Modeling aboveground carbon dynamics under different silvicultural treatments

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Forest carbon in the Pacific Northwest

- PNW forests cover 24.7 million acres of land

- Oregon Coast Range
  - Some of the most productive forests in the world
  - Favorable climate → fast growth → carbon sink

- Siuslaw National Forest
  - Greatest density of forest carbon out of all federal forest land in the state of Oregon

Photo source: Nikolova, 2023

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Management strategies for forest carbon

- Identification and selection of appropriate rotation ages for maximum carbon sequestration based on forest type and site conditions

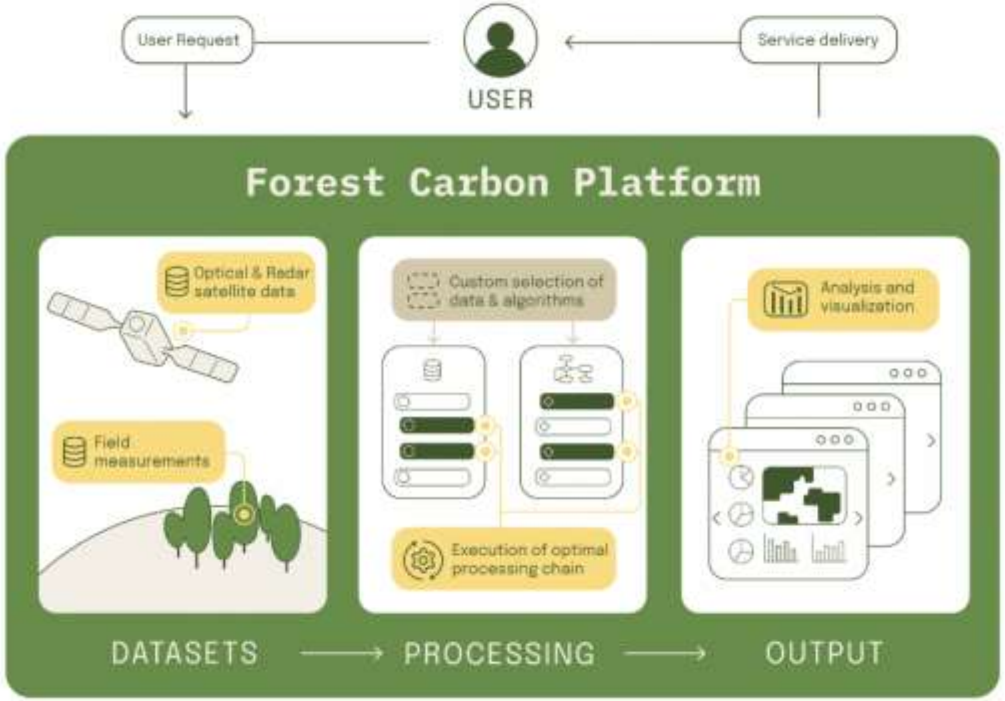
- Implementation of effective silvicultural strategies
  - E.g., thinning, fertilization, herbicide, selective cutting operations, etc.

- Incorporation of new objectives and information into long-term forest management plan frameworks

- **<u>Use of growth and yield modeling</u>** by forestland owners to help assess the impacts of management trajectories on forest carbon dynamics

Modeling forest carbon dynamics

- Use growth and yield models to predict rates of sequestration and long-term carbon storage over time
- Assess influence of management actions such as thinning and regeneration strategies
- Assess tradeoffs between forest carbon and other management objectives, such as harvesting and maintaining biodiversity



Source: Forest Carbon Monitoring Consortium, 2021

Objectives

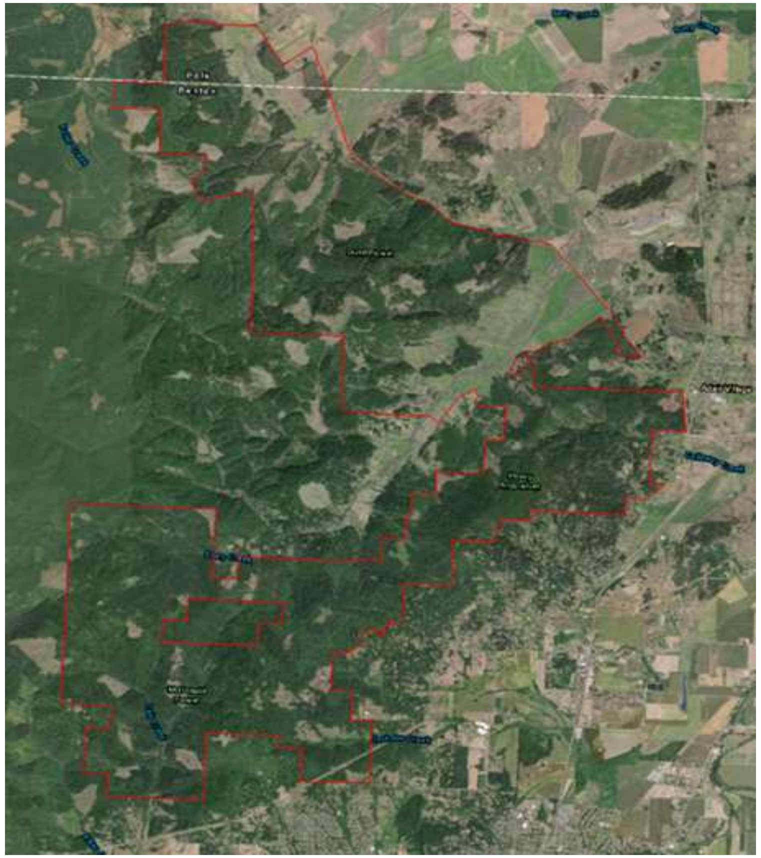
1. Compare efficacy of different forest management strategies in relation to maximizing long-term forest sequestration:
    - Optimal rotation age
    - Effective thinning regimes in terms of frequency and intensity between rotations

2. Examine patterns of aboveground live carbon fluctuations for all management trajectories assessed

Study area

<u>McDonald-Dunn Research Forest</u>

- 11,250 acres of forested land
- Within “Valley Margin Zone” on eastern foothills of Oregon Coast Range
- Predominant overstory species = Douglas-fir



Source: Oregon State University, College of Forestry, McDonald-Dunn Research Forest

Carbon projections

- Management scenarios modeled using the ORGANON-NWO variant of **Forest Vegetation Simulator (FVS)**

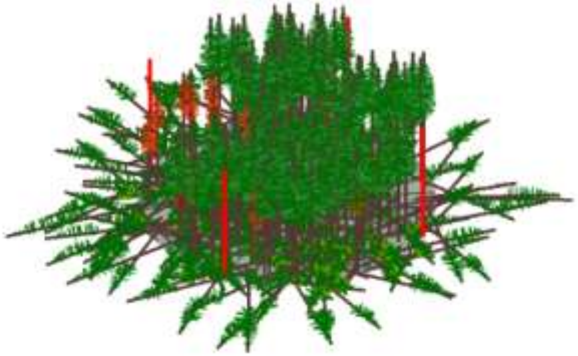
- Total gross carbon sequestration within aboveground live biomass was calculated by summing **harvested carbon** + **carbon lost to mortality over a 240-year projection period**

- Efficacy of treatments assessed by site class

- Optimal rotation age and thinning regime combination out of ALL treatments was identified for each site class

- Optimal thinning regime WITHIN each rotation age for each site class was identified as well

Source: USFS



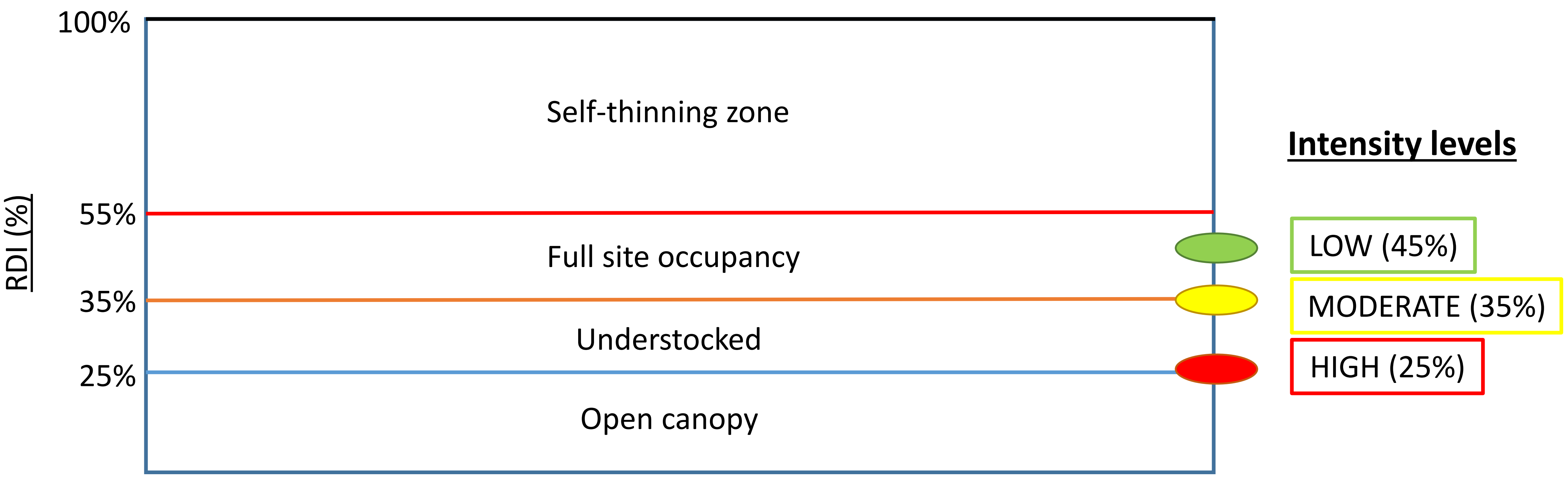
Source: USFS

Treatment design

Treatments varied by rotation age, thinning intensity, and thinning frequency on the selected stands

Rotation Age	Thinning Intensity	Thinning Frequency
• 40-year • 60-year • 80-year • 120-year	• Low • Moderate • High	• No thin • One thin • Two thins • Three thins

Thinning intensity



Maximum thinning frequencies by rotation length and site class

Site class	40-year	60-year	80-year	120-year
I	-	1	2	3
II	-	1	2	3
III	-	-	2	3
IV	-	-	-	3

Additional treatment specifications

- Initial harvest set to the year 2023
- Harvest = complete clearcut (no legacy trees) with min. cut DBH of 2”
- Douglas-fir seedlings planted one year post-harvest
  - Site class I & II: planting density of 400 TPA
  - Site class III & IV: planting density of 360 TPA
- Three herbicide treatments were applied at the start of each rotation
  1. Year of harvest
  2. One year post-harvest
  3. Two years post-harvest
- Natural regeneration was specified at 20-year age intervals
  - Appropriate quantities and species compositions of ingrowth within each age class determined from the 2019–2020 inventory data

Assumptions

- FVS projections provide reliable and unbiased predictions of stand development and carbon dynamics over time
- Recorded site indices accurately represent the productivity of the stand and how stands will respond to silvicultural treatments
- Environmental conditions will remain constant over an entire 240-year projection period
- Natural regeneration is determined only by stand age class instead of site class
- No measurement errors during collection of inventory data

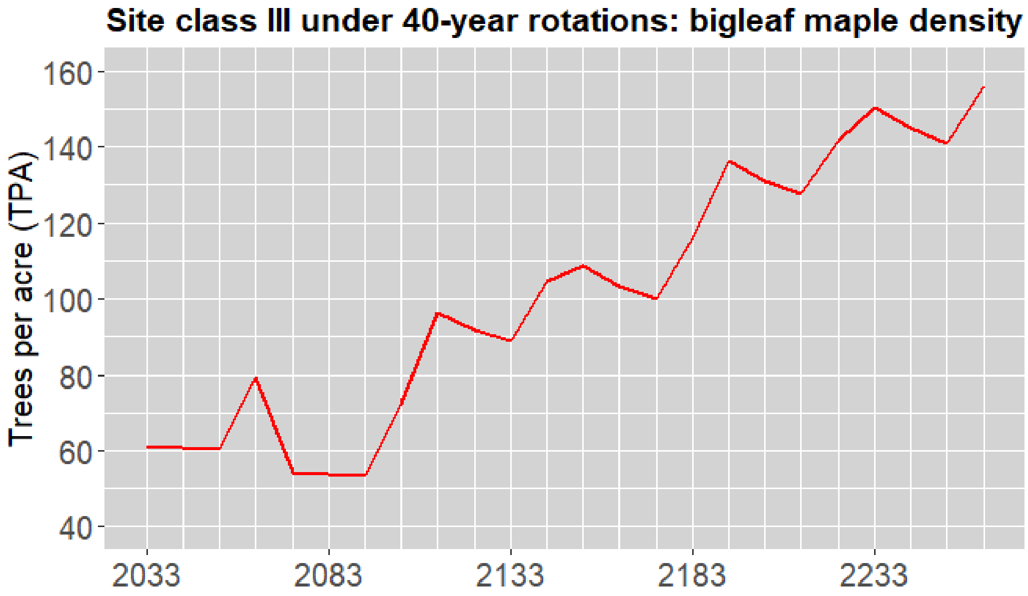
Results & Discussion

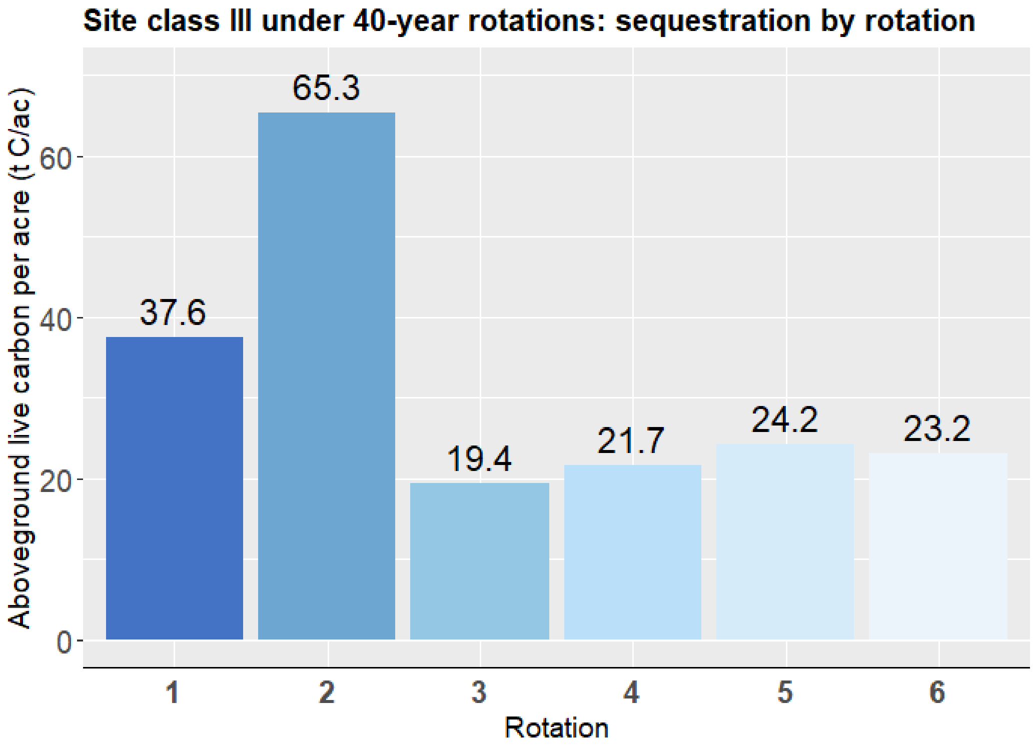
Optimal treatments by site class

Site class	40-year	60-year	80-year	120-year
I	No thin	Low thin 40	Low thin 50 + low thin 60	Low thin 60 + low thin 80
II	No thin	Low thin 40	Low thin 50 + low thin 60	Moderate thin 60 + low thin 80
III	No thin	No thin	Low thin 50 + low thin 60	Moderate thin 50 + low thin 60 + low thin 80
IV	No thin	No thin	No thin	Moderate thin 70 + moderate thin 80 + moderate thin 90

40-year rotations

- 40-year rotations produced the **lowest estimates** of C sequestration for **site classes I-III**
  - No thinning treatments → build up of bigleaf maple in understory → diminished sequestration in later rotations

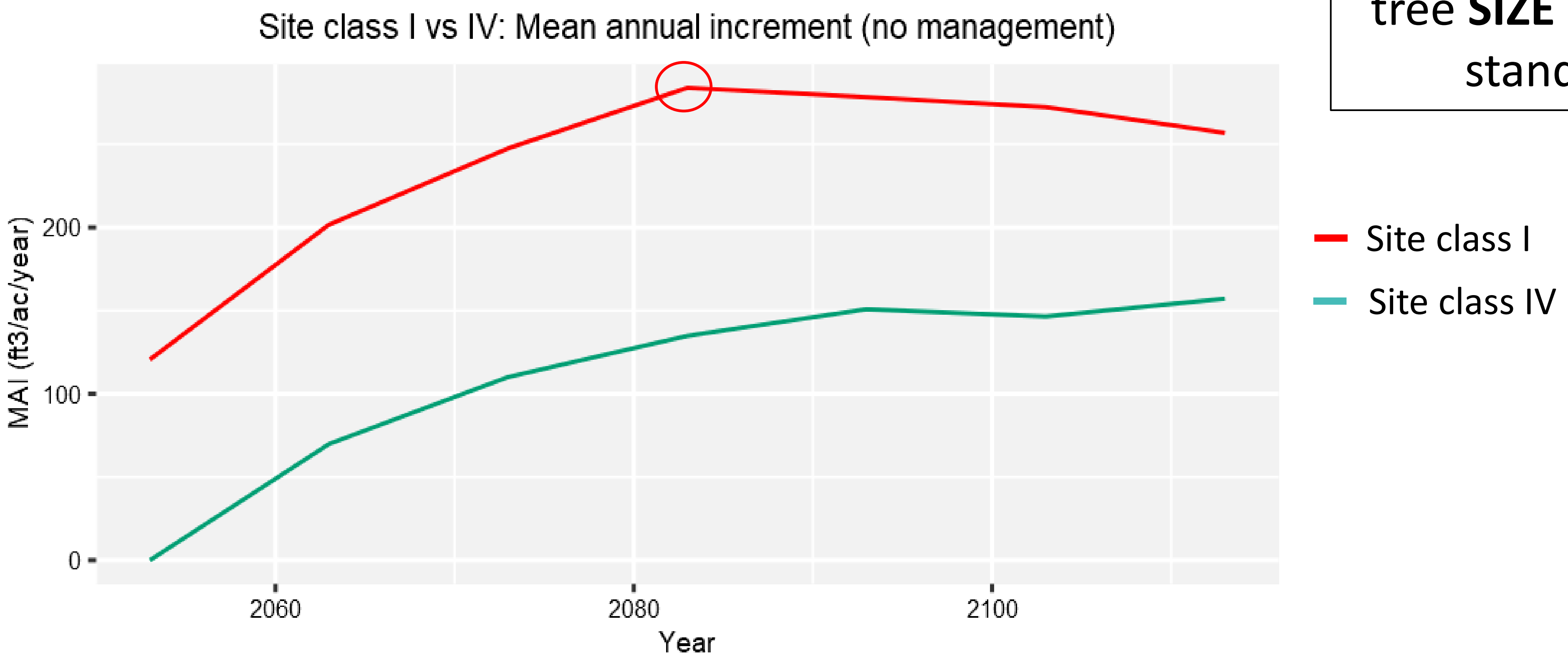




Rotation age vs site class

- High site productivity → ***shorter** rotations become advantageous
- Faster growth rates = earlier decrease in growth rates

Model predicts stand development with tree **SIZE** instead of stand **AGE**



*Does not apply to 40-year rotations

60-year vs. 80-year rotations: thinning frequency

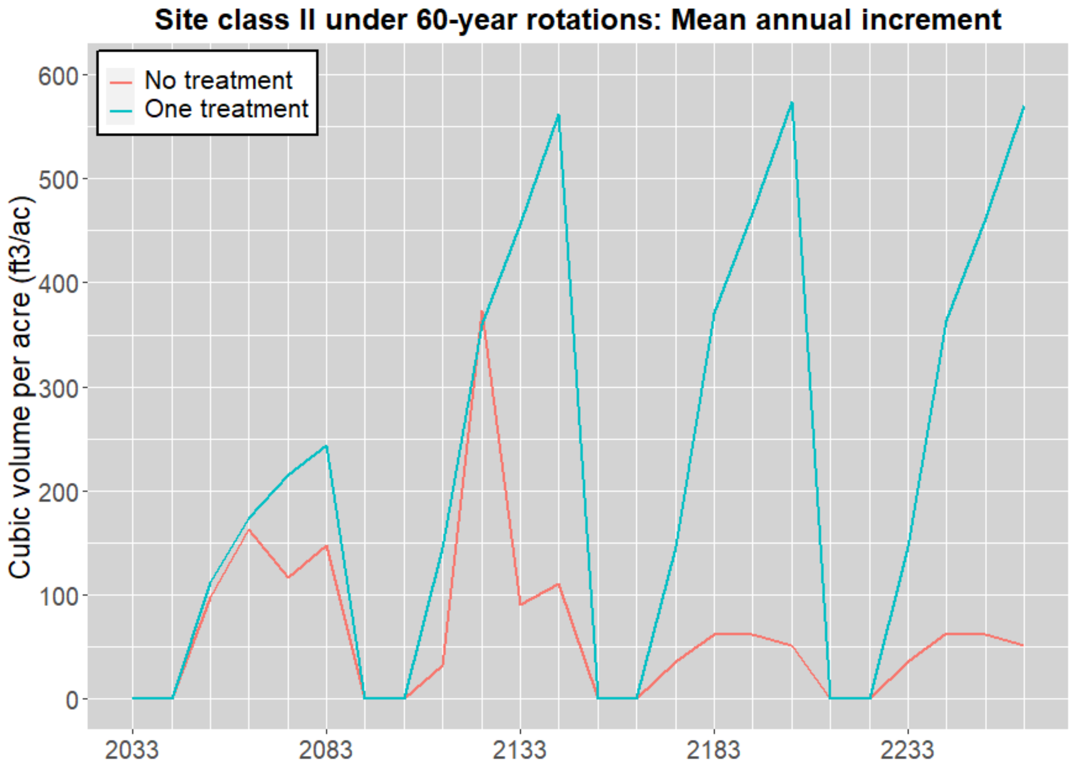
60-year rotation

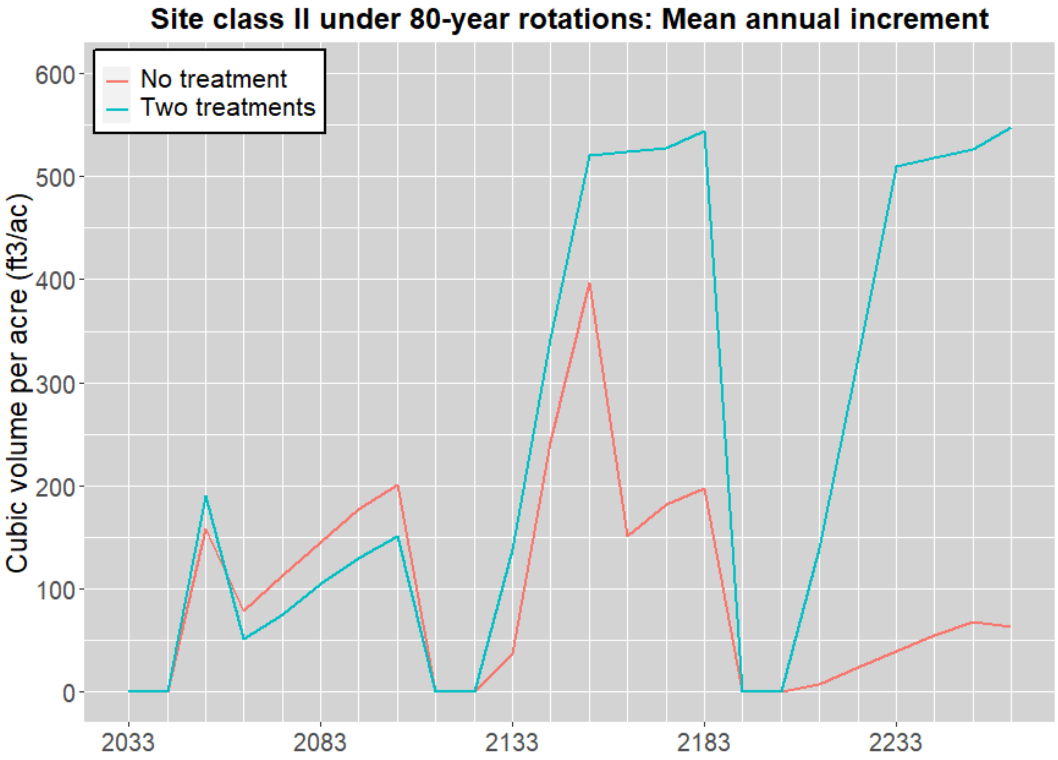
- **One treatment** at age 40 → **highest** estimated sequestration

80-year rotation

- **Two treatments** at ages 50 & 60 → **highest** estimated sequestration

Maintenance of stand growth rates

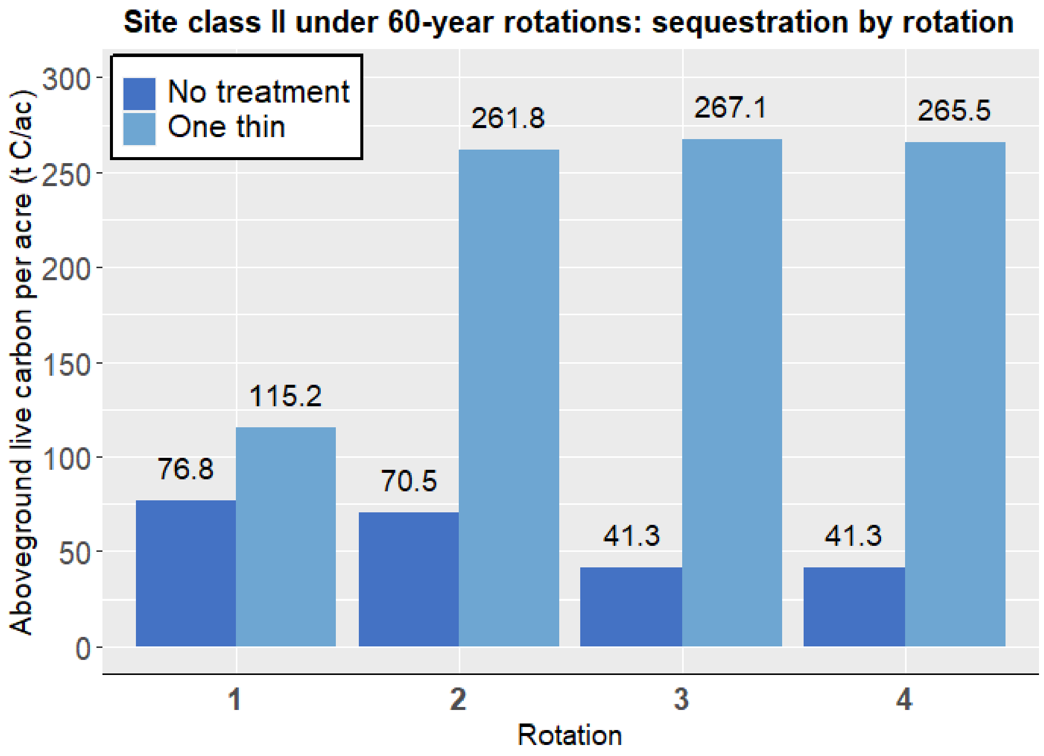


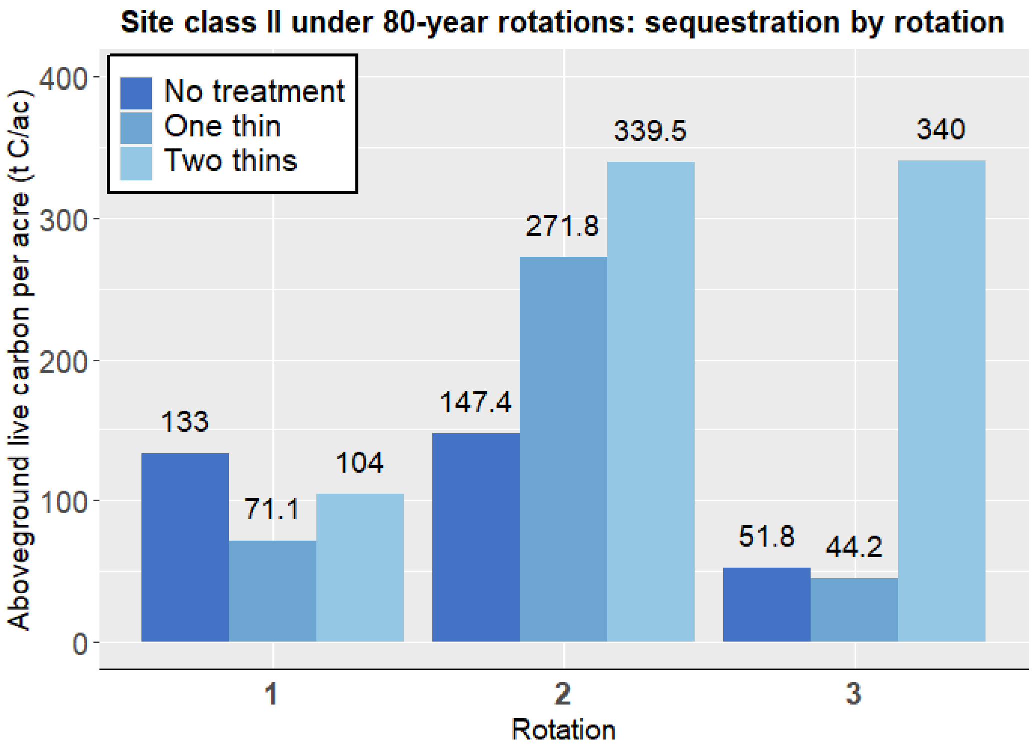


60-year vs. 80-year rotations: thinning frequency

60-year rotation	80-year rotation
• **One treatment** at age 40 → **highest** estimated sequestration	• **Two treatments** at ages 50 & 60 → **highest** estimated sequestration

Consistent C sequestration throughout rotations





120-year rotations: thinning frequency

Optimal thinning frequency within 120-year rotations was dependent on site productivity:

High productivity: site classes I & II

- **Two treatments**
- Less susceptible to growth stagnation because of vigorous conifer growth
- Three treatments = unnecessary biomass removal

Low productivity: site classes III & IV

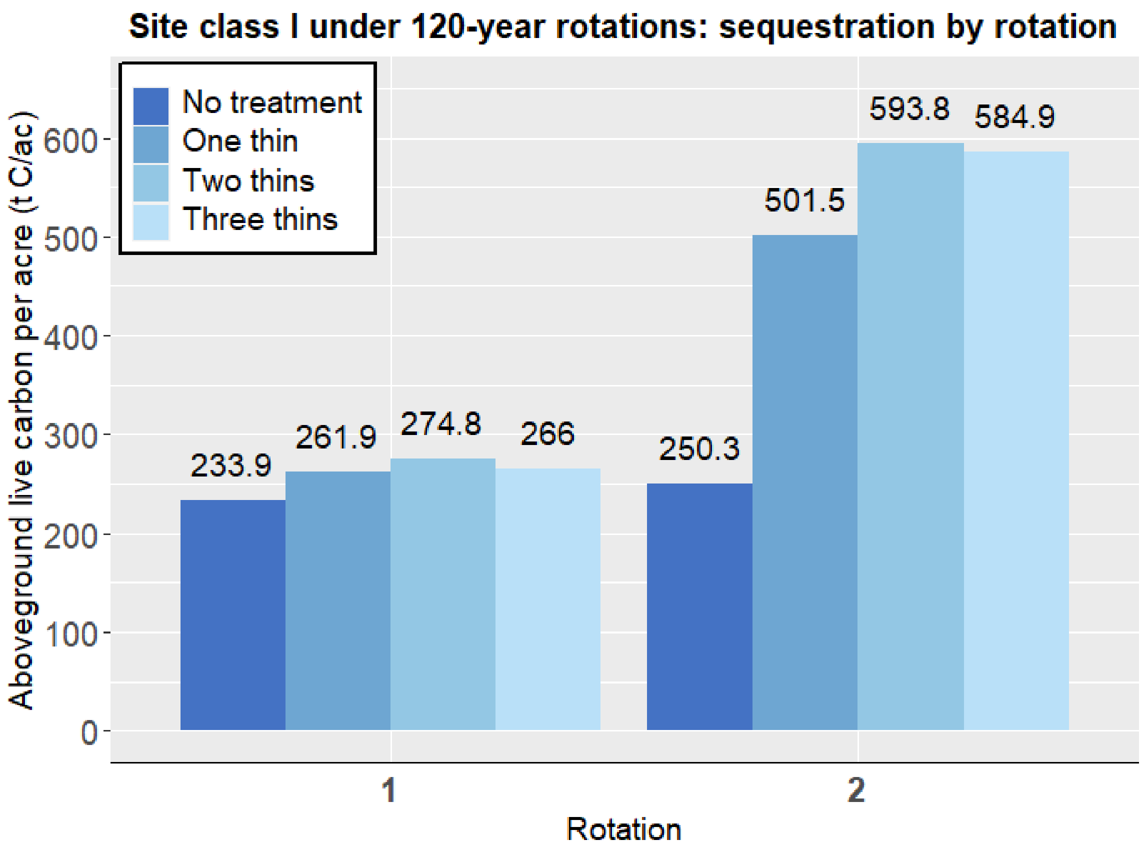
- **Three treatments**
- More susceptible to growth stagnation from understory competition
- Two treatments = inadequate vegetation control

Projections with zero or one treatment performed poorly for all site classes.

120-year rotations: thinning frequency

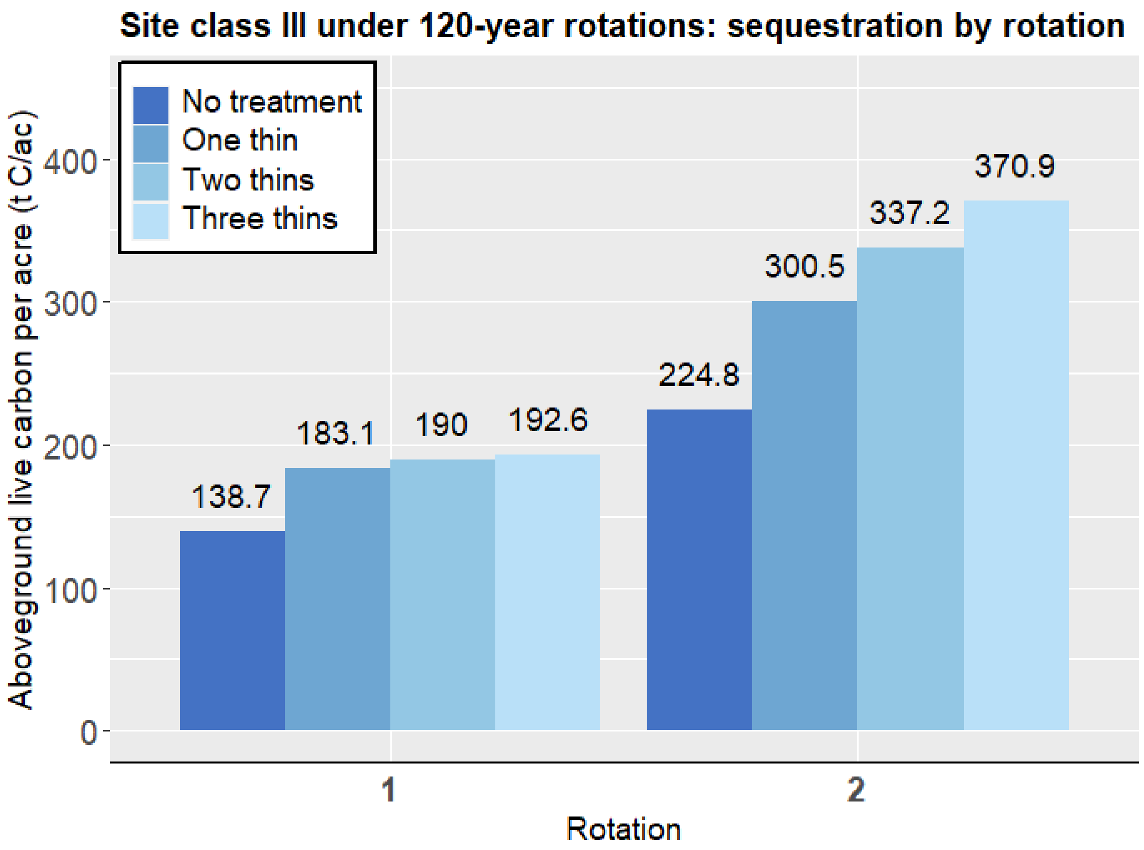
High productivity

- **Two treatments** → **highest** estimated sequestration



Low productivity

- **Three treatments** → **highest** estimated sequestration



60-year vs. 80-year rotations: thinning intensity

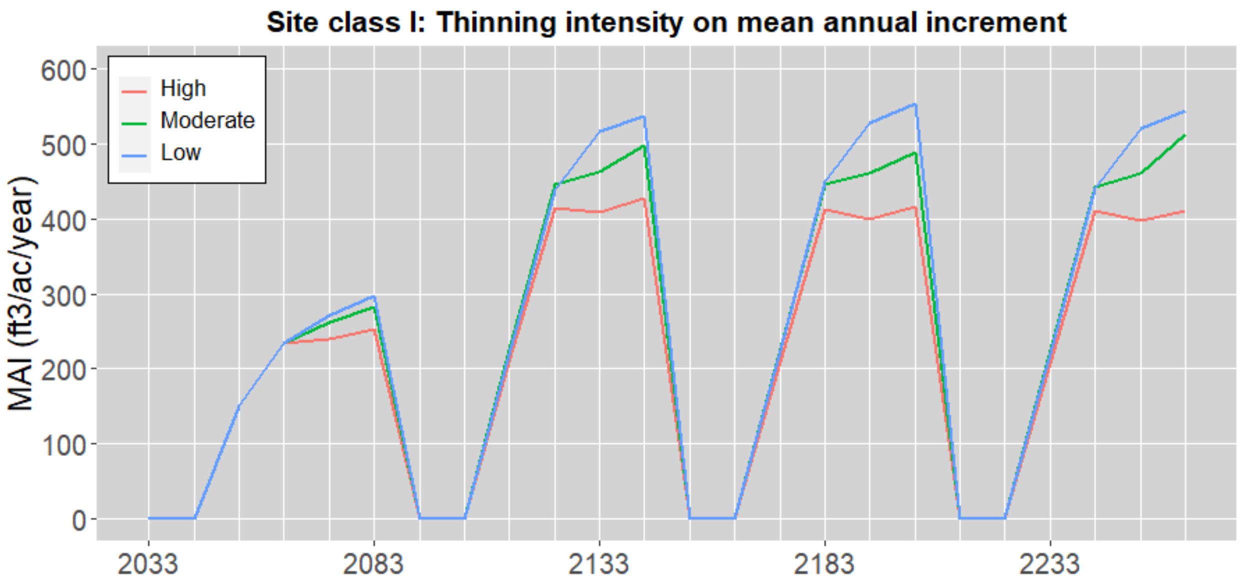
60-year rotation

- **Low-intensity** at age 40 → **highest** estimated sequestration

80-year rotation

- **Low intensity** at ages 50 & 60 → **highest** estimated sequestration

Increases growth rates without removing excess biomass



120-year rotations: thinning intensity

As productivity decreased, the inclusion of one or more moderate intensity treatments became more favorable:

- Site class I: low intensity only (two treatments)
- Site class II: moderate + low intensity (two treatments)
- Site class III: moderate + low + low intensity (three treatments)
- Site class IV: moderate intensity only (three treatments)

High intensity thinning was found to be ultimately detrimental to long-term sequestration.

120-year rotations: thinning intensity

- Essentially, the same principles that determined optimal thinning frequency also influenced the optimal intensity regime:

High productivity	Low productivity
Vigorous growth of overstory	Slower growing overstory conifers
Requires **less** understory tree removal to increase sequestration rates	Requires **more** intense understory removal treatments to decrease competitive pressures
Additional biomass removal only lowers sequestration potential of the stand	Less intense treatments will allow understory vegetation to suppress conifer growth

Conclusions

- Decreased productivity → increased length of rotation age to maximize 240-year sequestration
- Optimal thinning regimes for 60- and 80-year rotations are consistent across site classes
- Different site classes favored different thinning intensities & frequencies within 120-year rotations
  - Two general trends observed:
    1. Highly productive stands favored **TWO** thinning treatments while stands of lesser productivity favored **THREE**
    2. **Moderate** thinning became more advantageous as site productivity **decreased**
- High-intensity thinning was typically detrimental within each rotation age
- Failing to apply thinning treatments minimized sequestration overall

Additional considerations

- It was shown that no management decision (rotation age, thinning intensity, thinning frequency) would individually maximize sequestration.
    - The positive effects of implementing may not be observed unless the other factors are also appropriately aligned.

- Density of bigleaf maple significantly impacted sequestration for latter 40-, 60-, and 80-year rotations even with herbicide application.

- The optimal rotation age for each site class was heavily on dependent on the age at which the stand reached a QMD of 9.5”
    - No thinning during shorter rotations → significantly less sequestration

- The difference in planting densities between site classes I & II vs. III & IV may have acted as a confounding variable.

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Questions?