Plantation Management Research Cooperative
Warnell School of Forestry & Natural Resources
UNIVERSITY OF GEORGIA

Differential growth and structural responses of loblolly pine plantations to first and second thinning with fertilization and release treatments

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Introduction

- Thinning is a widely used silvicultural practice in managed plantations, aimed at
  - Reducing density-dependent mortality
  - Enhancing the growth of residual trees
  - Improving wood product distribution
  - Promoting structural uniformity
  - Maintaining forest health

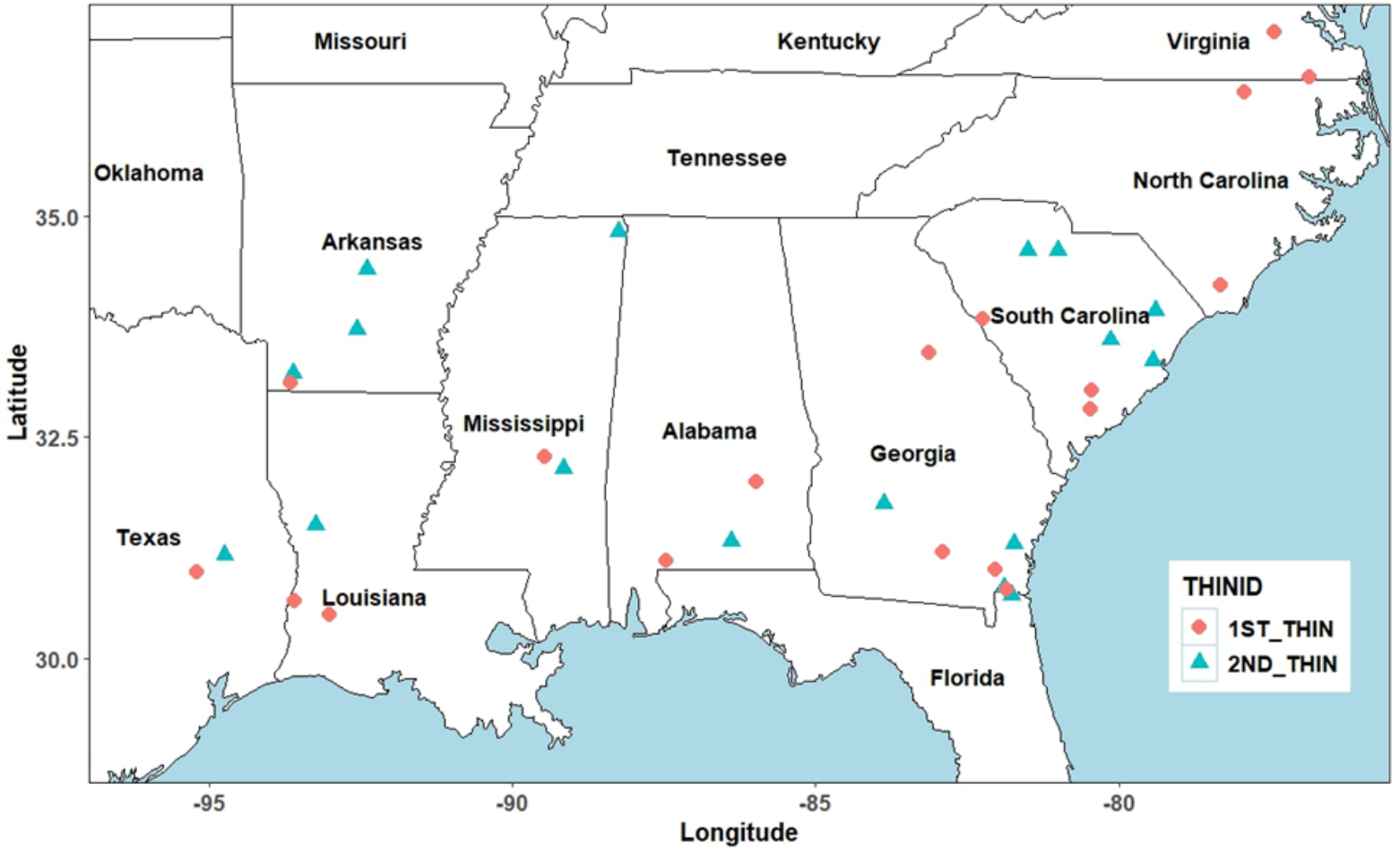
- When combined with mid-rotation treatments (fertilization, or release), thinning can further increase the quality and proportion of higher-value products, such as sawtimber, thereby improving financial returns

Introduction

- Stand growth is strongly influenced by stand density, tree size distribution (stand structure), and the relationship tree size and growth (growth dominance)
- By reducing stand density, thinning alters stand structure and growth dominance
- Tree- and stand-level growth responses to thinning vary by species, and are influenced by thinning timing, intensity, and method
- While most research has focused on first thinning, limited data and modeling efforts exist on second thinning and post-thinning treatments

Method – MRT Study

- PMRC initiated the Mid-Rotation Treatment Study (MRT) in 2009, completing all site installations by 2018
- To develop robust databases for modeling stand responses to 1st and 2nd thinning, and to quantify post-thinning fertilization and release treatment effects



Method – MRT Study

Expressed Site Index	Initial Stand Basal Area	
	Low (20.7 < BA ≤ 27.5 m^2/ha)	High (27.5 < BA ≤ 34.4 m^2/ha)
Low (16.8 ≤ SI ≤ 21.3 m)	3 (LCP +1st thin); 3 (UCPIE + 1st thin); 3 (LCP +2nd thin); 3 (UCPIE + 2nd thin)	3 (LCP +1st thin); 3 (UCPIE + 1st thin); 3 (LCP +2nd thin); 3 (UCPIE + 2nd thin)
High (21.3 < SI ≤ 30.5 m)	3 (LCP +1st thin); 3 (UCPIE + 1st thin); 3 (LCP +2nd thin); 3 (UCPIE + 2nd thin)	3 (LCP +1st thin); 3 (UCPIE + 1st thin); 3 (LCP +2nd thin); 3 (UCPIE + 2nd thin)

TRT #	Thin	Fertilization and/or Release
1	No	None
2	Yes	None
3	Yes	Fertilize (200 lbs/ac N, 25 lbs/ac P)
4	Yes	Release (operational treatment with follow-up to obtain excellent operational efficacy)
5	Yes	Fertilize + Release

Objectives – MRT Study

1. Effects of 1st and 2nd thinning (with/without post-thinning treatments) on Dq, H, BA, and TVob growth
2. Whether smaller or larger trees benefit more from thinning, and how post-thinning treatments influence the relationship between tree size and growth
3. Impacts of thinning and post-thinning treatments on proportion and yields of different wood products (sawtimber, chip-n-saw, pulpwood)

Method – MRT Study

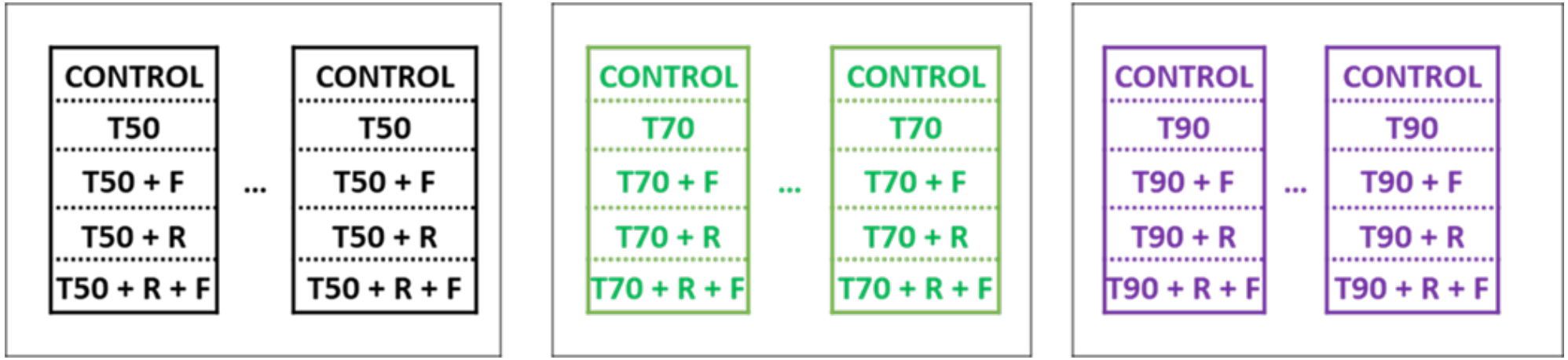
- Dq, HD, BA, and TVOB accumulated increments since thinning
- Yield and proportion of pulpwood, chip-n-saw, and sawtimber
  - Variable-top merchantable volume/weight equation (Zhao and Kane, 2017)
  - The corresponding taper equation (Lynch, Zhao, et al., 2017)
- Tree size inequality – Gini Index

$$G = \left(n+1-2\sum_{i=1}^{n}(n+1-i)y_i \Big/ \sum_{i=1}^{n} y_i\right)\Big/(n-1) \qquad \text{(Dixon et al., 1987)}$$

- Growth dominance index

$$DC_{growth} = 1-\left(\sum_{i=1}^{n} y_{iT_1}(y_{iT_2}-y_{iT_1}) - 2\sum_{i=2}^{n} y_{iT_1}\sum_{j=1}^{i-1}(y_{iT_2}-y_{iT_1})\right)\Big/\left(\sum_{i=1}^{n}(y_{iT_2}-y_{iT_1})\sum_{i=1}^{n} y_{iT_1}\right) \qquad \text{(Zhao, 2022)}$$

Method – Statistical Analysis

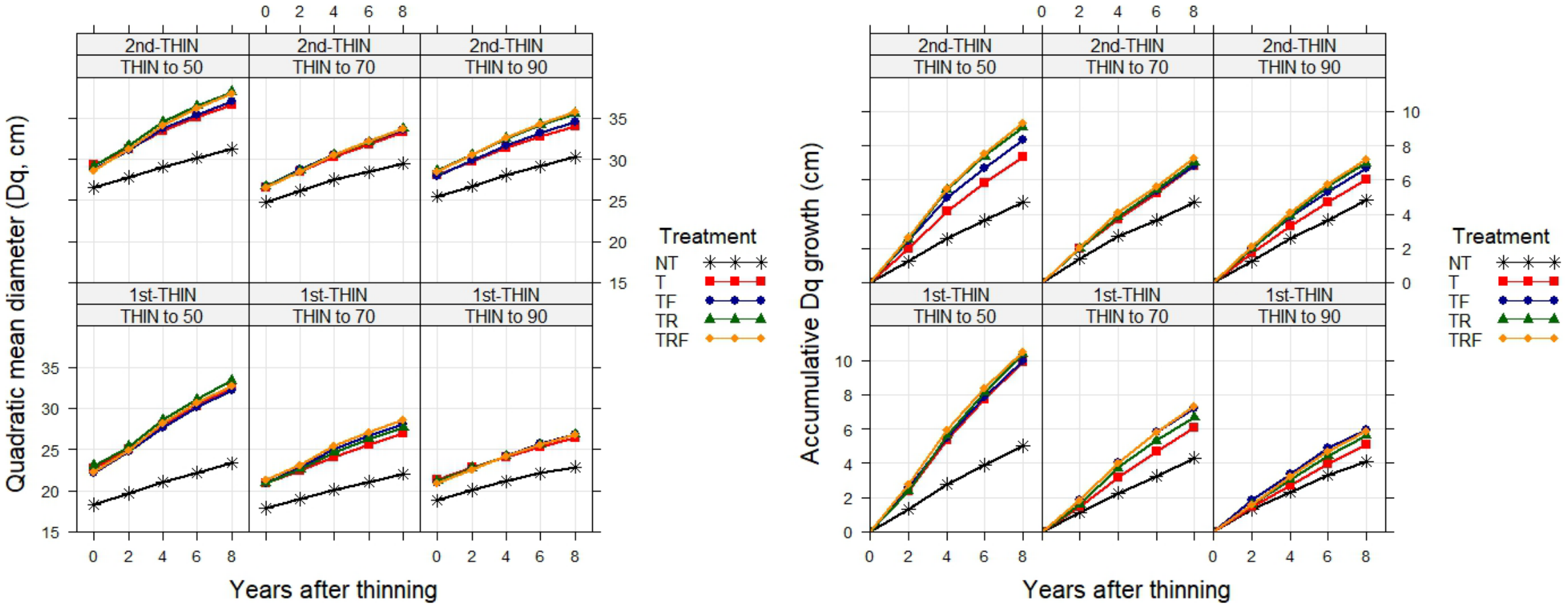


Mixed Effect Model:

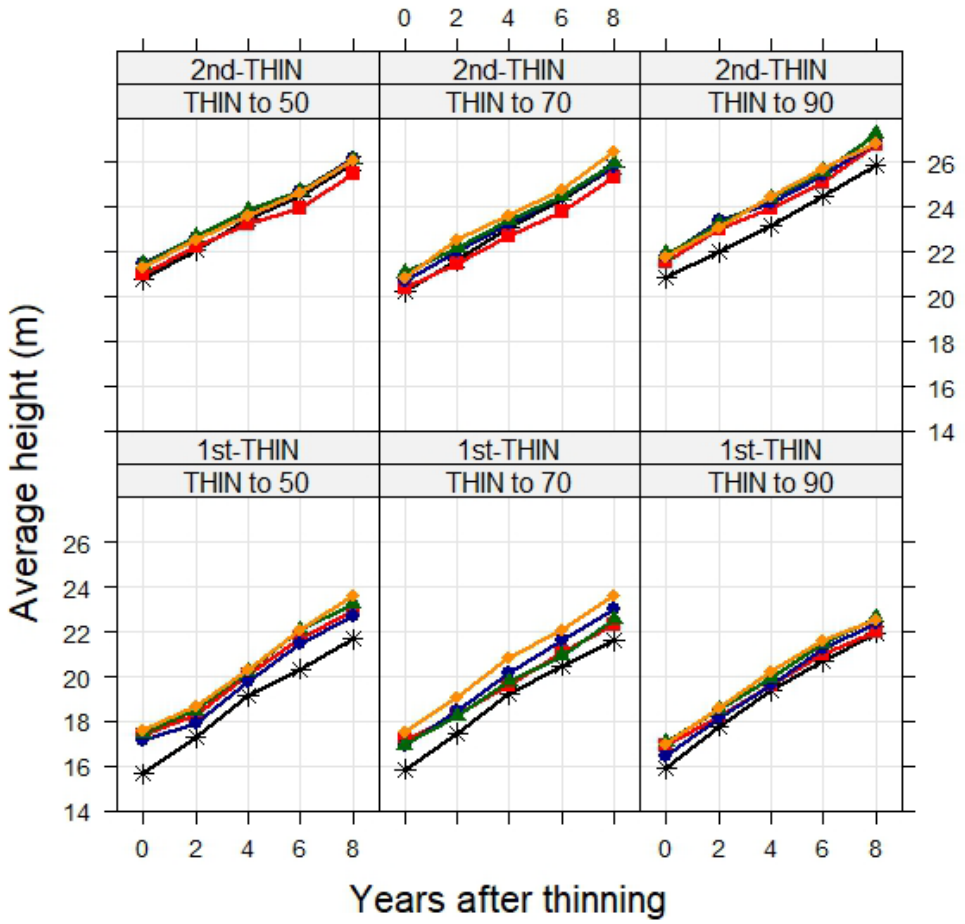
model $y = THINTOBA + TREAT(THINTOBA)$

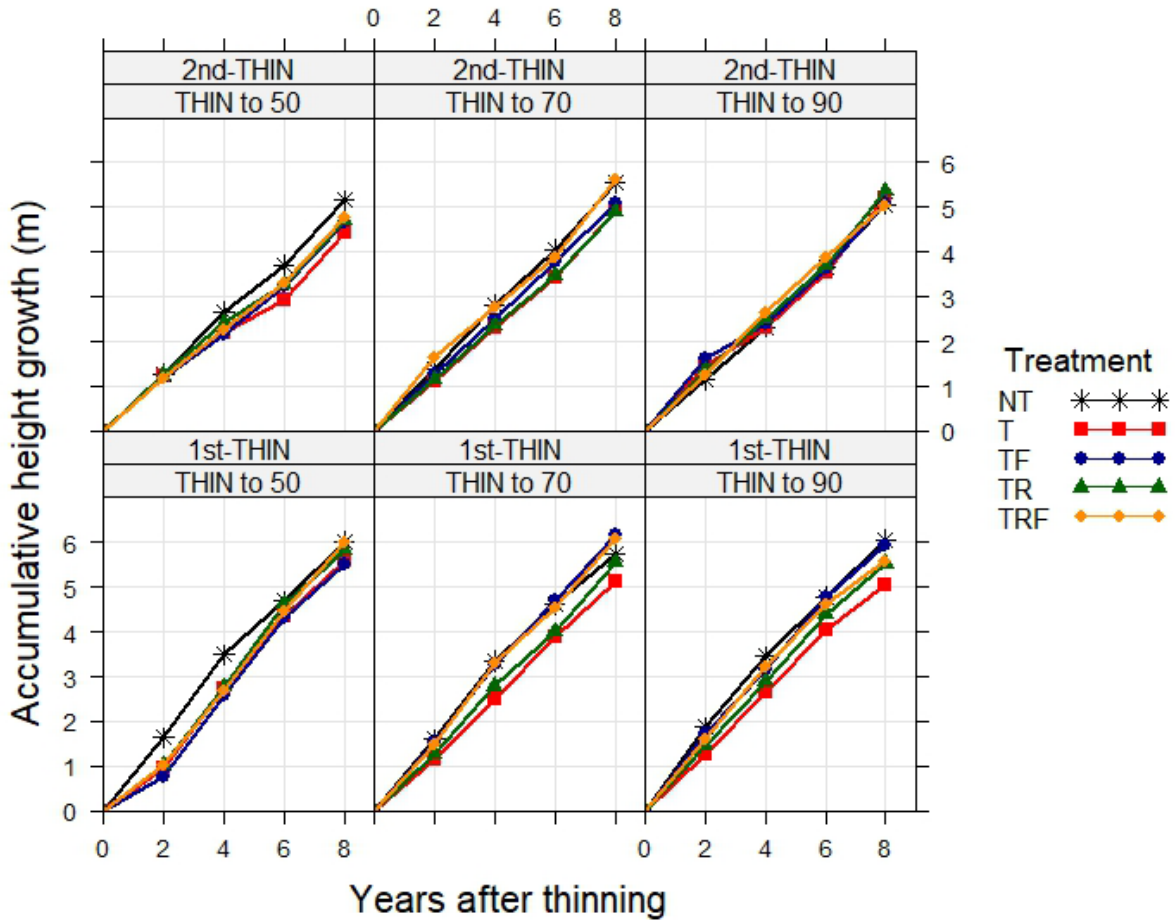
random $INST(THINTOBA)$

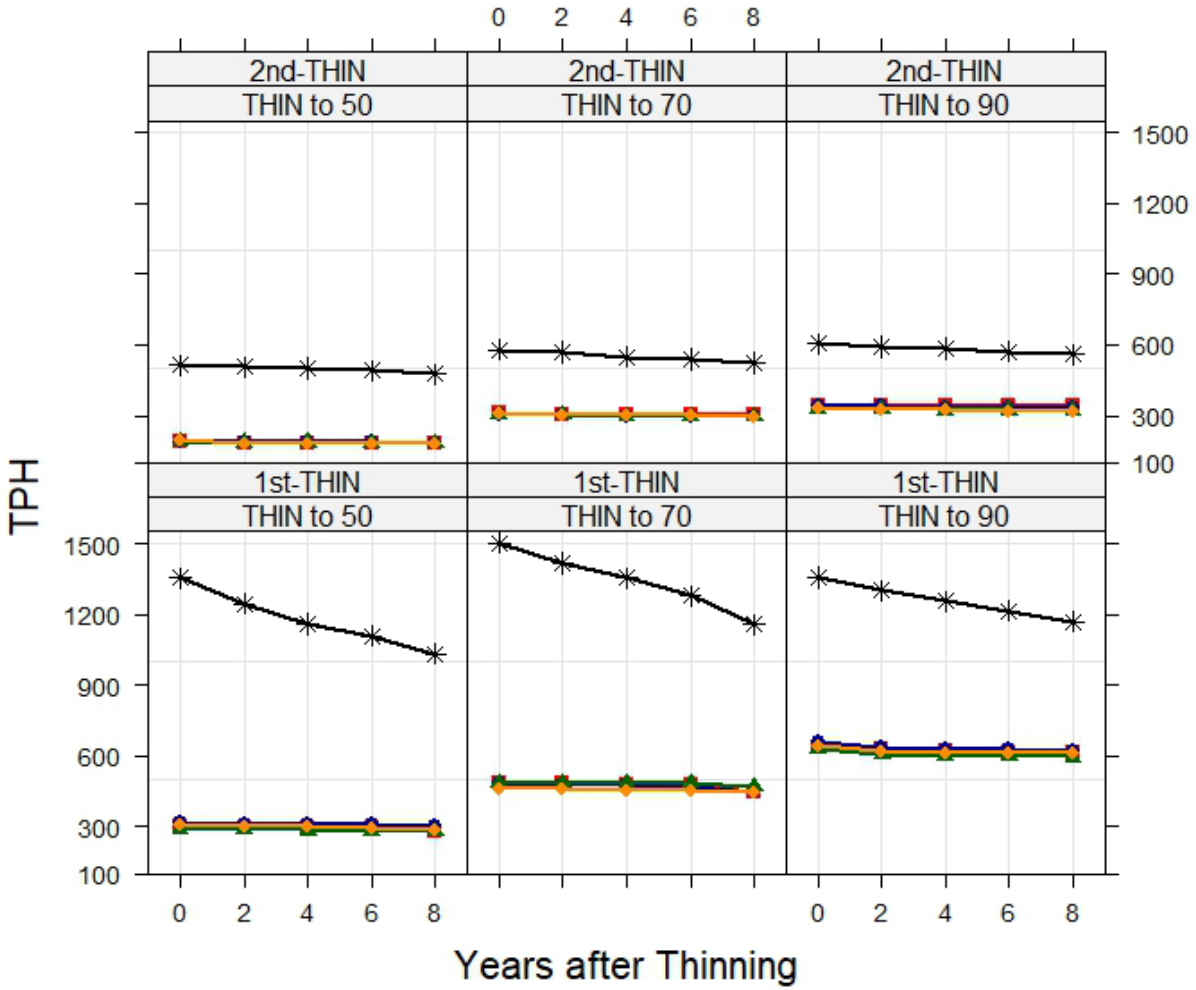
MRT Study – Quadratic Mean DBH (Dq)

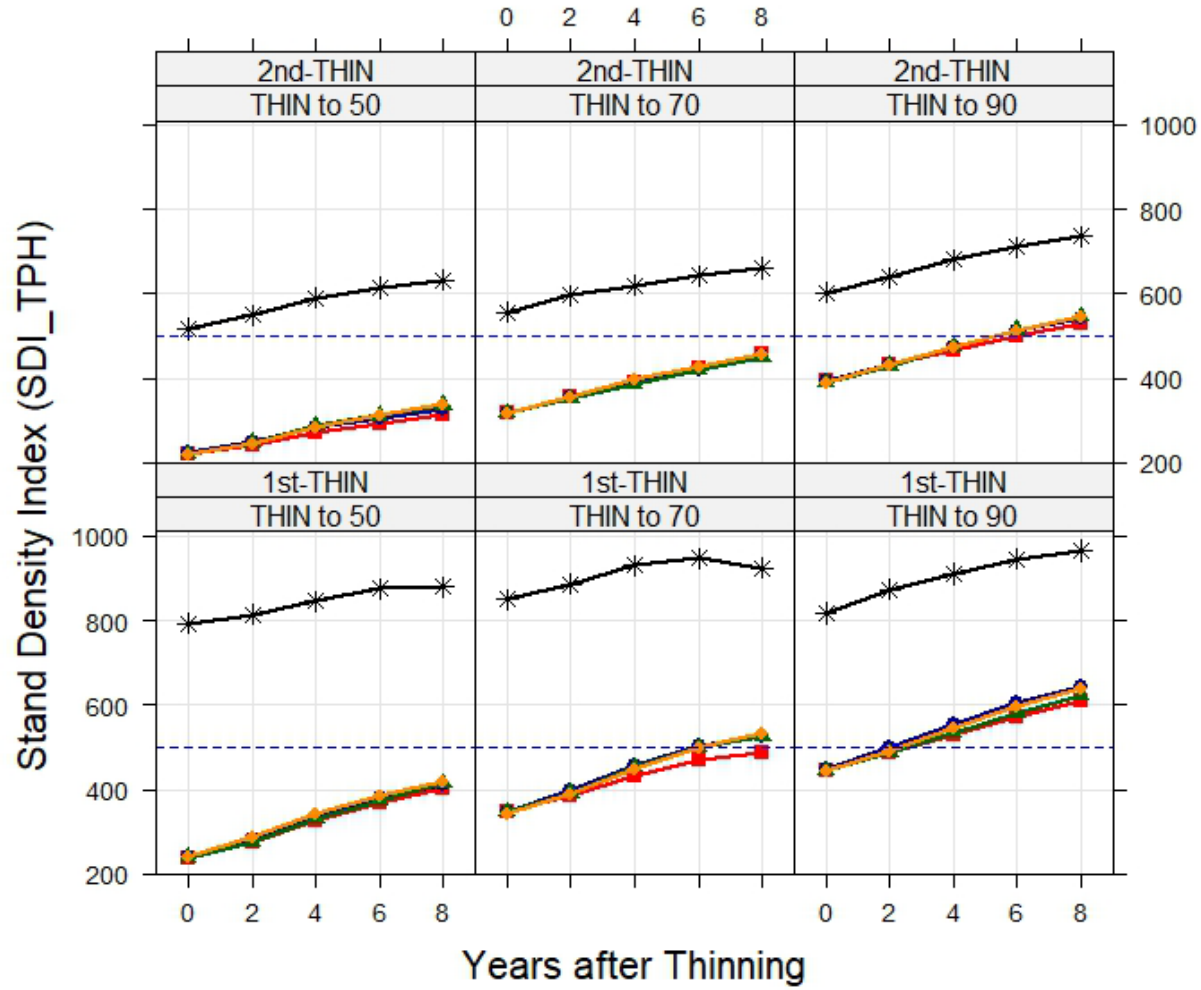


MRT Study – Height

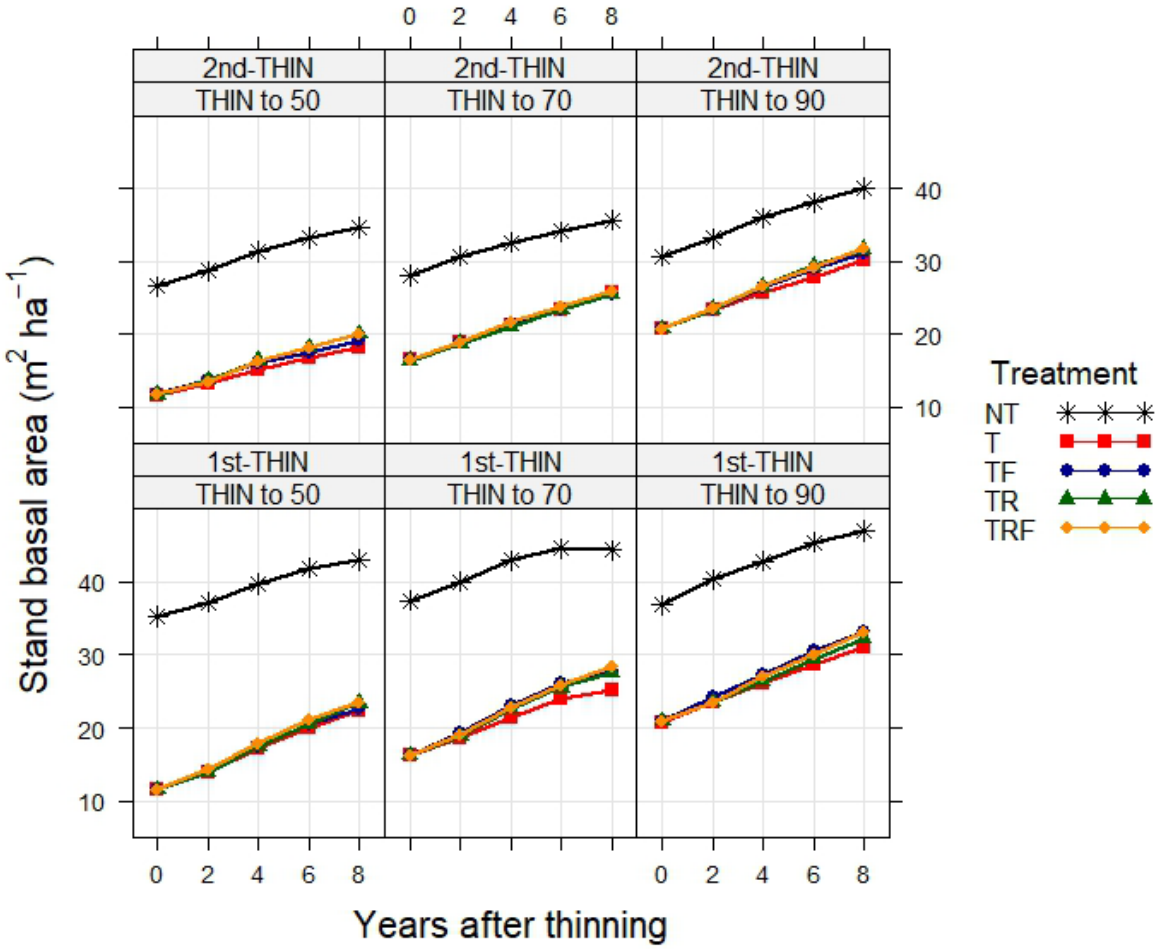


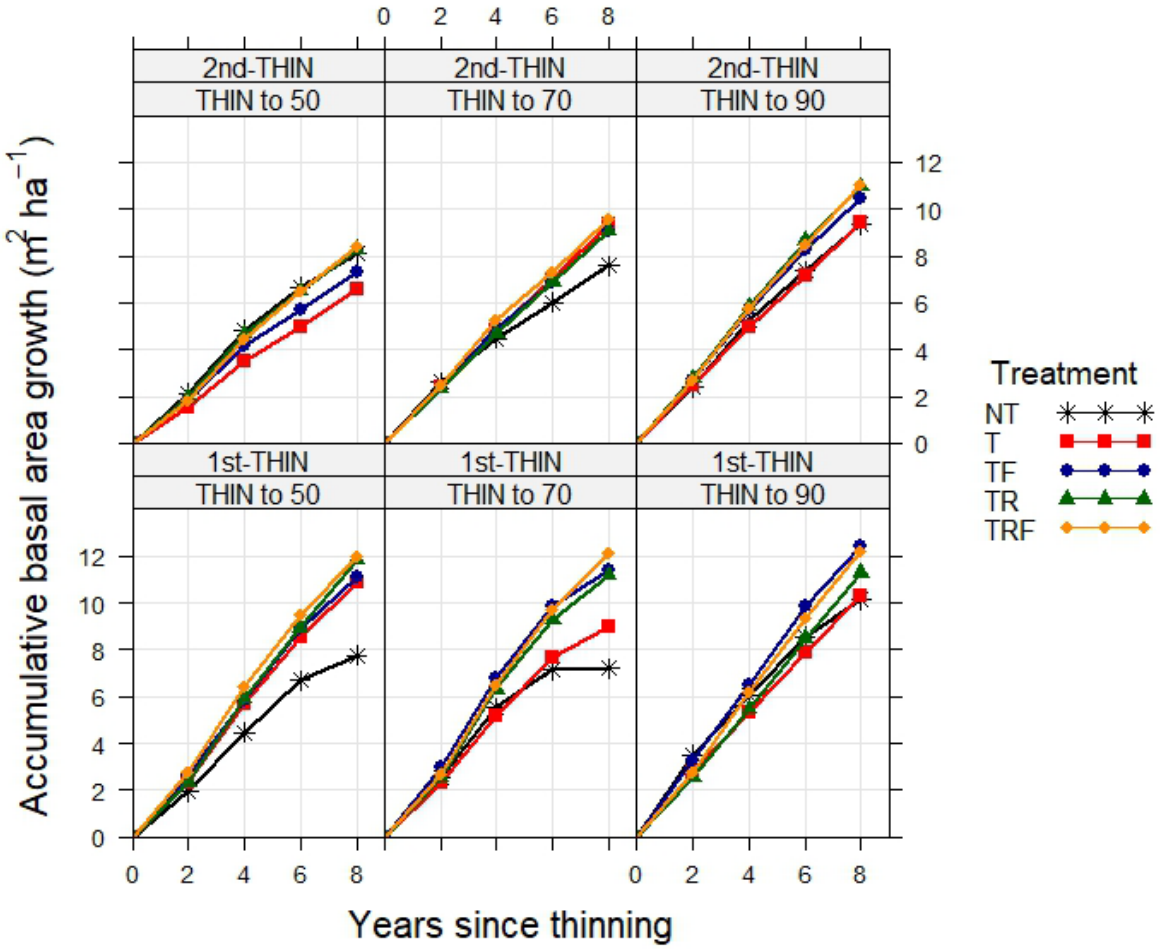



2nd-THIN
THIN to 50
2nd-THIN
THIN to 70
2nd-THIN
THIN to 90
1st-THIN
THIN to 50
1st-THIN
THIN to 70
1st-THIN
THIN to 90
TPH
Years after Thinning

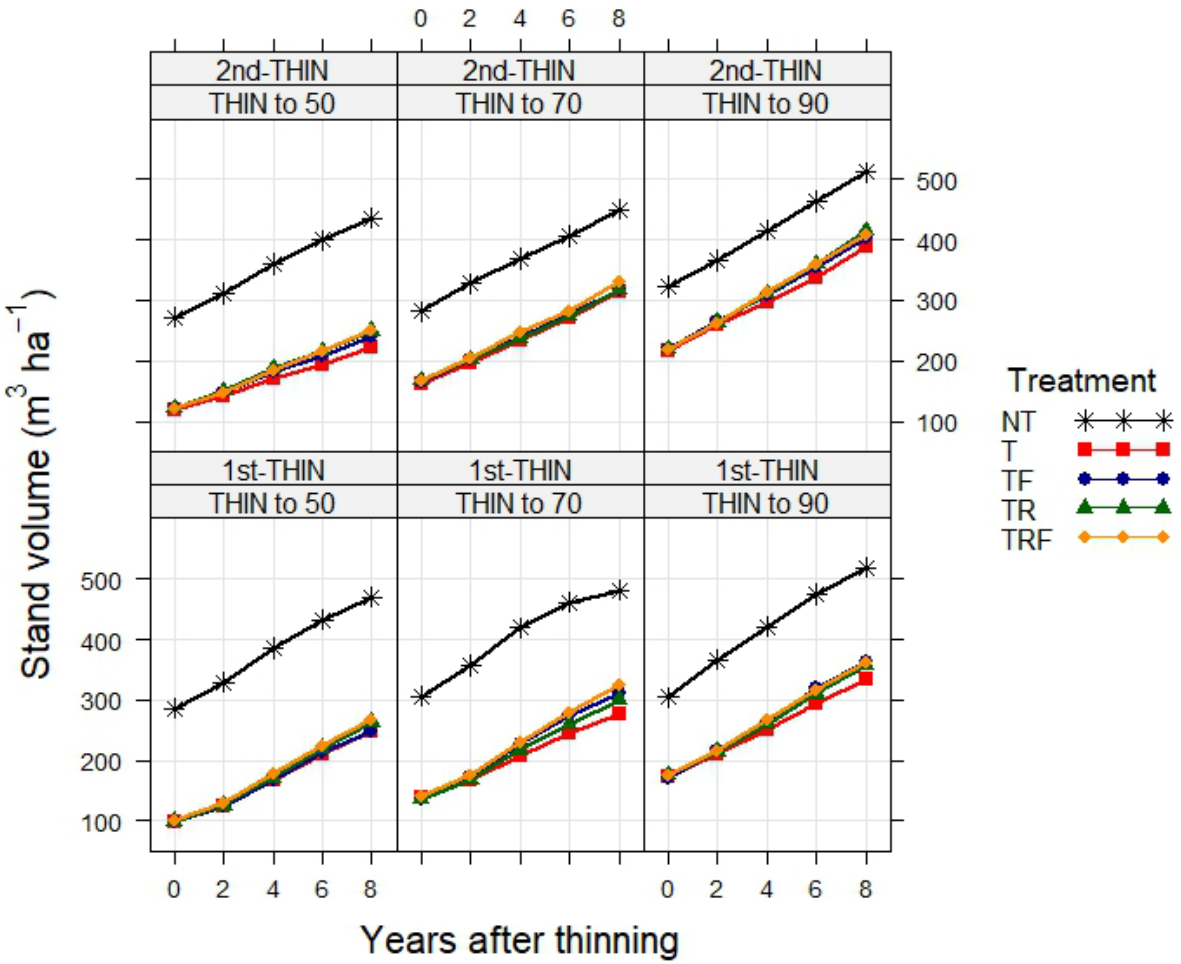

2nd-THIN
THIN to 50
2nd-THIN
THIN to 70
2nd-THIN
THIN to 90
1st-THIN
THIN to 50
1st-THIN
THIN to 70
1st-THIN
THIN to 90
Stand Density Index (SDI_TPH)
Years after Thinning

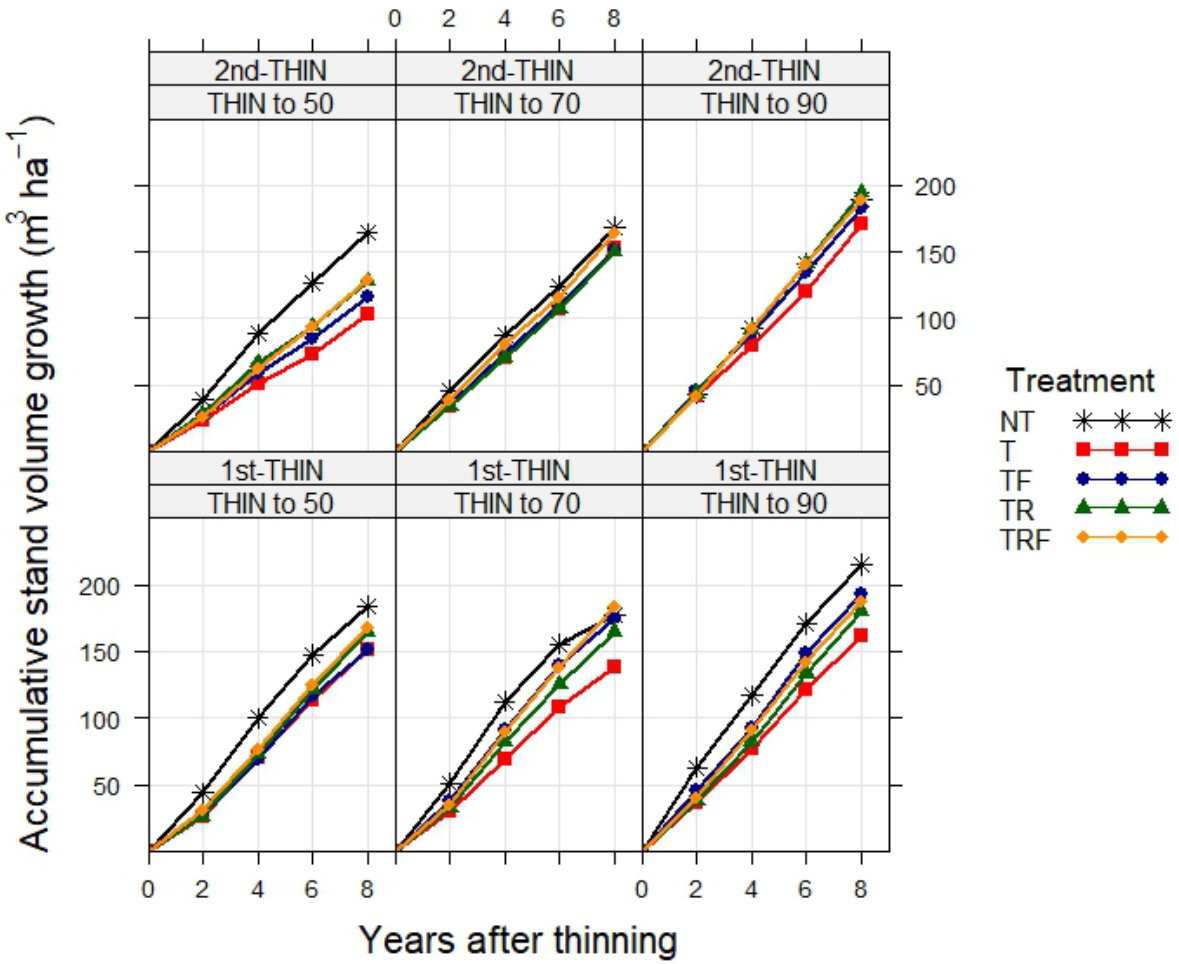
MRT Study – Stand Basal Area (BA)



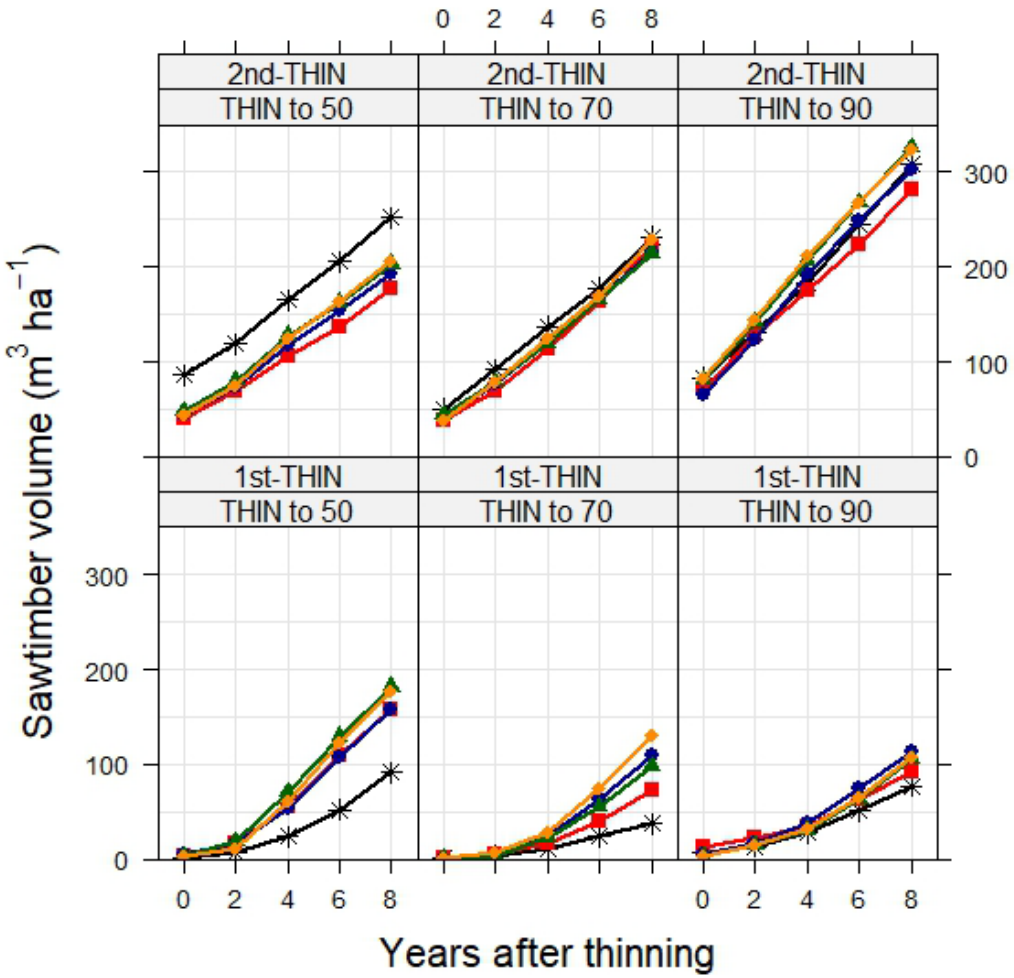


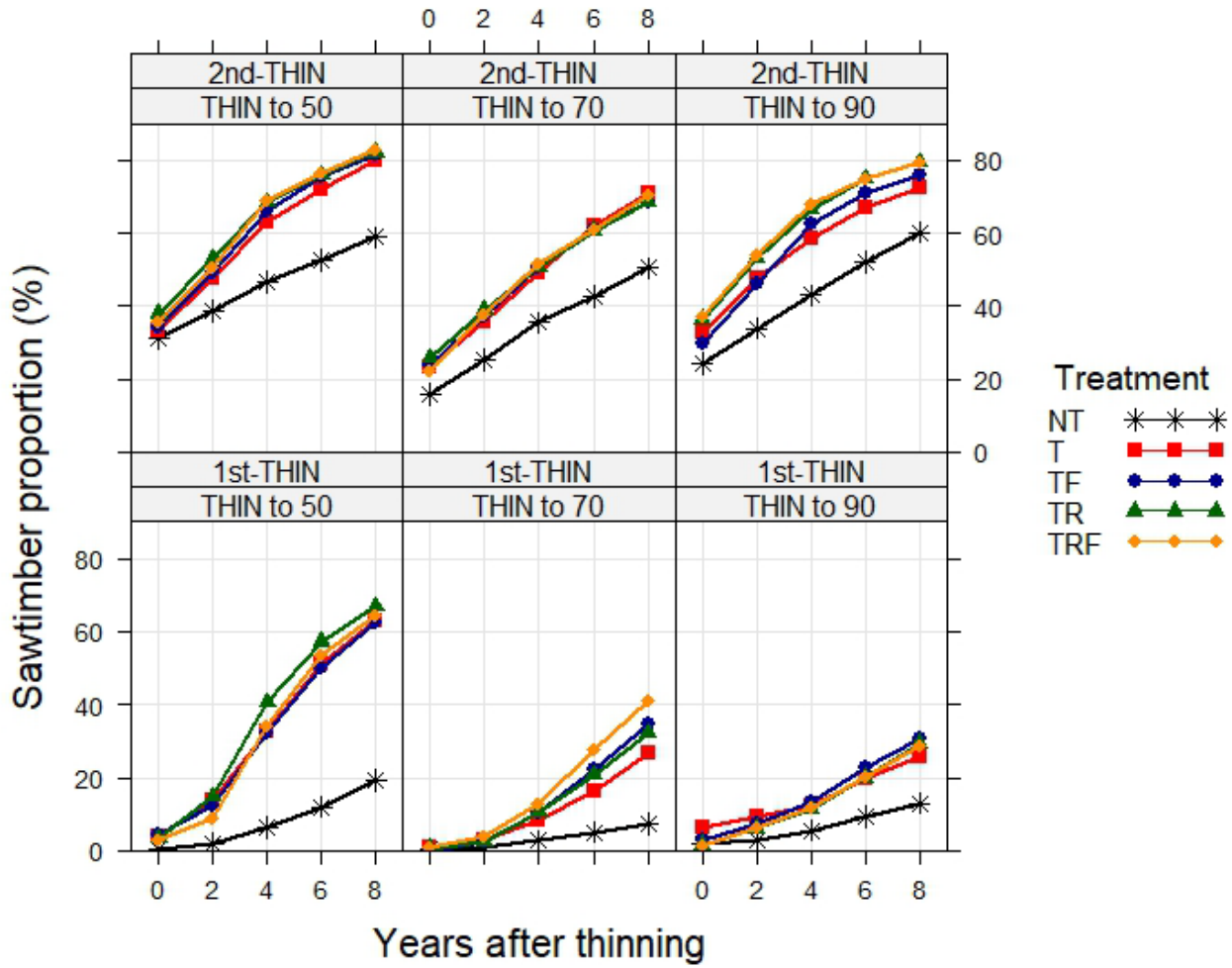
MRT Study – Stand Volume



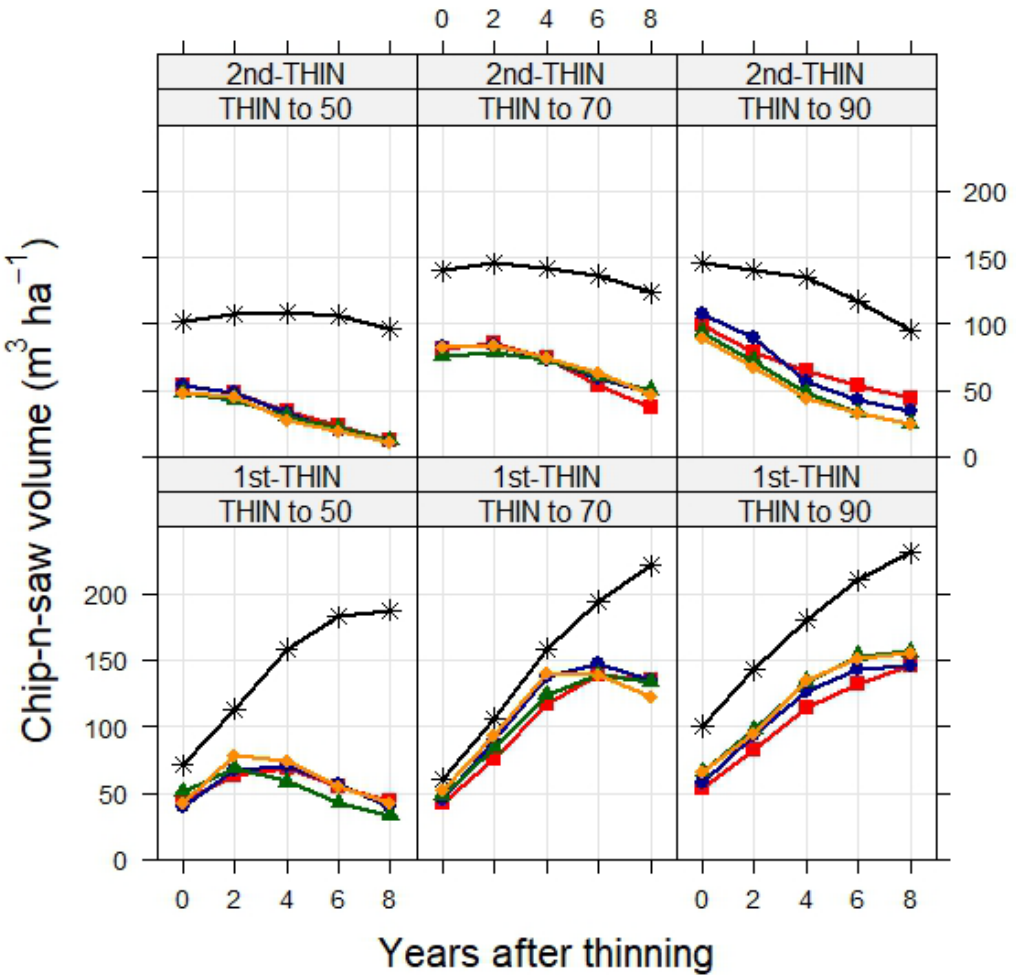


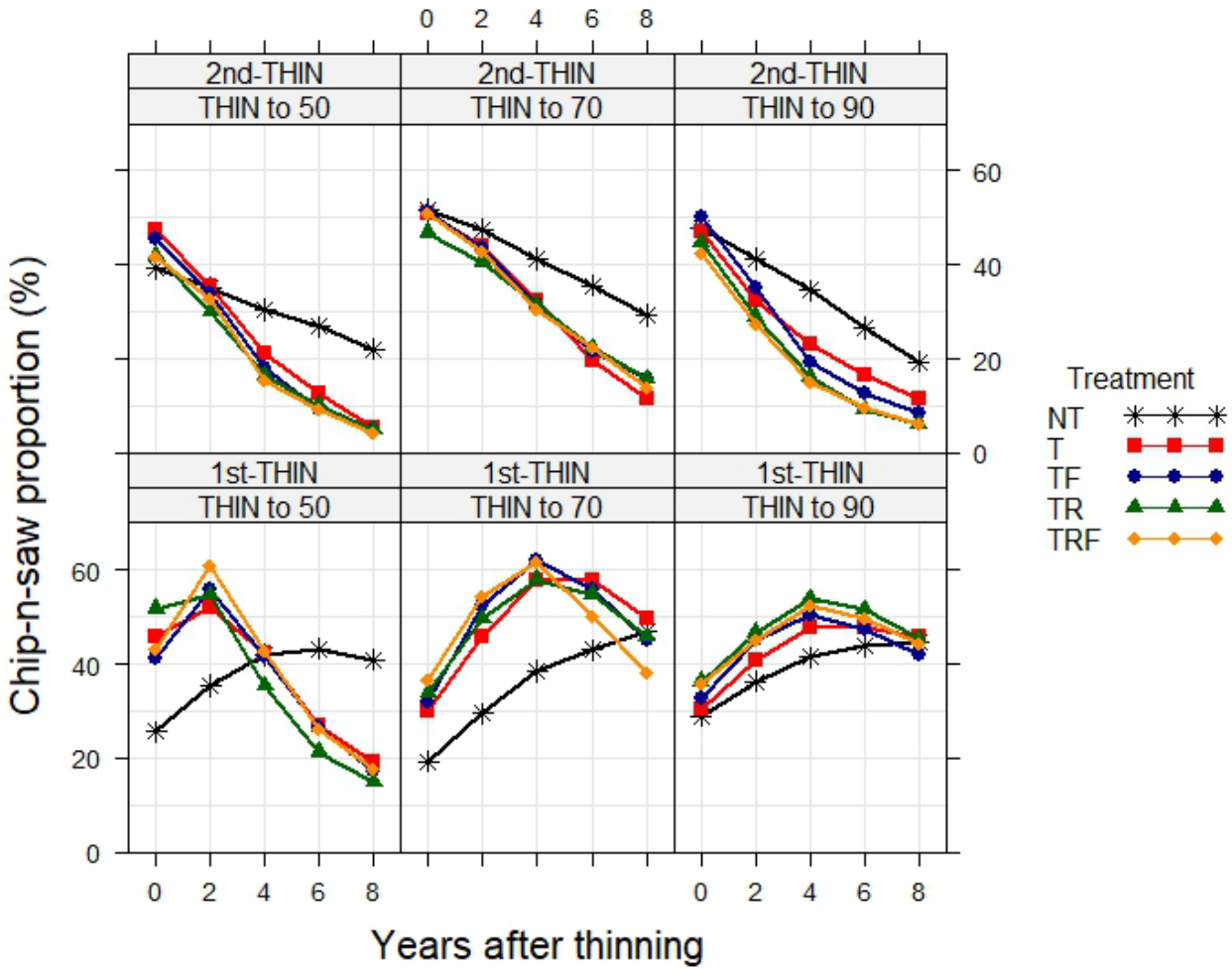
MRT Study – Sawtimber



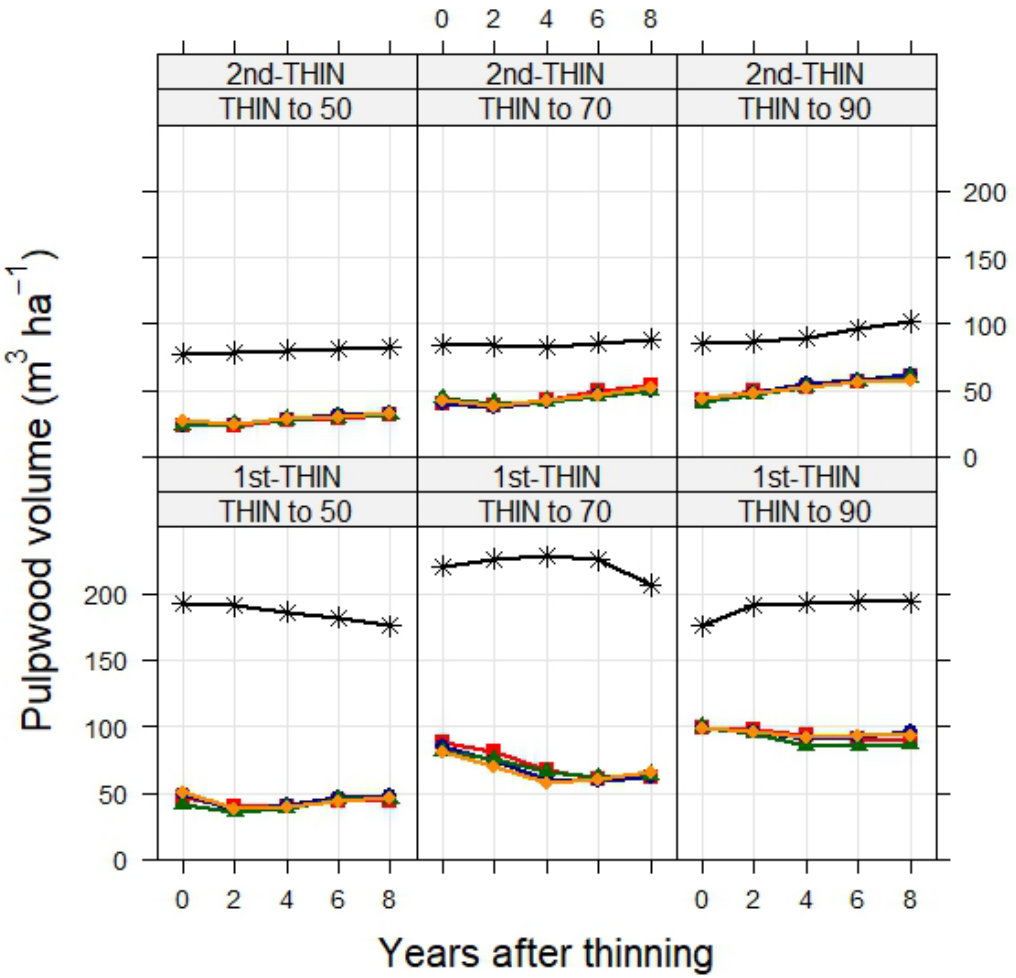


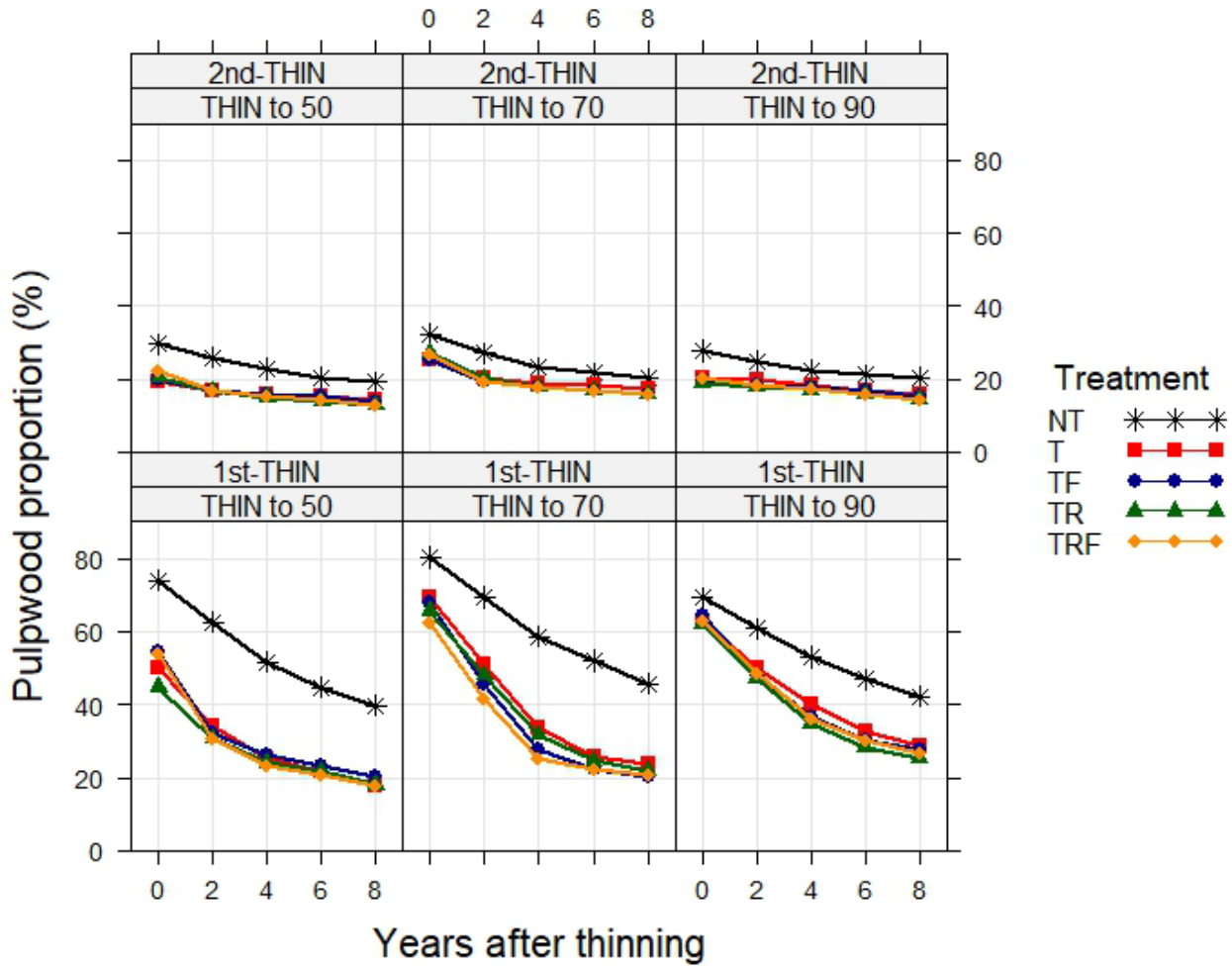
MRT Study – Chip-n-saw



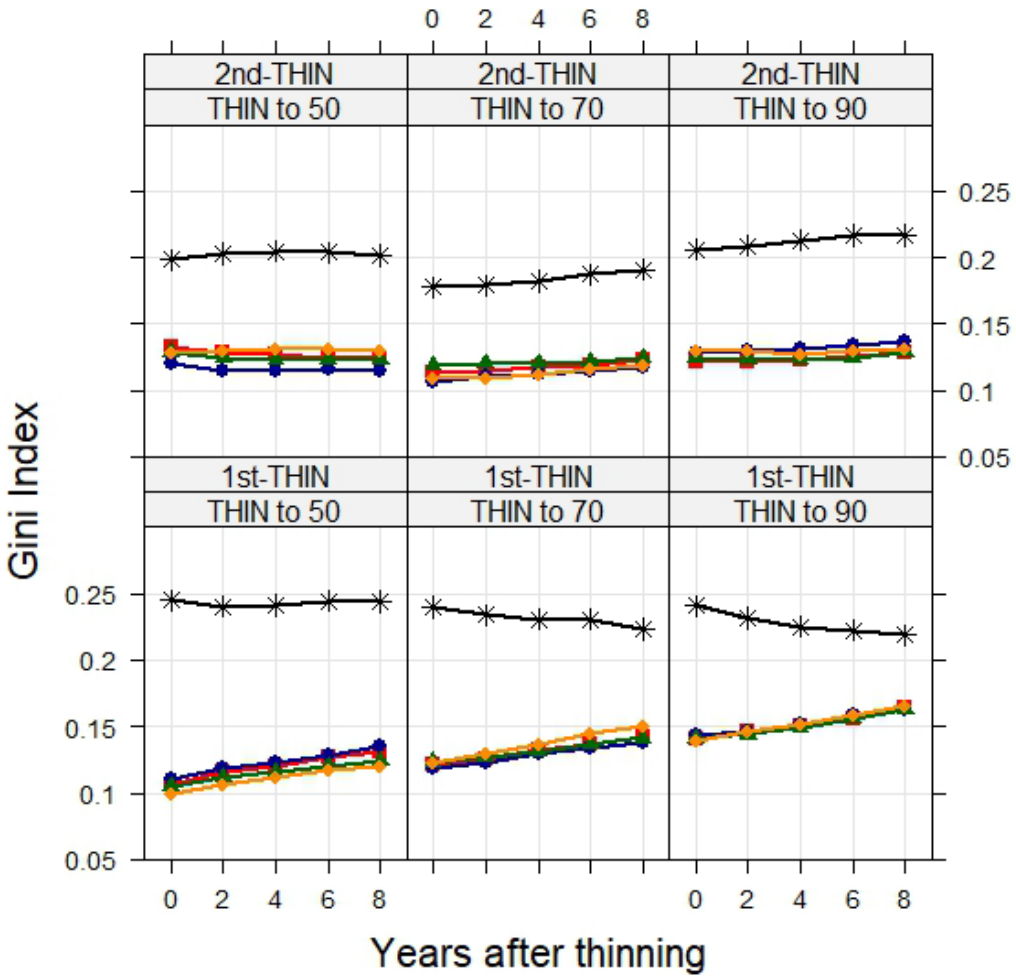


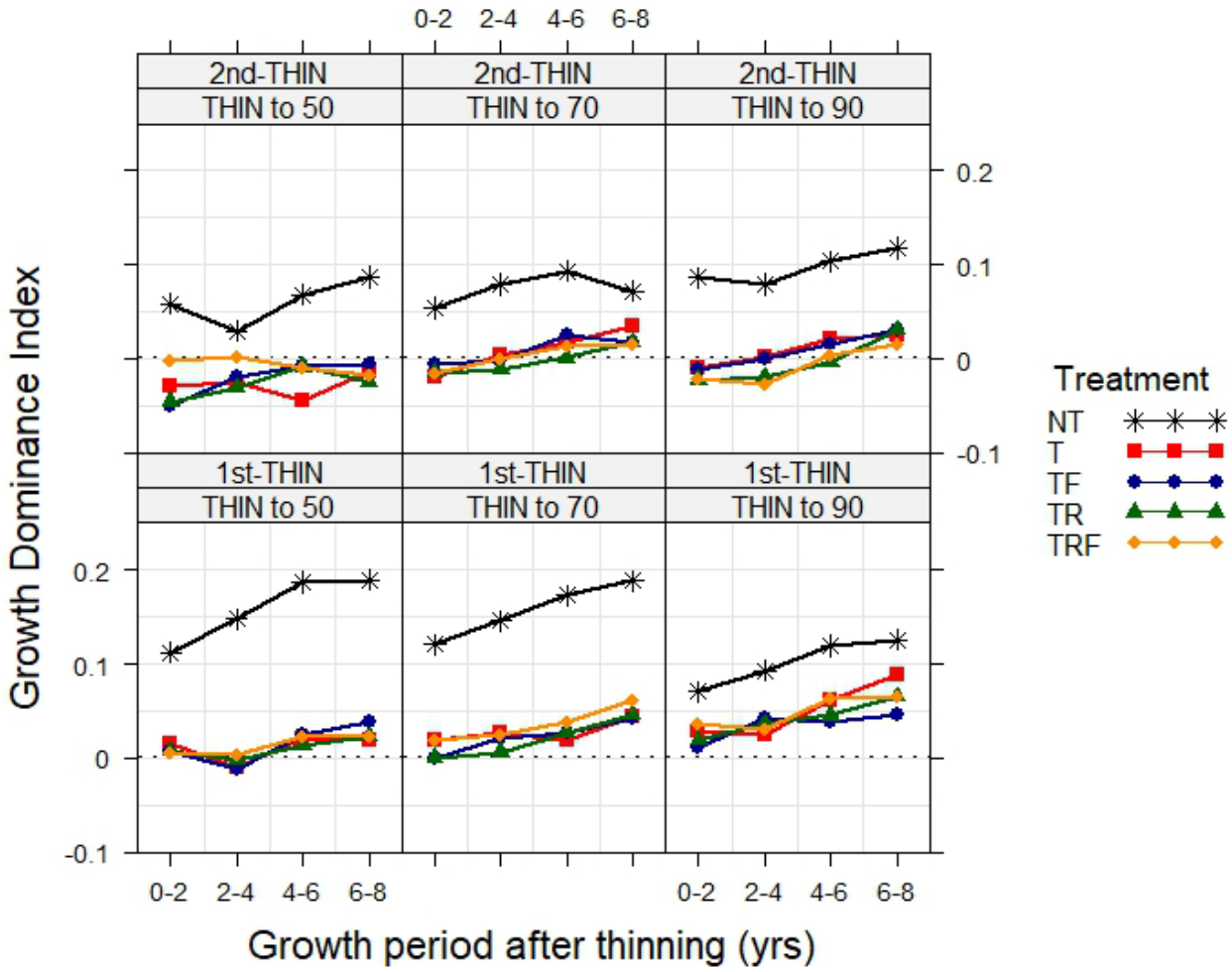
MRT Study – Pulpwood





MRT Study – Tree Size Inequality and Growth Dominance





Summary

- Both thinning event reduced tree size inequality and growth dominance, while enhancing tree diameter growth
- Unthinned stands maintained higher stand-level basal area, volume, volume growth
- Thinning shifted wood product distribution by increasing sawtimber proportion and reducing pulpwood proportion, with minimal impact from additional treatments
- Stands responded differently to treatments following the first and second thinning, likely due to differences in thinning timing, intensity, and methods, as well as structural changes induced by the first thinning

Summary

- Fertilization and release improved diameter, basal area, and volume growth after the first thinning at 70 and 90 ft^2/ac, but showed limited or no effects after the second thinning
- Fertilization also increased height growth after the first thinning at 70 and 90 ft^2/ac, whereas release had no effect on height.
- Additional fertilization and release did not significantly increase total stand yield or influenced tree size inequality, growth dominance, and wood product distribution at any stage

Acknowledgements

- PMRC Member Companies
- PMRC Field Crew