The Effects of Forest Management and Climate on Southern Pine Plantations over the 21st Century

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Overview

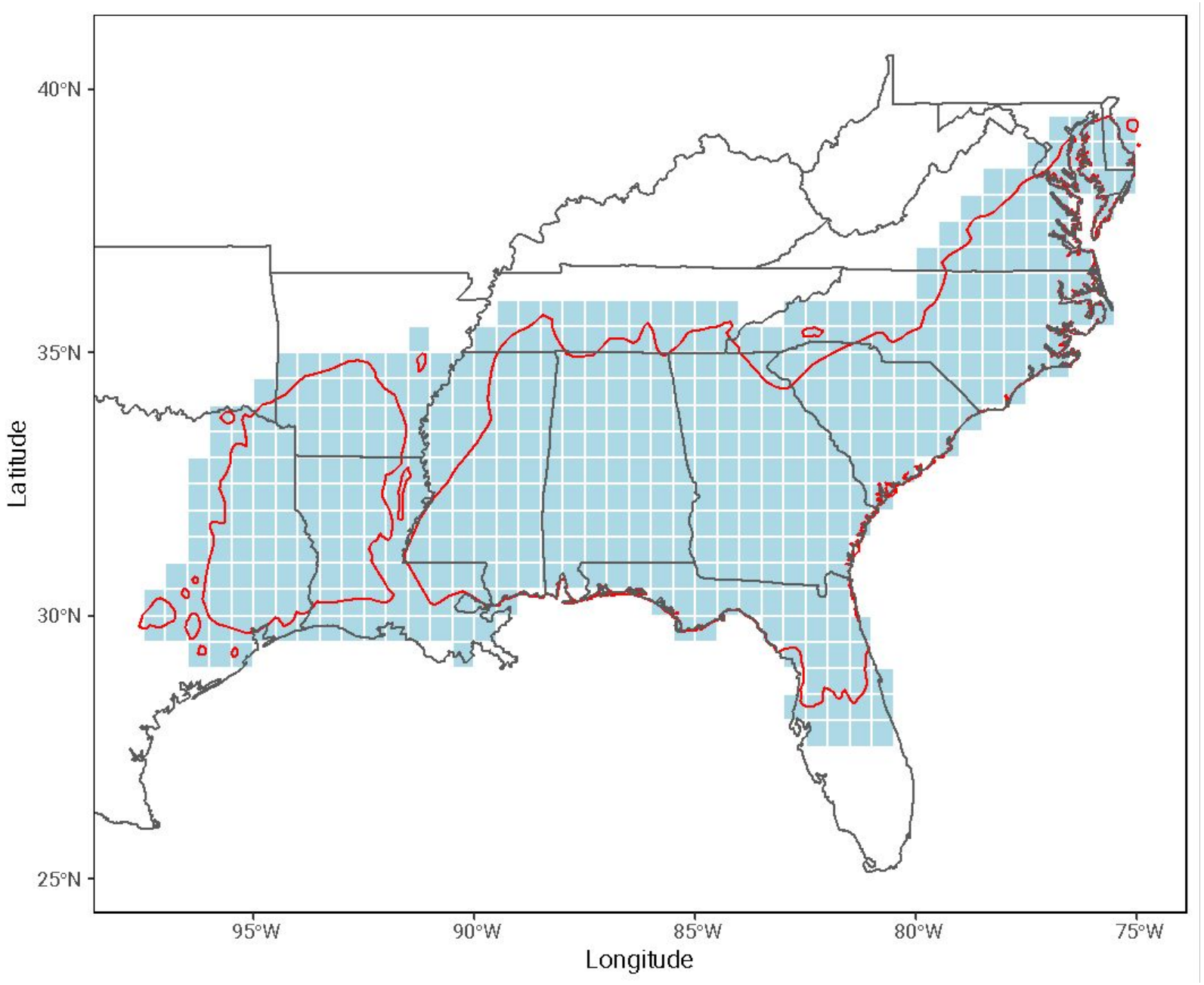
- The Southeastern United States (SEUS) is a major wood producing region, largely from loblolly pine (*Pinus taeda*) plantations.
- Provides a well studied system for examining forest management.
- I ran CLM-FATES simulations of loblolly plantations looking at:

1. Effect of future climate on loblolly productivity
2. Effect of management on yields under future climate
3. Effect of climate on management practices
4. Effect of climate and management on SEUS plantation area

Southeastern U.S. Study Region

Native loblolly pine range

Simulated loblolly plantations for each grid cell



Vegetation Management Module

https://github.com/JoshuaRady/VegetationManagement

Public Documentation:
https://joshuarady.github.io/VegetationManagement/

Extends FATES by adding:

- Planting
- Competition control
- Stand-thinning
- Harvest by carbon & fraction
- Target specific PFTs and sizes
- Control of event timing & location
- Conditional behavior

Dr. Katie Murenbeeld
Used the Vegetation Management Module in her dissertation.

More

How will climate change affect the productivity of loblolly plantations?

Grow Trees 2015-2100 with Different Climates

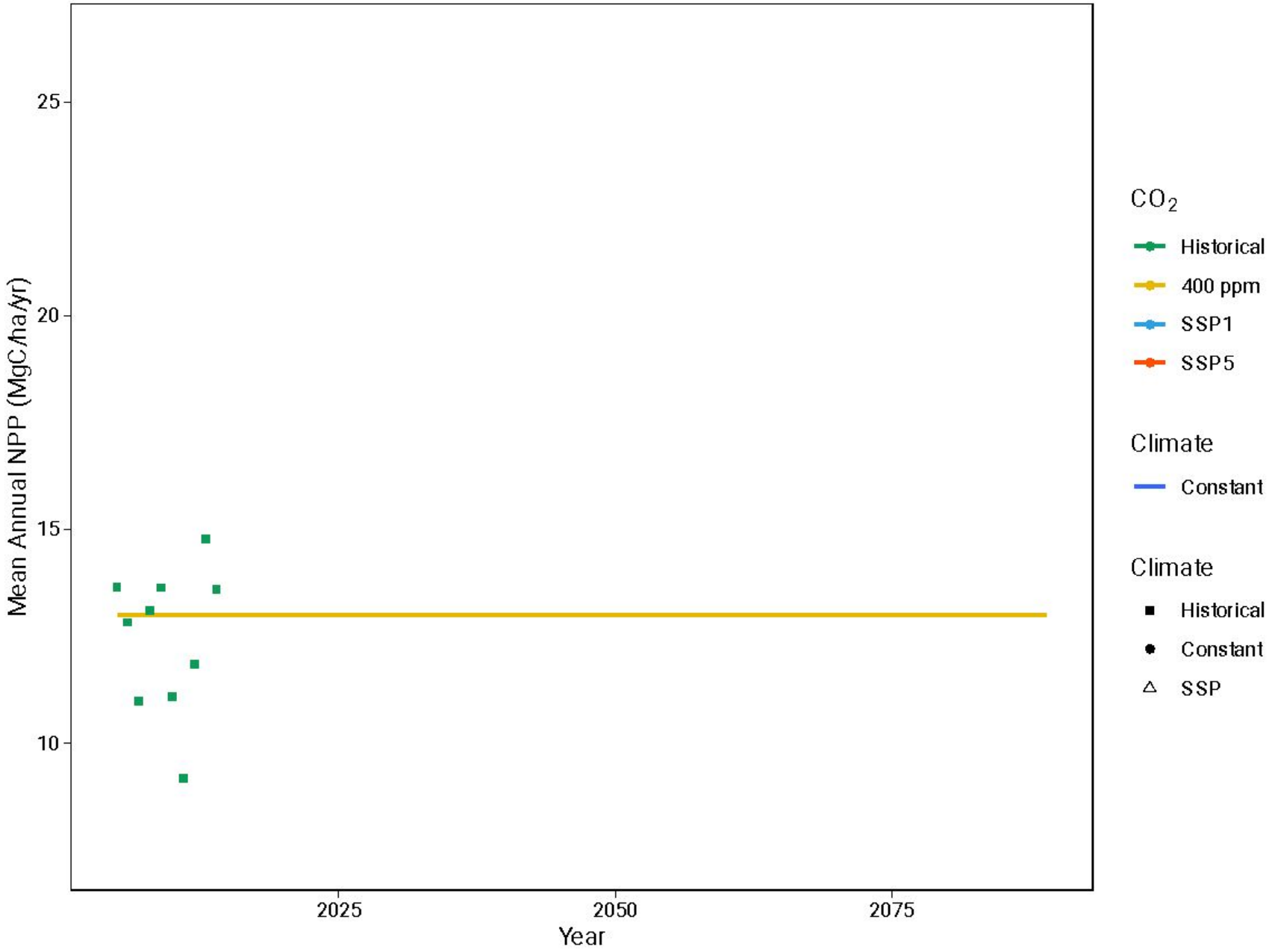
Constant Climate 400ppm CO_2	SSP1 Climate 400ppm CO_2	Constant Climate SSP1 CO_2	SSP1 Climate SSP1 CO_2
	SSP5 Climate 400ppm CO_2	Constant Climate SSP5 CO_2	SSP5 Climate SSP5 CO_2

Are changes in Net Primary Productivity (NPP) due to Climate or CO_2?

NPP with Constant Climate & Constant CO_2

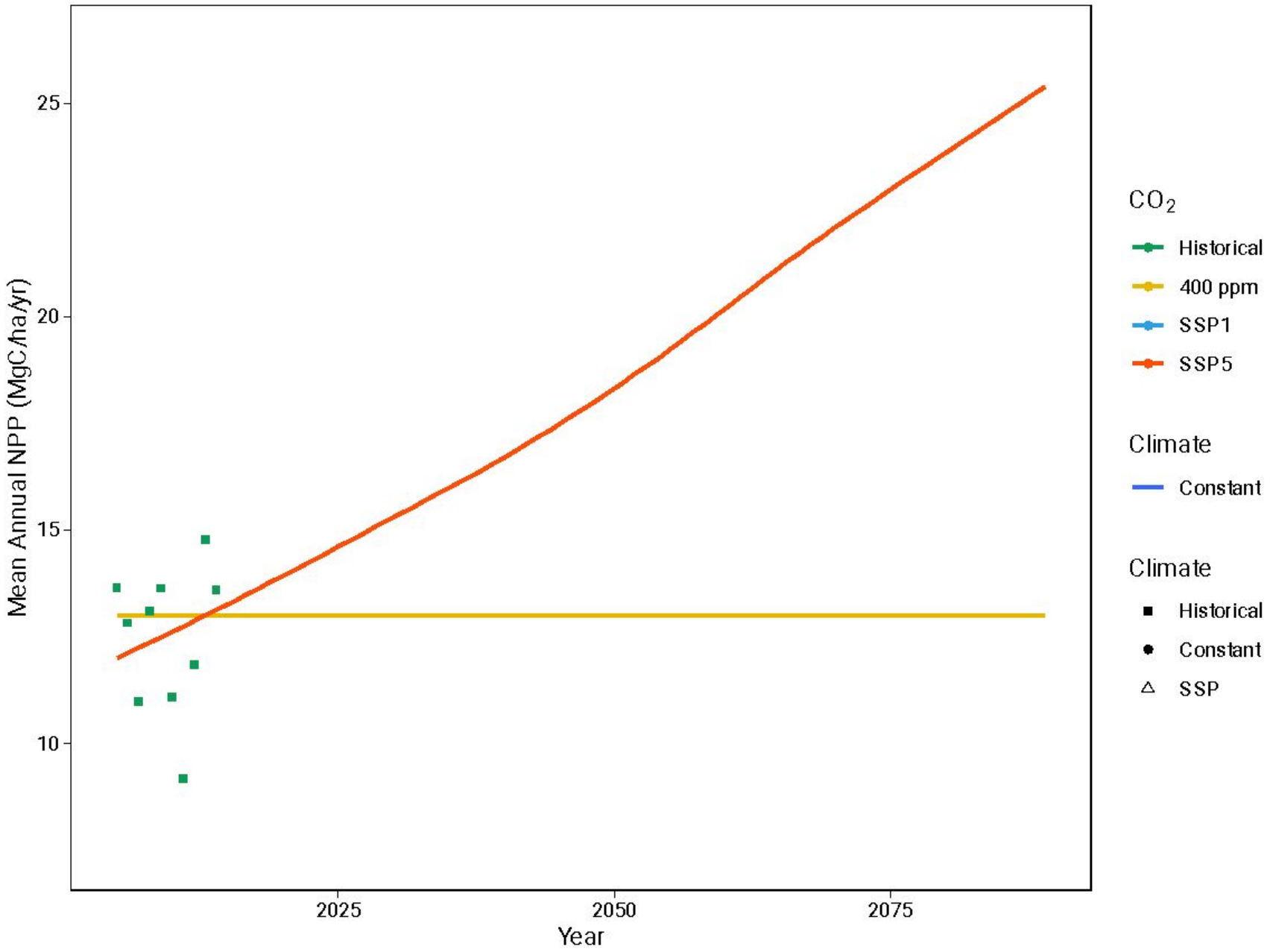
Historical NPP (2005-2014)

Future NPP with constant climate changes little.



NPP with Constant Climate & SSP5 CO_2

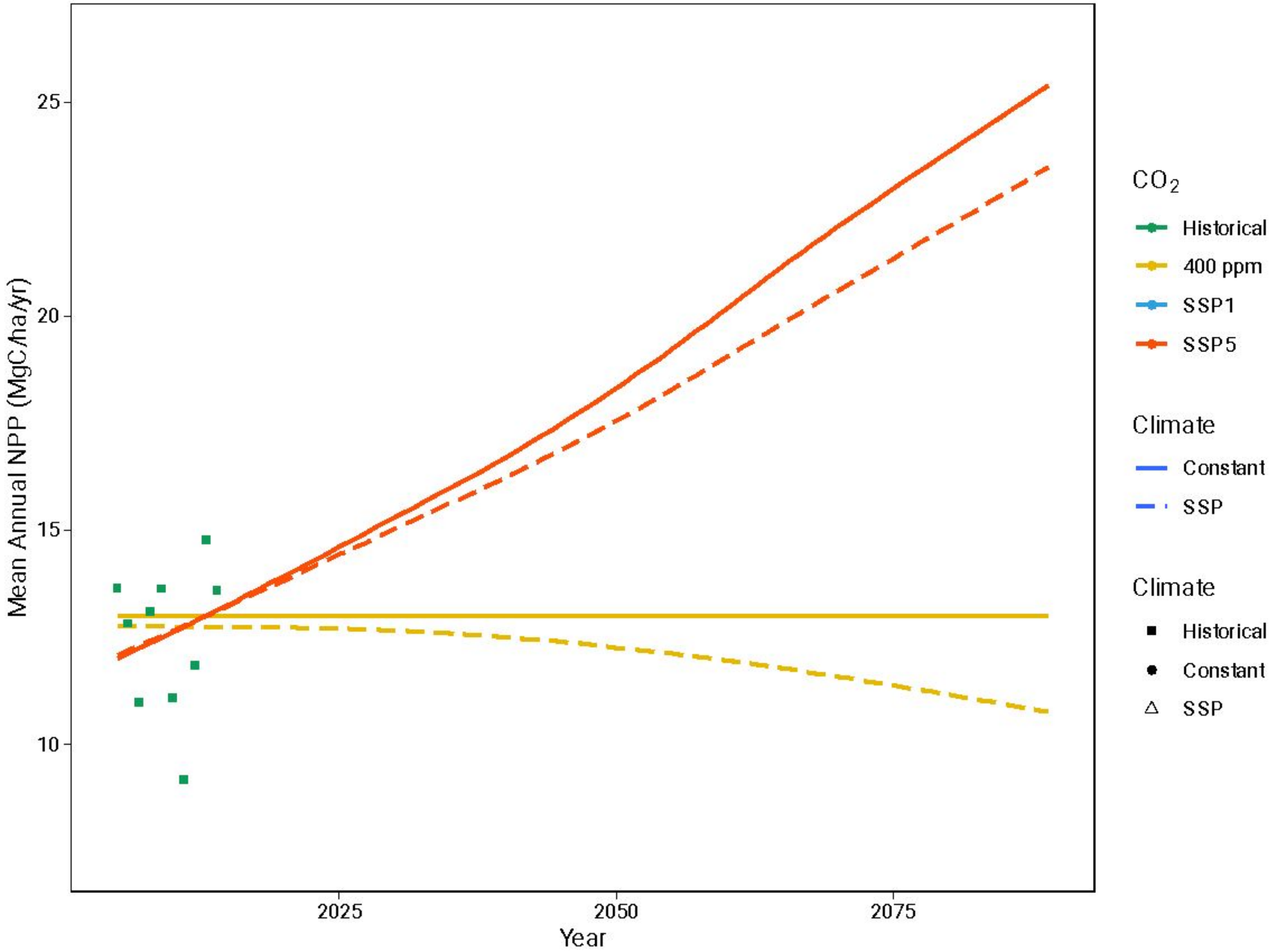
SSP5 CO_2 doubles NPP by the end of the century.



NPP with SSP5 Climate & SSP5 CO_2

Adding SSP5 climate decreases NPP.

83.8% increase for combined effect

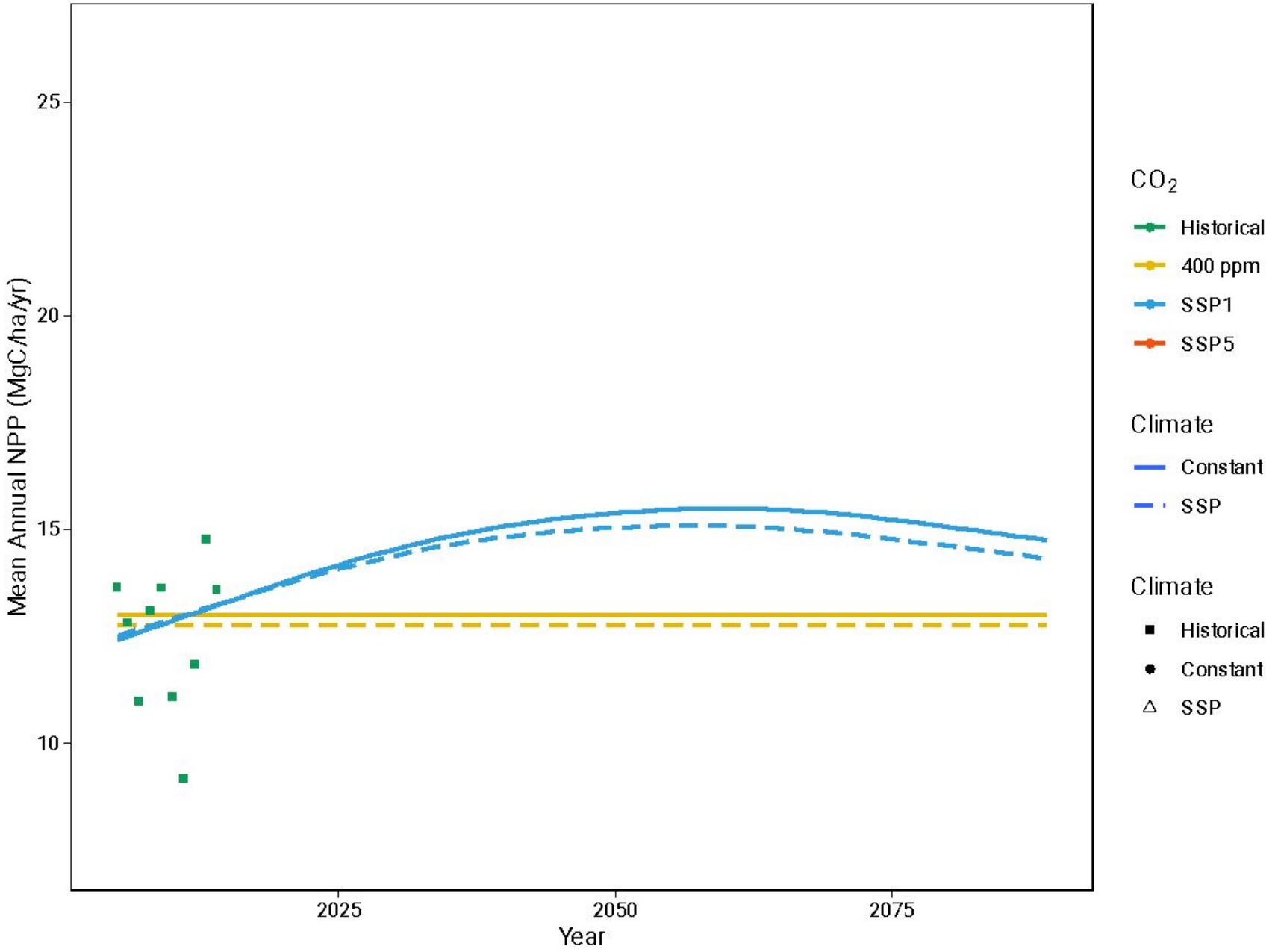


NPP with SSP1

NPP increases moderately with SSP1 CO_2.

Adding SSP1 climate has a small negative effect.

13.7% combined increase



How will forest management practices change wood yields with climate change?

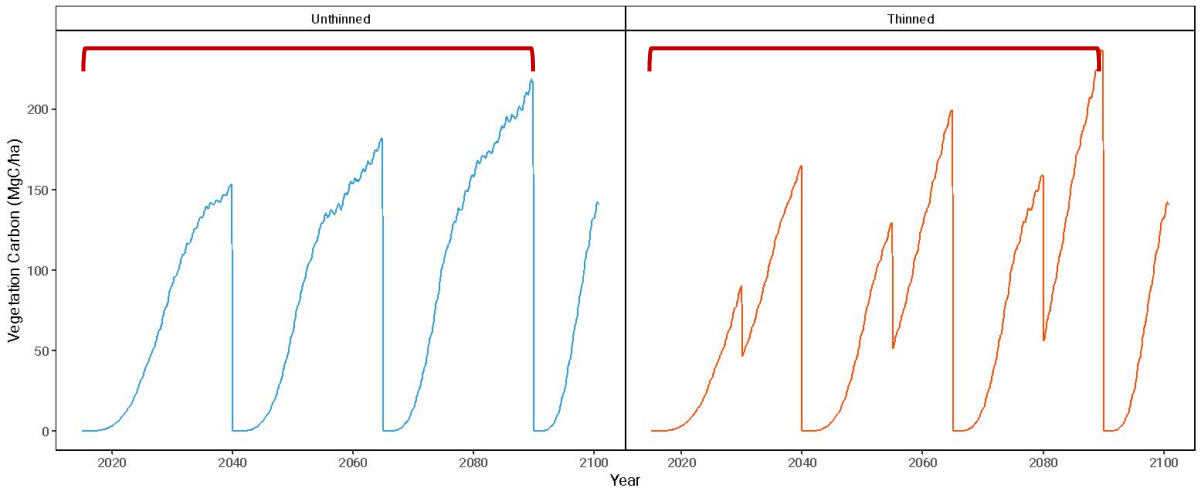
Examined Three Management Practices

1. Planting density: 1250 vs. *2000* trees per hectare
2. Without or *With* mid-rotation stand thinning
3. Rotation length: 25 vs. *40* years

Compare annual wood yields for all complete rotations 2015-2100.

Baseline Control vs.

Alternate Management Treatment

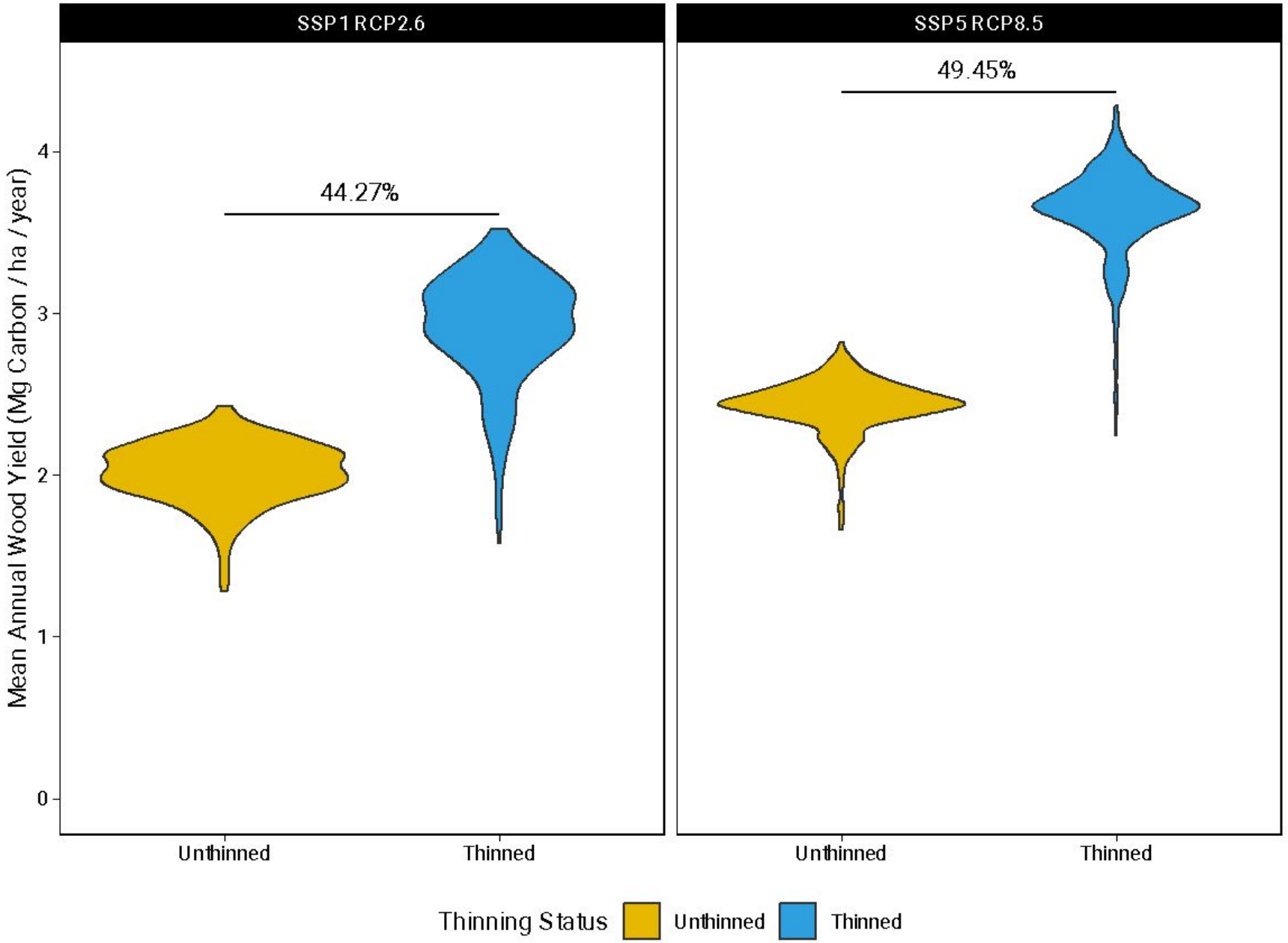


Results *in Brief*

- Increasing planting density decreases wood yields for both SSPs.
- Increasing the rotation length decreases wood yields for both SSPs.
- Thinning was the most influential management practice.

Stand Thinning Increases Wood Yields

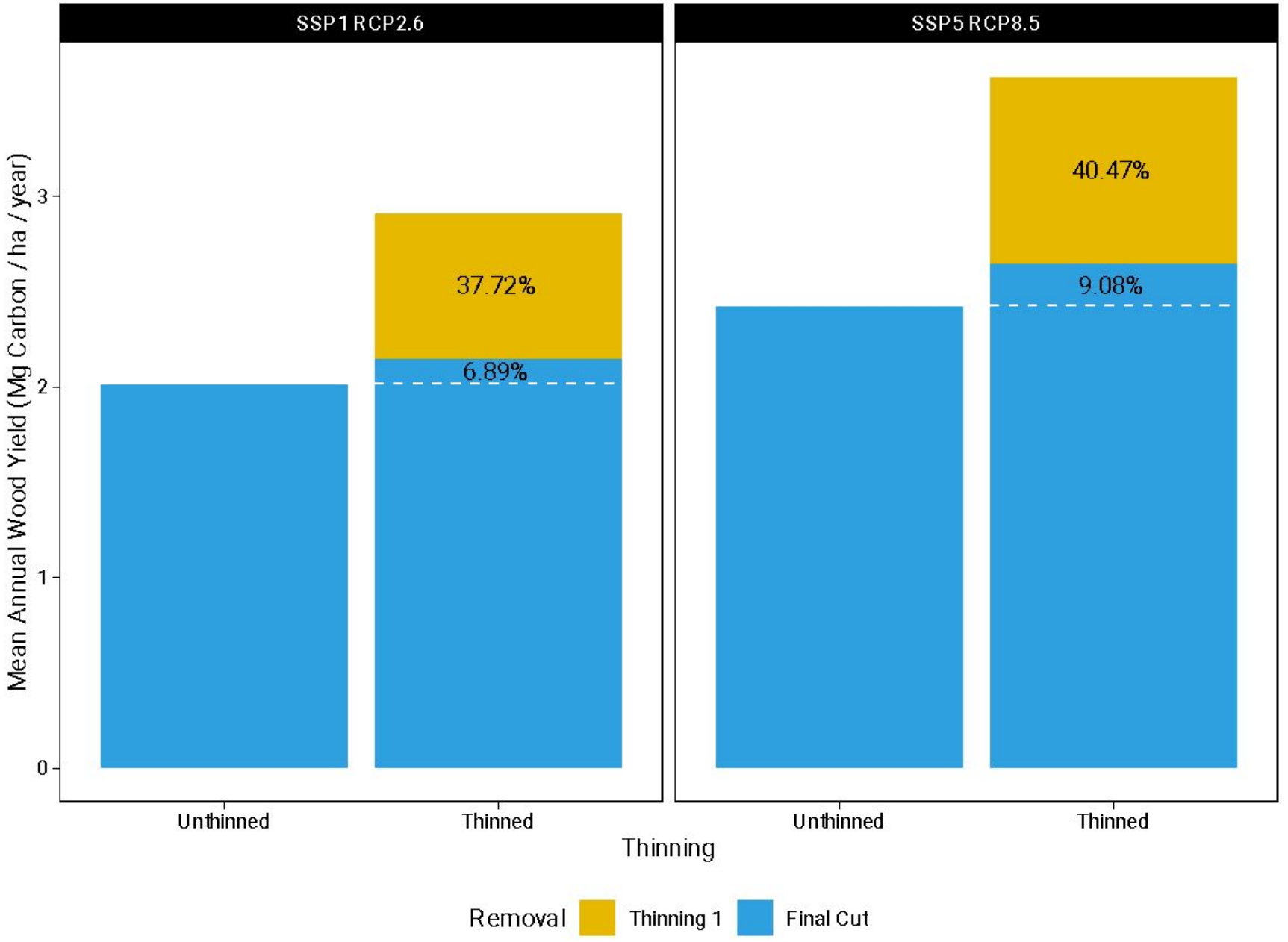
Adding mid-rotation stand thinning increase wood yields for both SSPs.



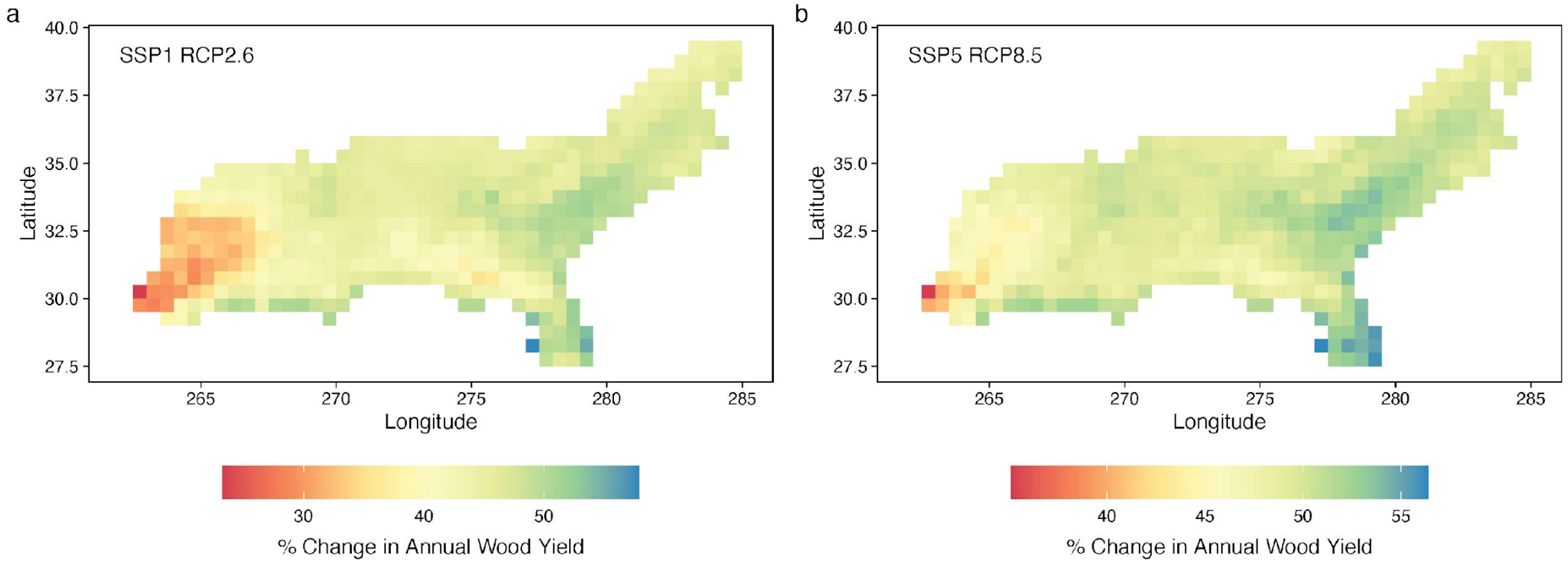
What Increases Wood Yields?

Most of the increase is from wood removed during thinning.

The wood removed at the final harvest (clearcut) increase as well.



Regional Patterns of Increases with Thinning



The western part of the region benefits less than the East of the region.
The west has slow growth and lower wood yields.

How will the timing of forest management change with climate change?

Let the Model Determine Management Timing

Tell the Vegetation Management Module:

Think like a forester:

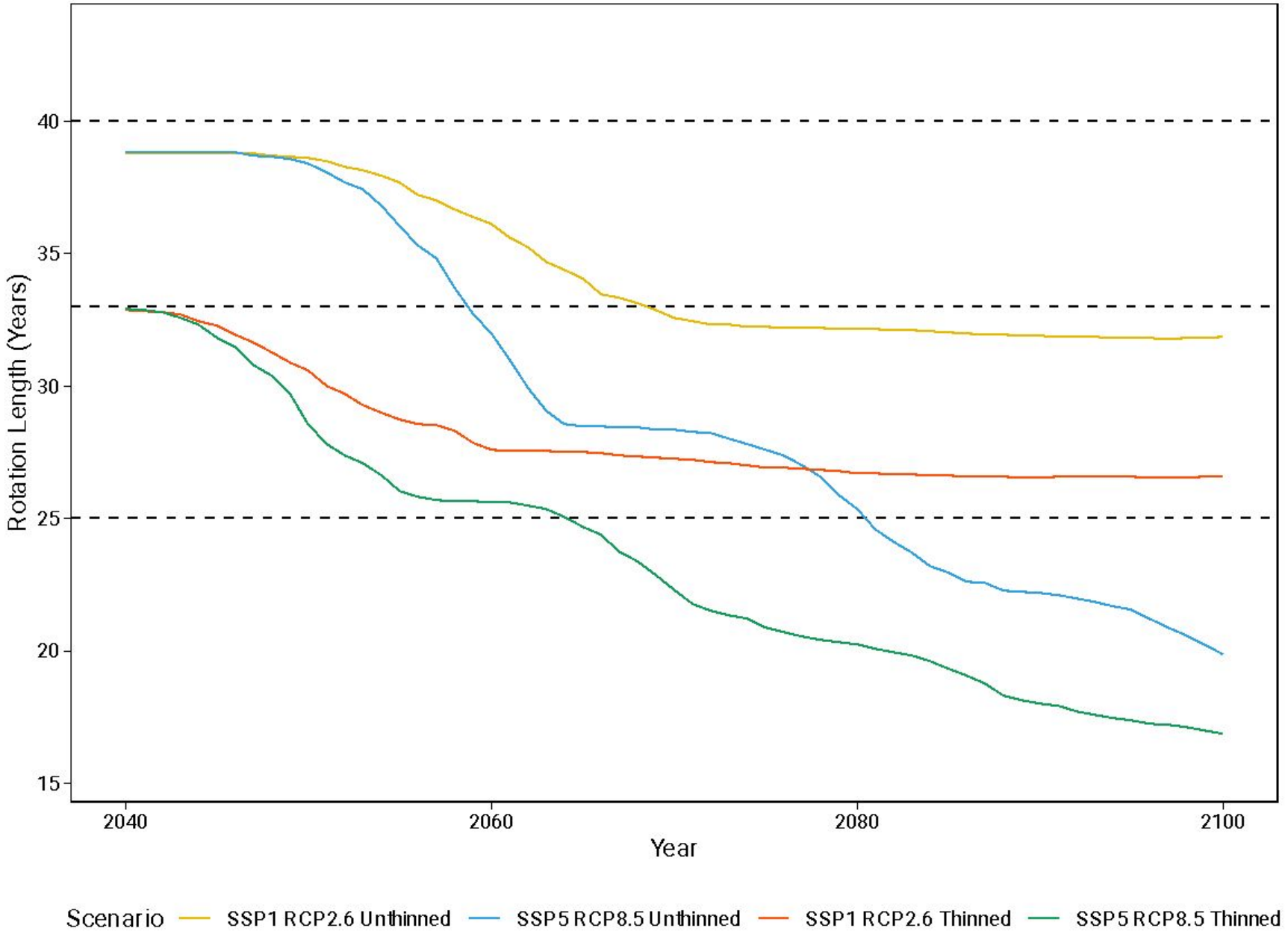
- Thin the stand at an appropriate basal area.
- Clearcut the stand when trees reach commercial size.

- Management: With and Without Thinning
- Compare rotation lengths.

Let the Model Determine Management Timing

Rotation length:

- Decreases with SSP1 climate.
- Decreases more with SSP5.
- Decreases with addition of thinning.



More

How could increasing loblolly pine productivity affect the area of pine plantation in the Southeastern US?

Calculating Forest Area Required

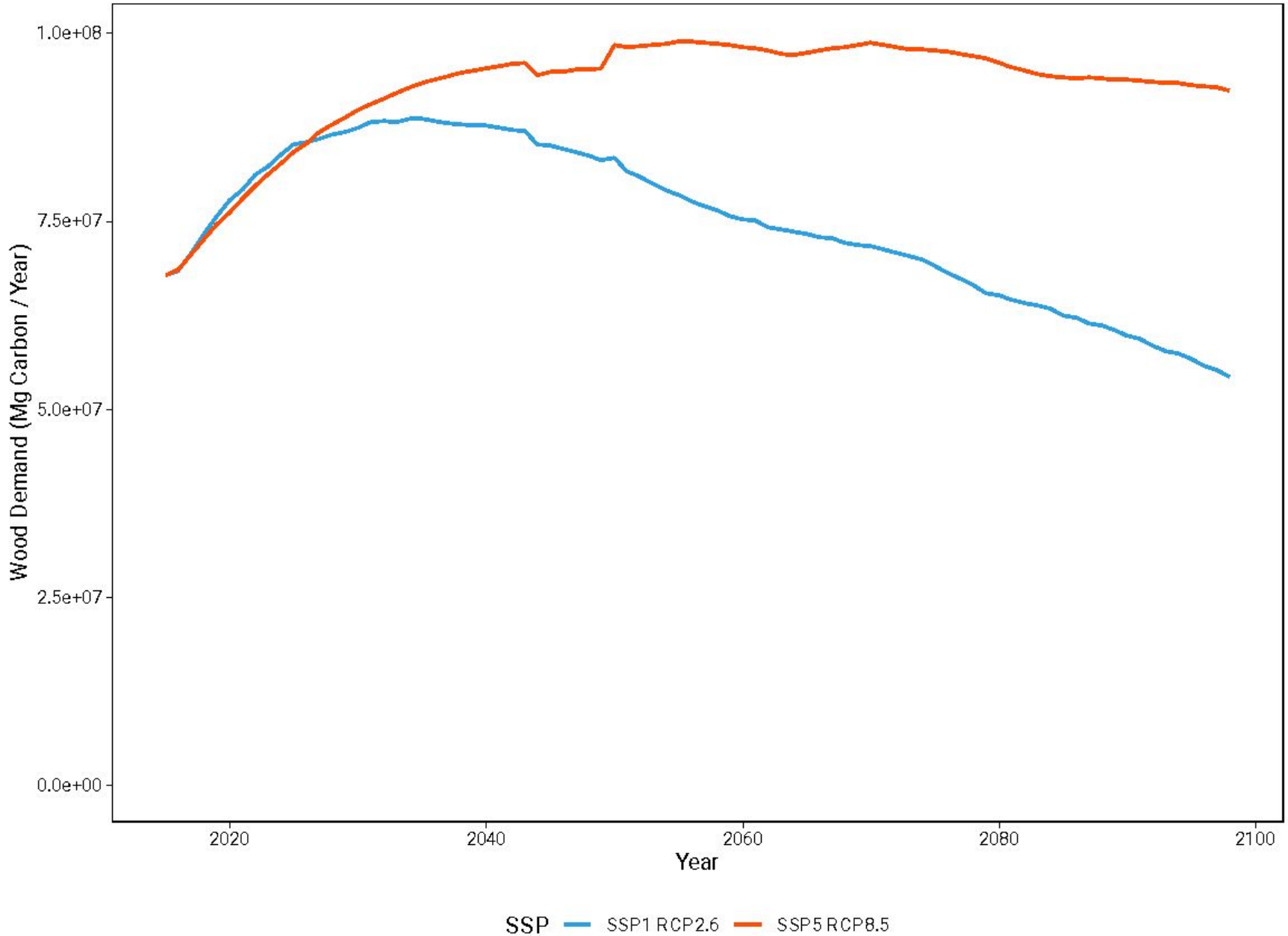
- Get wood demand from LUH2.
- Estimate yields and rotation length for each for year.
- Demand / Yield = area of plantation for each location and each year

Forest stands take decades to grow:

- Extrapolate area back in time from harvest.

- Sum the area for all overlapping stands for each year and grid cell.
- Add up the entire region and we have our total plantation area.

SEUS Regional Wood Demand from LUH2

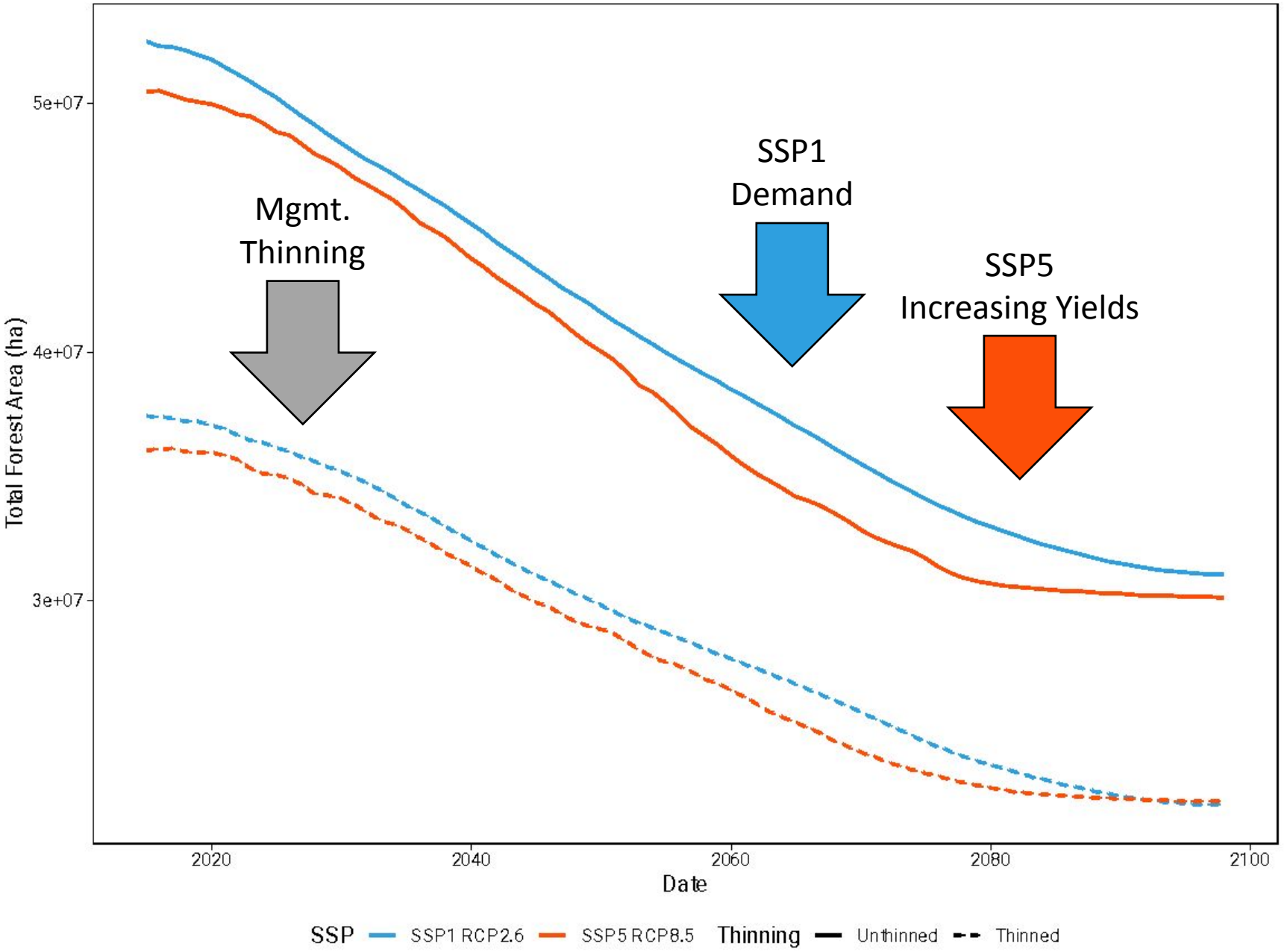


Change in Plantation Area

Plantation area needed to meet harvest demand decreases with both climate scenarios.

Area for the scenarios is similar, but for different reasons.

Thinning decreases plantation area further.



More

Conclusions

- With CLM-FATES and VM we can simulate realistic forest management in the SEUS.
- Climate increases loblolly productivity and wood yields.
- Some management practices are as influential as climate.
- Climate change will alter the management cycle timing.
- Increased wood yields could decrease the area needed to meet societal demands for wood products.
- This has potential land use and land cover implications.

Remaining Challenges

- Quantifying how management influences:
  - Total system carbon storage = forest + wood products
  - Exchange of energy between forests and the atmosphere
  - How to manage these for climate change mitigation.
- What about nutrient limitation?
  - These results may overestimate forests to response to increased $C0_2$.
  - At midcentury, our productivity increases are similar to other studies.
- How do we simulate management processes and effects *globally*?
  - Data for managed forest area is available globally.
  - But for management practices it is not.
  - More managed tree PFTs might be needed.

Acknowledgements

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National Institute of Food and Agriculture


Questions?
Photo: Corey Green

Example Vegetation Management Driver File

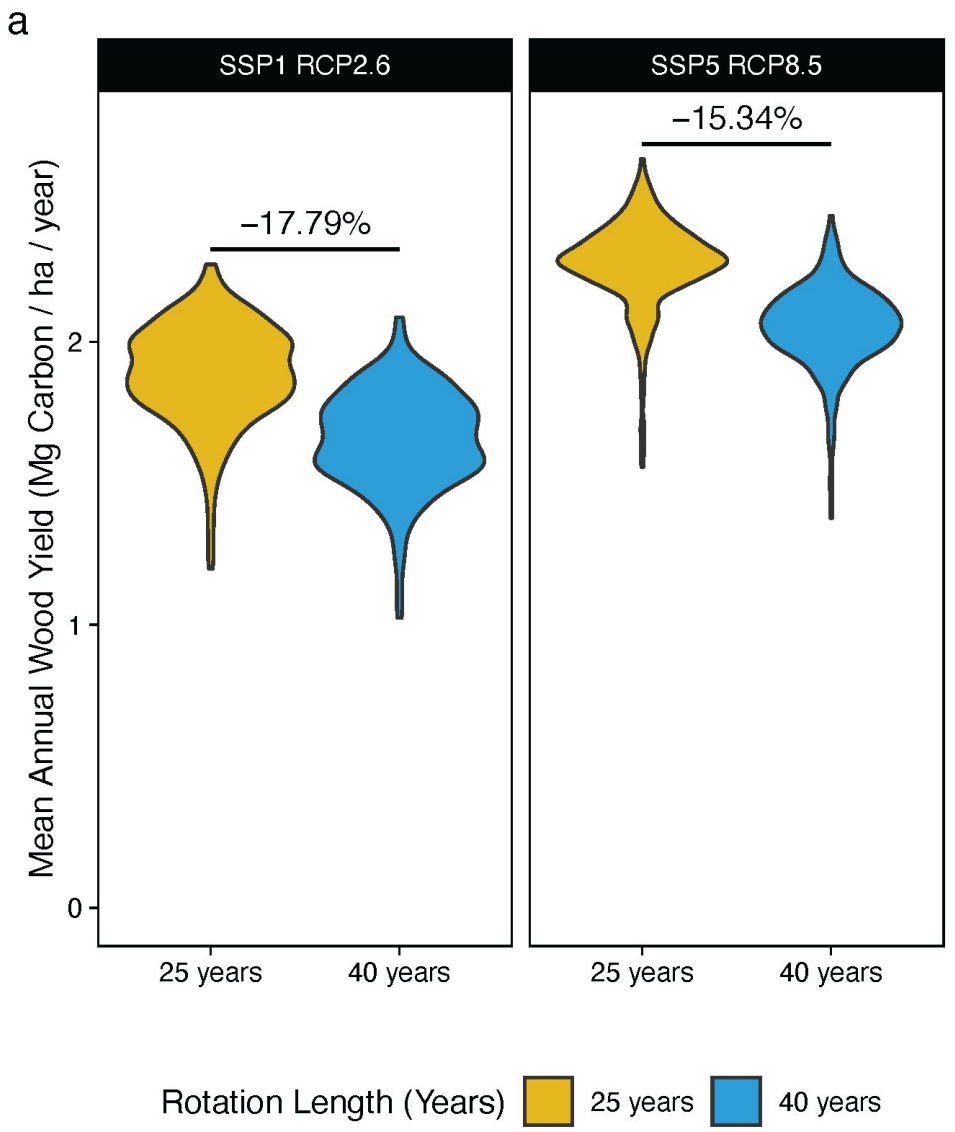
```
! VMDF_SEUS2_1250T_CCR_Auto_2000D.txt
! Exp. 7/73 6/13/2022
! Dynamic loblolly clearcut rotation, with thinning.  Corrects thinning month in
VMDF_SEUS2_1250T_CCR_Auto_2000B2.txt
Date        Latitude  Longitude EventSpec
2***-01-01  -999      -999      clearcut_if(if_dbh_mean = 32.0)

2***-03-01  -999      -999      replant(pfts = 2, density = 0.125, if_age_min = 1)

2***-02-01  -999      -999      thin_low_probabilistic_if(final_basal_area = 16,
                                    if_age_min = 6, if_bai = 28, if_dbh_max = 24)
```

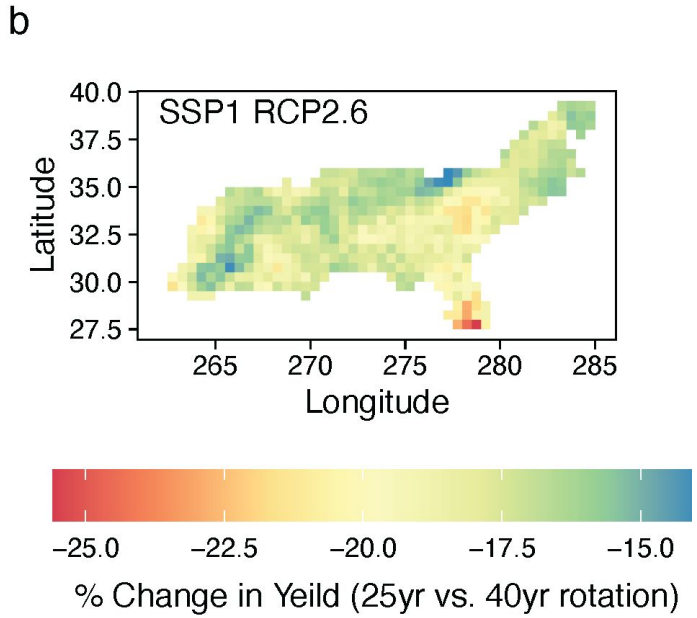
More on Management Effects

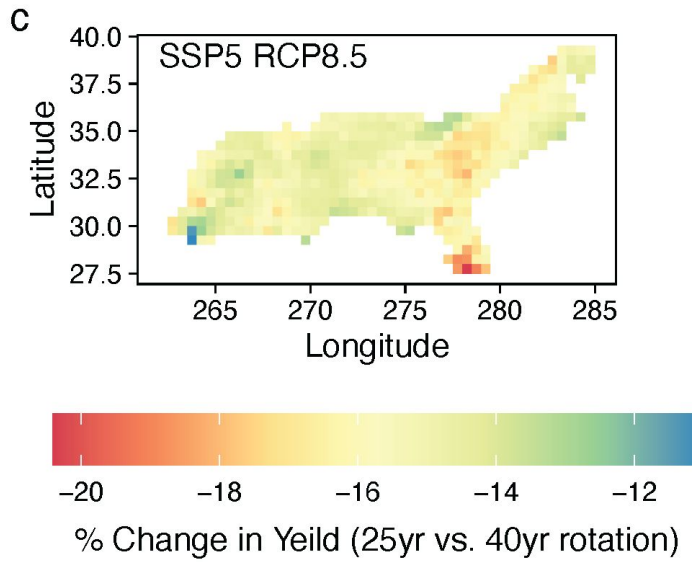
Increasing Rotation Length Decreases Yields

Increasing the rotation length decreases wood yields for both SSPs.

The effect is greatest for Florida and the Central East Coast interior.



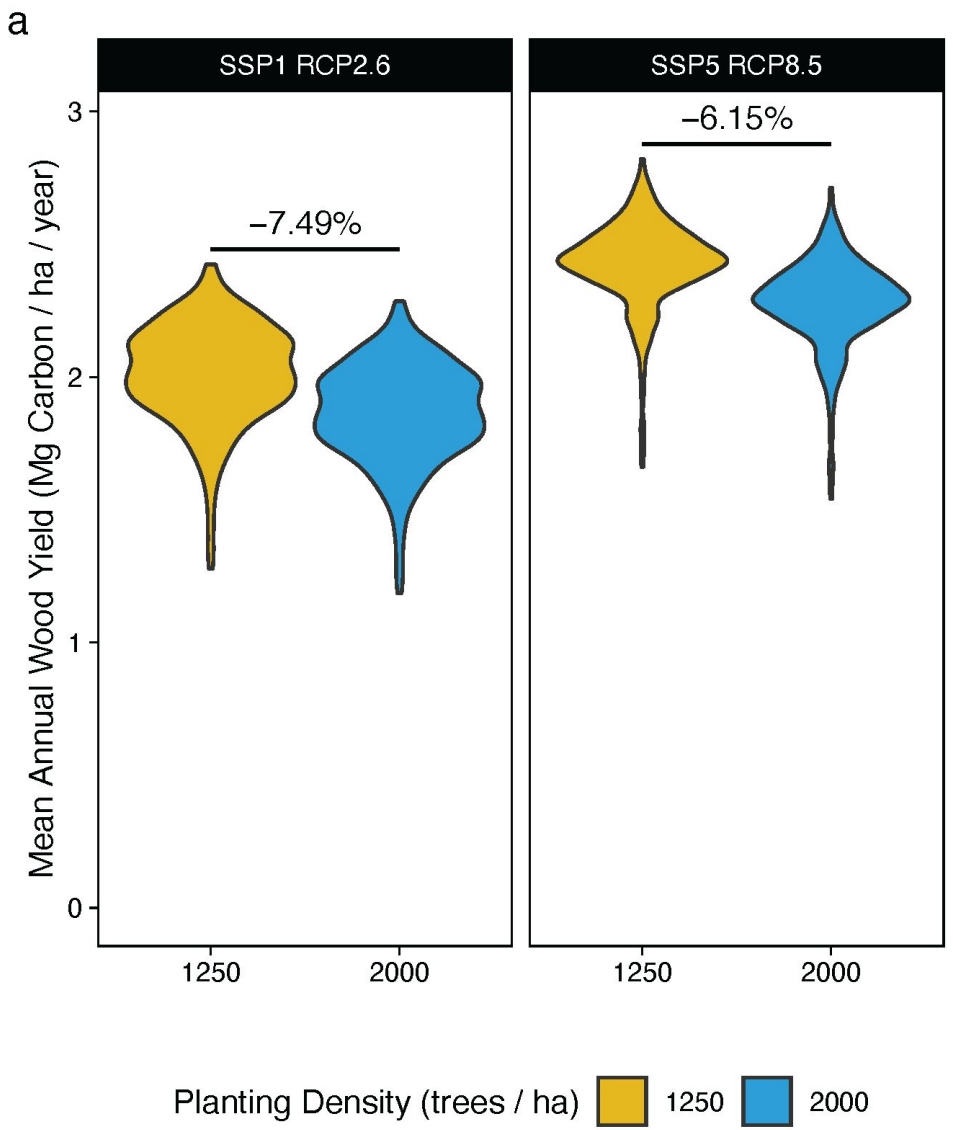


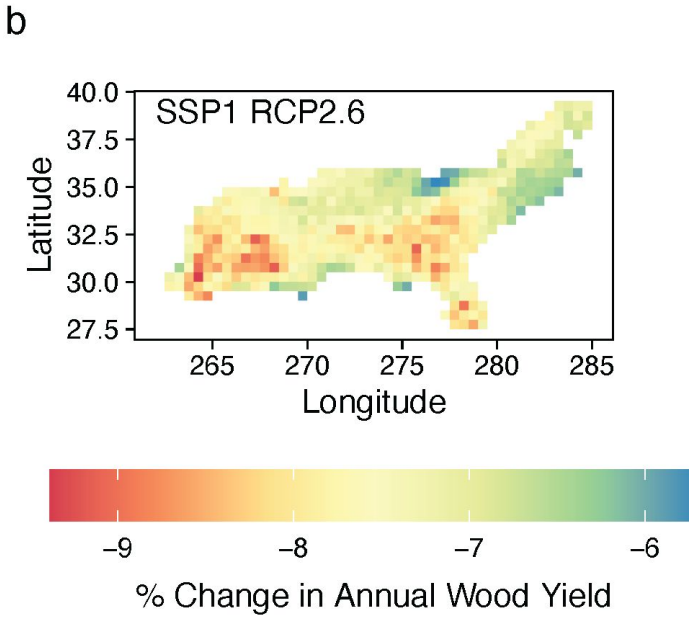


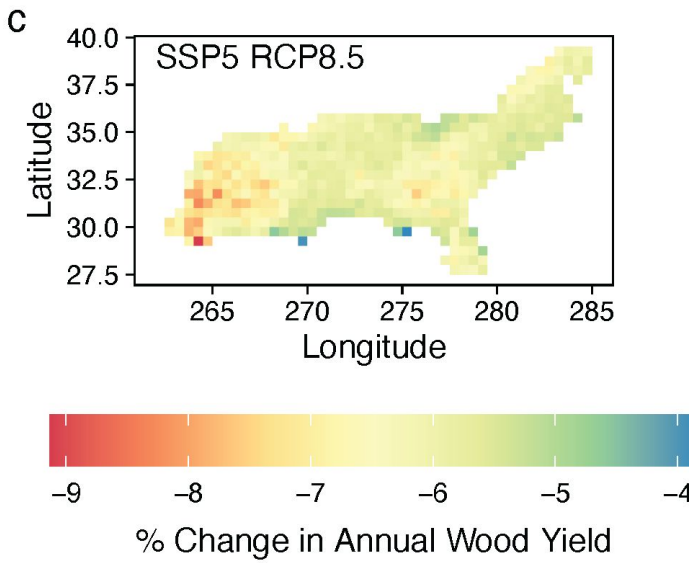
Increasing Planting Density Decreases Yields

Increasing planting density decreases wood yields for both SSPs.

The effect is greater in the Western and Southeastern parts of the region.



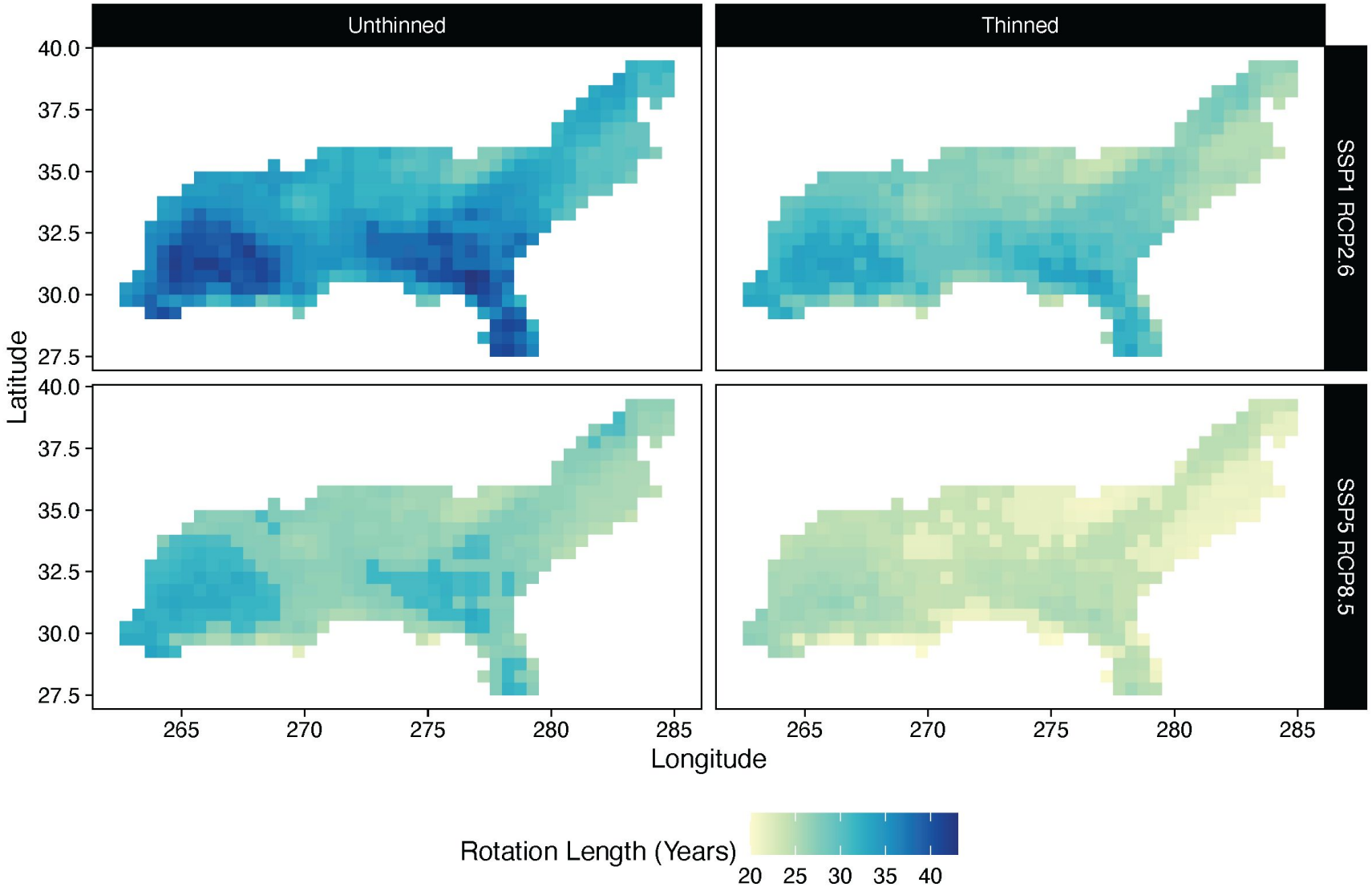




More Management Timing Details

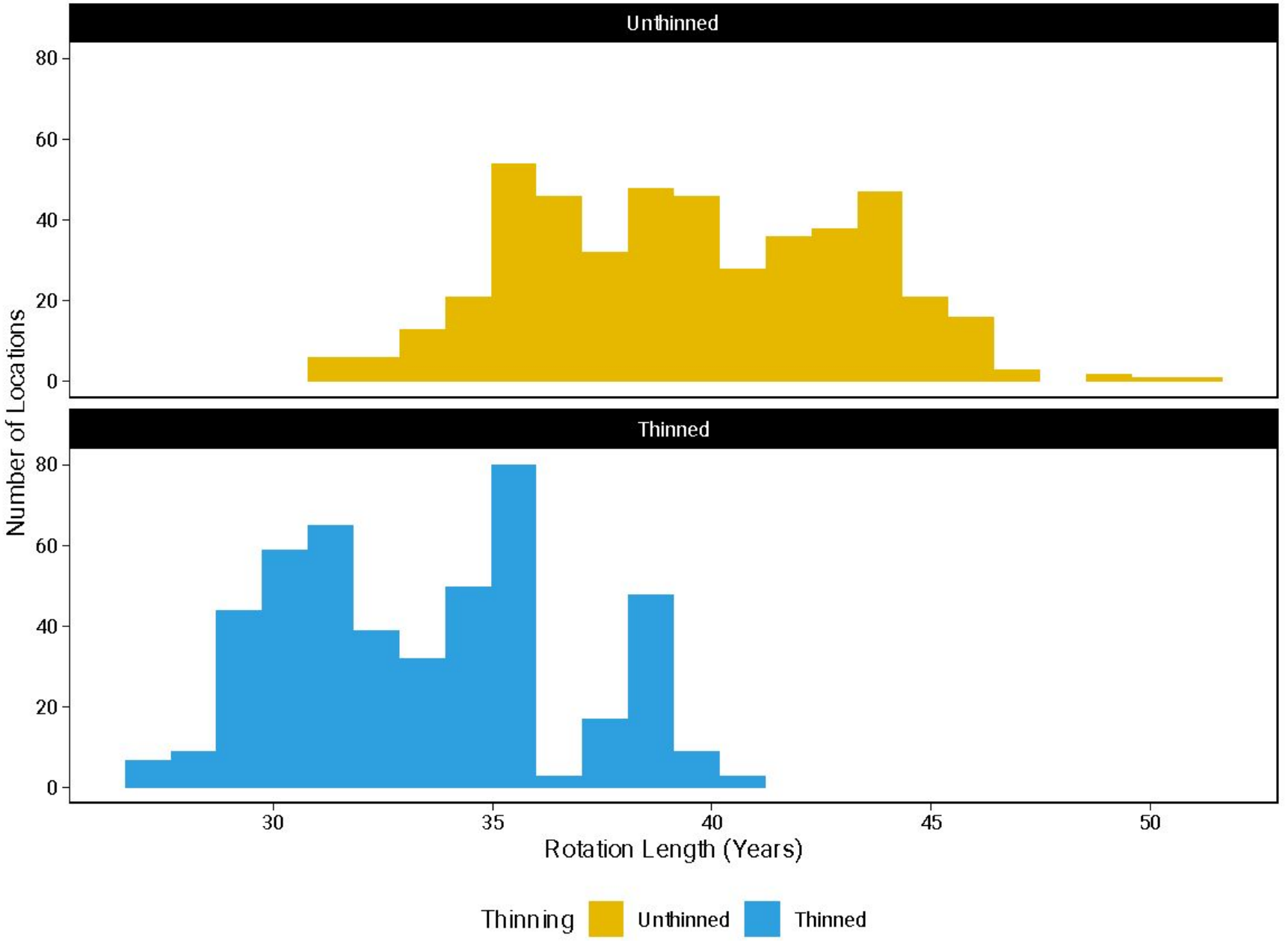
Let the Model Determine Management Timing

Rotation length varies across the region.



Let the Model Determine Management Timing

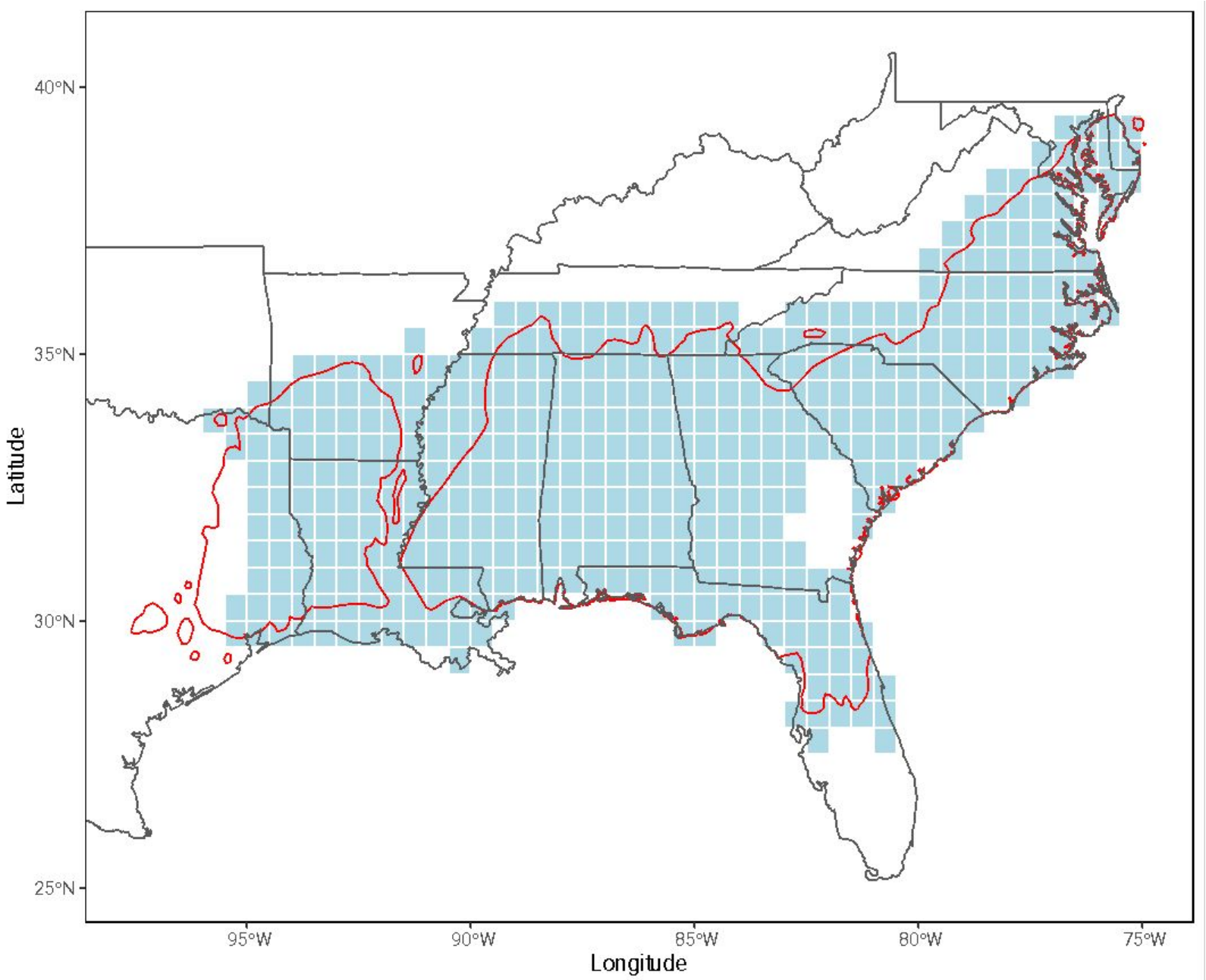
Rotation lengths at the start of the century are similar to our estimates for the region.



More on Required Planation Area

Harvest Area Study Region

Parts of the species range have no wood harvest demand.



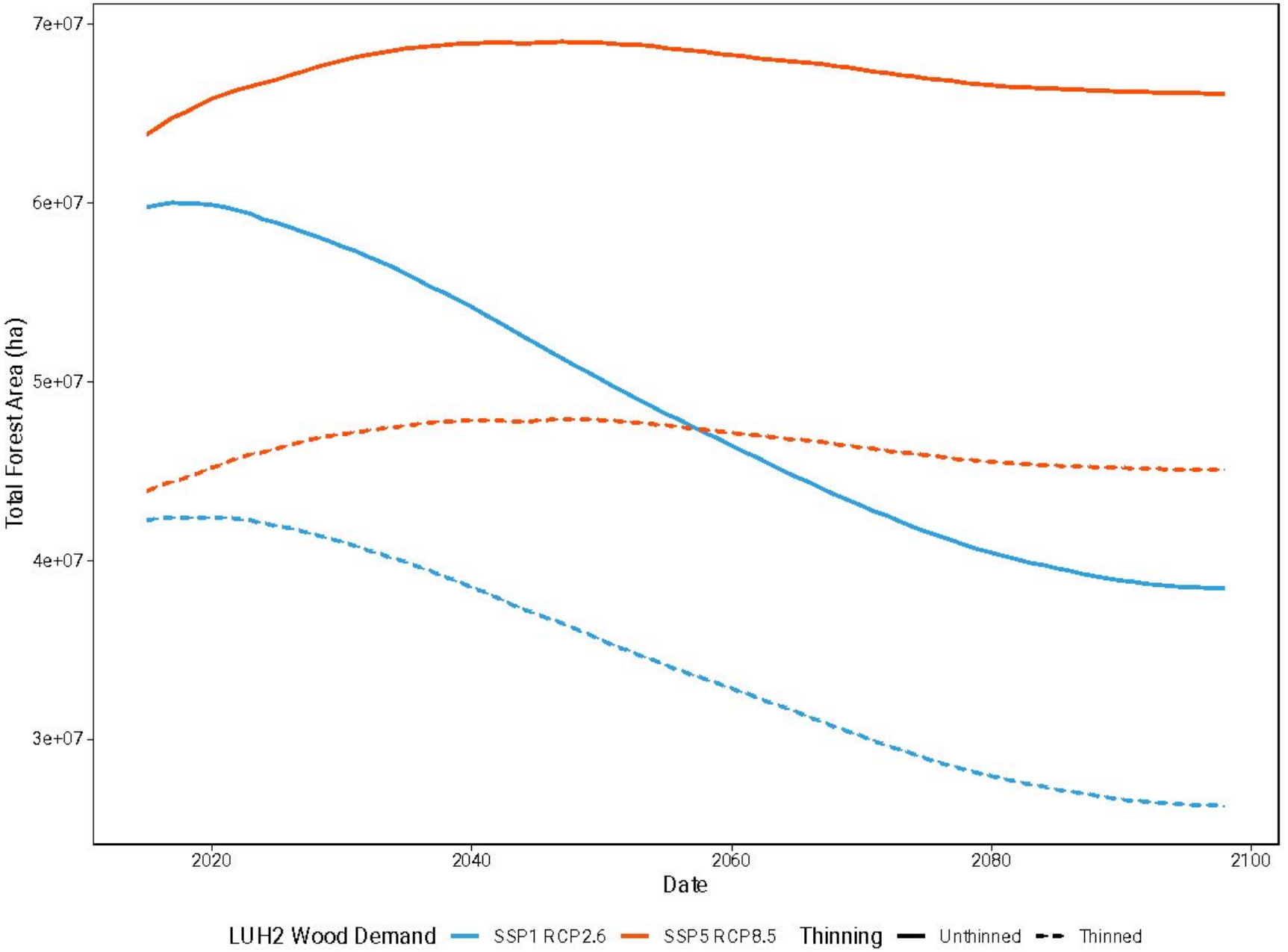
Change in Plantation Area *without Climate Change*

SSP1:

- Area decreases with SSP1 demand.
- Decreasing demand drives decrease in the area.

SSP5:

- Area stays flat with SSP5 demand.
- Productivity increases drives decrease in the area.



Logging Module Limitations

- Harvests occur from all woody PFTs (trees and shrubs). Harvesting from specific PFTs is not possible.
- The module only allows harvest from woody PFTS. Other forms of management induced mortalities, planting, and alterations to understory are not implemented.
- Logging events can be scheduled on a periodic basis or at one specific date.
- Events cannot be scheduled to occur at an arbitrary sequence of dates or when certain conditions are met.
- Wood is harvested from all patches and grid cells. Harvest cannot be targeted at specific locations or patches.
- Logging occurs as a fraction of plants present. Harvest cannot be specified by amount or goal, e.g. by a specific biomass removal.
- A minimum diameter at breast height (DBH) can be set but no other size controls are provided for harvest. This prevents simulation of management activities that target small or mid-sized trees.
- The only mode of harvest mortality is a bole harvest (harvest of the trunk wood).