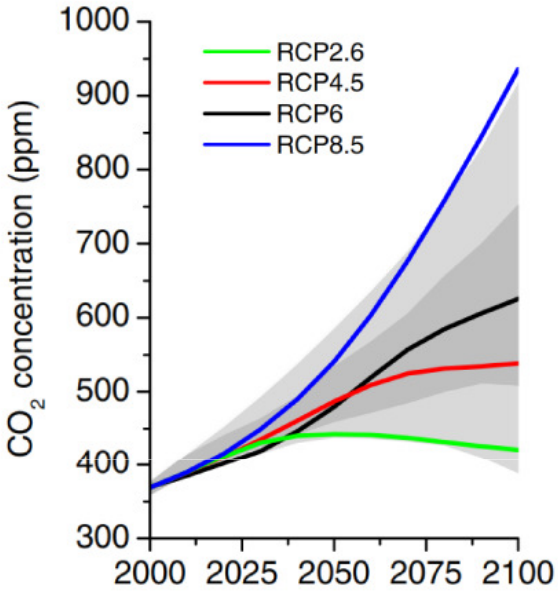
Gonzalez-Benecke et al. 2014

Case Study:
Climate Change Effect on Slash Pine Productivity

Future Climate Data: **CanESM2 model**

Downscaled using **MACA** method
(Multivariate Adaptive Constructed Analogs)

http://maca.northwestknowledge.net/



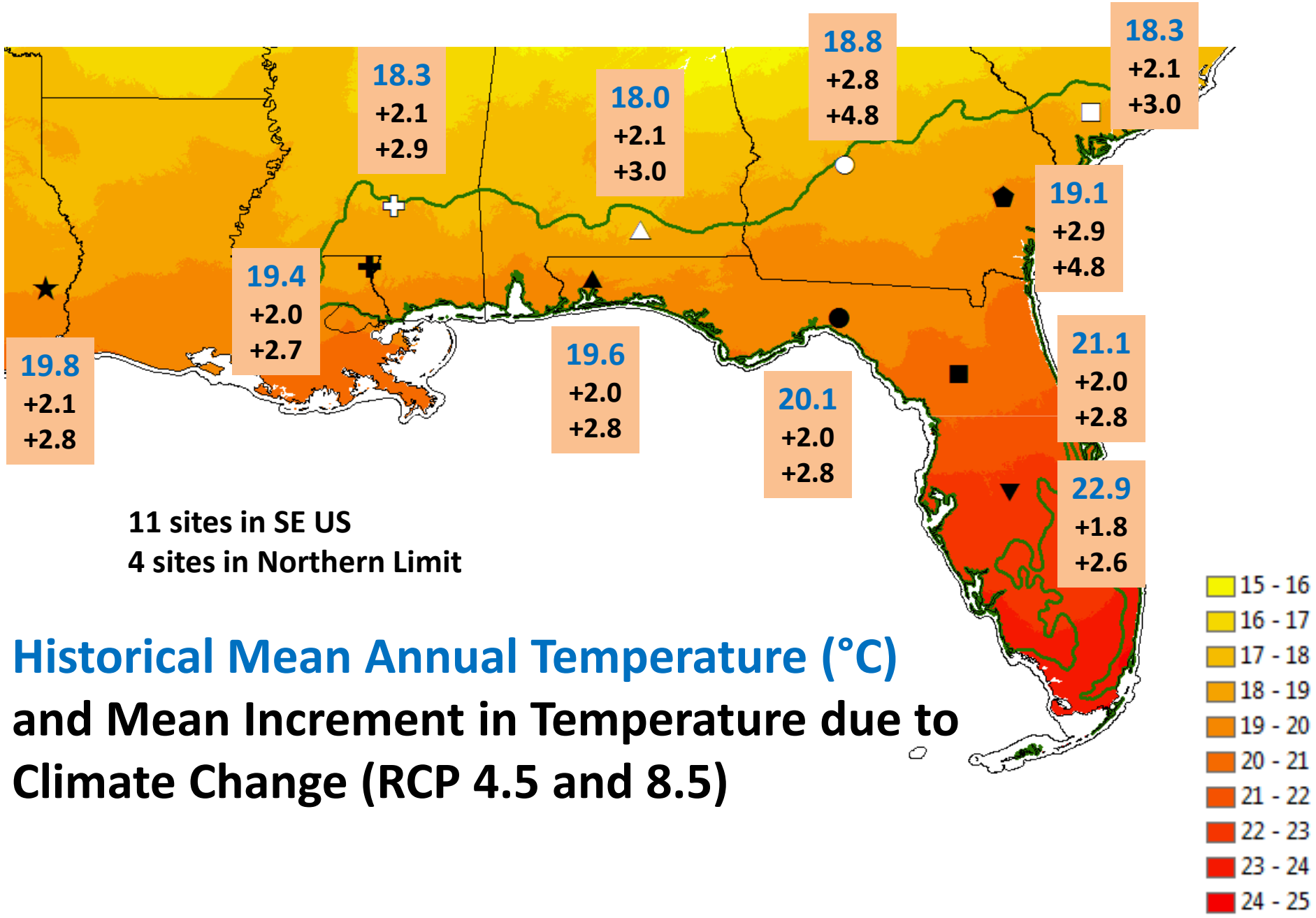
Scenarios (combination of climate and site quality):

- Based on 2 **RCP**s (**Representative Concentration Pathways**)
- Based on **Site Quality** (site index)

Scenario	Climate Data	CO_2
- Historical	1950 – 2010	400 ppm
- RCP 4.5	2070 – 2100	550 ppm
- RCP 8.5	2070 – 2100	850 ppm

Productivity	Site Index
- Low	19 m
- Medium	23 m
- High	28 m

Sites location



11 sites in SE US
4 sites in Northern Limit

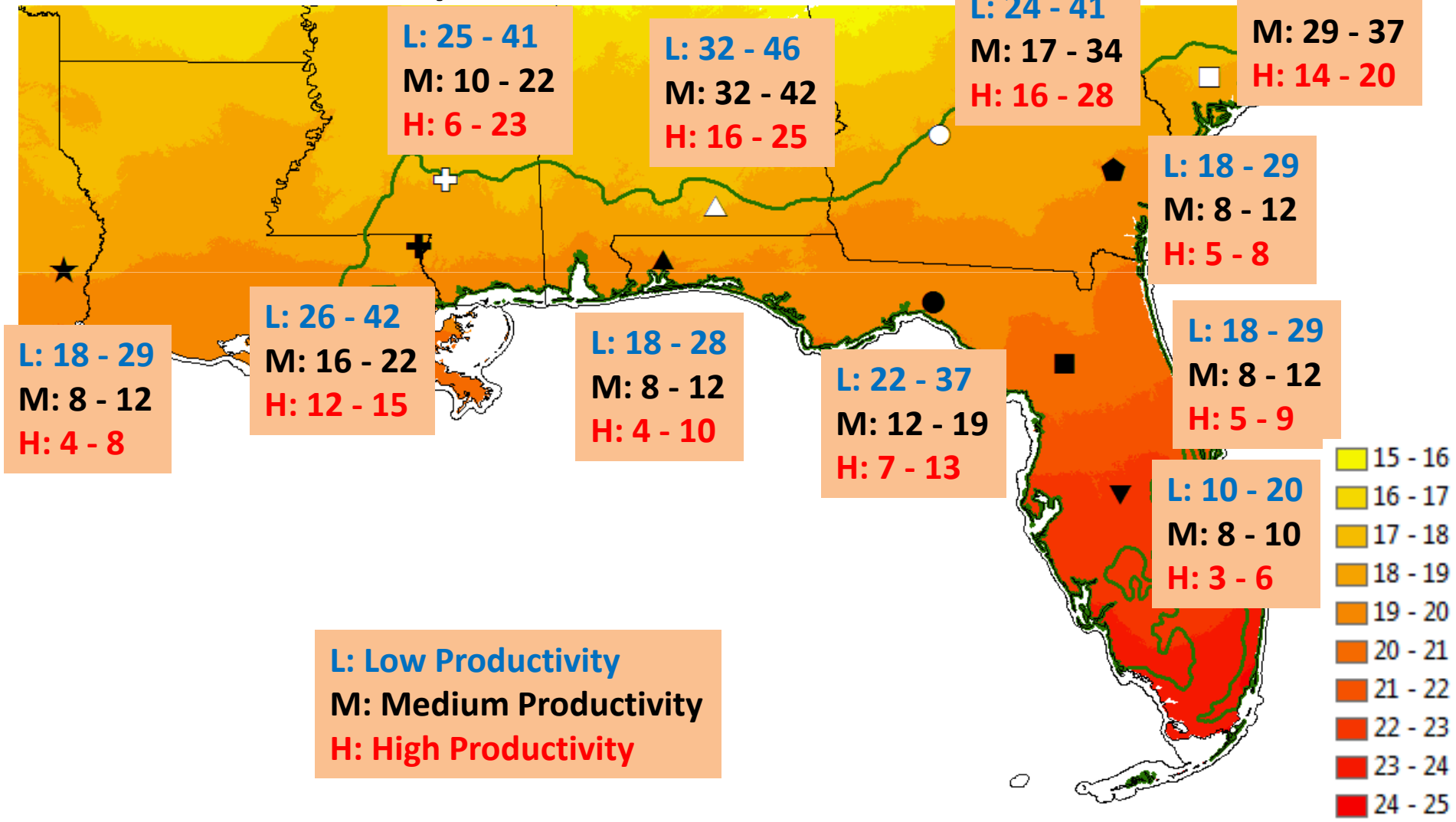
Historical Mean Annual Temperature (°C)
and Mean Increment in Temperature due to Climate Change (RCP 4.5 and 8.5)

Summary

Variable	RCP4.5	RCP8.5
Tmax (C)	+ 1.8 to +2.9	+ 2.6 to +4.8
Tmin (C)	+ 1.8 to +3.0	+ 2.7 to +4.8
Rain (mm)	- 49 to + 67	- 66 to 45
Radiation (%)	+2% to + 6%	+1% to + 6%

Climate Change Effect on Slash Pine Productivity

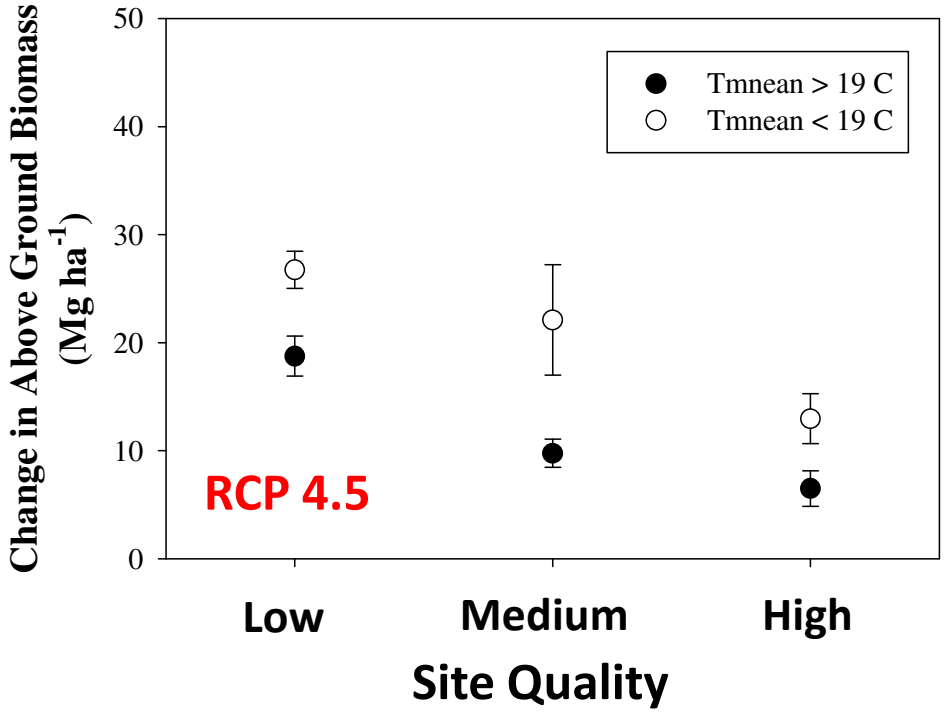
Change in Above Ground Biomass (Mg/ha)
at age=25 years
RCP's v/s Historical Scenarios

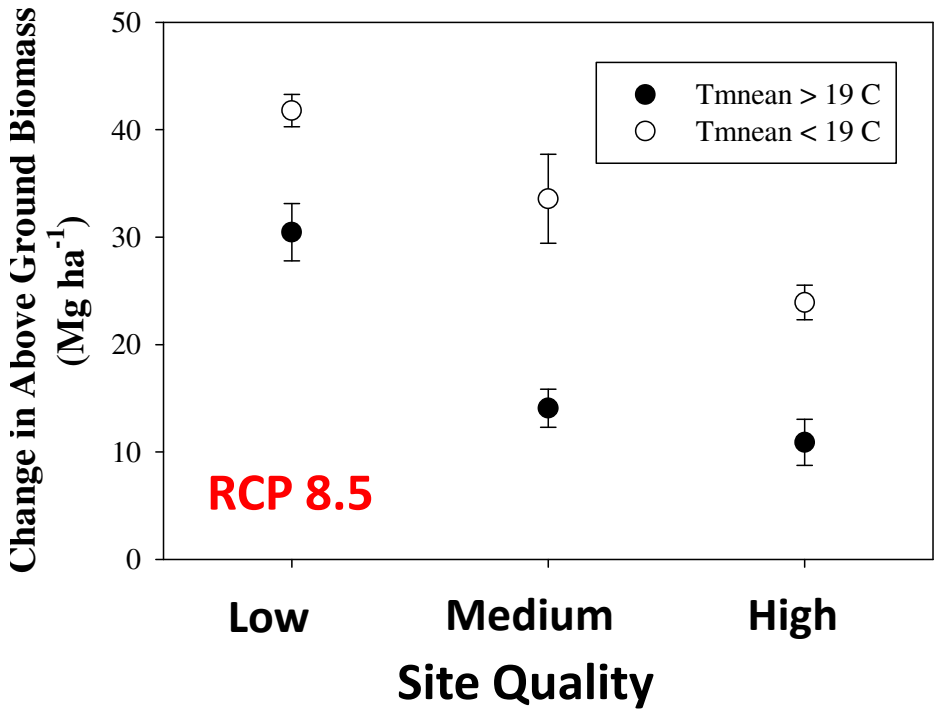


L: Low Productivity
M: Medium Productivity
H: High Productivity

Climate Change Effect on Slash Pine Productivity

Change in Above Ground Biomass (Mg/ha) at age=25 years
RCP's v/s Historical Scenarios





Conclusions:
Climate Change Effect on Slash Pine Productivity

Under Future Climate Scenarios Used:

For Sites with Mean Annual Temperature > 19 C:

- Under RCP4.5 : AGB can be increased between **2% to 27% (Mean=8%).**

- Under RCP8.5 : AGB can be increased between **2% to 44% (Mean=13%).**

For Sites with Mean Annual Temperature < 19 C (North Limit):

- Under RCP4.5 : AGB can be increased between **2% to 44% (Mean=17%).**

- Under RCP8.5 : AGB can be increased between **8% to 63% (Mean=27%).**

Conclusions:
Climate Change Effect on Slash Pine Productivity

Under Future Climate Scenarios Used:

- **Responses to Climate Change should be larger in colder range of distribution.**

- **Responses to Climate Change should be larger in low productivity sites.**

Acknowledgements







