Density management opportunities for stand enhancement, bioenergy production and climate change adaptation

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Forest density management needs on federal lands

Inland NW federal forestlands are over stocked because:

- Fire suppression, limited extraction, positive net growth

Management Objectives:

- Transform overstocked, infested forest stands
- Create resilient stands that resist
  - Wildfire, Pests & disease, Drought

Forest density management on timber production lands

- **Working forests** must capture site growth potential
- Growth decreases with competition
- Adequate growing space provides:
  - Light, Nutrients, Moisture
- High planting density:
  - Assures full stocking
  - Avoids competition and in-growth

Ecosystem services benefit from density management

- Climate change adaptation
- Stress resistance
- Habitat
- Water quality and yield
- Aesthetics

Forest bioenergy and density management

Bioenergy demand creates challenges and opportunities

Challenges

- What's optimal biomass removal?
- What impacts on sustainability

Opportunities

- Market for nuisance biomass:
- Avoid burning,
- Slash removal for best practices

Density management
Research needs

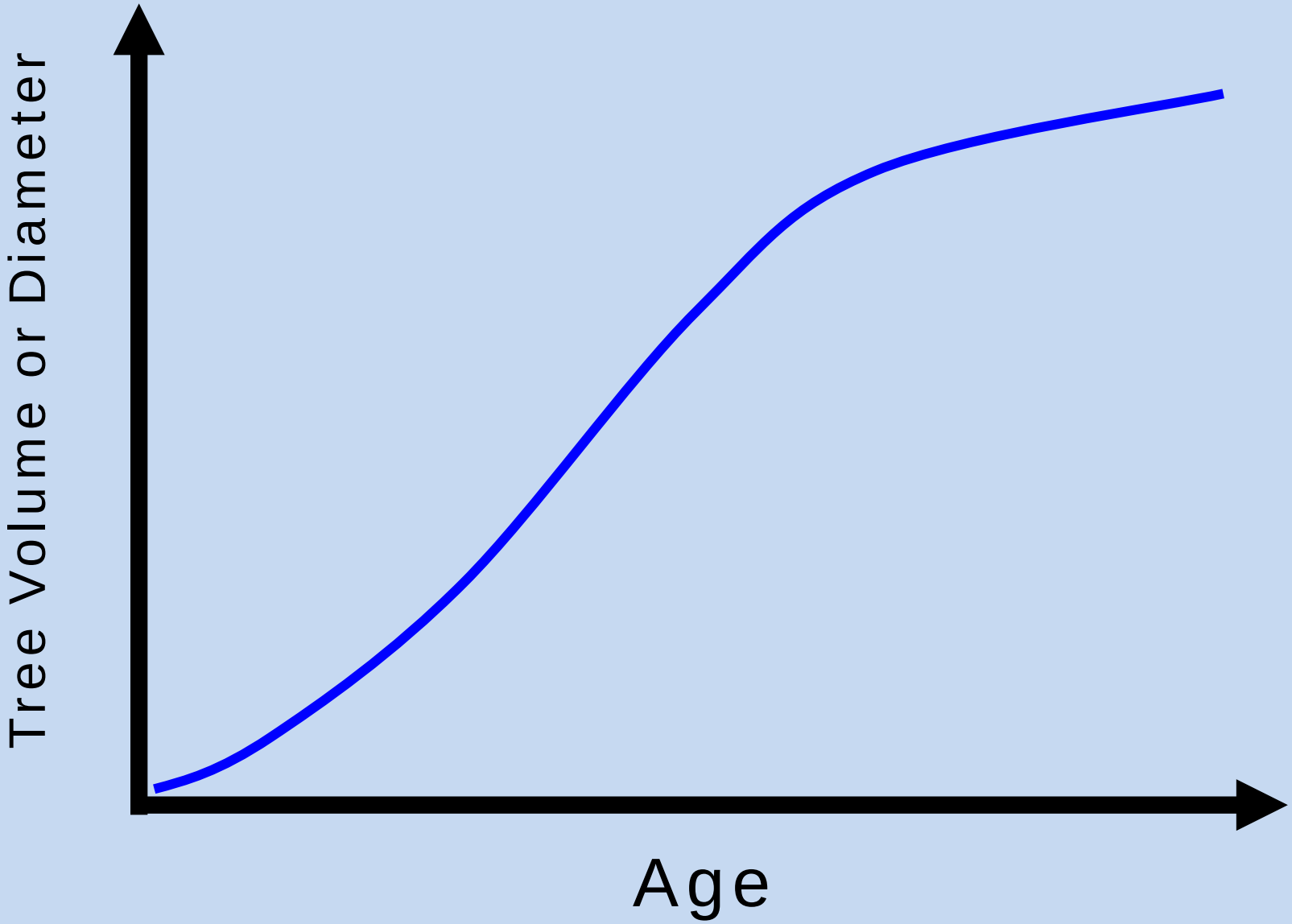
- Urgent questions involve small diameter stands
- Thinning knowledge largely for older stands
- Pre-commercial stands can be old, unresponsive
  - 20 years
  - 40’ height
  - 30% crown ratios
  - H/D over 100

Stand Density Management

Guiding Principles

- As stand density increases:
  - Tree diameter and volume decrease
  - Stand growth increases
  - Height is largely not affected
- Thinning response depends on:
  - Site quality
  - Time of thinning
  - crown condition

Tree size-age trends



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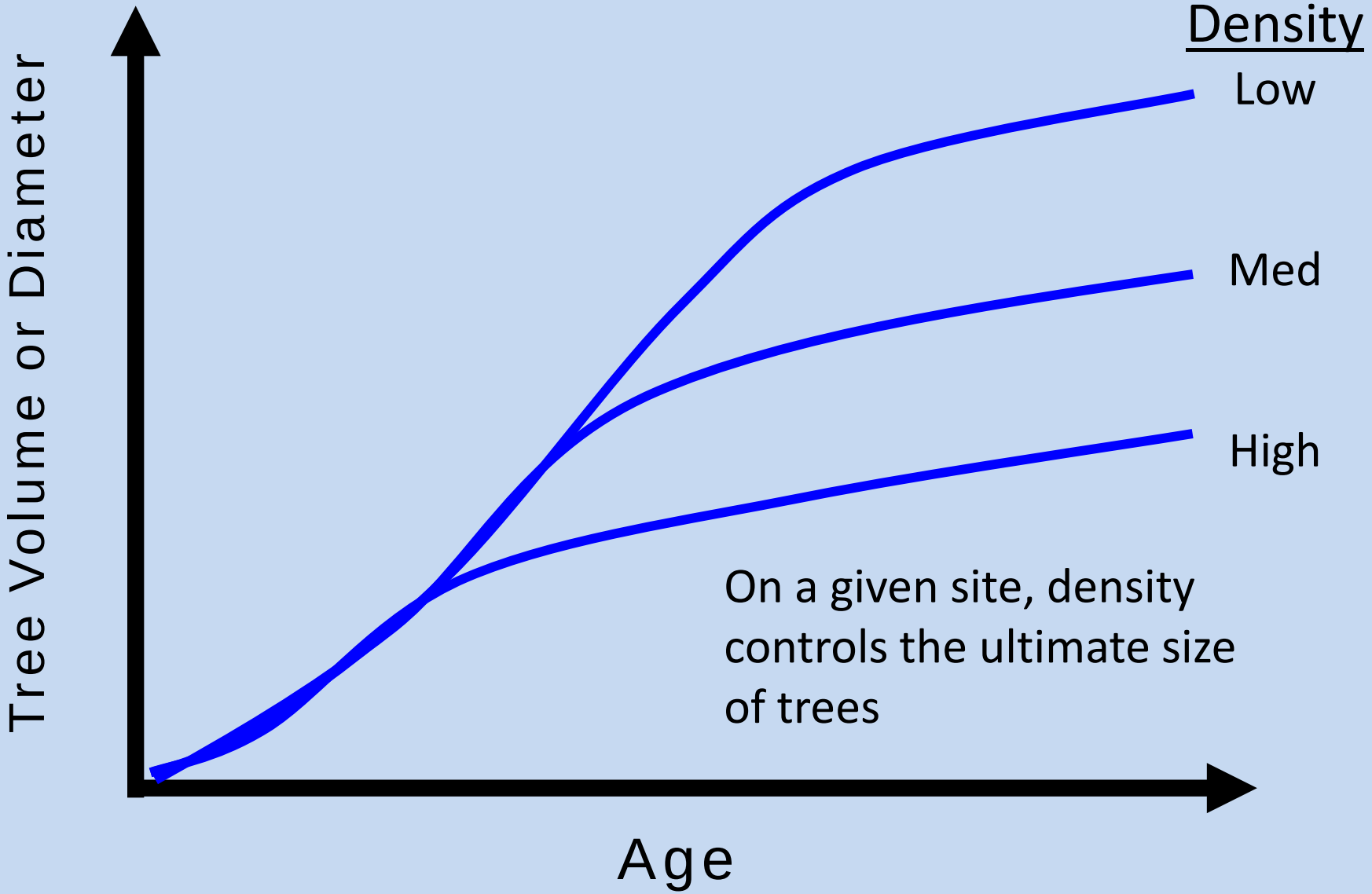
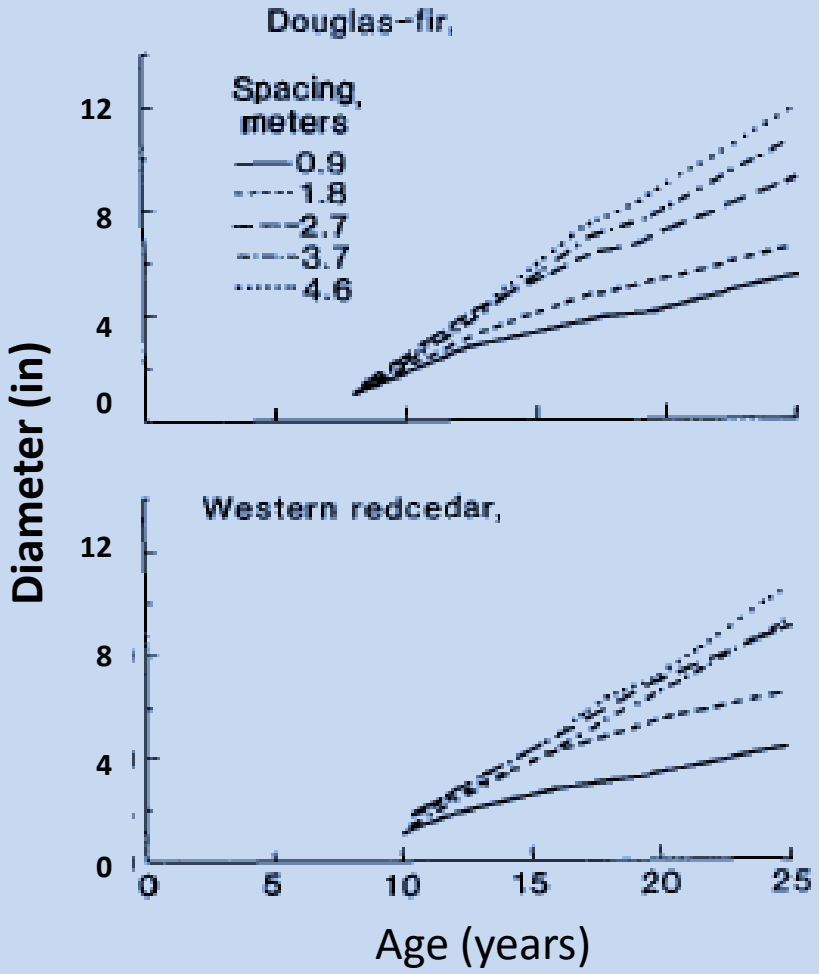


Initial growth of a tree is diminished by competition

Fraser River, Site I, 25-yr-old



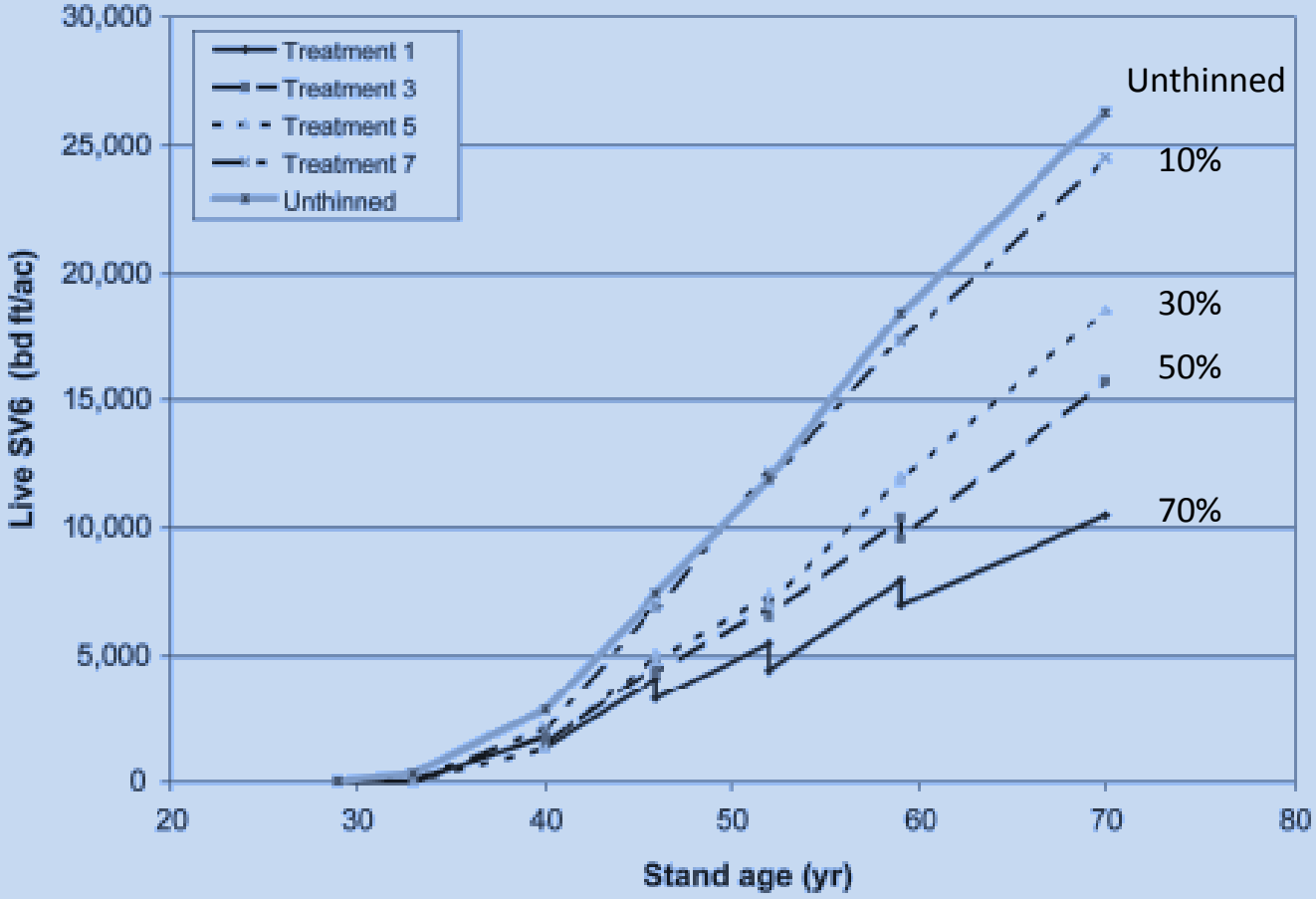
- Low density maintains linear growth trajectory
- Decreased with density

Reukema & Smith 1987 pnw_rp_381

Contrasting tree and stand growth

STAND growth increases with density

Rocky Brook, Site IV, LOGS Study

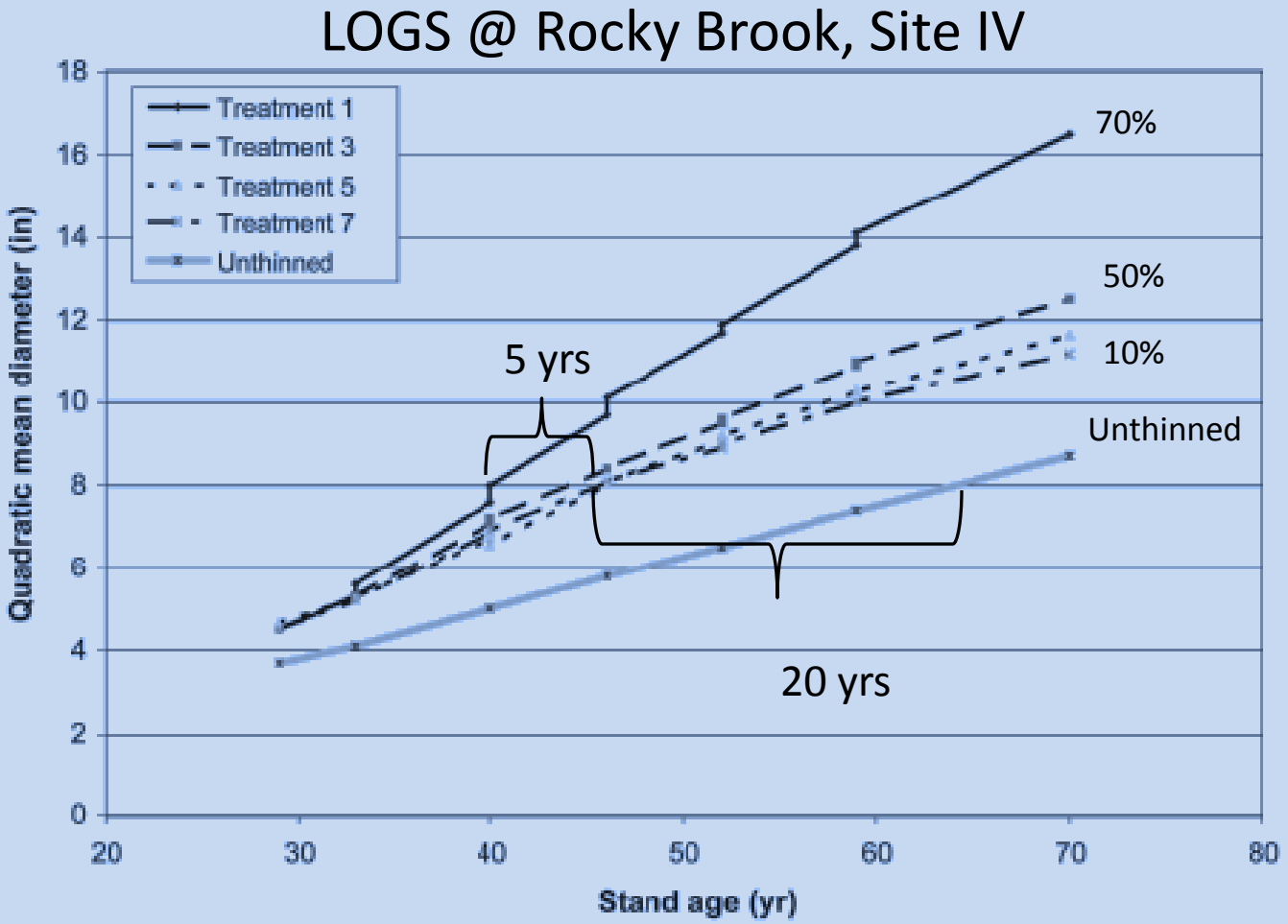


- Lower volume in thinned stands

Curtis and Marshall 2009 PNW-RP-578

Contrasting tree and stand growth

TREE growth decreases with density



- Thinning results in greater tree diameters
- Thinning shortens time to reach diameter limit

Curtis and Marshall 2009 PNW-RP-578

Summary of stand density controls on tree and stand characteristics

- Individual tree size decreases with density
- Stand volume increases with density
- Time to target diameter increases with density
- Height is largely not affected by density
- Live-crown ratio decreases with density

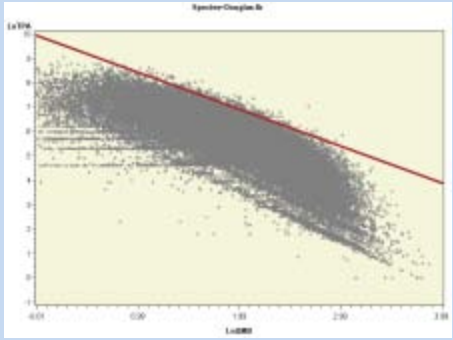
Size-density relationships define stand development thresholds

- Maximum Density (D_{MAX}) defined by self-thinning line (-3/2 power law)
- Developmental thresholds are defined relative to D_{MAX}

Relative Density, *RD*

$$RD = \frac{Actual\ Density}{Maximum\ Density}$$

- Initial Competition, RD=15%
- Initial Stagnation, RD=60%
- Management zone 40-60%
  - Zone of maximum stand volume growth



Timing a 1st thinning

- Early thinning or wide planting density favors tree growth
  - but stands under utilizes the site
- Delay thinning beyond 60% risks repressed growth potential
  - small crowns and slow growth response
- Optimal timing increases log size and fully utilizes site potential

Timing a 1st thinning

- Optimal time of thinning not quantitative
  - May depend on site quality
- Rules of thumb:
  - 60% live-crown ratio
  - Maximum stand volume growth
  - Spacing in proportion to height
  - Relative density
- Must be expressed quantitatively in terms of relative density

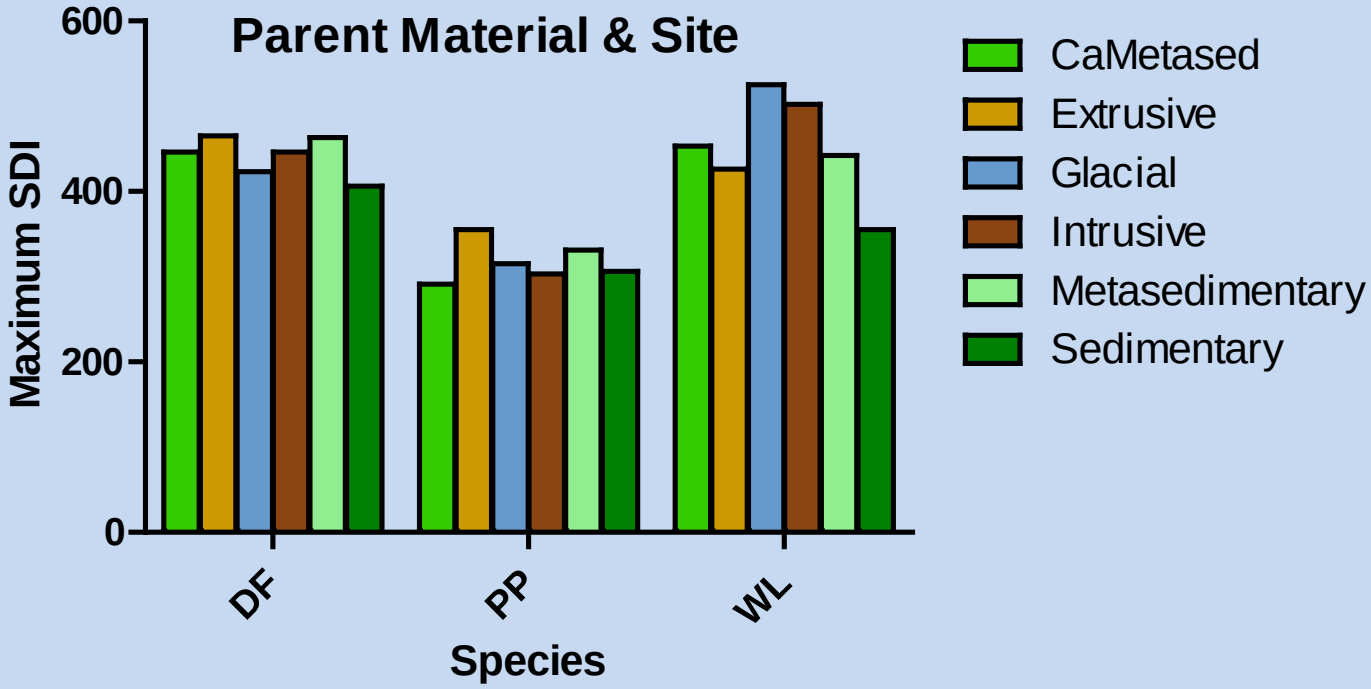
IFTNC Priority Research Topic

Test and extend knowledge of site-specific density parameters

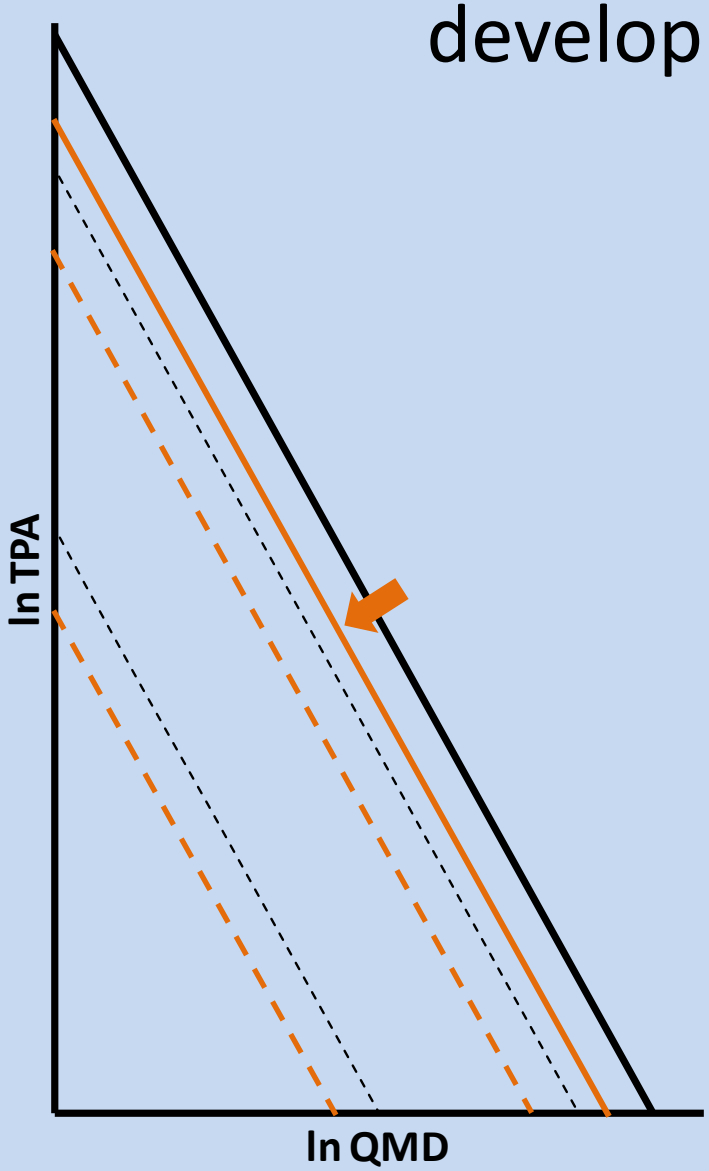
Site Type Initiative, Phase II

STI Phase II Priority research Topic

Site-specific maximum densities are needed to develop the most accurate estimates of growth response to thinning.



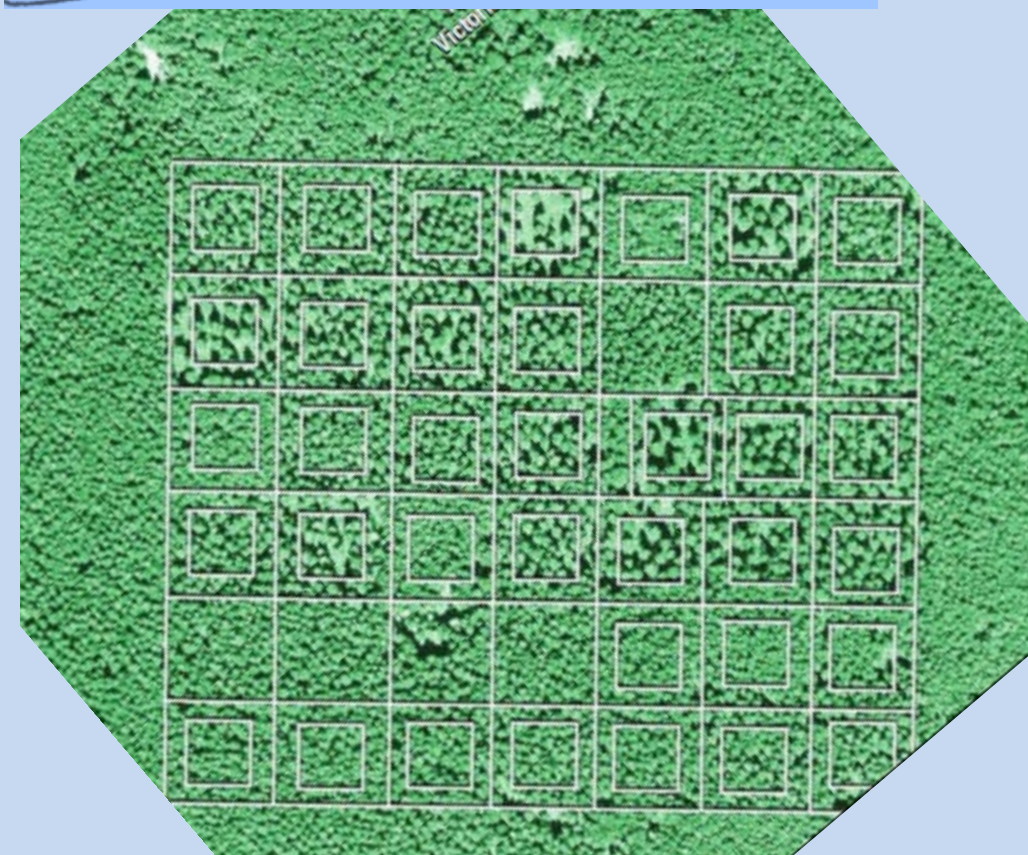
Size-density relationships define stand development thresholds

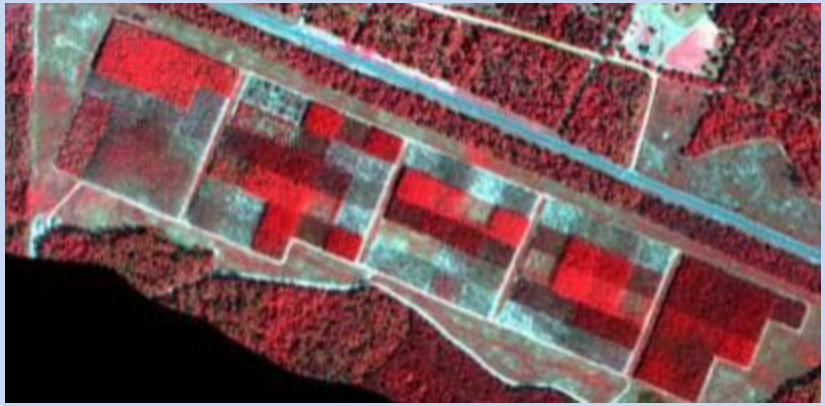


- Shifts in maximum density affect position of thresholds

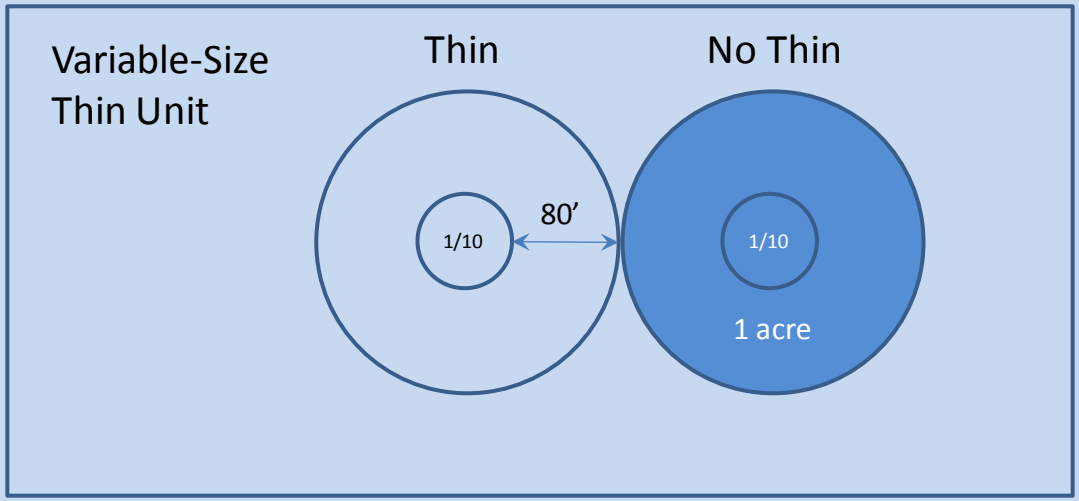
Evaluating Forest Density Response

- Thinning studies require large study installations
- Replicated plots for statistical power
- Replicated locations to determine site effects



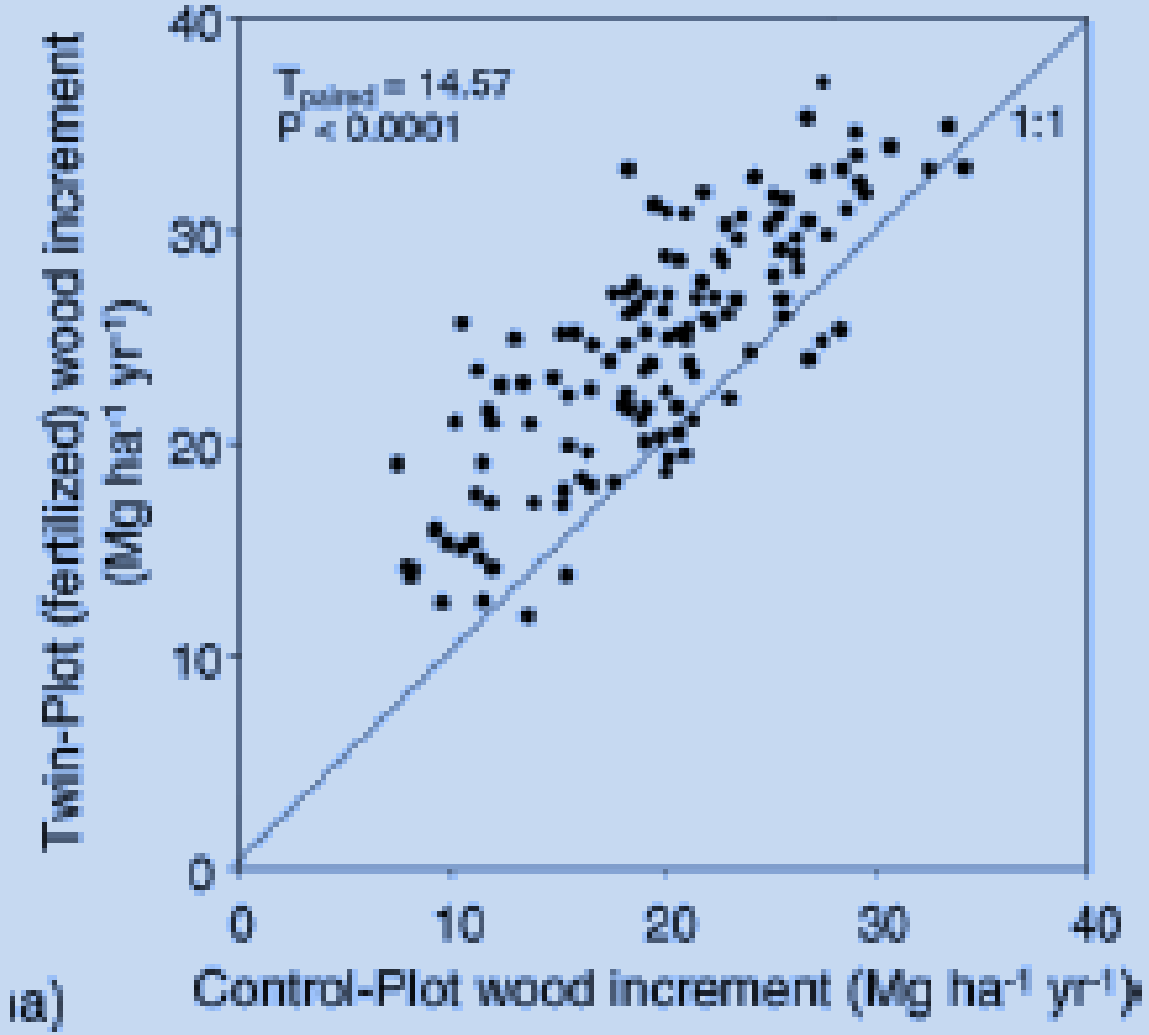


Paired-Plot Design



- Minimal treatments, i.e. thinned and unthinned
- Uniformity between plots
- Unreplicated within location
- Stratified and replicated among locations
- Numerous locations (+100) possible within a region

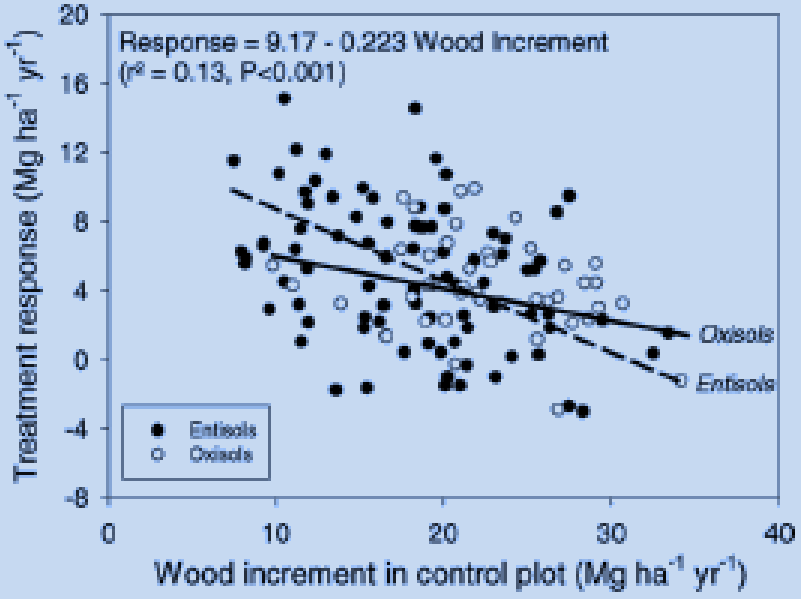
Comparison between treatment plots regionally

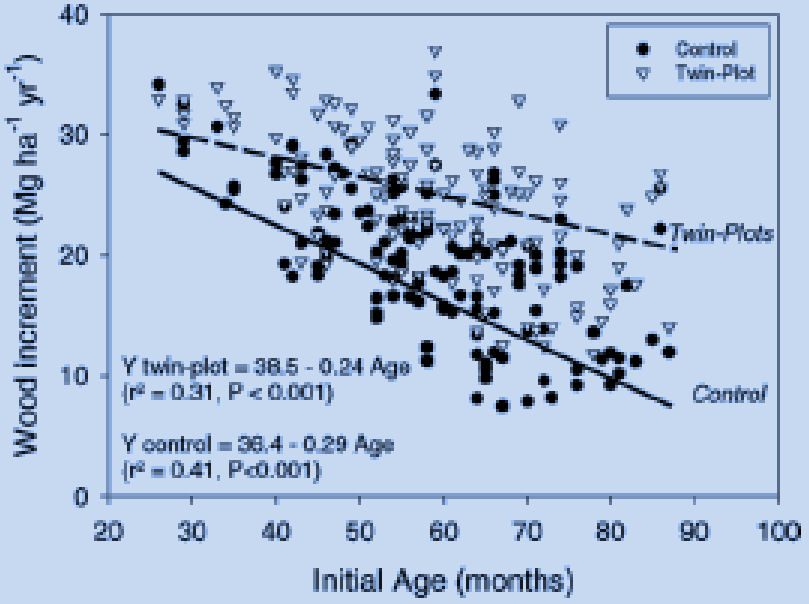


Stape et al 2006

Comparison among cofactors

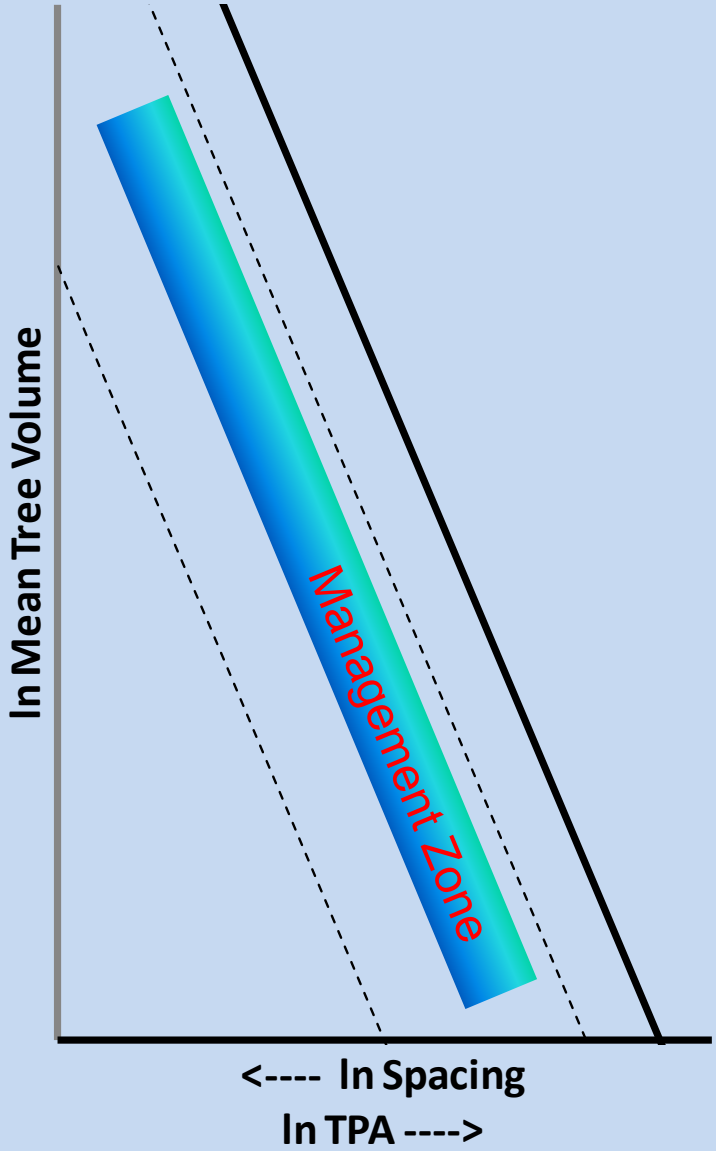
- Stratify locations across range of interest factors
  - Age/RD
  - Soils
  - STI site classes





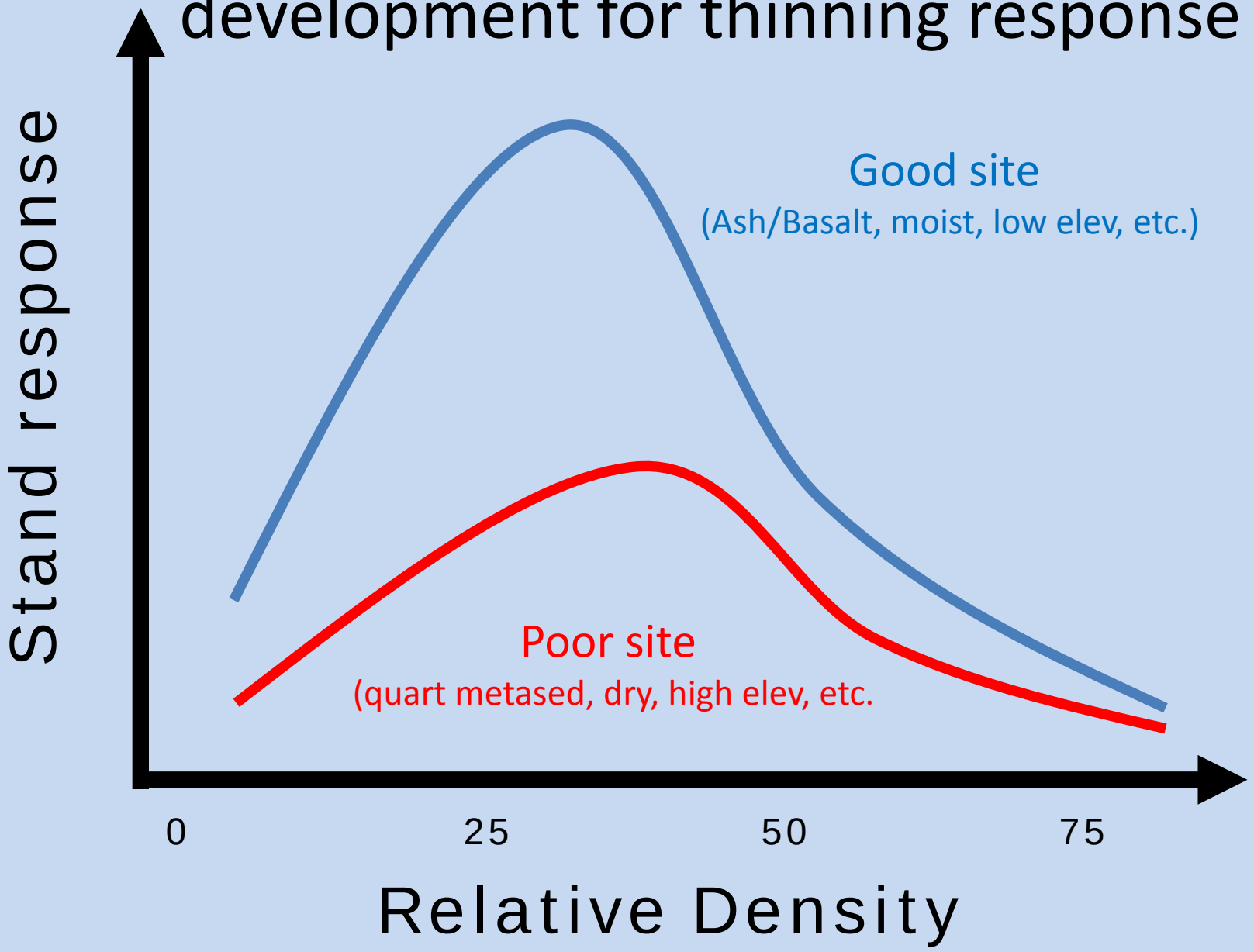
Stape et al 2006

Testing primary hypotheses



- Hyp: Optimal growth response to thinning will occur at the lowest density of the management zone, i.e. RD=40%

Determine site effects on optimal stage of development for thinning response



Density Management Conclusions

- Central to many modern forestry questions
  - stress resistance, bioenergy, climate change
- Rapid and permanent impacts on stand structure
- Questions :
  - site impacts and resource availability
  - Time of thinning optimum
- Paired plot design is efficient for regional impacts
- Supports improved young-age G&Y model estimates