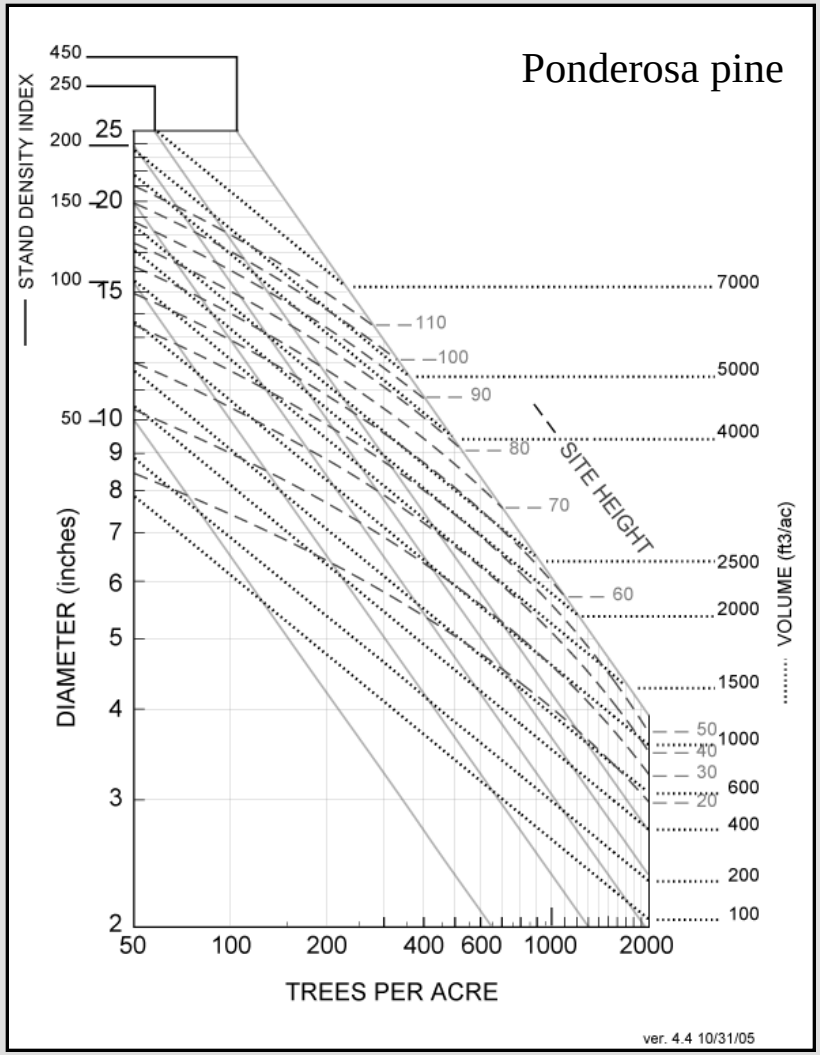
Density management:
from the conceptual to the applied

James N. Long

Department of Wildland Resources & Ecology Center

Utah State University



Long and Shaw 2005

Overall objectives

- Review some basics of stand dynamics, including size-density relationships;
- Review techniques for translating this understanding into reasonable and effective density management regimes;
- “implement” some density management regimes for particular structural objectives;
- Somethings we don’t know for sure.

Stand-level objectives

- … must be characterized in terms of stand **composition** and **structure**

  often, objectives have more to do with structure than species composition

- a key attribute of structure characterization is quantification of relative density

Stand dynamics

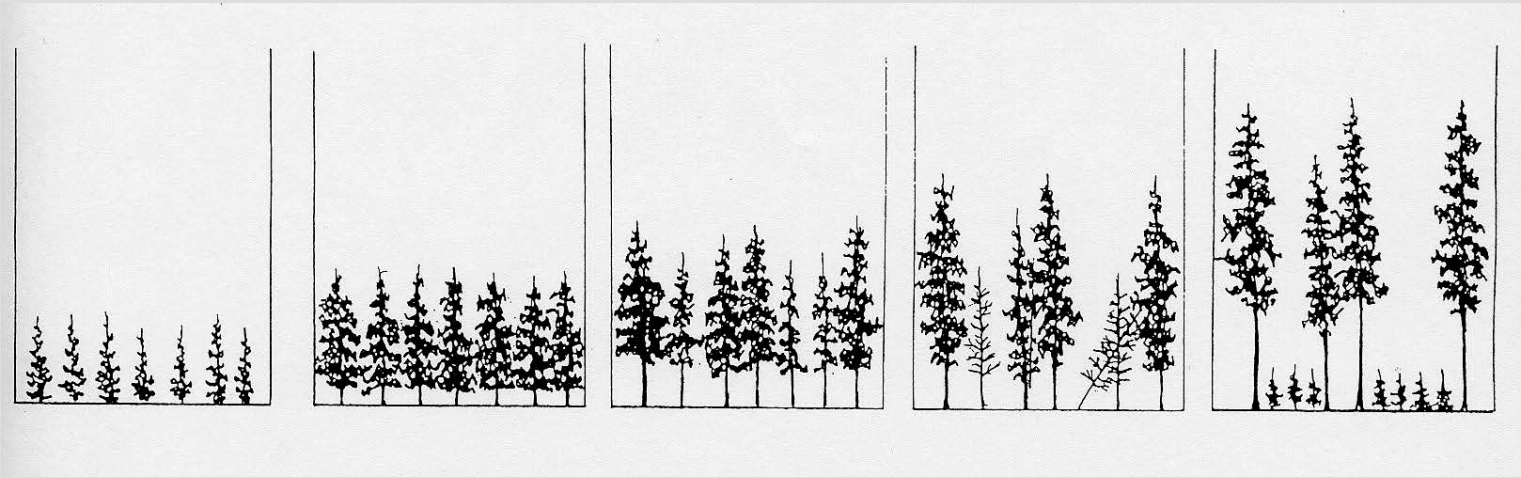
- Stand development
- Site occupancy
- Size-density relationships
- Individual tree vs stand growth
- Relative density and density management

Stand dynamics

- **Stand development**
- Site occupancy
- Size-density relationships
- Individual tree vs stand growth
- Relative density and density management

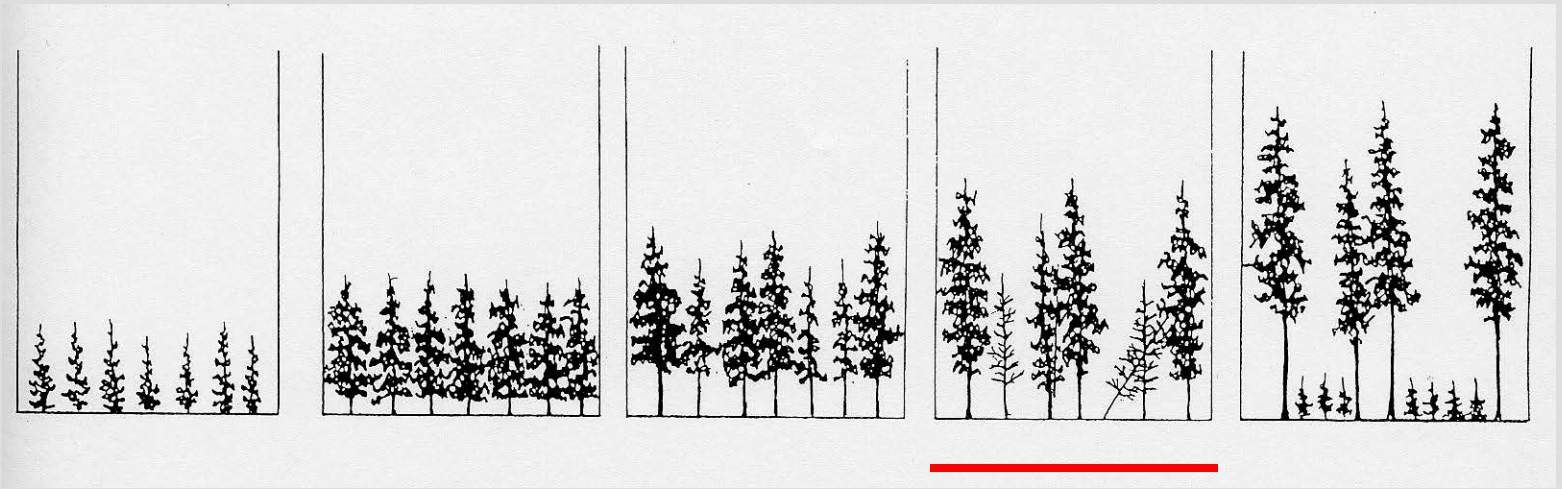
Stand development

- Assumptions of model:
  - Single species
  - Even-aged
  - Homogeneous

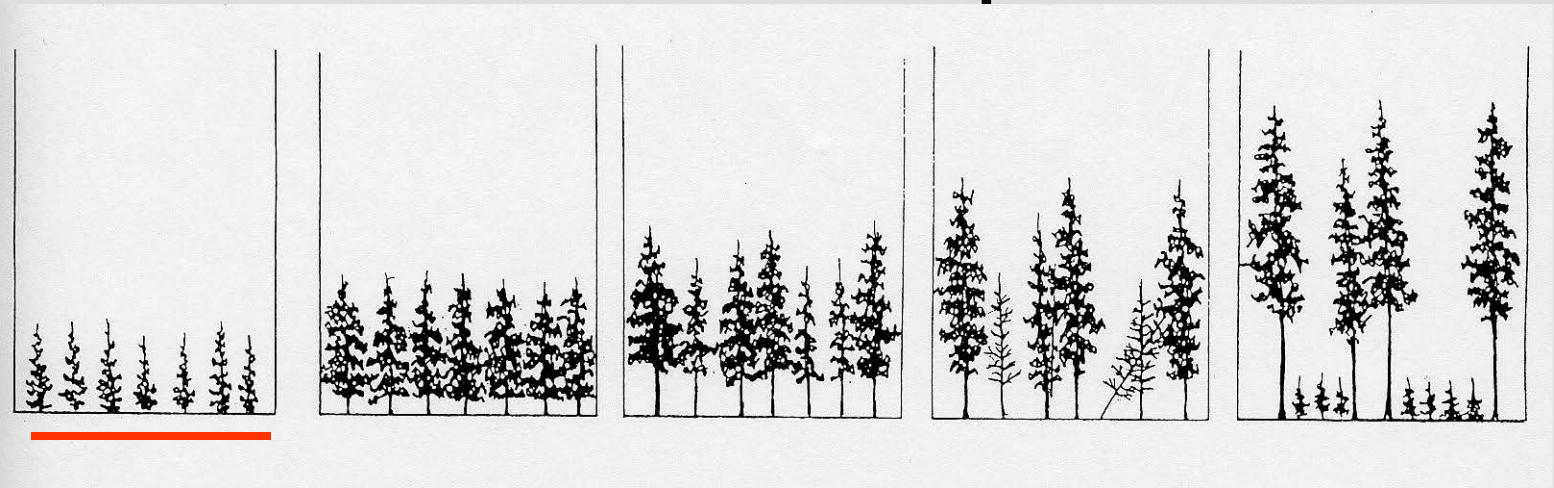


Stand development

- Comparison w/ Oliver and Larson (1996)



Stand development



Lodgepole pine

Stand development

Jack pine

Forest Service

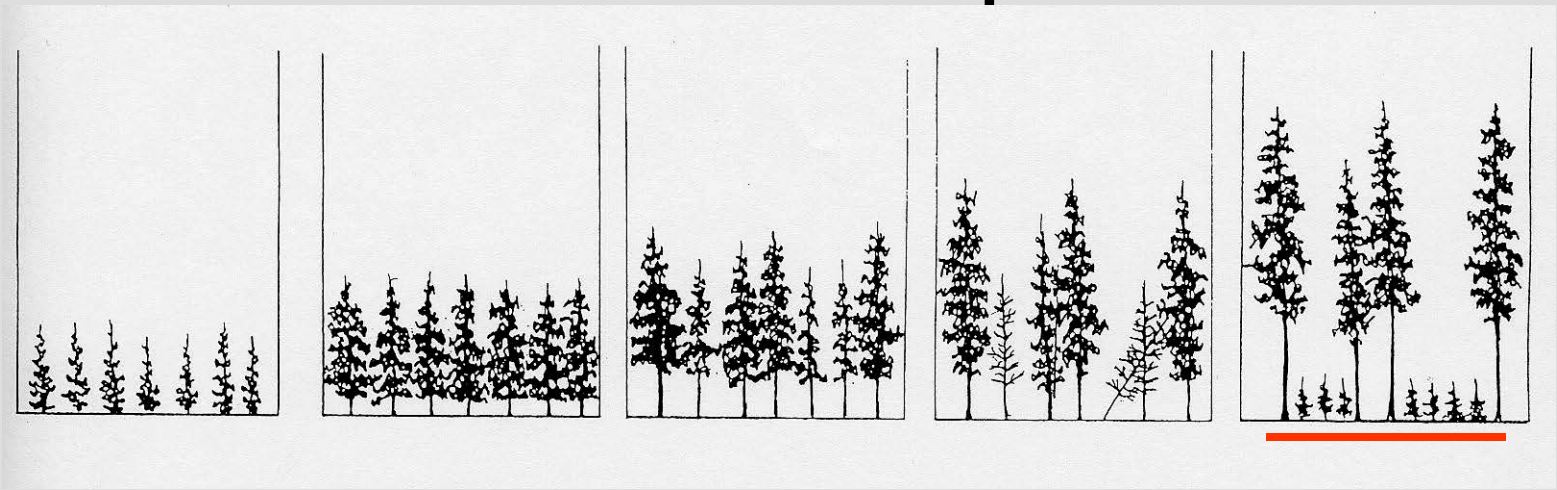
Stand development

Douglas-fir

Stand development

Engelmann spruce/subalpine fir

Stand development



Ponderosa pine

Aspen/white fir

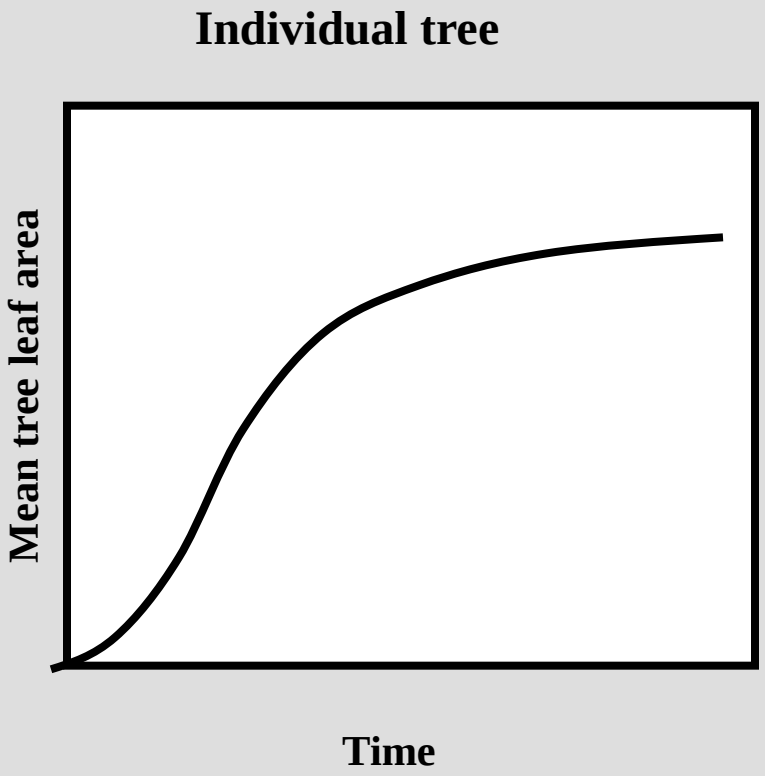
Stand dynamics

- Stand development
- **Site occupancy**
- Size-density relationships
- Individual tree vs stand growth
- Relative density and density management

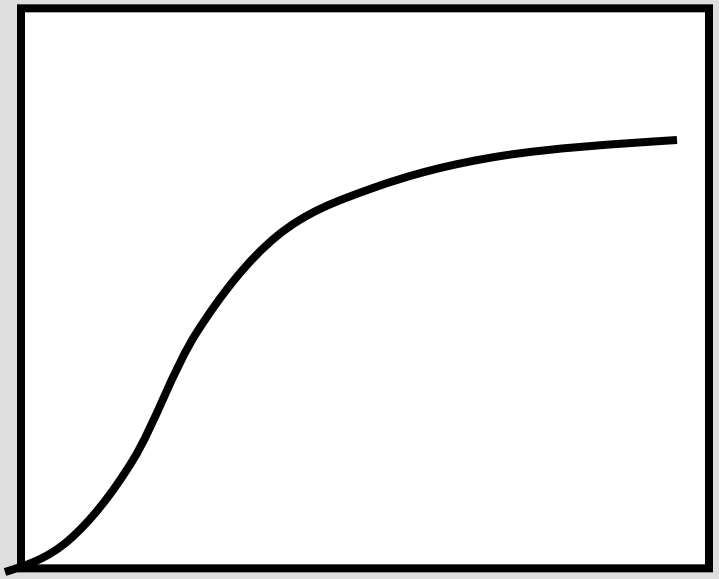
Stand dynamics

- Lots of interesting detail associated w/ canopy development, e.g., changes in architecture
- An important emergent property of a developing forest population is the upper limit to the amount of foliage a population can carry

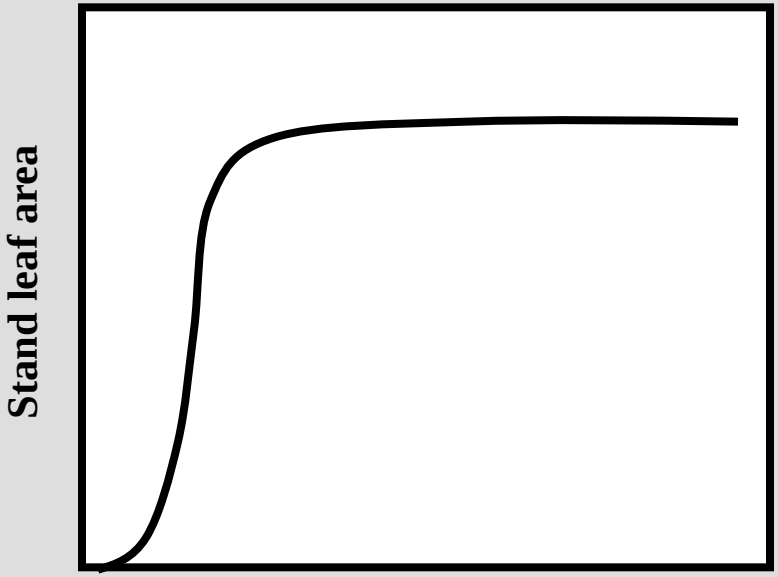
Pinus contorta var. latifolia


Individual tree
Mean tree leaf area
Time

Individual tree



Stand-level



An emergent property

Stand dynamics

Pinus contorta var. latifolia

- Upper limit is species- and site-specific “constant”
- However, it can be carried on a few big trees or many small trees
- Implications of this emergent property are extremely important

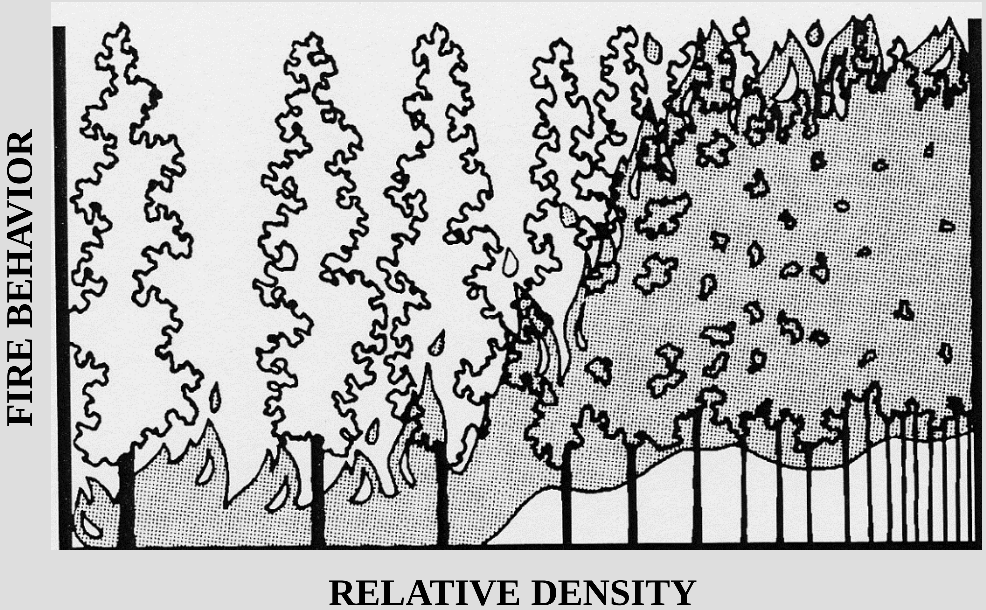
Stages of stand development

- Some key concepts
  - Nature of competitive interaction at various stages
  - Increasing average size coupled with decreasing numbers
  - Interaction of growth rates and initial density
  - The leaf area “plateau”

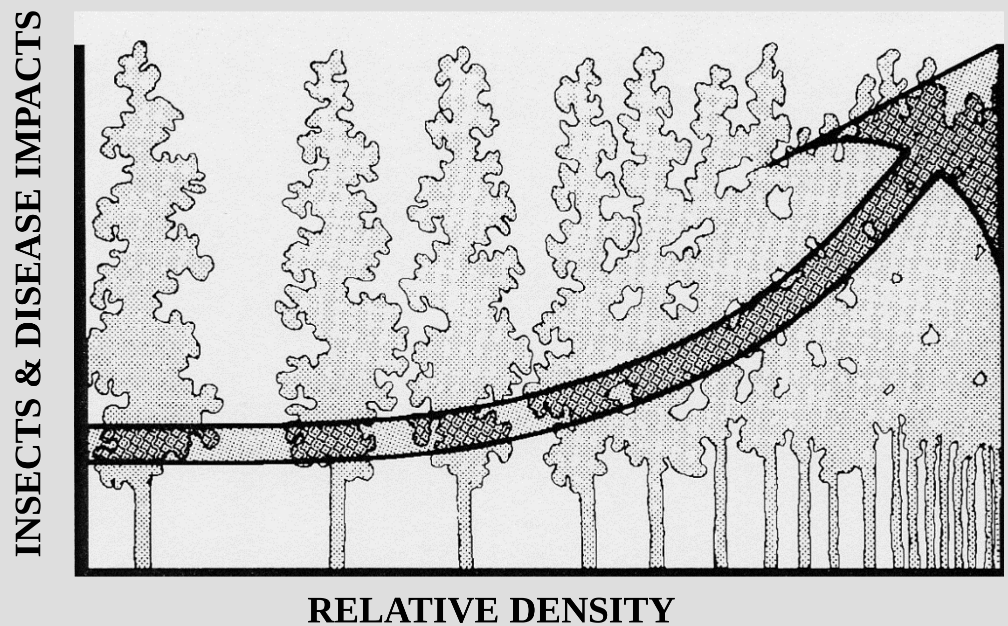
Size-density relations

- A way to quantify relative density
- A way to characterize structural elements of DFC
- Basis for designing density management regimes

DFC = Desired future condition



after Powell

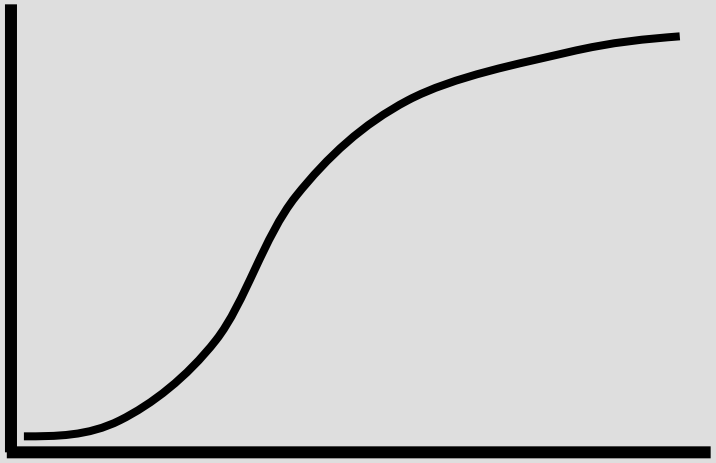


Size-density relationship

- The predictable relationship between mean size and density in crowded (e.g., self-thinning) populations
- Another ***emergent property***

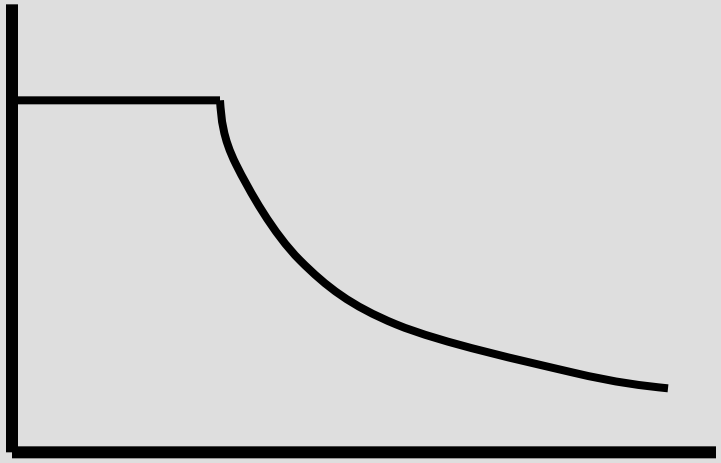
Size-density relationship

Mean size



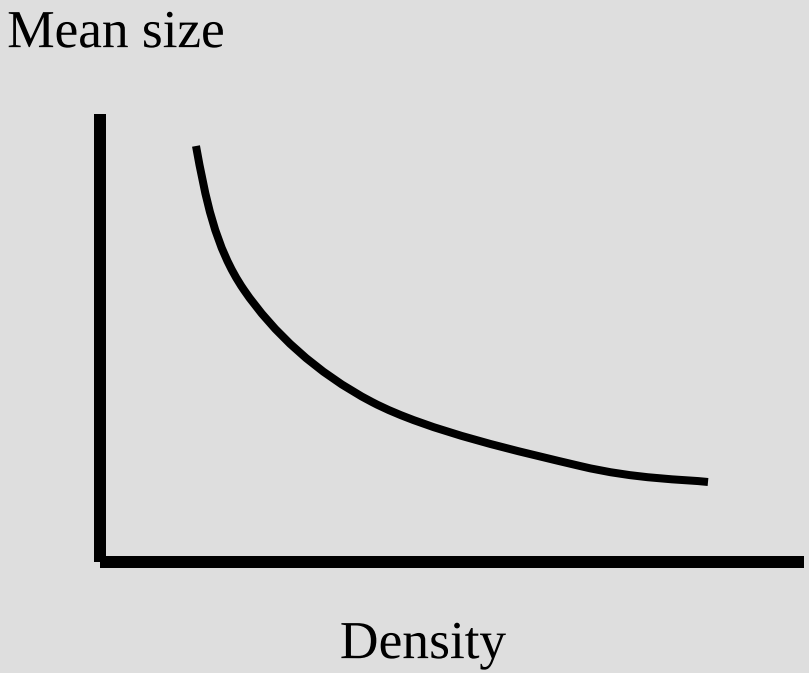
Age

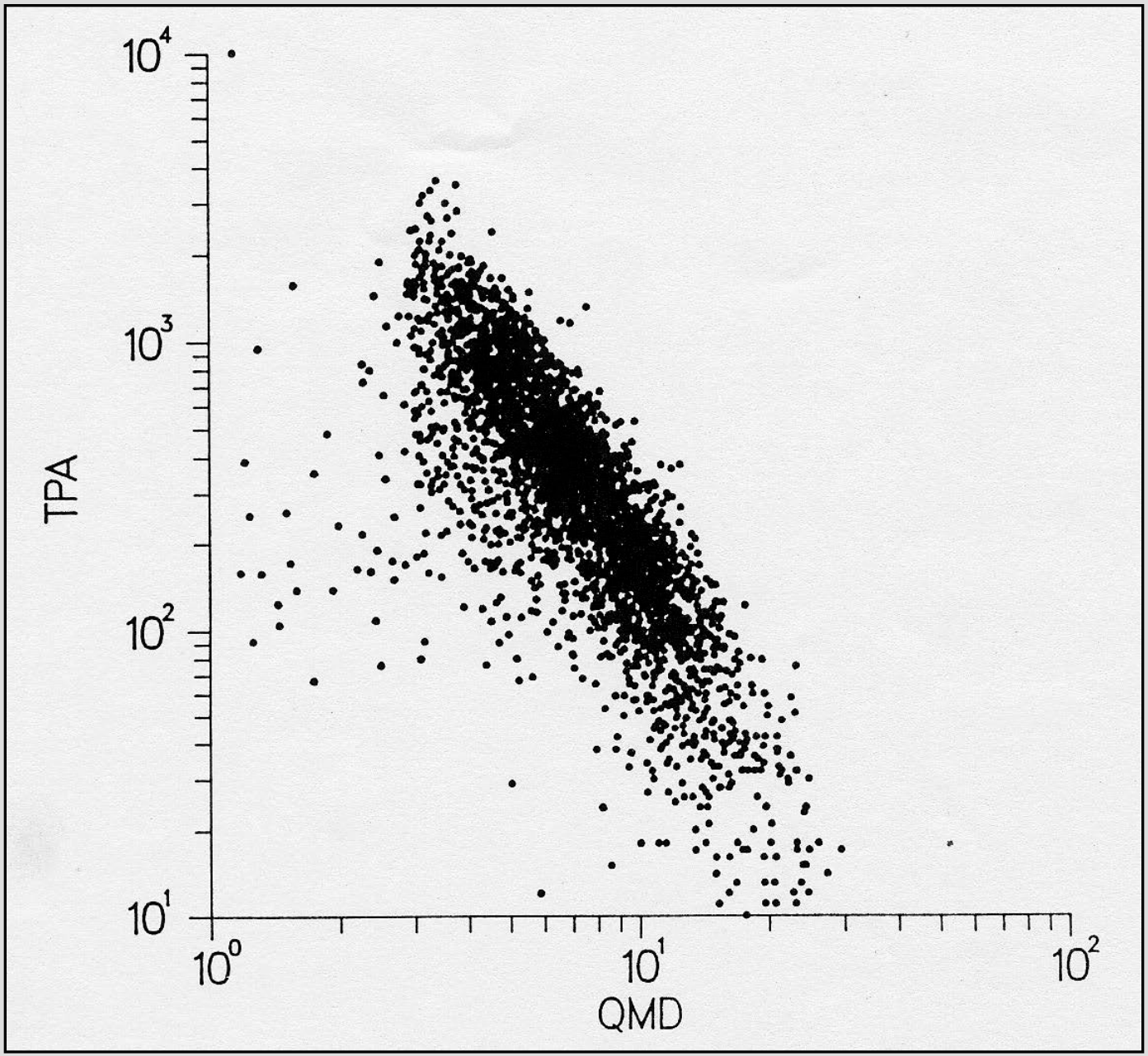
Density

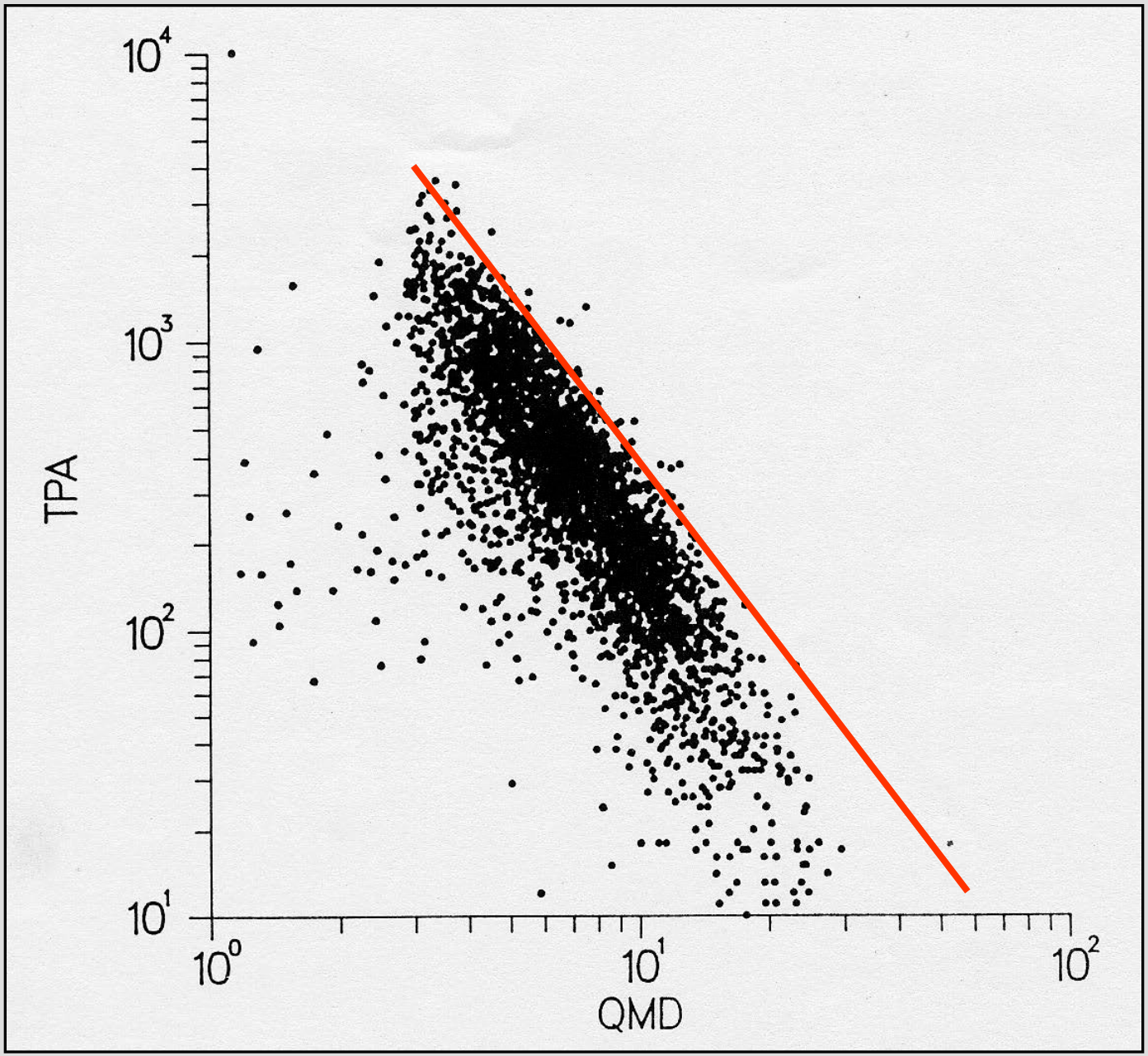


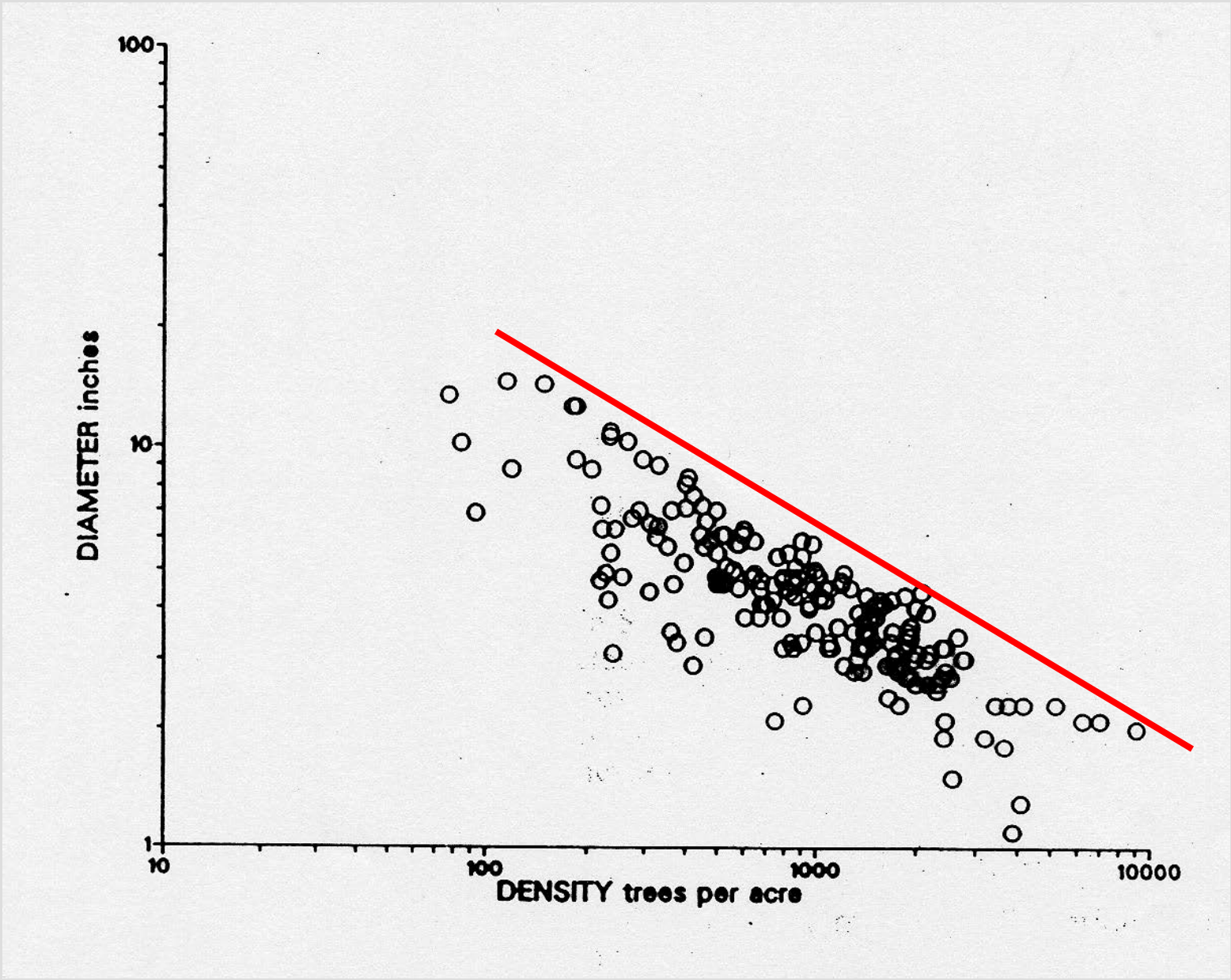
Age

Size-density relationship



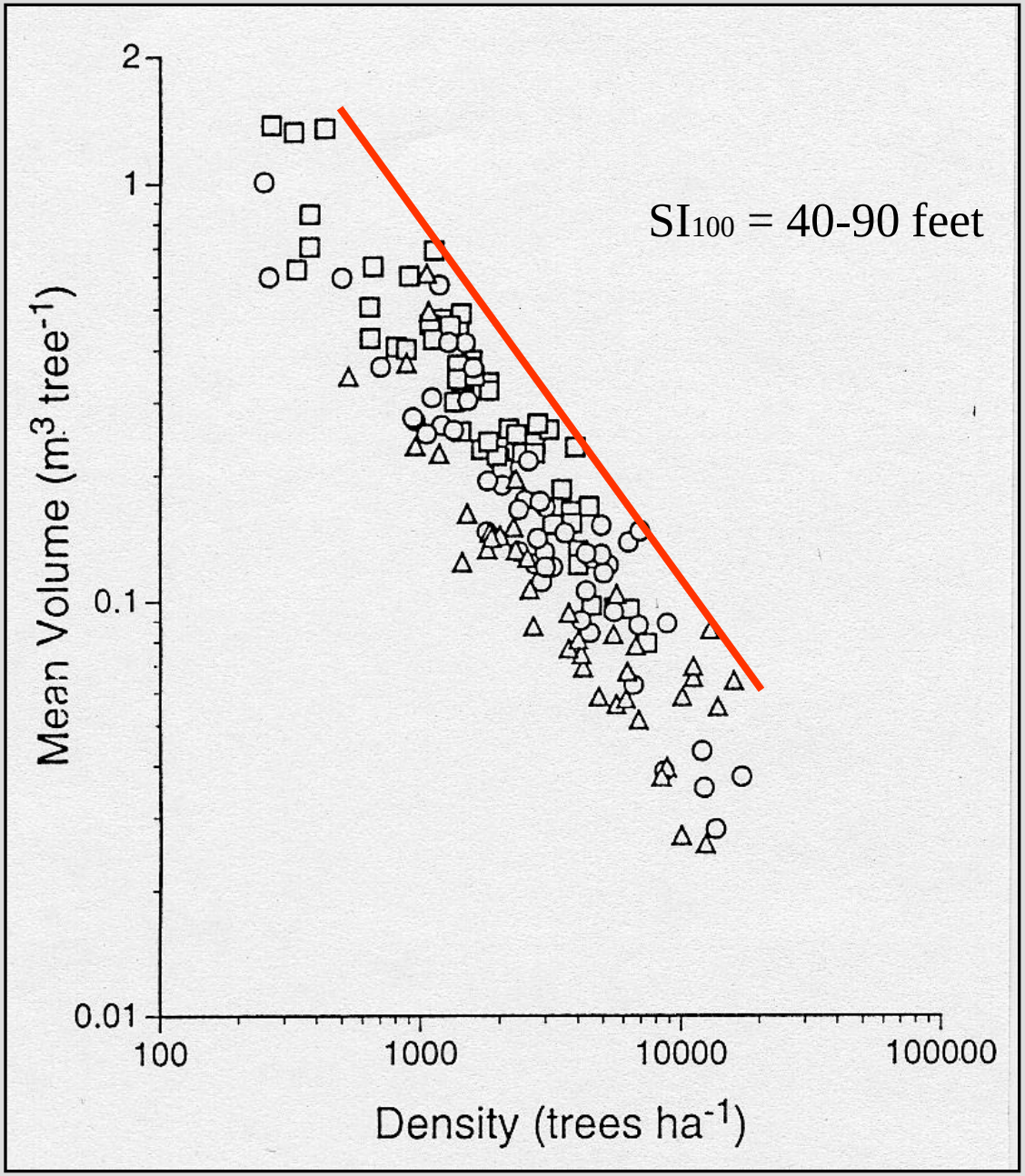

10^4
10^3
10^2
10^1
TPA
10^0
10^1
10^2
QMD


10^4
10^3
10^2
10^1
TPA
10^0
10^1
10^2
QMD


100
10
1
DIAMETER inches
10
100
1000
10000
DENSITY trees per acre

The boundary line

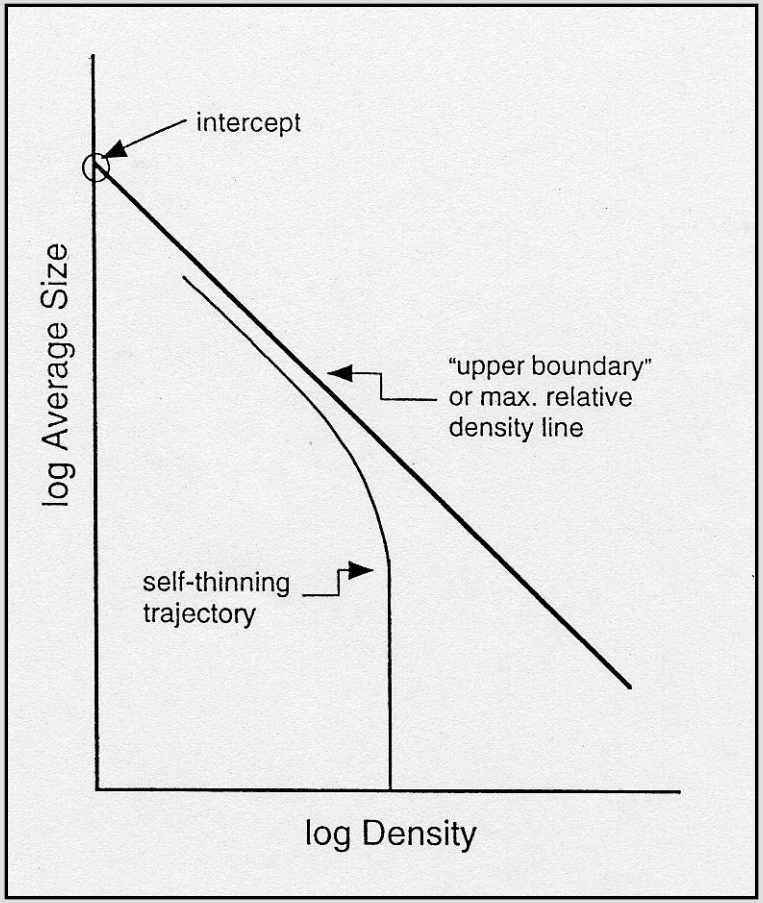
- Slope
- Intercept (level)
  - Species-specific
  - Independent of site quality



Lodgepole pine

Trajectory

- Influence of initial density
- Influence of site quality



Relative density

- Maximum size-density relation (i.e., boundary line) as a reference
- Relative density as ratio of actual density & theoretical maximum density (for a given mean size)
- *How close is the stand to the boundary line?*

Size-density based indexes

- Crown competition factor (CCF) (Gingrich 1967)
- ρr (Drew and Flewelling 1979)
- Spacing as % of height (Wilson 1979)
- RD (Curtis 1982)
- SDI (Reineke 1933)

From a theoretical viewpoint, all of the size-density based indexes are equally good

Reineke's stand density index (SDI)

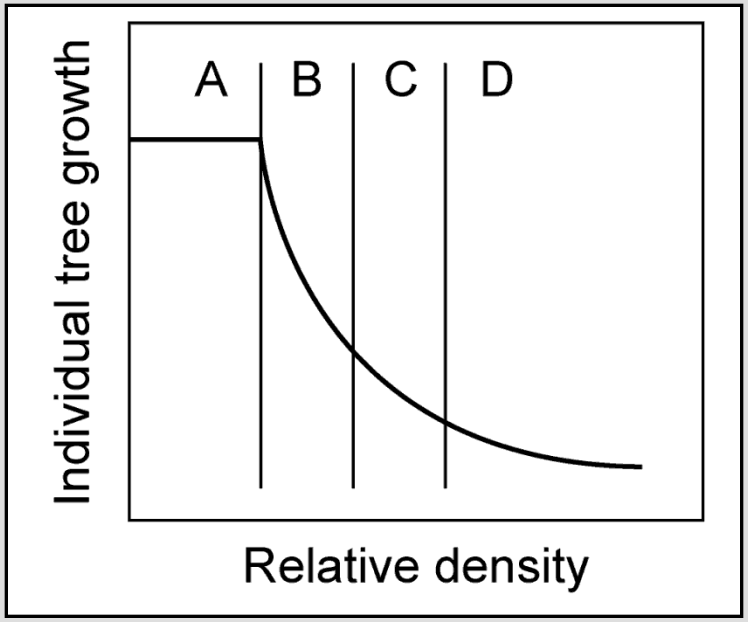
- Maximum size-density relation (Dq-tpa)
- SDI = tpa as if Dq were 10"
- $SDI = tpa * (Dq/10)^{1.6}$
- $SDIsum = \sum DBH/10^{1.6}$
- SDImax is the boundary
- % stocking (%SDI): actual SDI/SDImax

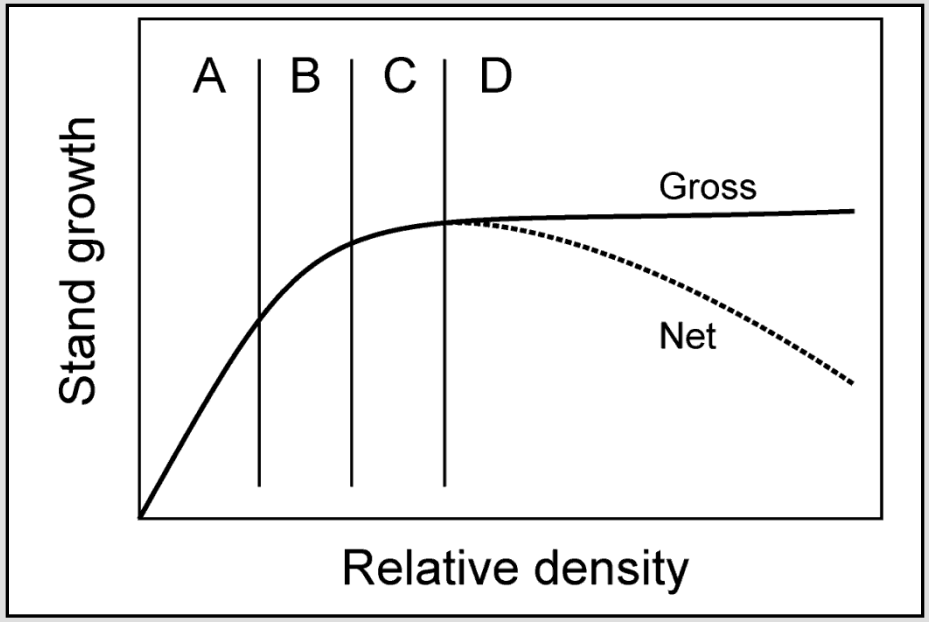
Stand dynamics

- Stand development
- Site occupancy
- Size-density relationships
- **Individual tree vs stand growth**
- Relative density and density management

Growth-growing stock relations

- Individual tree growth versus stand growth
- *You **cannot** have your cake and eat it too*





Growth-growing stock relations

- You can maximize tree growth …
- You can maximize stand growth …
- But cannot do both simultaneously
- *Almost all density management regimes involve some situationally appropriate compromise*

Stand dynamics

- Stand development
- Site occupancy
- Size-density relationships
- Individual tree vs stand growth
- **Relative density and density management**

Density management

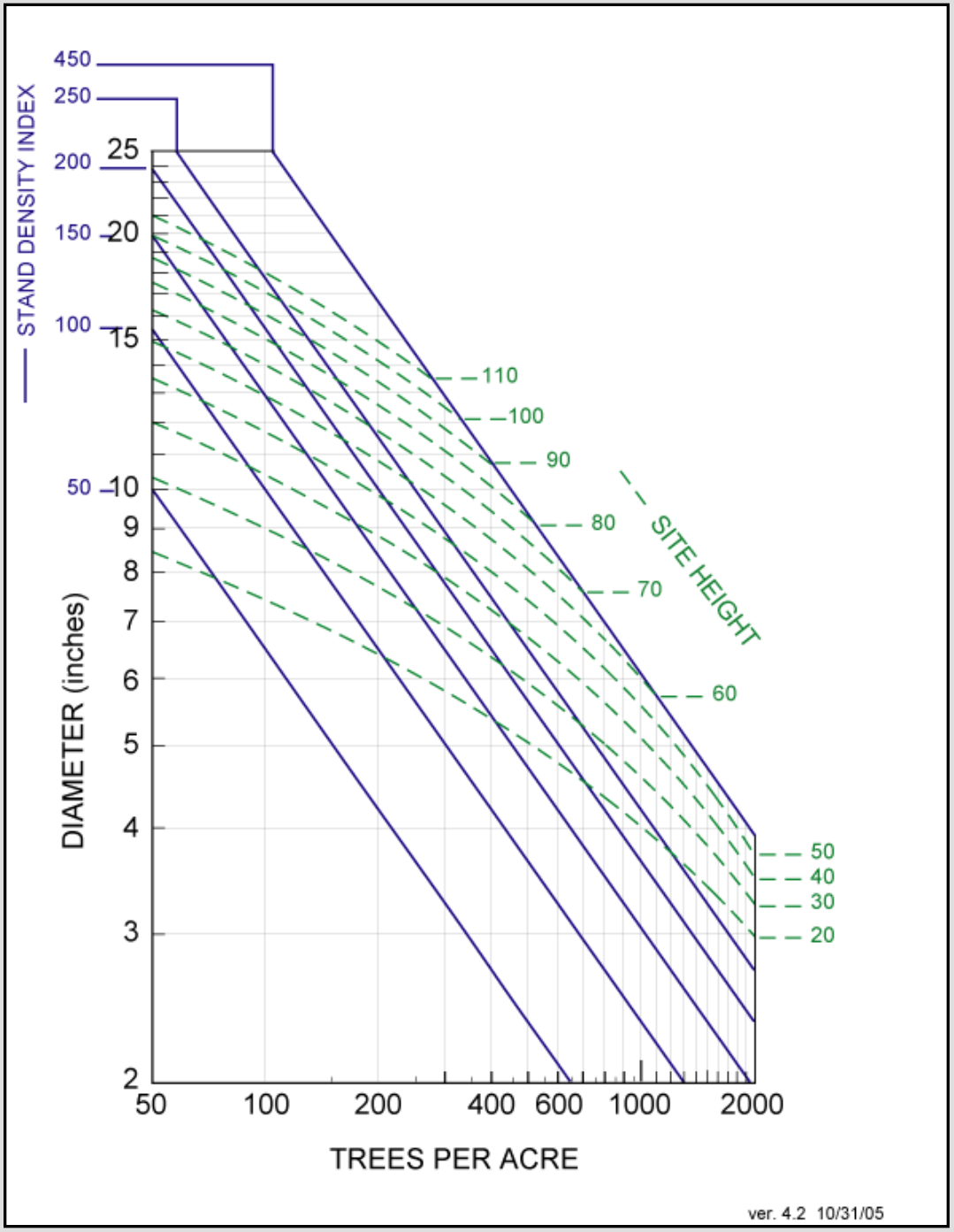
- Relative density is basic tool for translating qualitative objectives into a quantitative density management regime
- We use an index of relative density to:
  - assess current condition;
  - characterize desired future condition; and
  - develop a tactical plan for achieving DFC

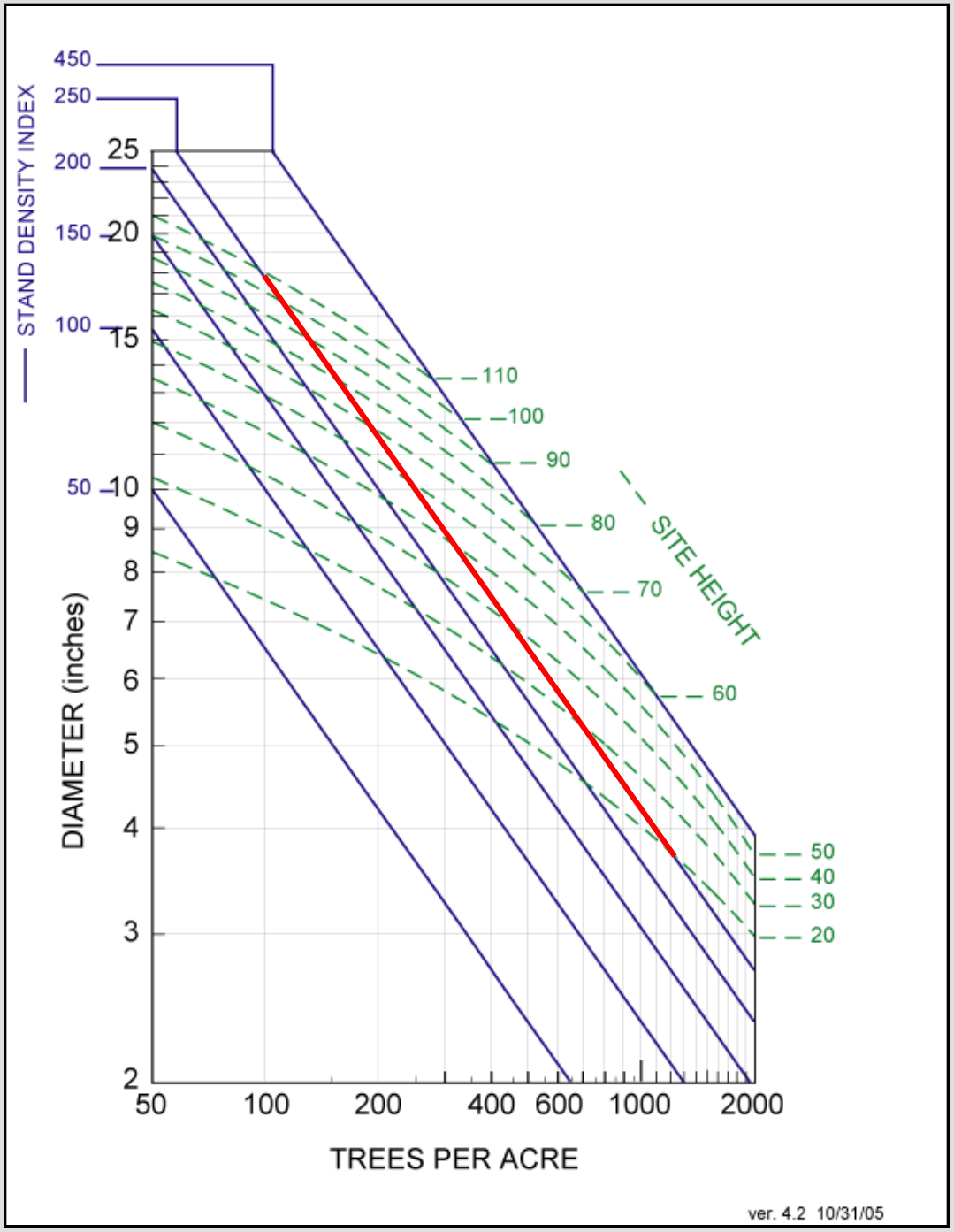
Density management

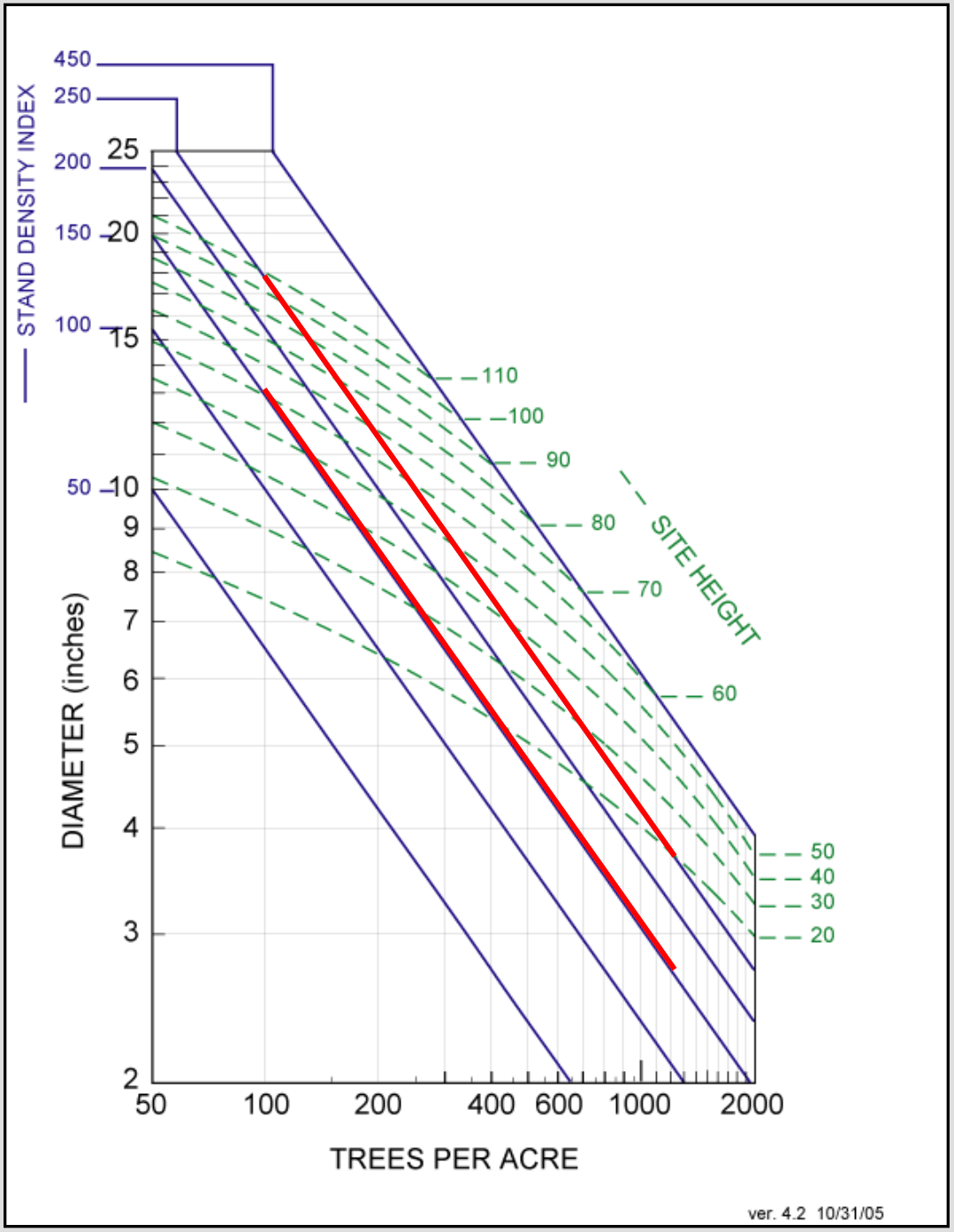
- Must decided on appropriate upper and lower limits
- Choices depend on management objectives

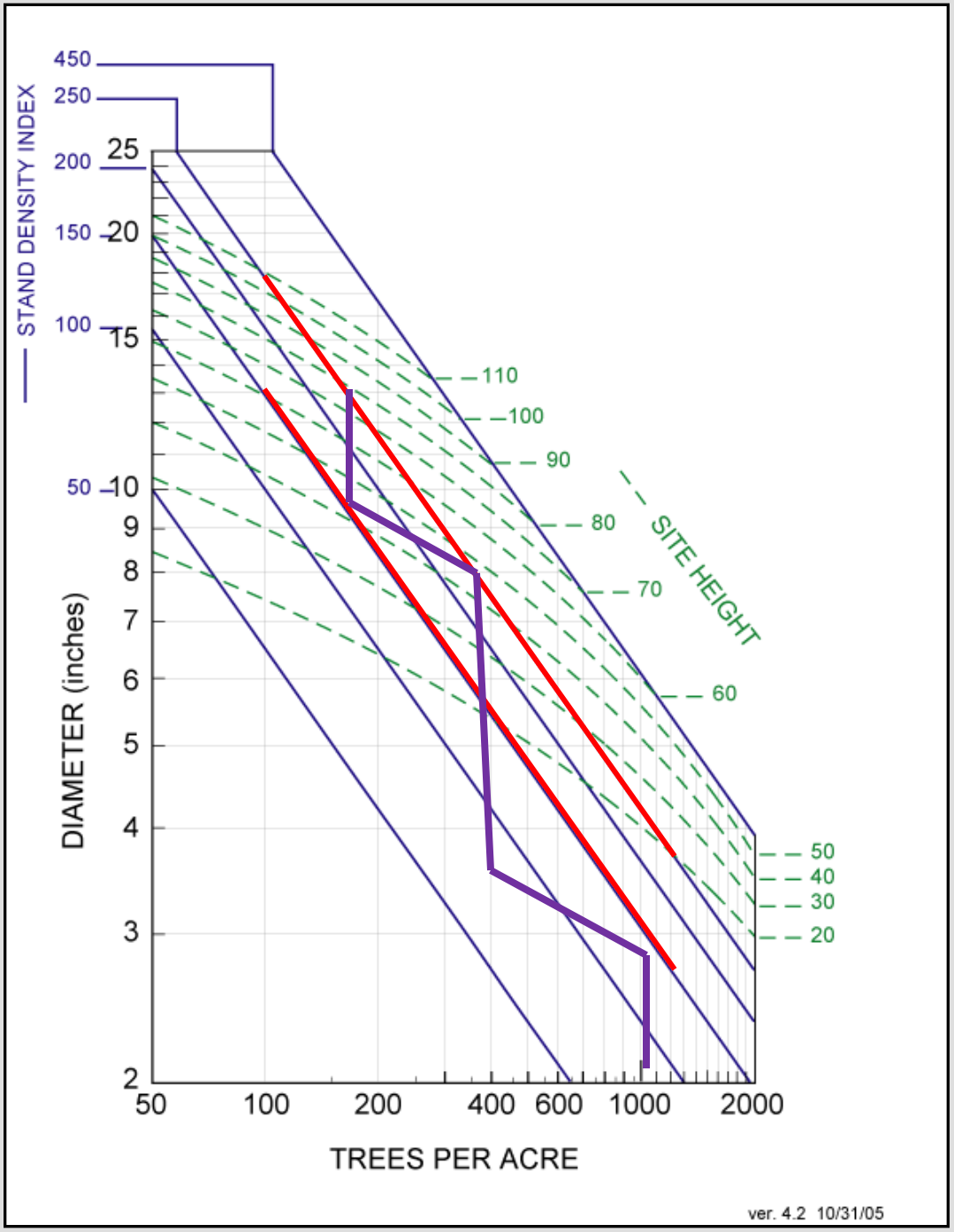
Examples of (situational) appropriate limits

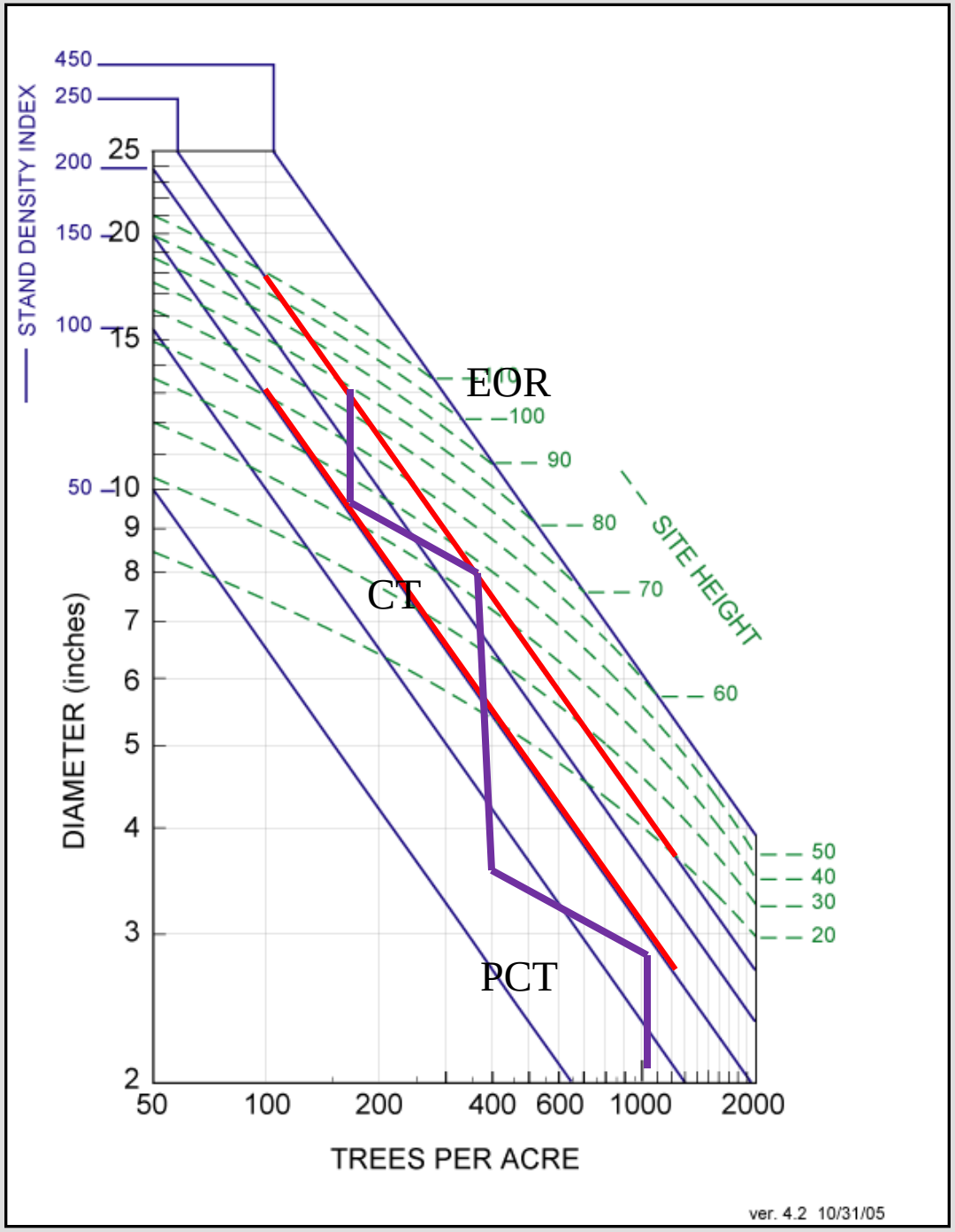
- Maintain vigor, avoid self-thinning < 60%
- Delay self-pruning < 25%
- Promote self-pruning > 25%
- Full site occupancy > 35%

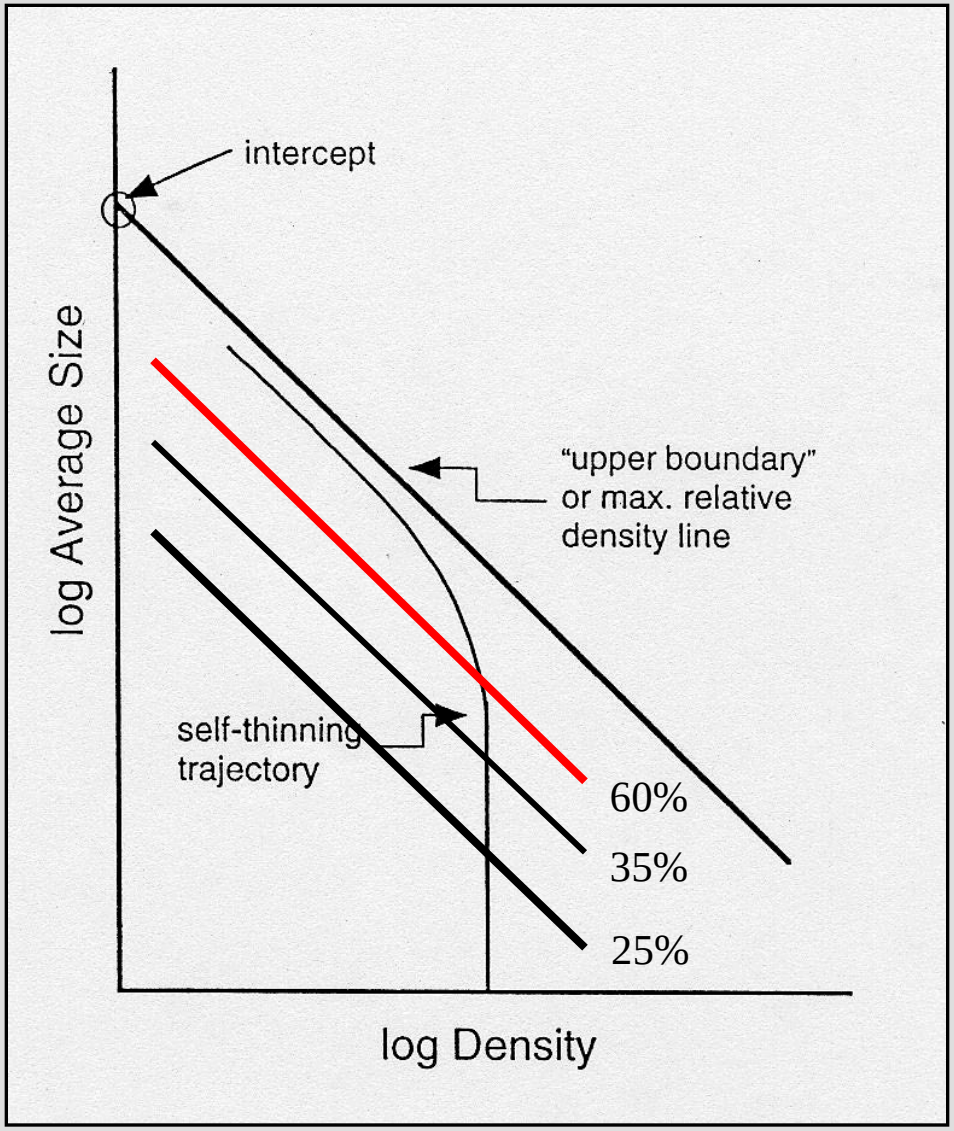

STAND DENSITY INDEX
450
250
200
150
100
50
25
20
15
10
9
8
7
6
5
4
3
2
DIAMETER (inches)
50
100
200
400
600
1000
2000
TREES PER ACRE
110
100
90
80
70
60
50
40
30
20
SITE HEIGHT
ver. 4.2 10/31/05


STAND DENSITY INDEX
450
250
200
150
100
50
25
20
15
10
9
8
7
6
5
4
3
2
DIAMETER (inches)
110
100
90
80
70
60
50
40
30
20
SITE HEIGHT
50
100
200
400
600
1000
2000
TREES PER ACRE
ver. 4.2 10/31/05


STAND DENSITY INDEX
450
250
200
150
100
50
25
20
15
10
9
8
7
6
5
4
3
2
DIAMETER (inches)
50
100
200
400
600
1000
2000
TREES PER ACRE
110
100
90
80
70
60
50
40
30
20
SITE HEIGHT
ver. 4.2 10/31/05


STAND DENSITY INDEX
450
250
200
150
100
50
25
20
15
10
9
8
7
6
5
4
3
2
DIAMETER (inches)
110
100
90
80
70
60
50
40
30
20
SITE HEIGHT
50
100
200
400
600
1000
2000
TREES PER ACRE
ver. 4.2 10/31/05


STAND DENSITY INDEX
450
250
200
150
100
50
25
20
15
10
9
8
7
6
5
4
3
2
DIAMETER (inches)
EOR
CT
PCT
SITE HEIGHT
100
90
80
70
60
50
40
30
20
50
100
200
400
600
1000
2000
TREES PER ACRE
ver. 4.2 10/31/05



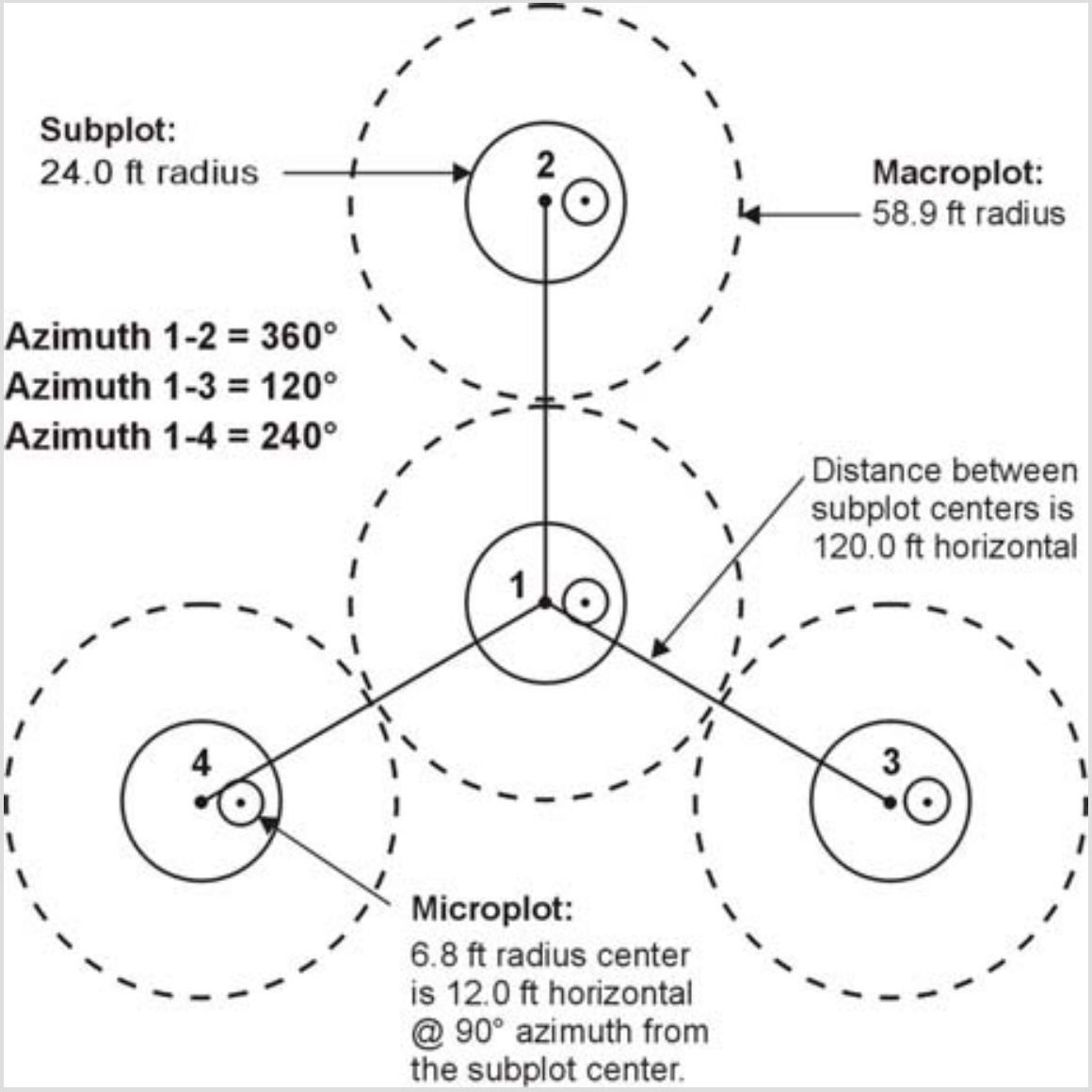
Utility depends on appropriate estimates of species- and site-specific SDI_{max}

Estimating SDI_{max}

- FIA database
- ‘pure’ stands were those with 80% or more basal area of the target species
- This breakpoint is a compromise

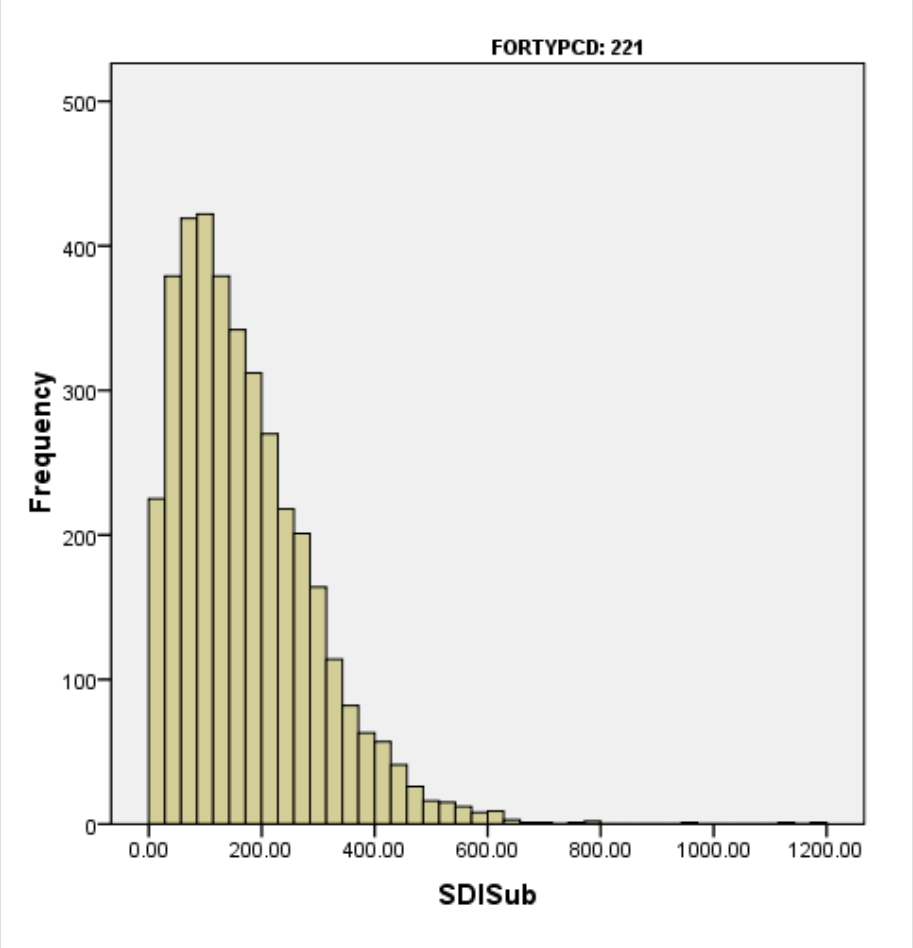
Estimating SDI_{max}

- SDI_{max} is theoretical maximum relative density of a species or mixture of species
- It is only observed at fairly small scales (i.e., homogeneous ‘crowded’ patches)
- Therefore estimates of SDI_{max} should avoid the paradox of a stand-level maximum which can be exceeded at small scales of silvicultural manipulation


Subplot:
24.0 ft radius
2
Macroplot:
58.9 ft radius
Azimuth 1-2 = 360°
Azimuth 1-3 = 120°
Azimuth 1-4 = 240°
Distance between
subplot centers is
120.0 ft horizontal
1
4
3
Microplot:
6.8 ft radius center
is 12.0 ft horizontal
@ 90° azimuth from
the subplot center.

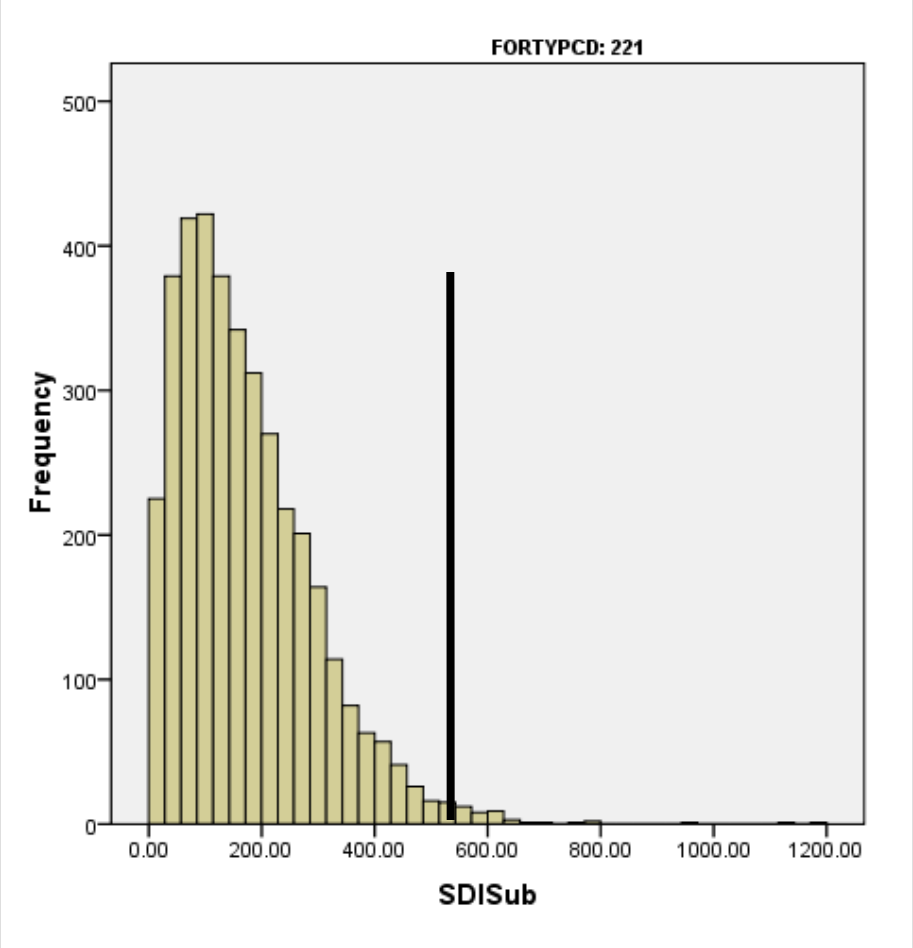
Estimating SDI_{max}

Subplot



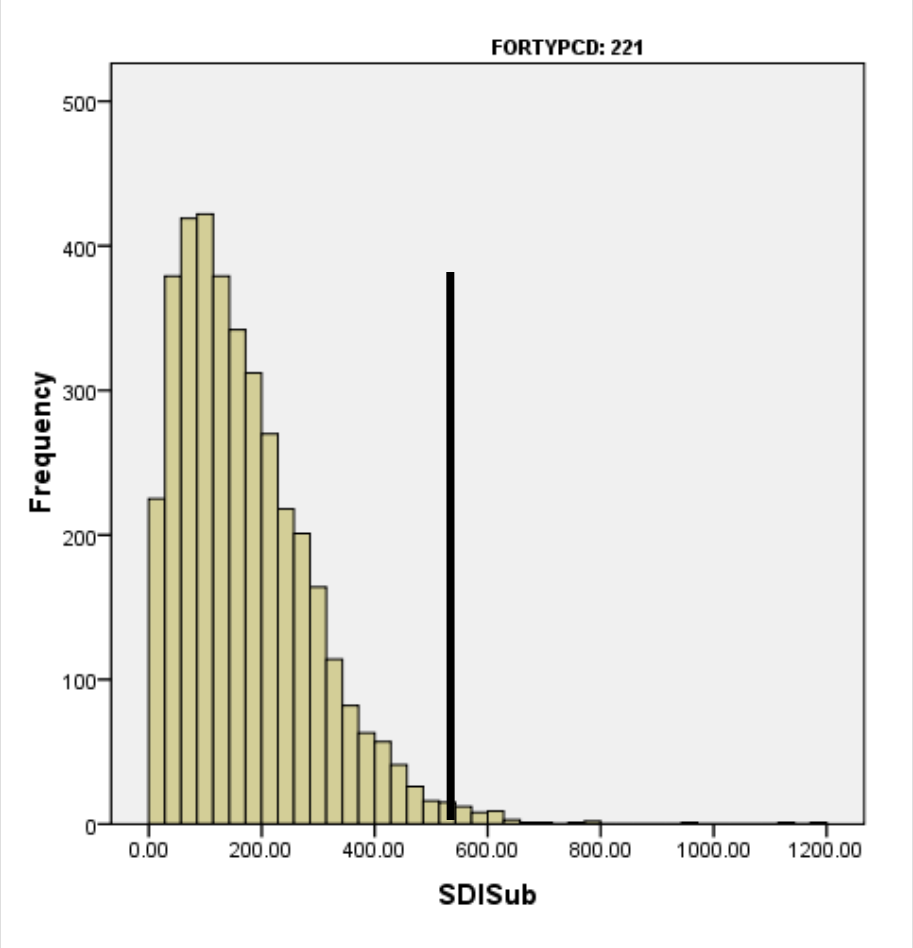
Ponderosa pine
N = 3785

Estimating SDI_{max}
Subplot, 98th percentile

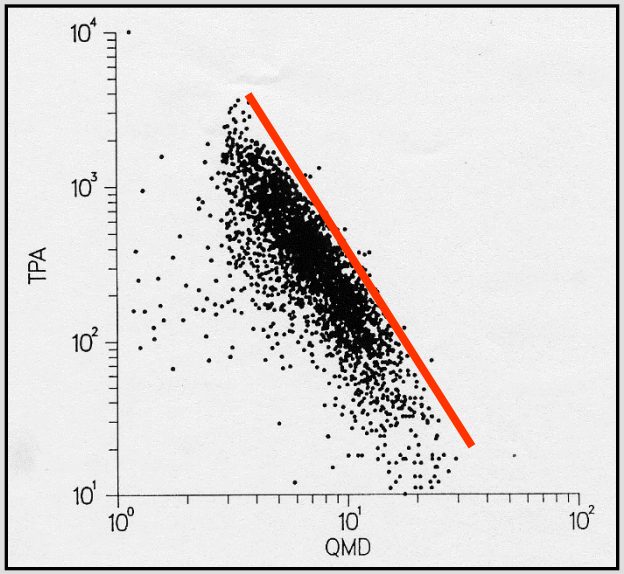


Ponderosa pine
N = 3785
SDImax = 480

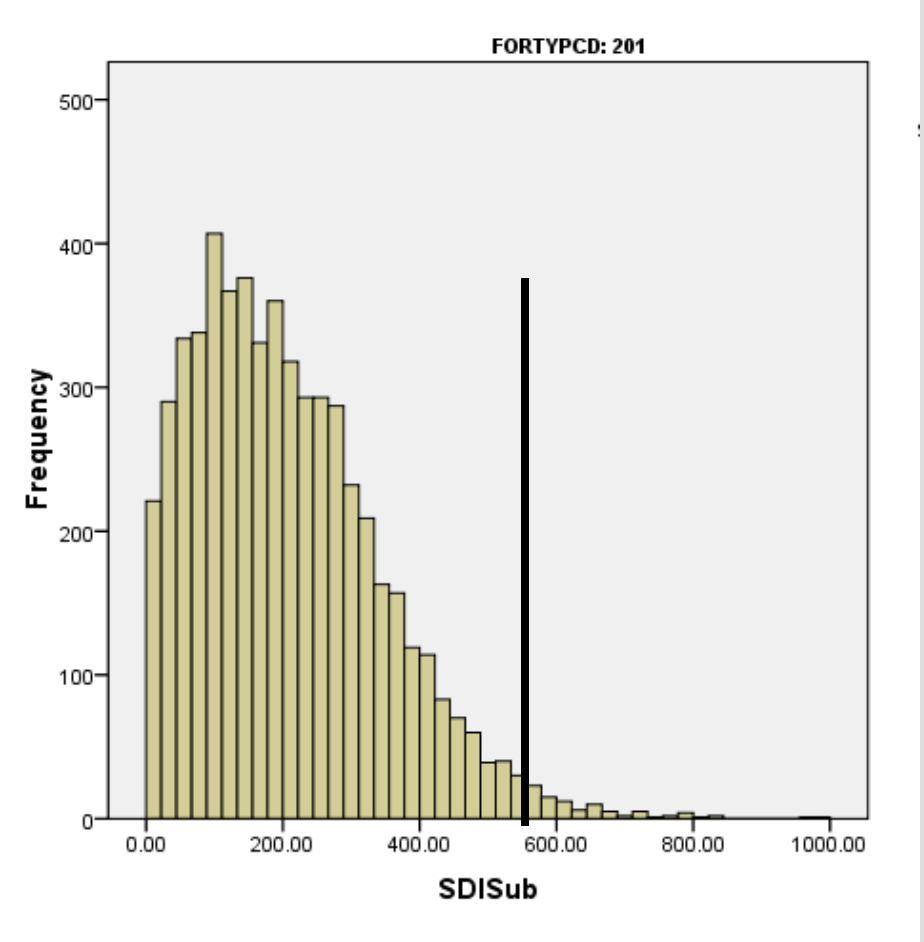
Estimating SDImax
Subplot, 98th percentile



Ponderosa pine
N = 3785
SDImax = 480



Estimating SDI_{max}
Subplot, 98th percentile



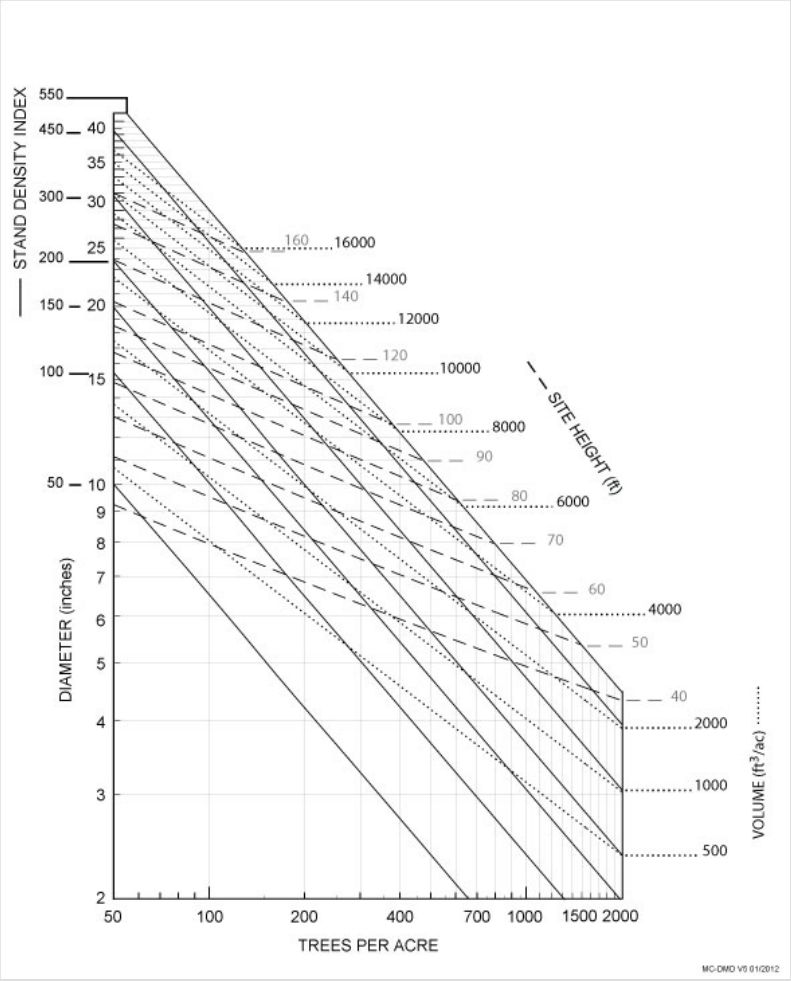
Douglas-fir
N = 5621
SDImax = 537

Estimating SDI_{max}

- Results (for most, not all) species are consistent with ‘benchmark’ SDI_{max}
- For some species, there are considerable differences compared to various estimates (e.g., Reineke’s estimate for ponderosa pine)

Estimating SDI_{max}

- Relative tolerance
- Congeners
- Compatible mixtures



Sierra Nevada mixed-conifer DMD

Estimating SDI_{max}

- Are these results consistent with postulate that SDI_{max} is independent of site quality?

Estimating SDI_{max}

- Are these results consistent with postulate that SDI_{max} is independent of site quality?
- For several important species with broad ecological amplitudes in RM, estimates of SDI_{max} differ as much 25% between xeric and mesic sites

Summary

- Size-density relationships are basis for indexing relative density
- An index of relative density is the basic tool for translating qualitative objectives into a quantitative density management regime

Summary

- We use SDI to:
  - assess current stand condition;
  - characterize desired future condition; and
  - develop a tactical plan for achieving DFC

Summary

- Utility depends on appropriate estimates of species- and site-specific SDI_{max}
- There is a way to objectively estimate SDI_{max}
- Results are not consistent with postulate that SDI_{max} is independent of site quality

John D. Shaw, RMRS FIA