Western conifer tree and stand responses to timing of thinning on various productivity classes:

Current knowledge and future directions

Mark Coleman

University of Idaho
Intermountain Forestry Cooperative

Purpose for thinning

Influence development of remaining stock

- Composition
- Growth
- Value
- Vigor
- Services
- Fuels

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Tree and stand responses to thinning

… *are controlled by competitive interactions*

Tree- and stand-density principles [laws]

1. Crowded stands will self-thin
2. Two-phased self-thinning trajectory
3. Competition decreases average tree size

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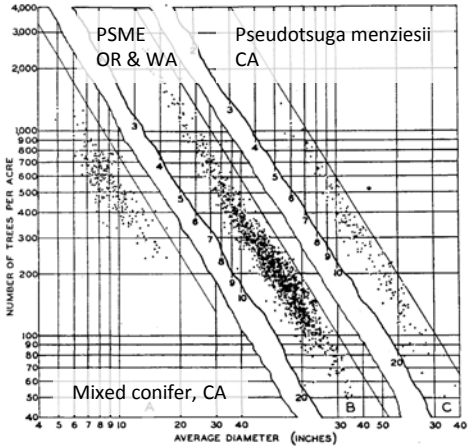
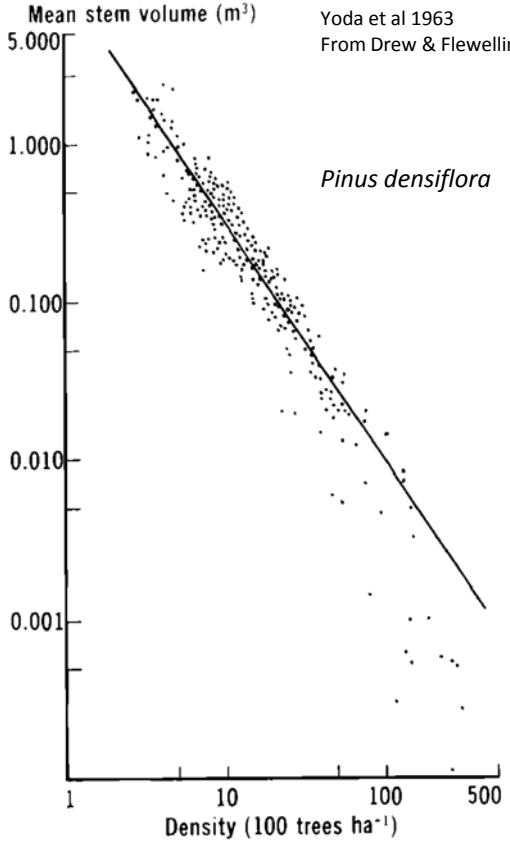
1. Crowded stands self-thin

- Reineke's Stand Density Index
- Yoda's −3/2 Power law
- Maximum average size is a function of density
- Continued tree growth requires lower density
- Maintains constant yield
  - as piece size increases
  - stand density decreases

Reineke 1933



Yoda et al 1963
From Drew & Flewelling 1977



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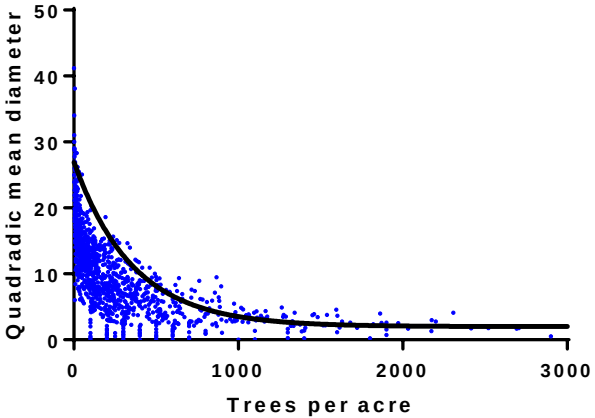
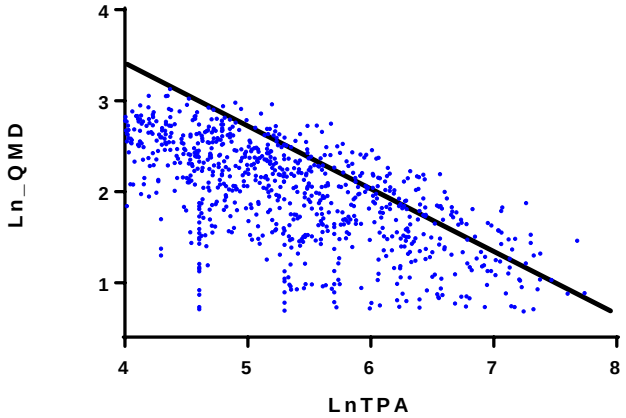
Maximum size-density function

- Non-linear exponential function
- Log transformed into linear function

$y = \beta_0 e^{\beta 1x}$



$\ln(QMD) = \beta_0 + \beta_1 \ln(TPA)$



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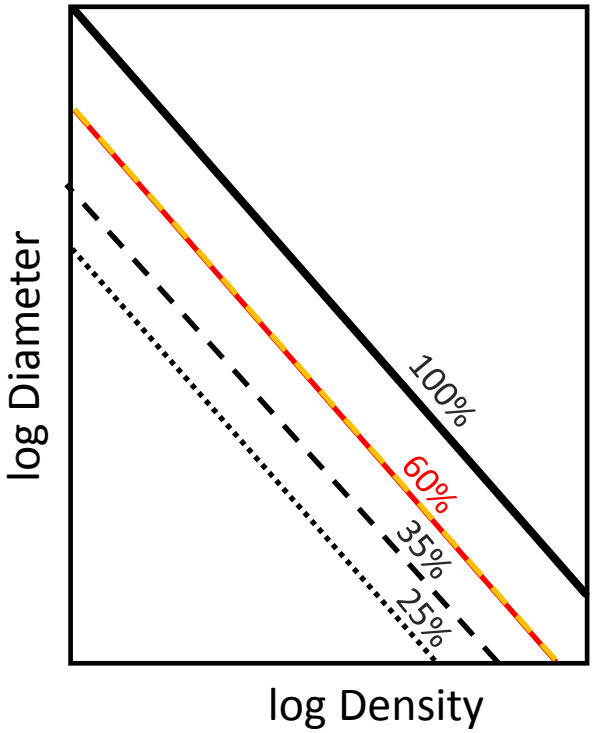
Stand density relative to Normal stands



100% - Normal
60% - Eminent mortality
35% - Lower Management Zone
25% - Crown closure

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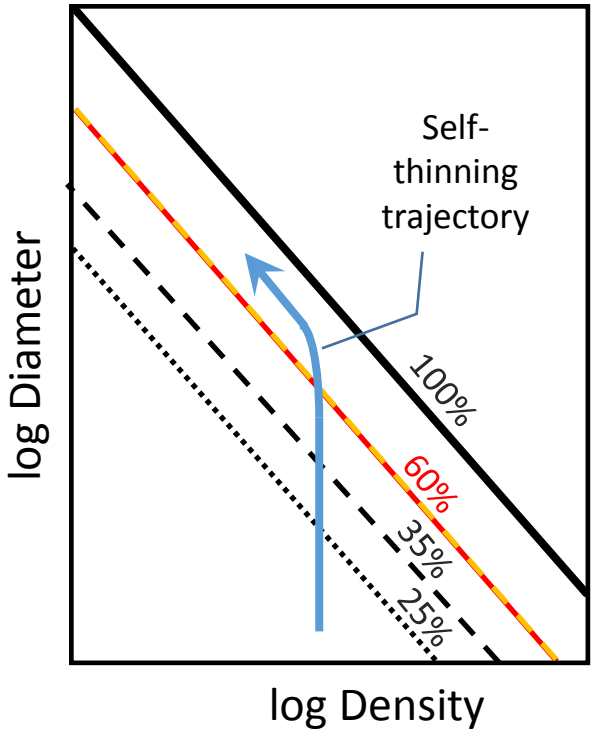
2. Two-phased self-thinning trajectory

1. Non competitive
   - Rate of growth depends on SQ
2. Competitive
   - Parallel to normal line

SQ = Site quality, analogous to resource availability



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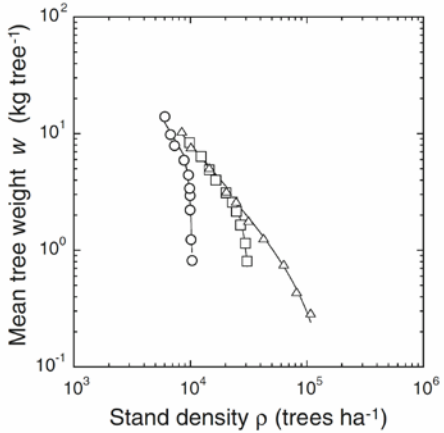
Growth-density trajectory

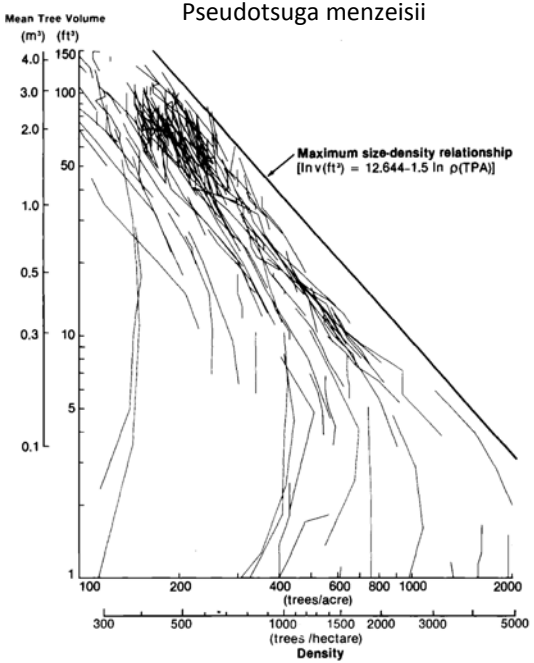
Xue et al 2010

Pinus densiflora



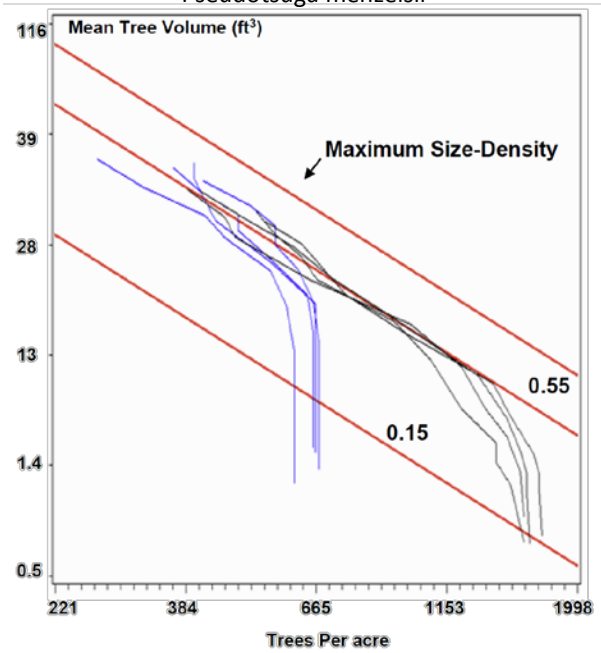
Drew & Flewelling 1977

Pseudotsuga menzeisii



Hyink 2005

Pseudotsuga menzeisii



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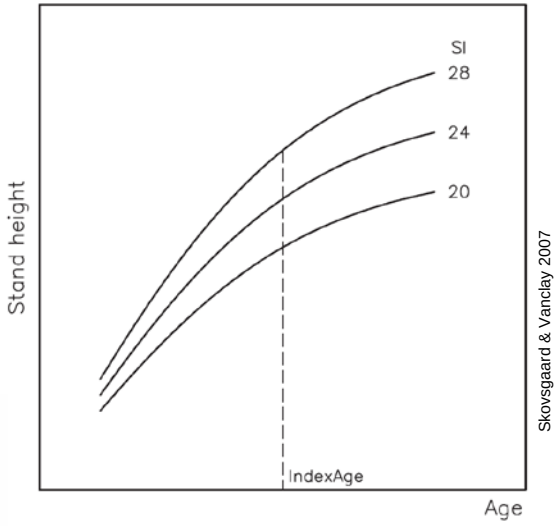
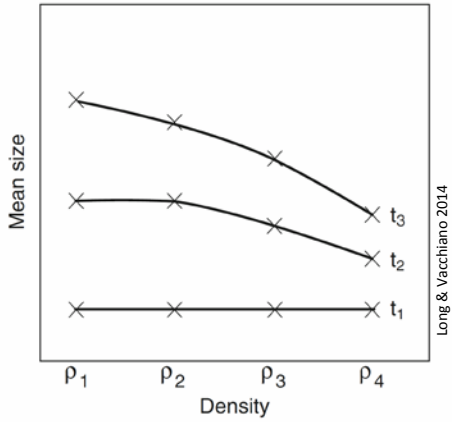
Before mortality occurs

3. Competition decreases tree size

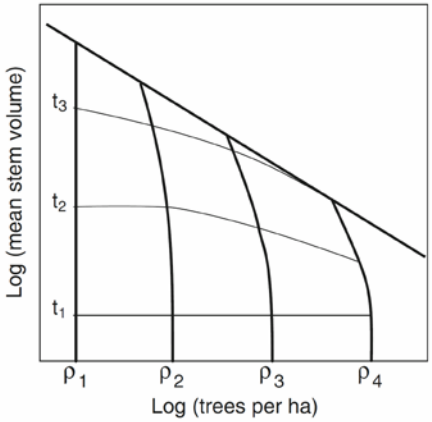
- Tree size is highest at low density
  - Stronger pattern as stands develop
- To control for stage of development
  - Height is a scale for tree age within same SQ
- Self-thinning trajectory defined by connecting time lines, i.e. height curves



Skovsgaard & Vanclay 2007



Long & Vacchiano 2014



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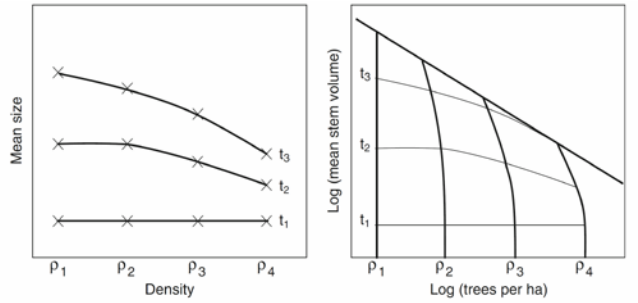
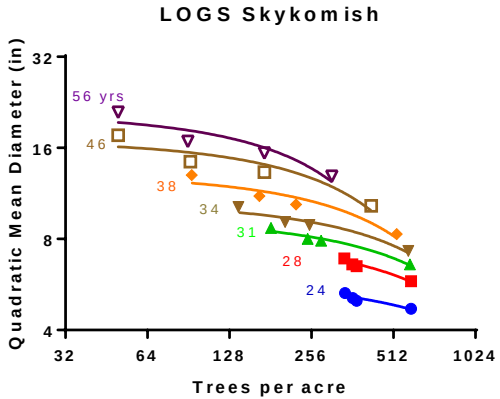
Per-tree response to competition

Examples

Long & Vacchiano 2014

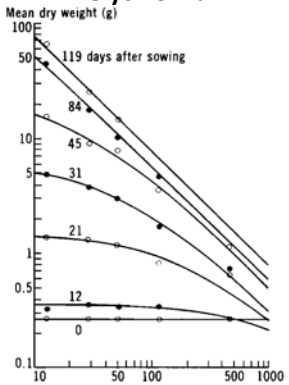
Theoretical competition-density (c-d) response





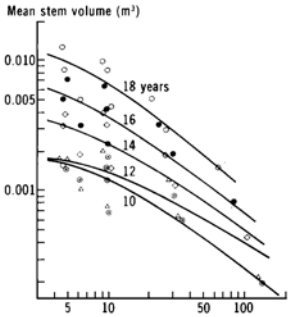
Shinozaki and Kira 1961

Glycine max

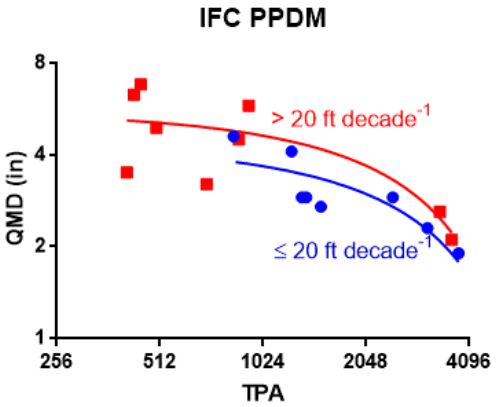


Ando 1968

Pinus densiflora



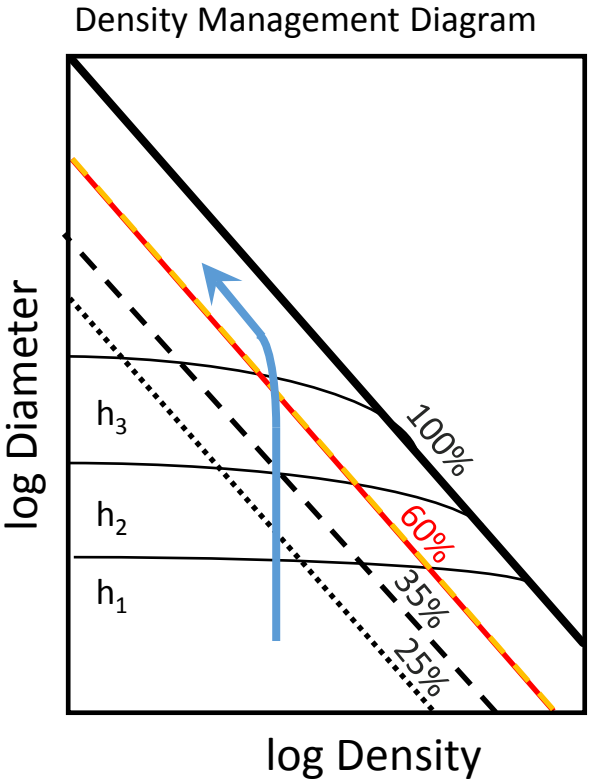
From Drew & Flewelling 1977



DMD provide decision support

Include three principles

- Graphical models
- Maximum size-density defines normal stands
- Relative density lines define management zone
- A family of tree size-density-height curves define development
- Stand conditions initiate self-thinning trajectory



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Thinning responses emerge from three principles

Targets:

- Simultaneously achieve largest piece size and greatest site occupancy
- Avoid competition related growth decreases
    - Including mortality

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Ponderosa pine

Long & Shaw. 2005

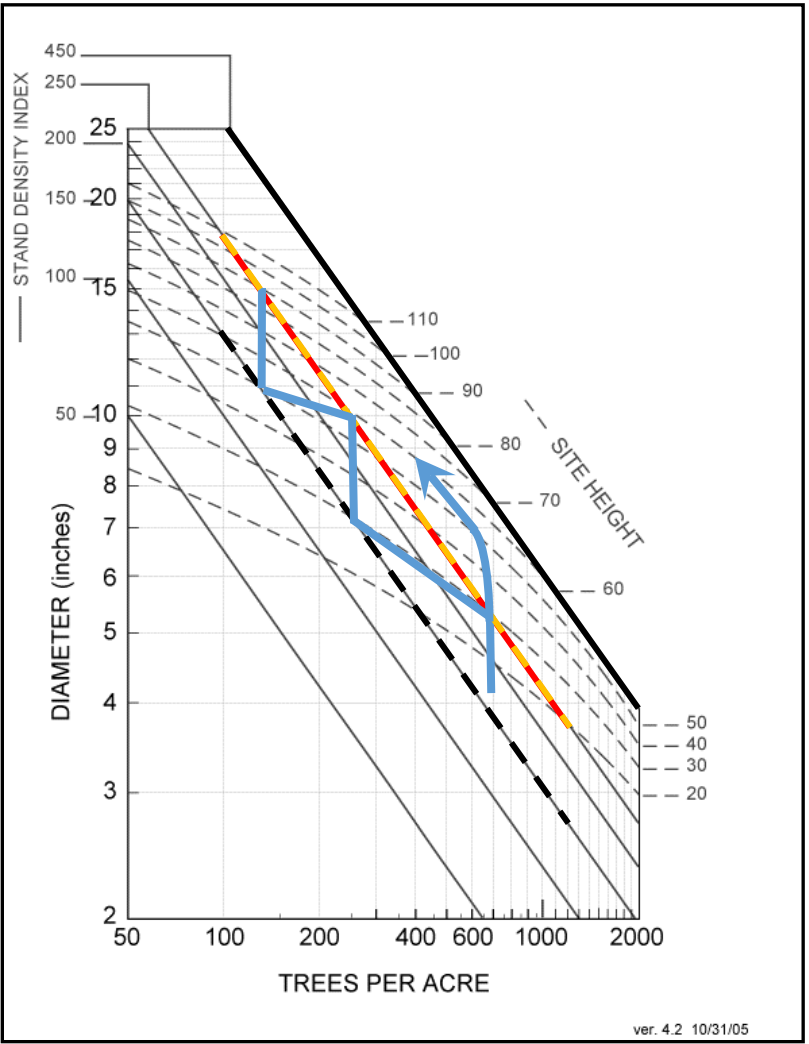
Stand w/ 700 tpa

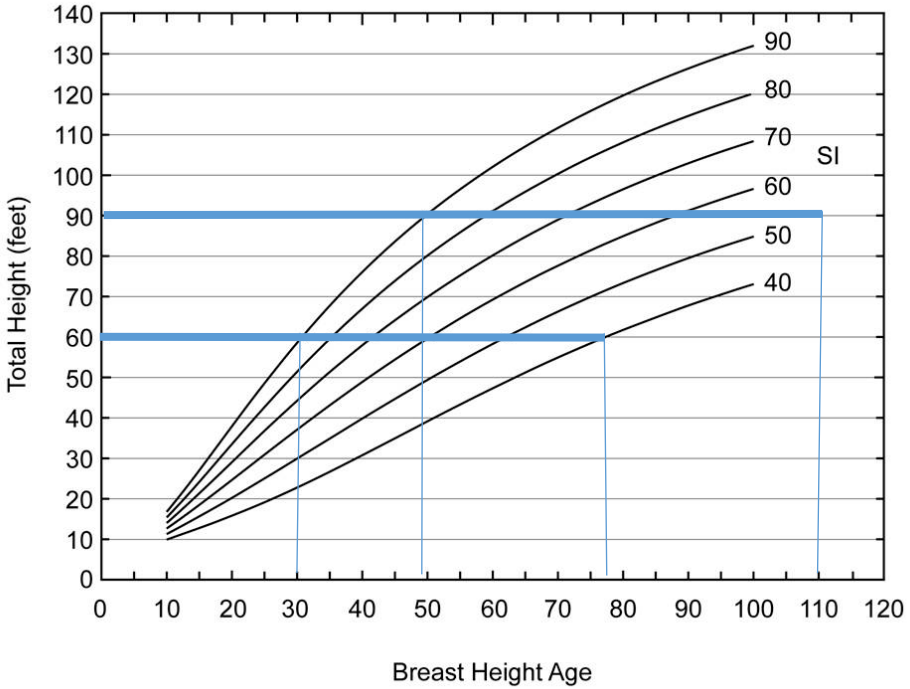
PCT before H=30’ to 12’ spacing

Reaches 10” QMD at 60’

CT to 16’ spacing

Reaches 15” QMD at 90 ft



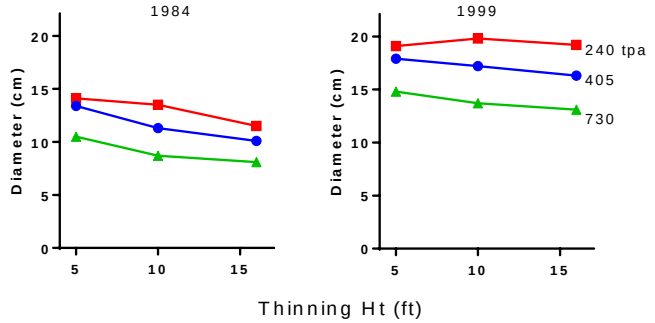


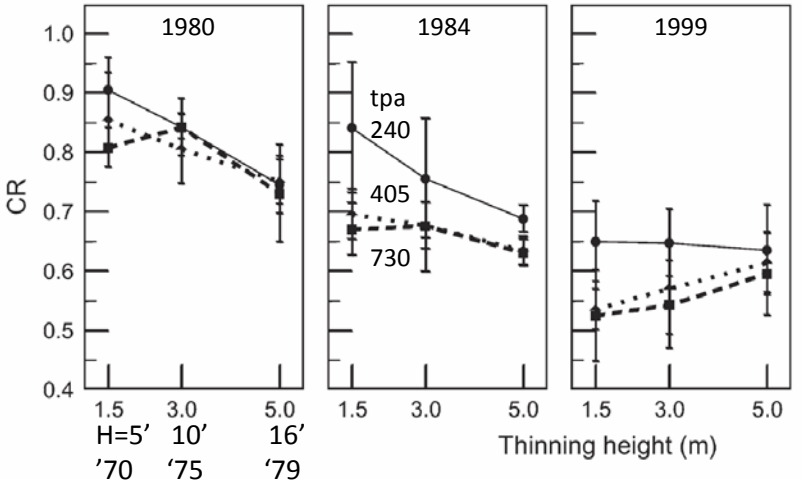
Pinus Sylvestris
Ulvcrona et al 2007

Timing impacts

Open-grown, non-competitive growth

- Fastest tree growth
- Little effect of timing
- High crown ratio, large branches



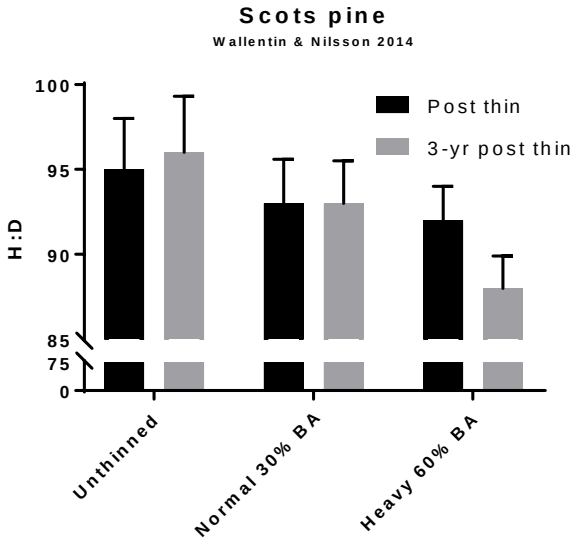


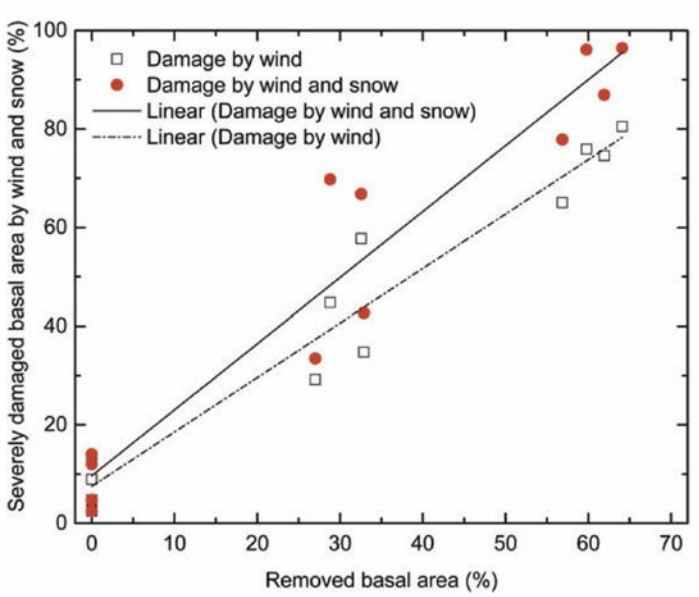
Timing impacts

Un-thinned trees

- Large H:D ratio
- Low stem taper

Thinned stands are vulnerable to storm damage.





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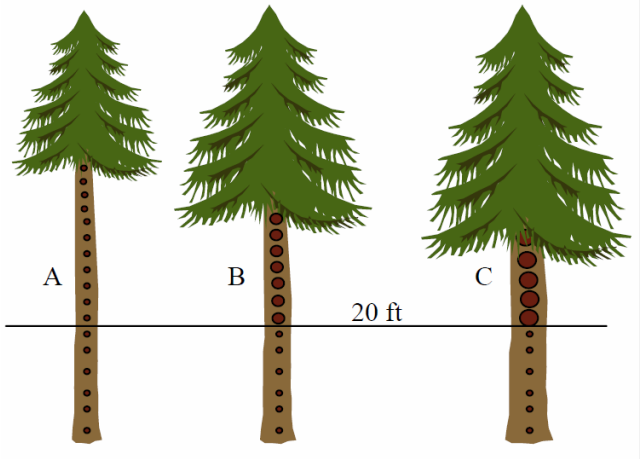
Desired future condition:

1. Uniform stocking of high quality 15” logs
   - Planting density
   - Veg control to maintain free tree growth
   - Thin to maintain stand in MZ, train stem
2. Rapid development of old growth structure
   - Follow above to accelerate development
   - Heavy second or third thinning
     - Encourage tall crowns and large branches

Maguire 2005



MZ=Management zone 35-60% RD

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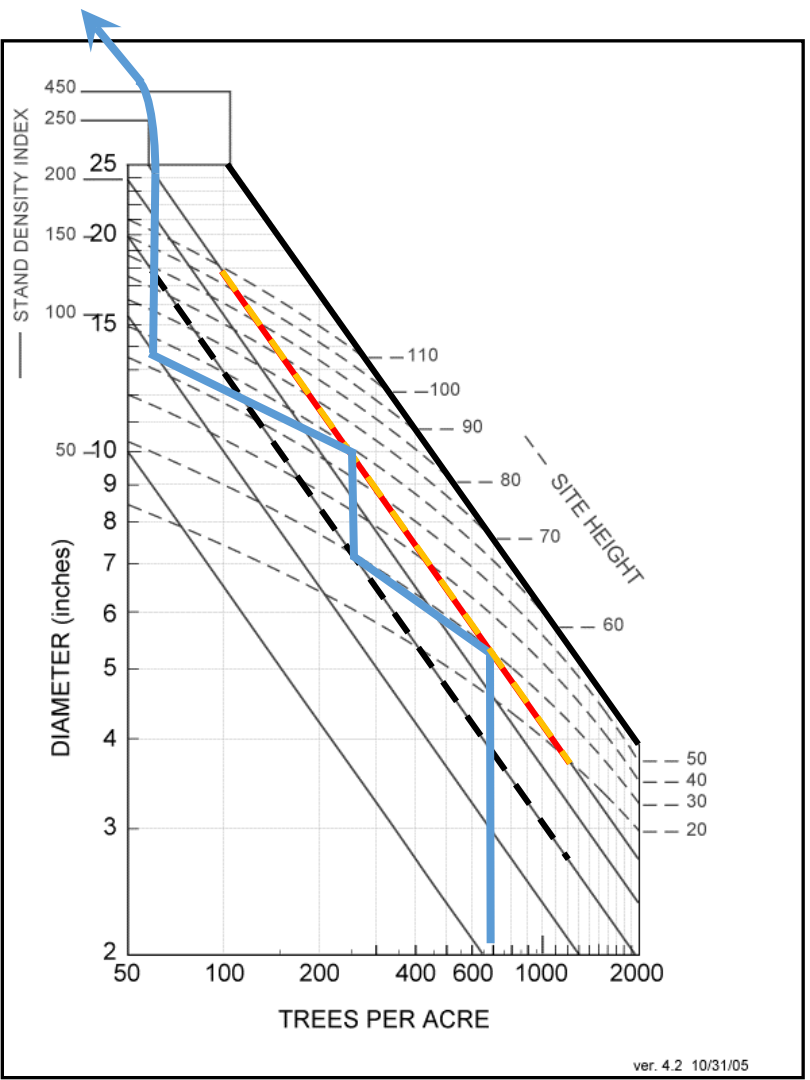
Ponderosa pine

Long & Shaw. 2005



Stand w/ 700 tpa

PCT before H=30’ to 12’ spacing

Reaches 10” QMD at 60’

CT to 24’ spacing

Promote old-growth structure

- Heavy thin to less than 35% RD
- Open stand to encourage branch retention
- Provide light for diverse understory
- Allow stand to follow self-thin trajectory

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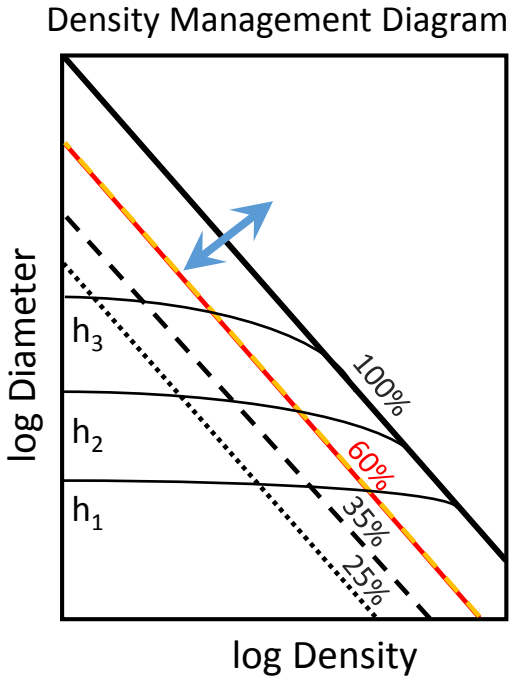
Variable maximum size density line

- Complicated by variation in position of self-thinning line
- Need for dynamic Density management diagrams
  - Relative density lines to locate MZ
  - Family of height curves to set development targets
  - Couple with site index curves (G&Y models) to adjust for SQ



MZ=Management zone 35-60% RD

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For a give site and composition there's

Plateau in total stand productivity-density curve

Growth phases:

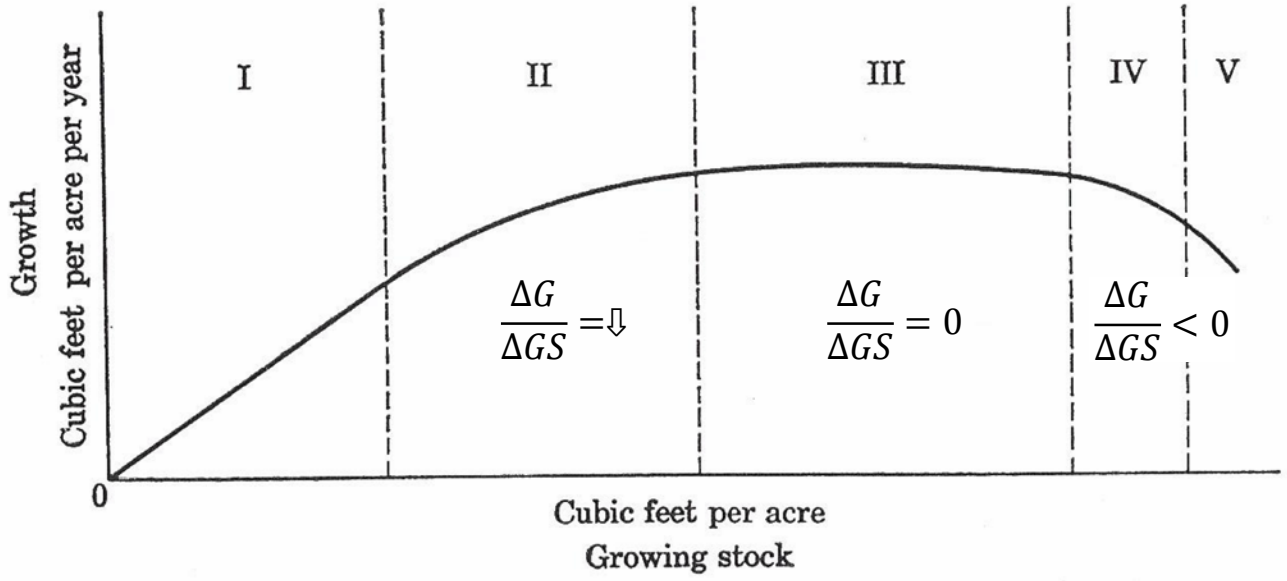
I. No competition

II. Growth decline

III. Constant wide optimum

IV. Competition-caused decline

Langsaeter's Curve



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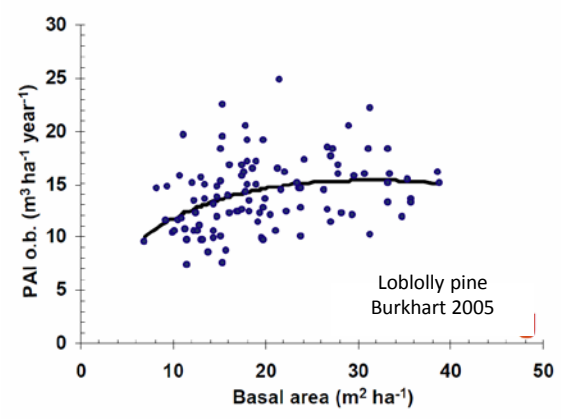
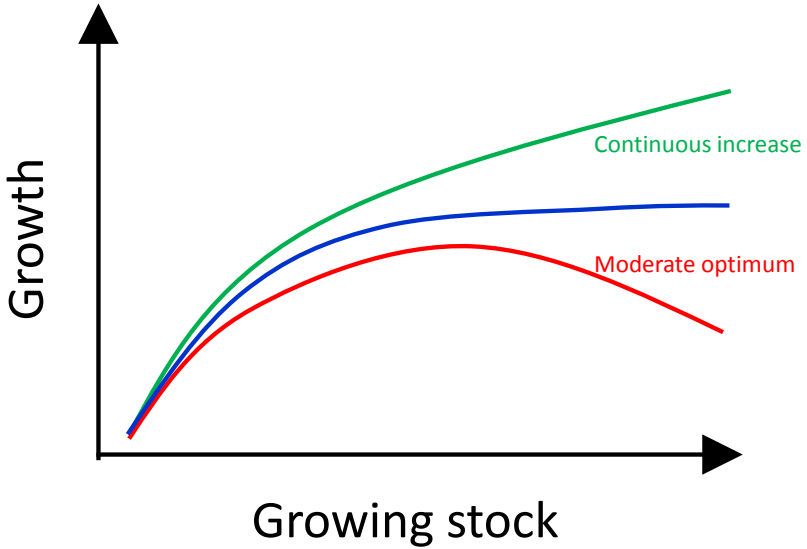
To plateau or not to plateau

- Uncertain width of plateau
- Uncertain effect of site quality
- Gross production vs Net production
- Typically noisy data causes the uncertainty





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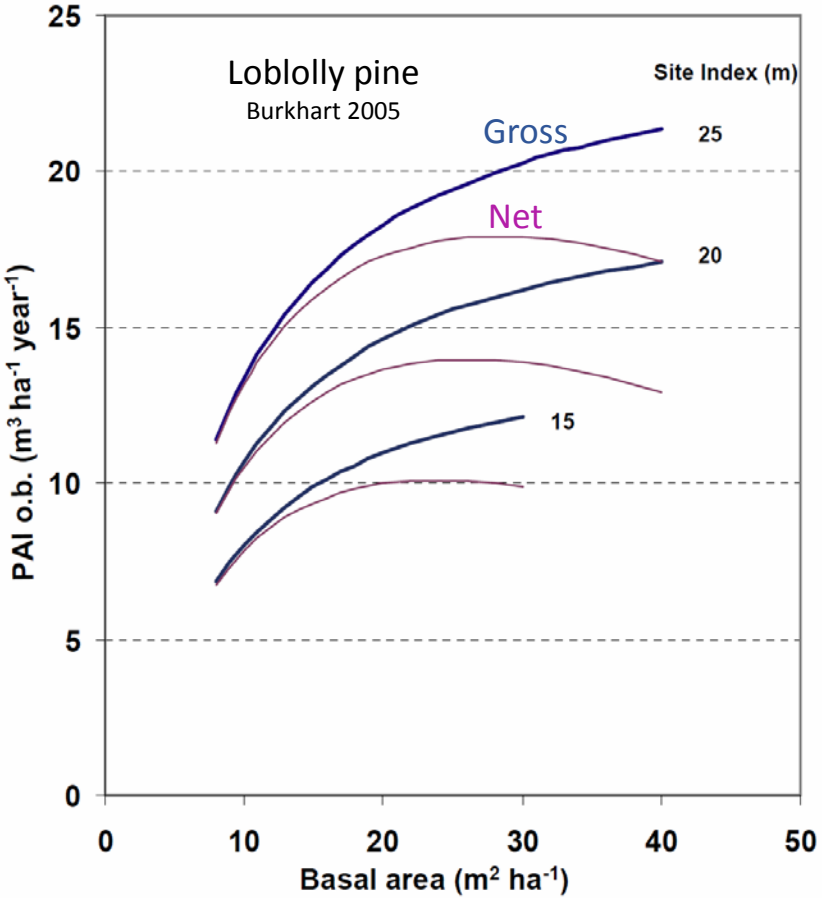
What effects the growth-density curve?

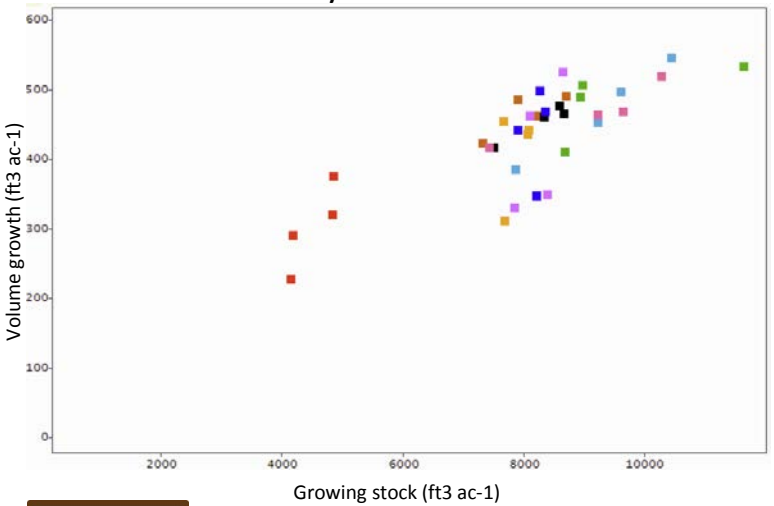
- A broad plateau creates management flexibility
  - High SQ may provide greater flexibility
  - Allows faster recovery from intensive thinning
- Low SQ follow same pattern, but develop slower
- Gross production shows continuous increase, net production peaks



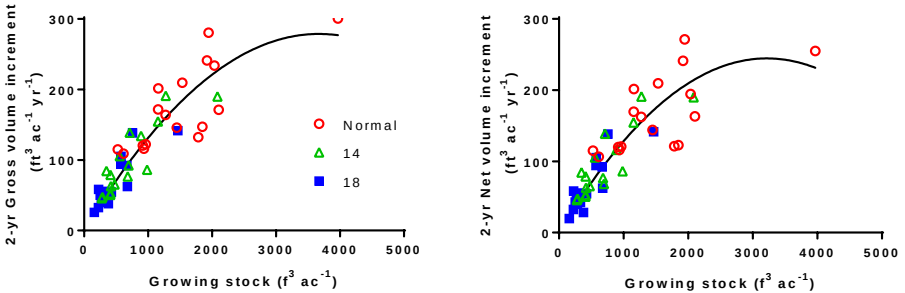
Growth-density curve

Examples for Douglas-fir

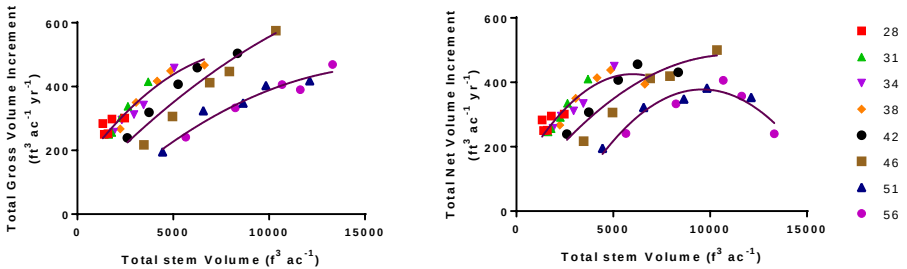
Hyink 2005



PPDM DF 2015



LOGS Skykomish



- Gross production shows continuous increase, net production peaks
- Capture mortality through thinning

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Summary

- Forest stands are controlled by self-thinning limit, family of tree size-competition curves, and self thinning trajectory
- Density management diagrams use principles to predict thinning responses; achieve management objectives
- Timing of thinning affects stem and crown characteristics
- DMD must be adapted to account for effects of composition and site
- Thinning will capture the difference between gross and net production