Stand dynamics, fire frequency, and carbon storage across lodgepole pine landscapes of the Rocky Mountains

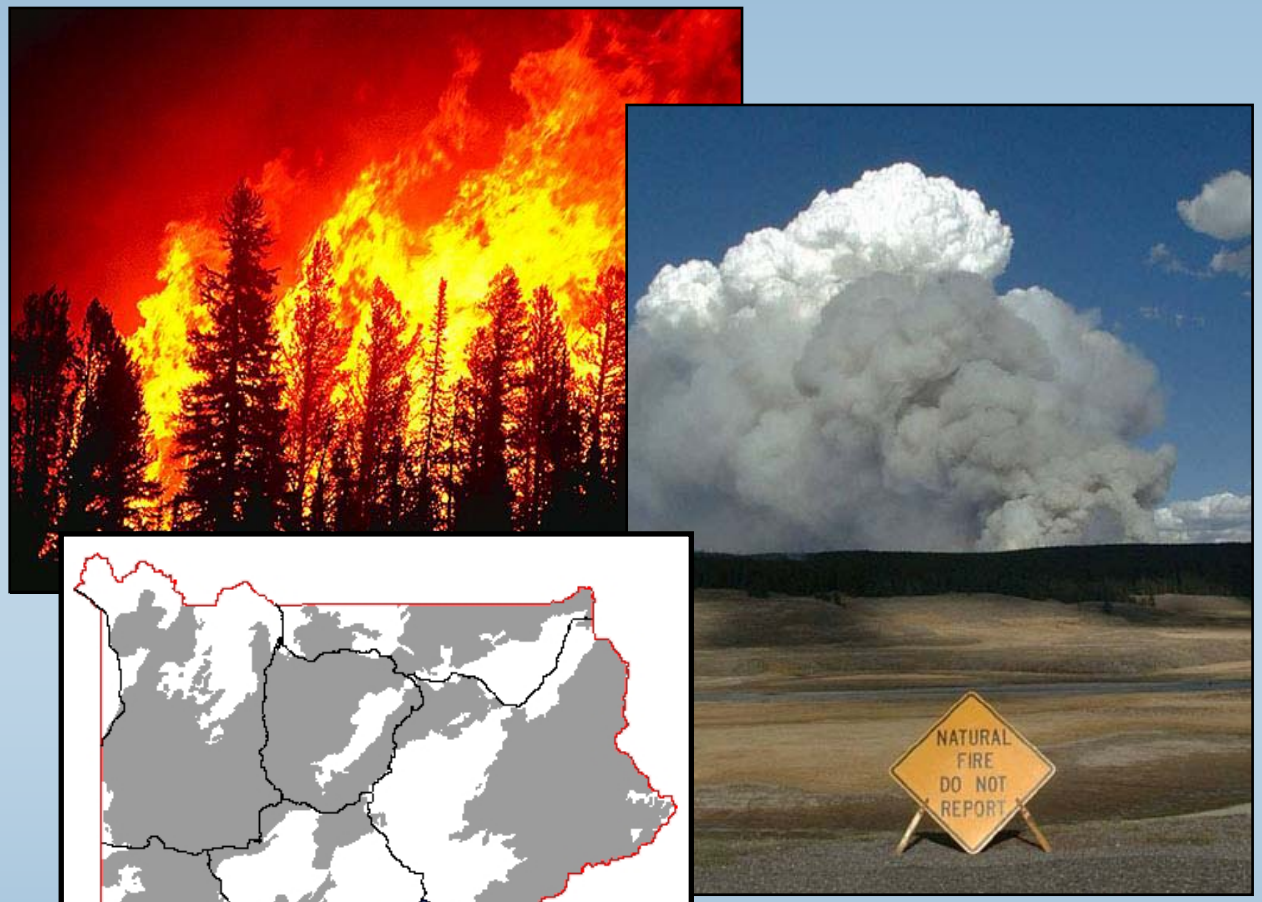
Dan Kashian

Department of Biological Sciences
Wayne State University

Outline

- The 1988 fires in Yellowstone
  - Post-fire heterogeneity in forest regeneration
- Variability and convergence in forest structure
- Climate change and carbon cycling on the Yellowstone landscape
- Variability in carbon storage with stand age and density: The Data

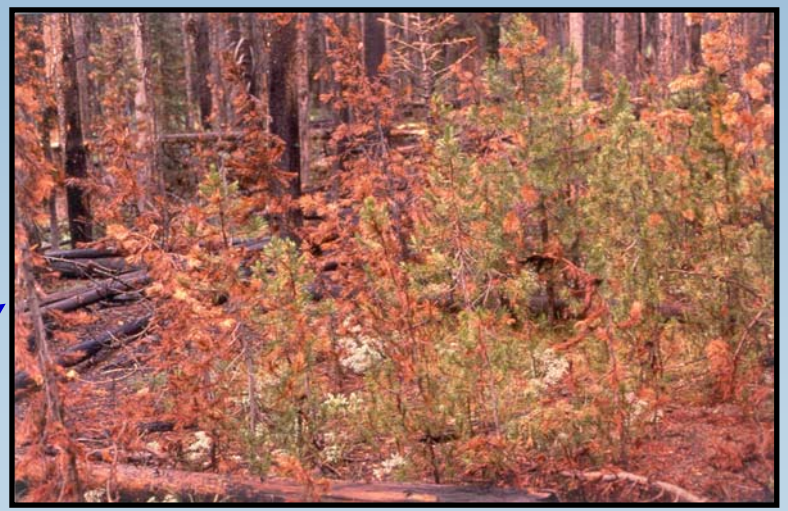
The Yellowstone landscape



- Stand-replacing fires
- 100-300 year fire interval
- Large, "natural" landscape

Variation in burn severity

Yellowstone Burn Mosaic, 10/88

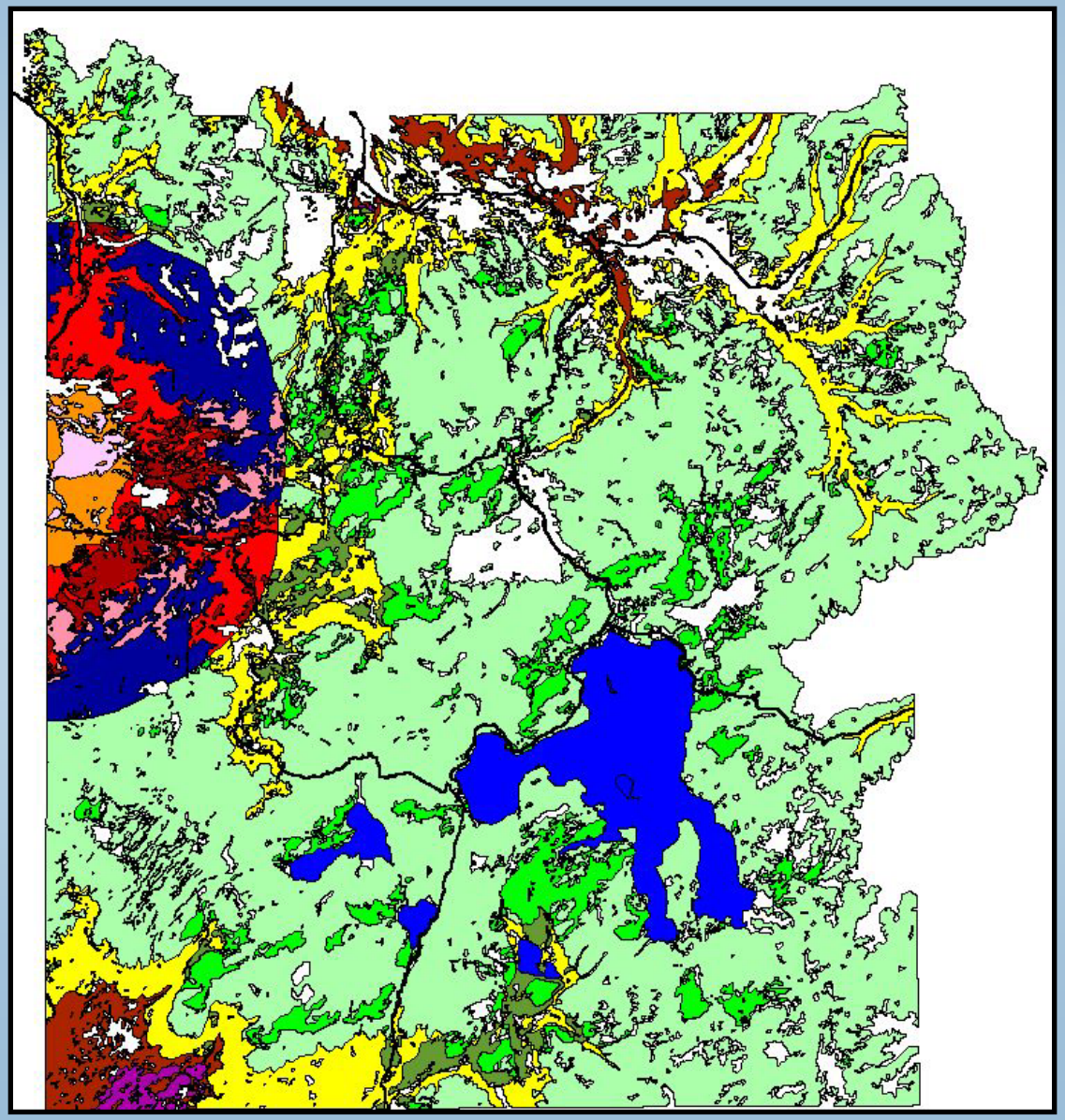


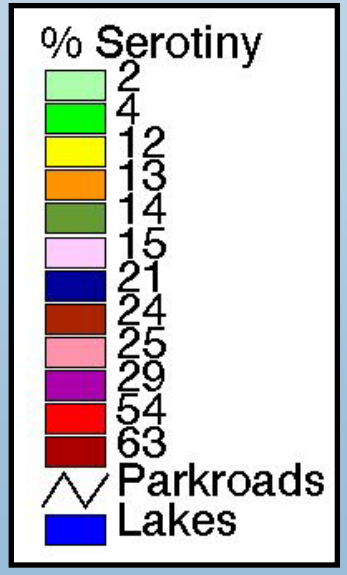
Light/Severe Surface Fire

Severe Surface/Crown Fire

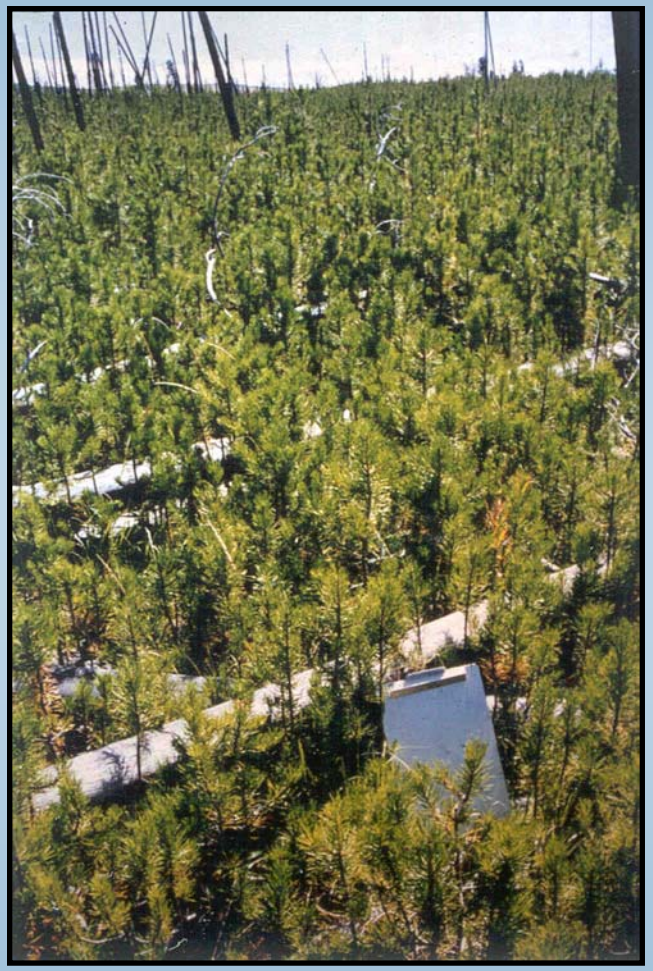
Serotiny in lodgepole pine

Variation in lodgepole pine serotiny





Variation in regeneration density

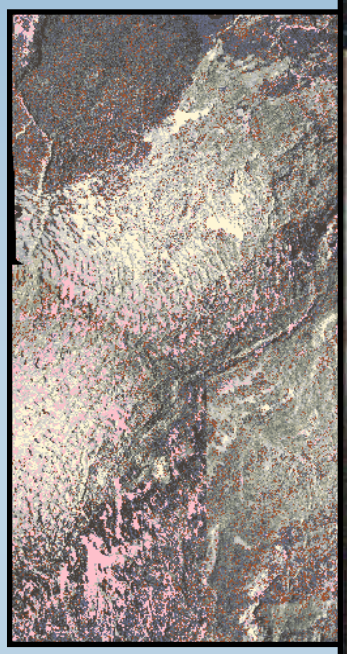


>50,000 stems/ha

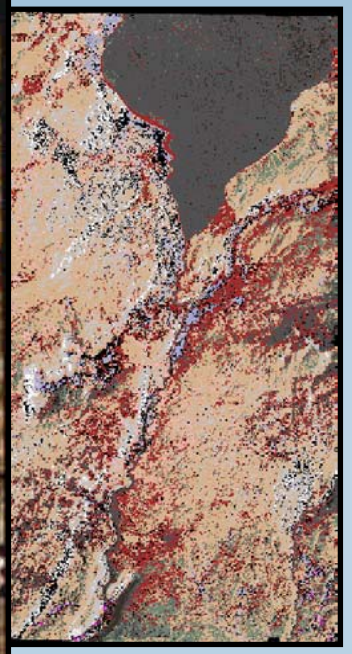
1,000 stems/ha

0 stems/ha

Mapping regeneration density



Orthore

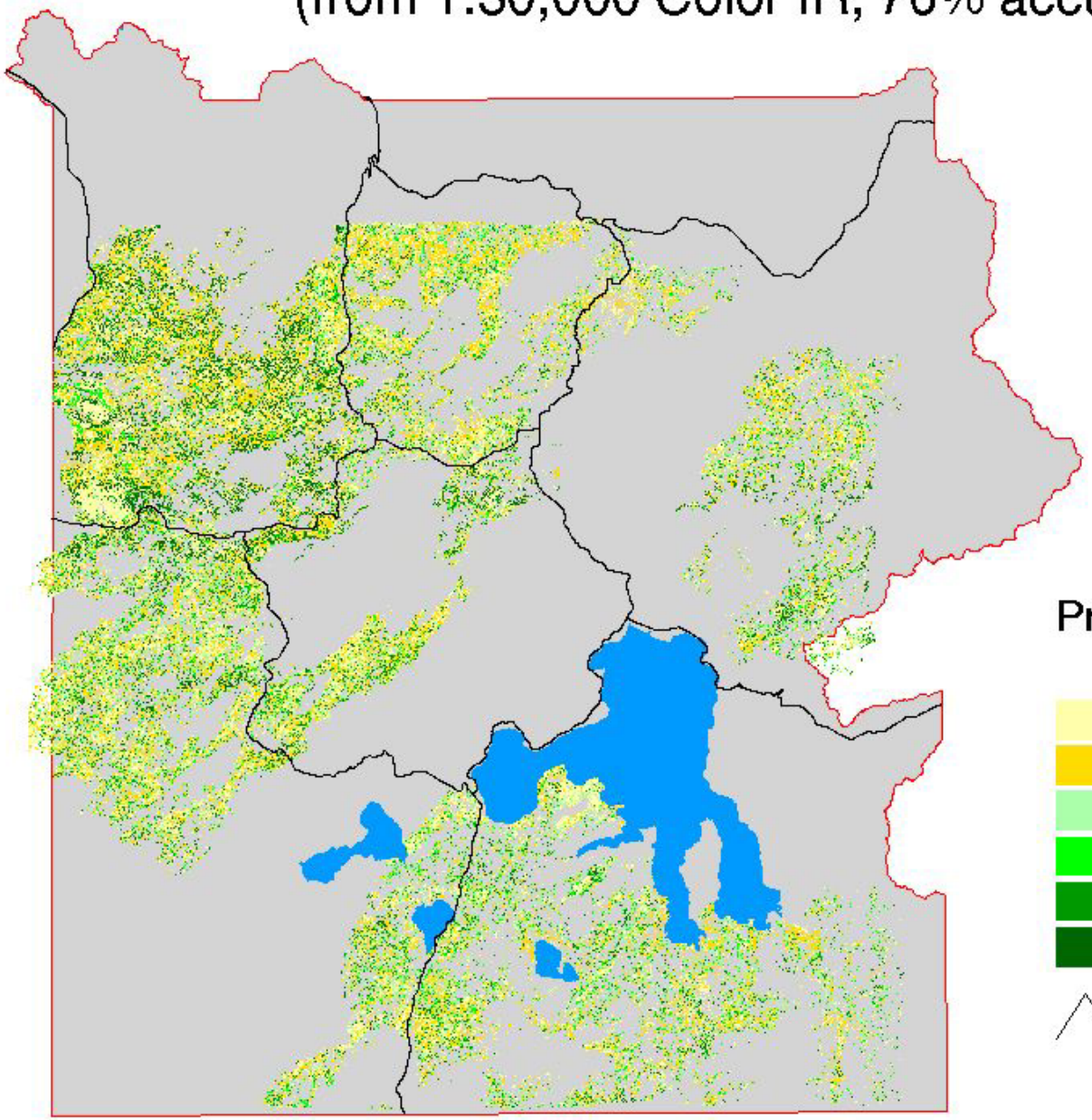


ised

cation

1998 Lodgepole Pine Sapling Density

(from 1:30,000 Color IR, 76% accuracy)



N

5 0 5 10

Kilometers

Predicted Sapling Density
(stems/ha)

- 0-1000
- 1001-5000
- 5001-10000
- 10001-20000
- 20001-50000
- >50000

Park Roads

Do initially dissimilar stand structures eventually converge?

???

???

Stand Structure Methods

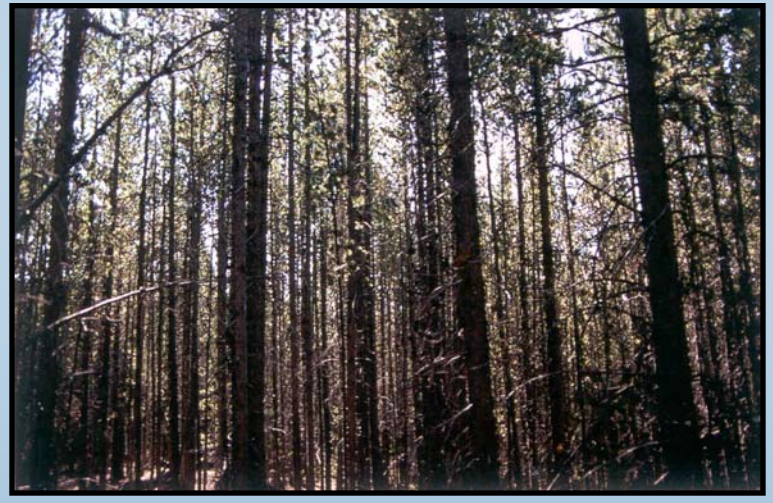
- Chronosequential measurements of unburned stands across the landscape.

- Analyses of size and age structures and spatial patterns

- Regression analyses to reconstruct past density of stands using tree ring widths.

Variation in Stand Density

Stands shown are in the 50-100 year age class

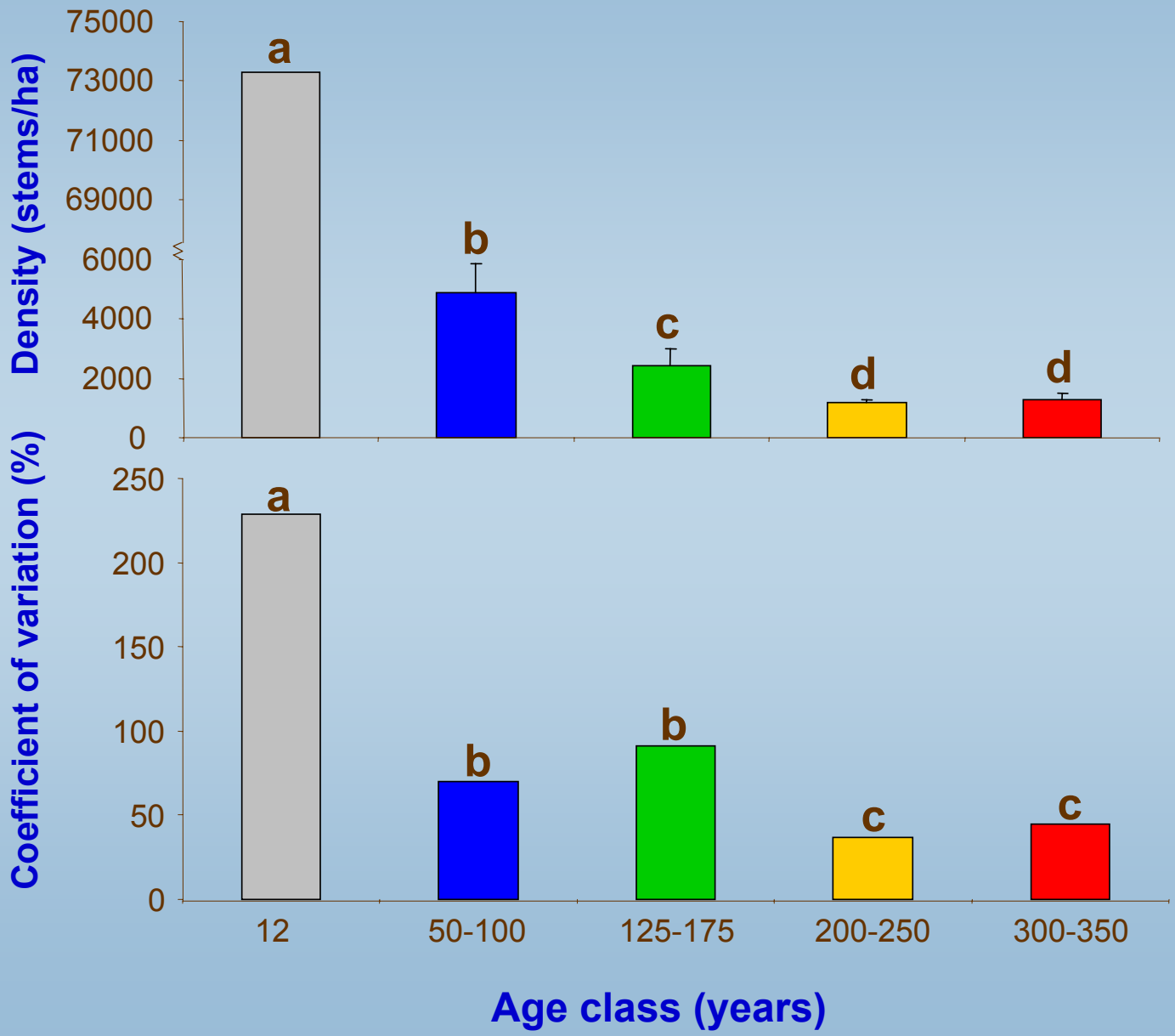


11,000 stems/ha

3,000 stems/ha

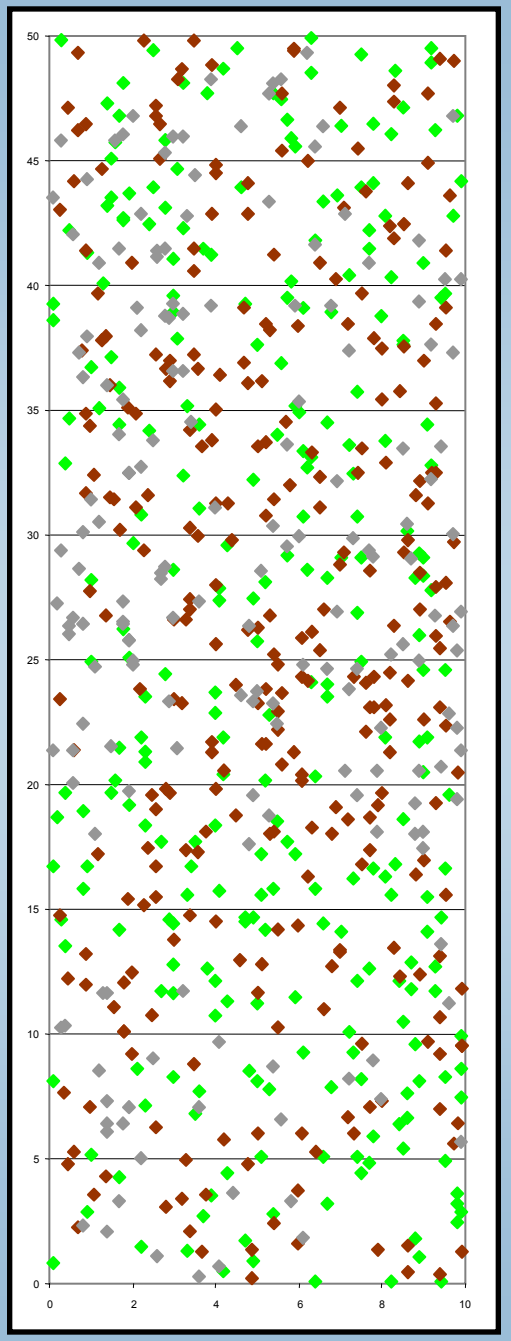
1,100 stems/ha

Variation and change in stand density with age



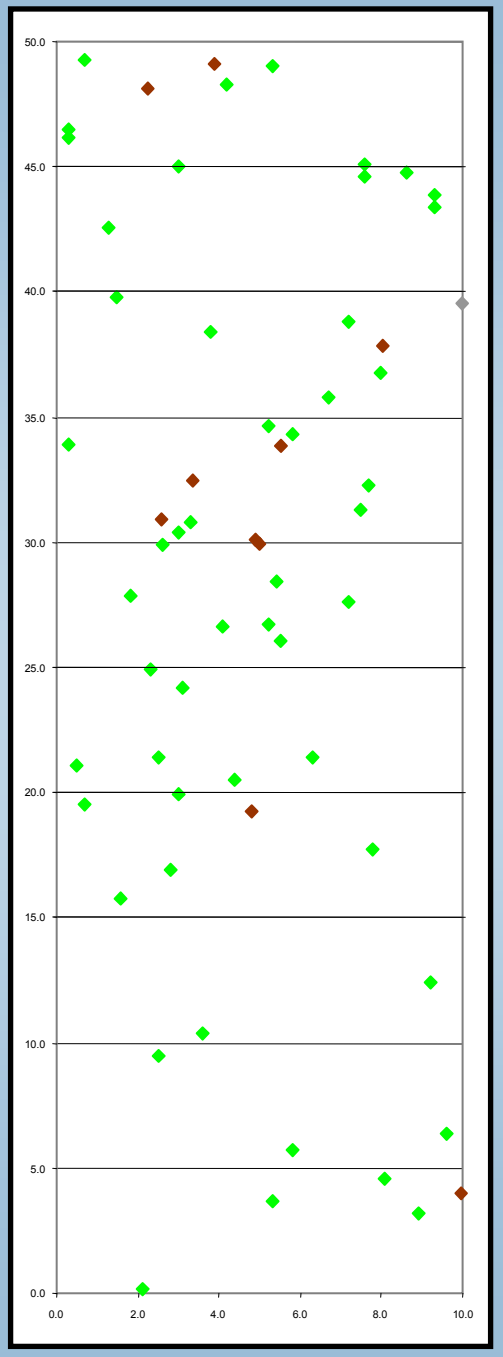
Stand A: Initially dense

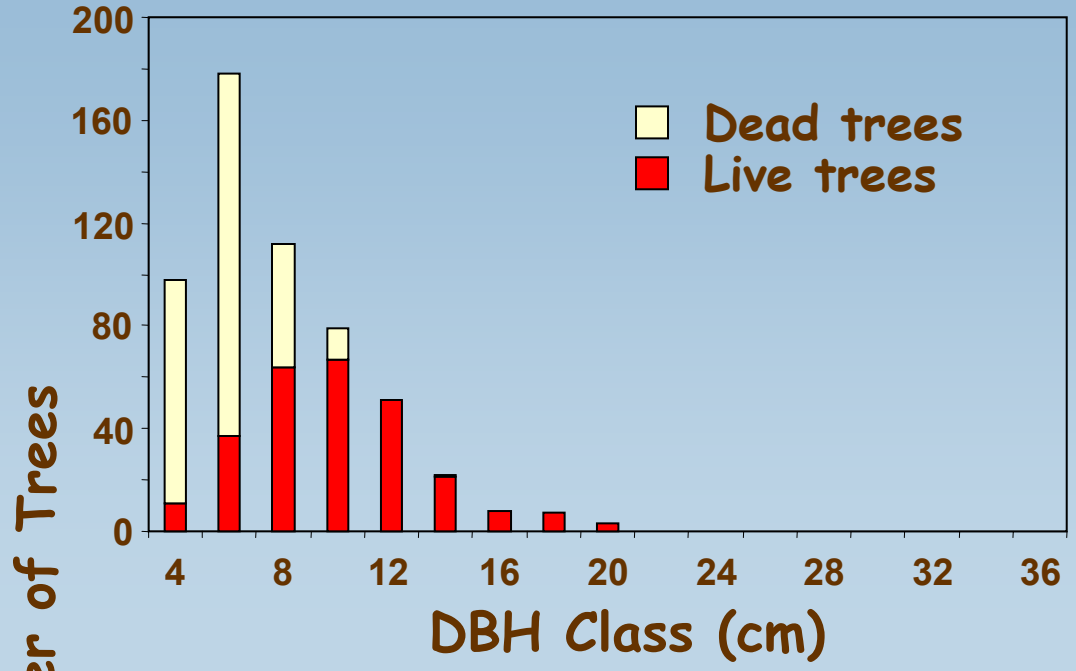
Age: 130 years
Density: 5,400 stems/ha

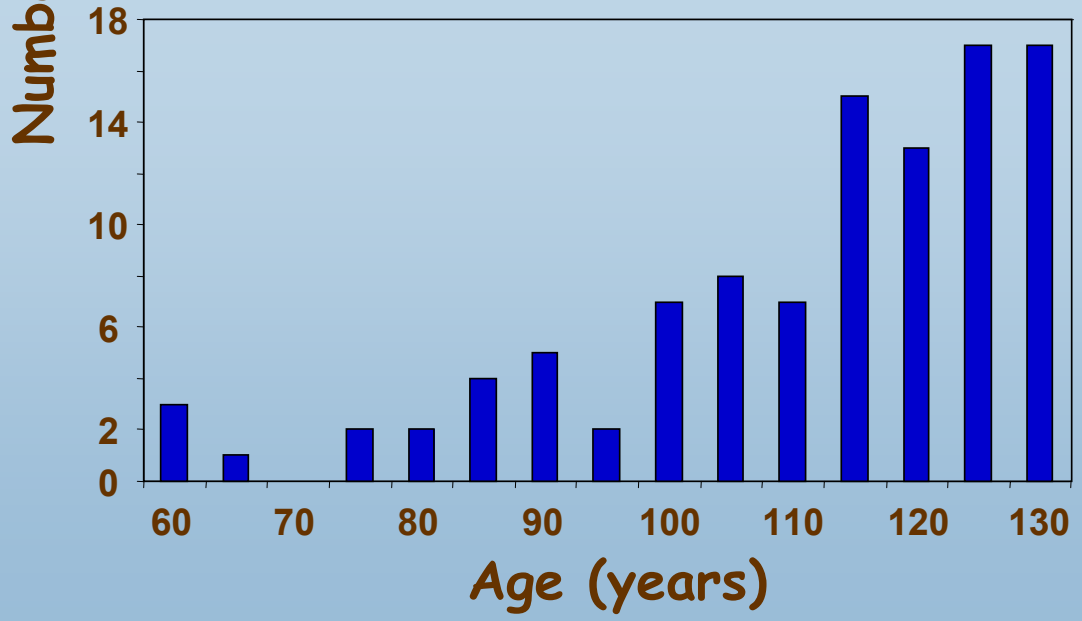


Stand B: Initially sparse

Age: 130 years
Density: 1,020 stems/ha

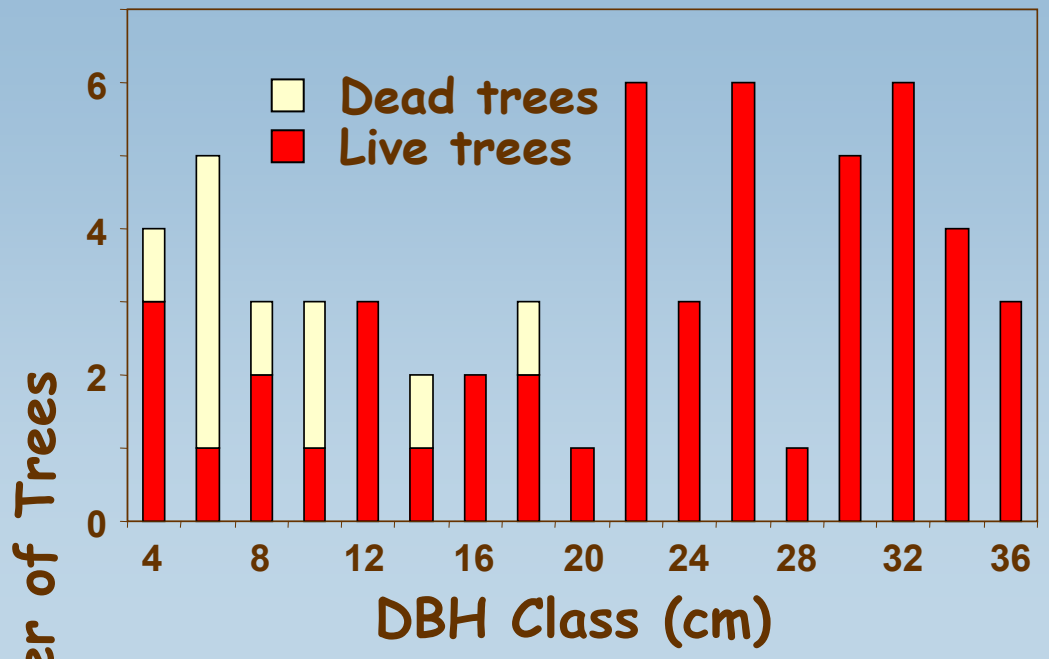


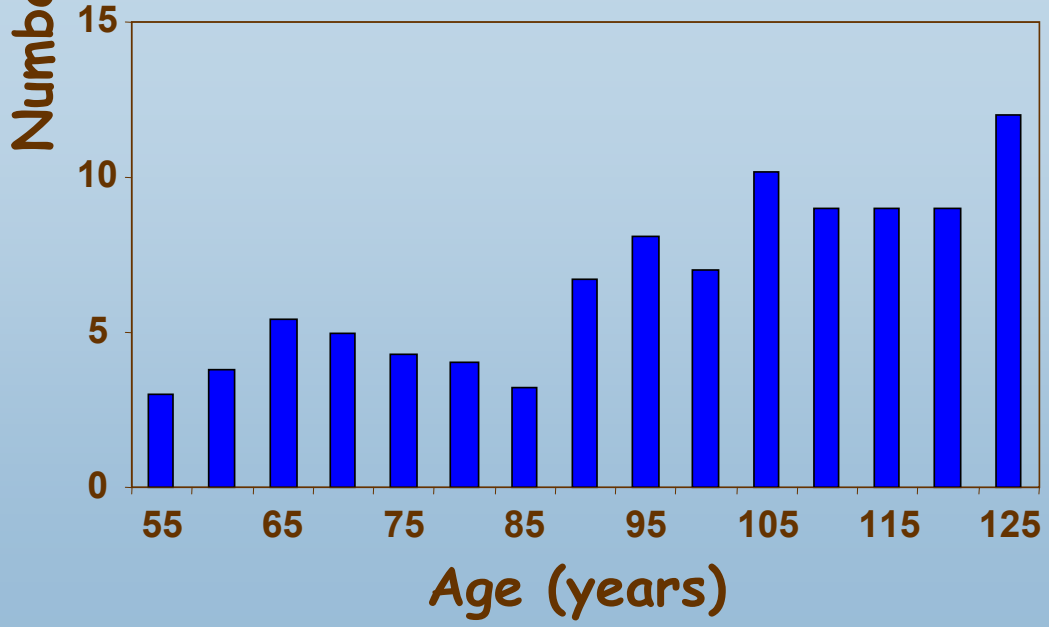




Initially dense stand

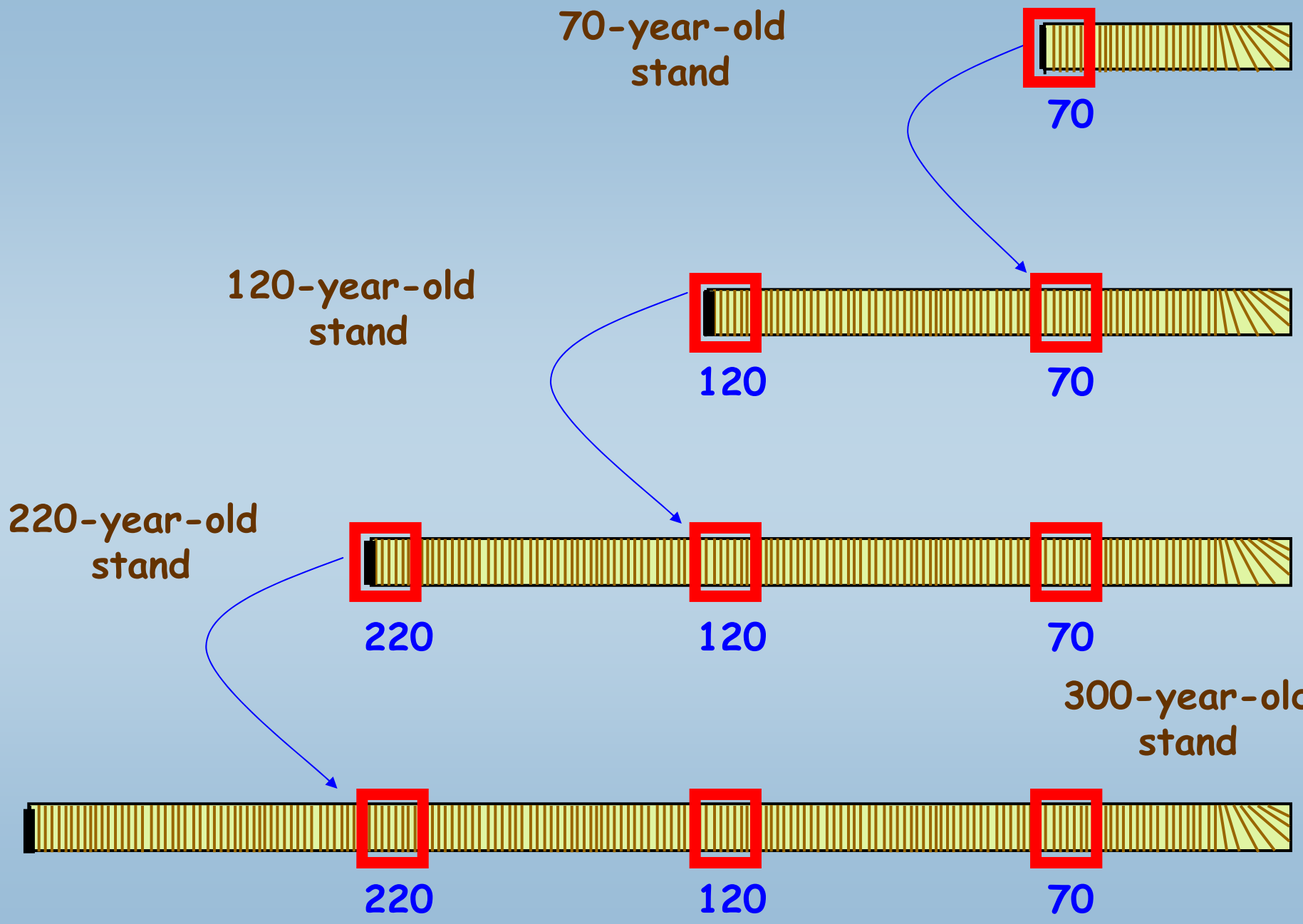
- Unimodal, steep distributions
- Dead trees common and small



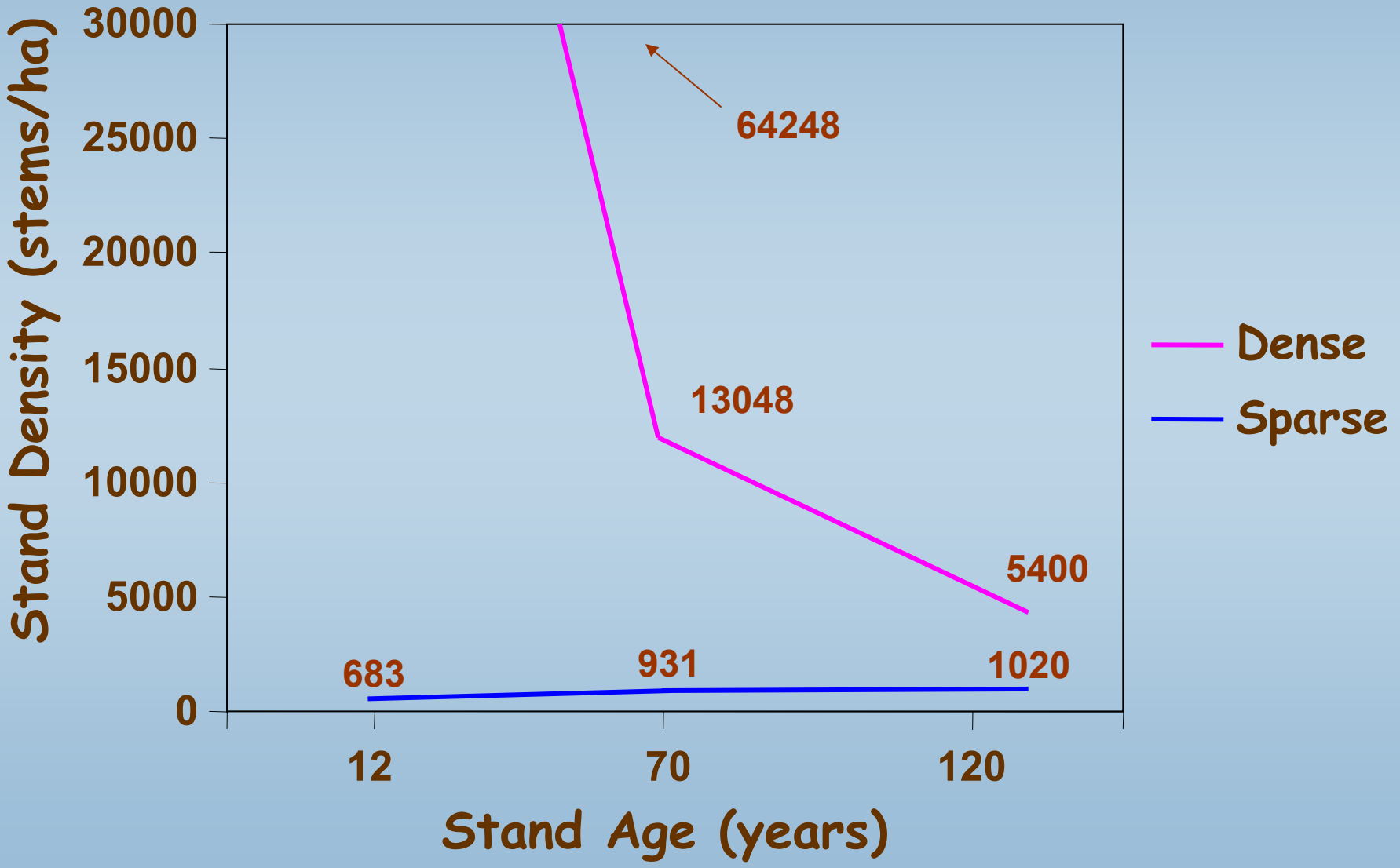


Initially sparse stand

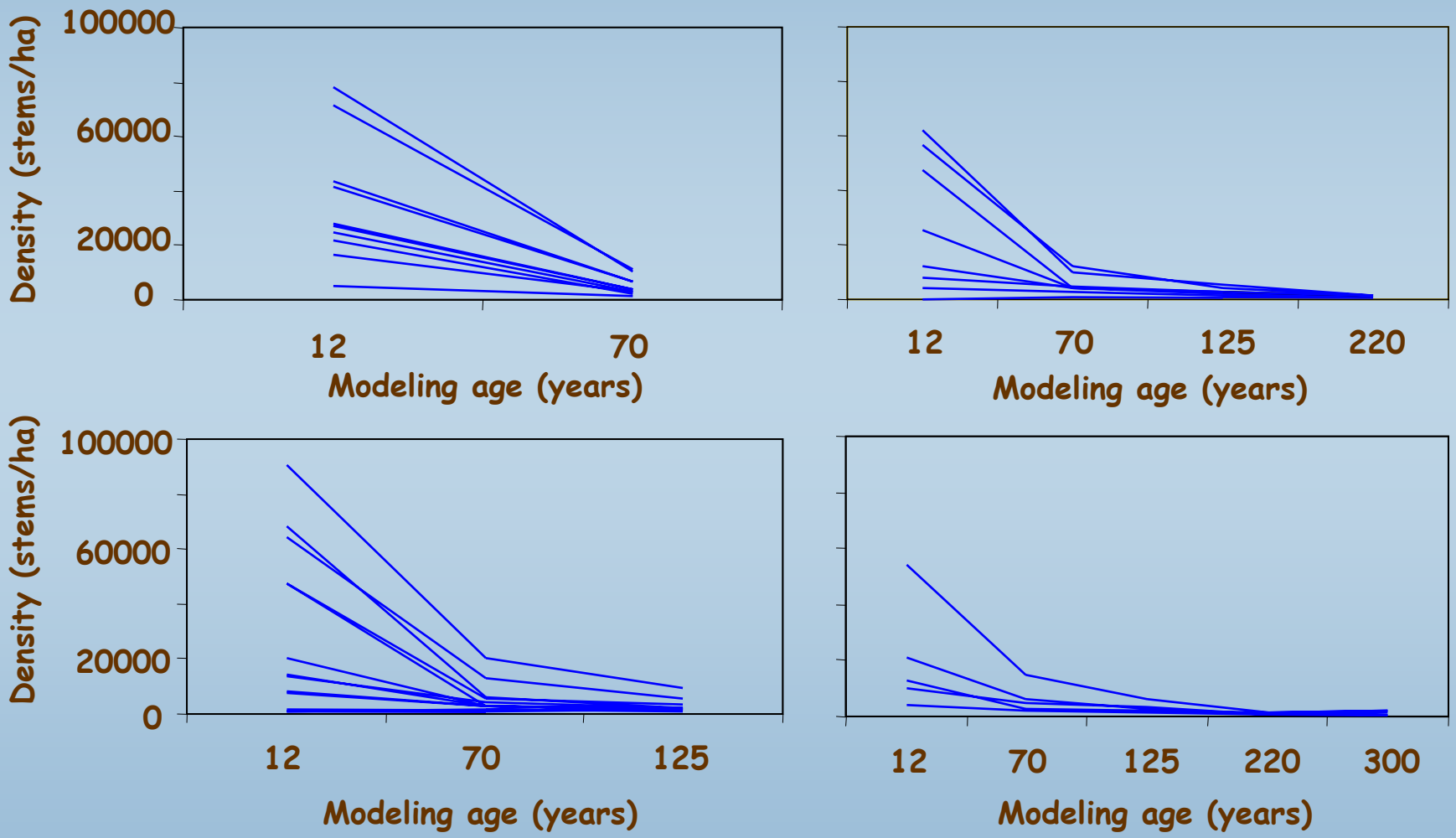
- Bimodal or wide distributions
- Dead trees much less common


70-year-old stand
70
120-year-old stand
120
70
220-year-old stand
220
120
70
300-year-old stand
220
120
70

Stand Density Trajectory Reconstruction



Stand Density Trajectory Reconstructions



Conclusions: Structure

- Structural variability is related to initial variation in postfire density but converges near 200 years.

What are the implications of dissimilar stand structures for landscape carbon storage?

- How sensitive is landscape carbon storage to large disturbances (short-term)?

- How sensitive is landscape carbon storage to changes in disturbance regimes (long-term)?

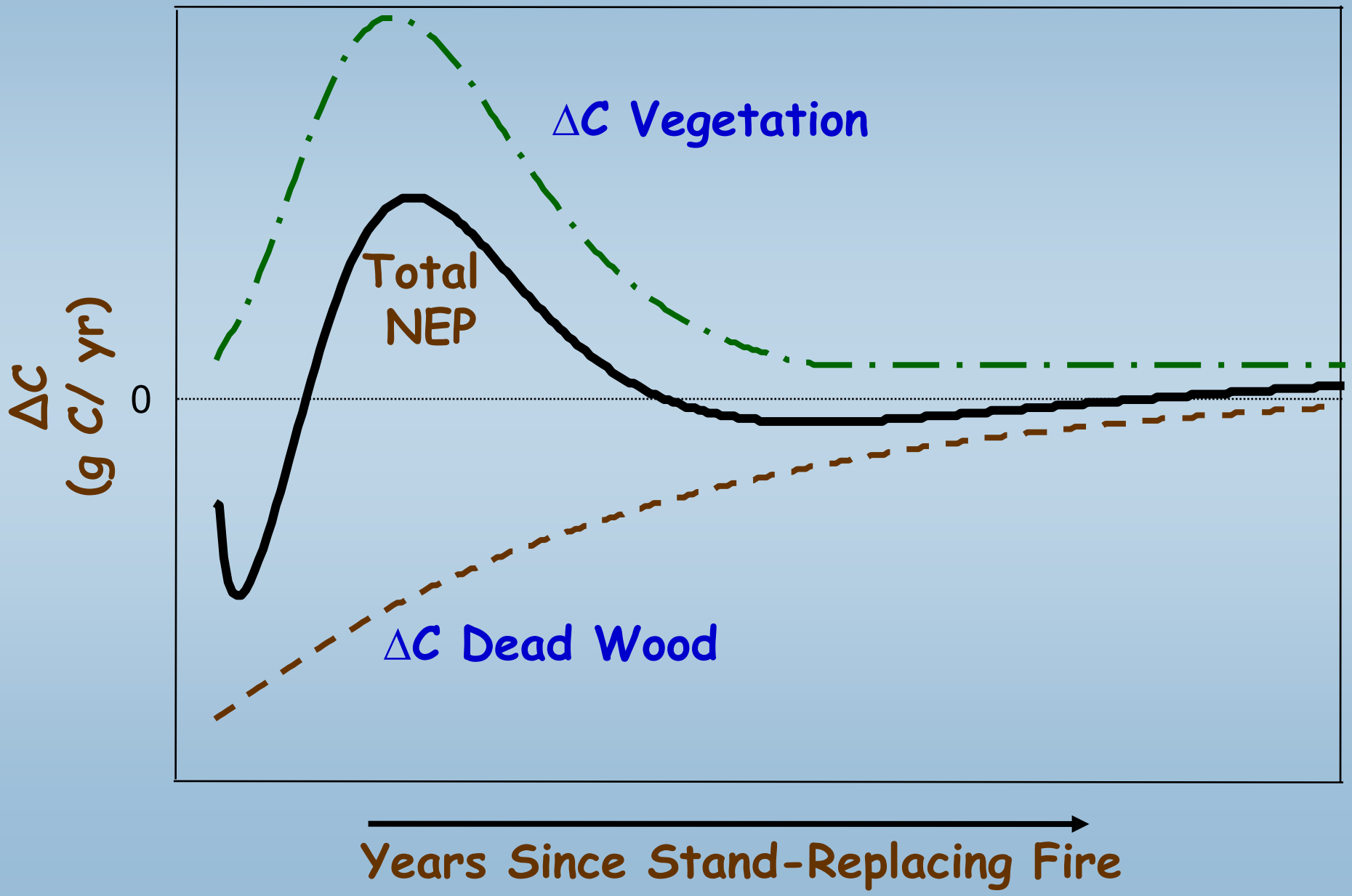
Landscape carbon storage is affected by:

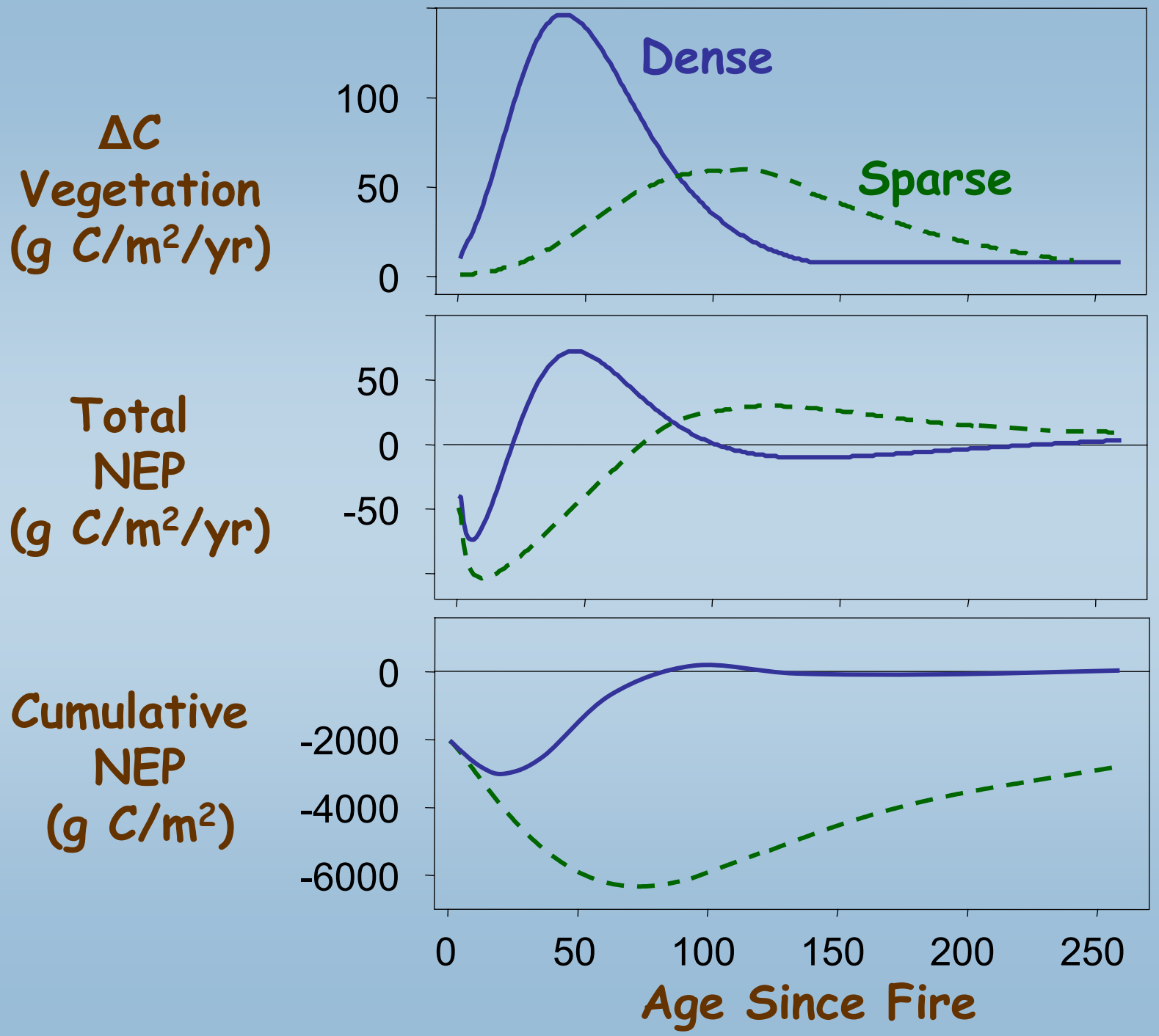
- **Balance** between C accumulating in vegetation and forest floor and C lost through decomposition of dead wood.

- Changes in the **stand density distribution** across the landscape following fires.

- Changes in the **stand age distribution** across the landscape following fires.

NEP = C gained (NPP) – C lost (decomposition)




ΔC
Vegetation
(g C/m²/yr)
Dense
Sparse
100
50
0
Total
NEP
(g C/m²/yr)
50
0
-50
Cumulative
NEP
(g C/m²)
0
-2000
-4000
-6000
0
50
100
150
200
250
Age Since Fire

Do stand structures "replace themselves"?

Sparse pre-fire

Sparse post-fire

Little change = in C stored over fire cycle

Dense pre-fire

Dense post-fire

Little change = in C stored over fire cycle

Do stand structures "replace themselves"?

Sparse pre-fire

Sparse post-fire

= C lost over fire cycle

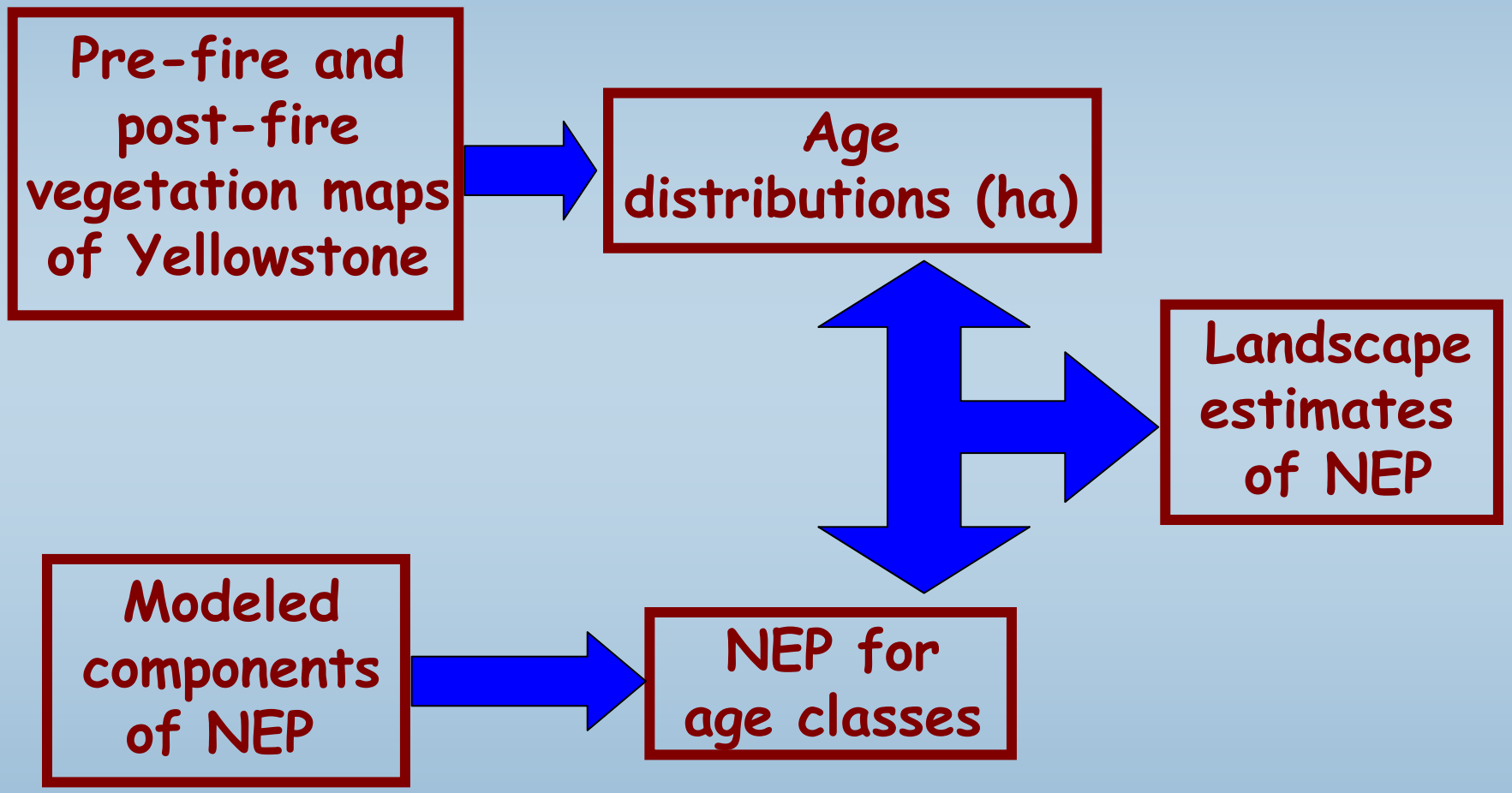
Dense pre-fire

Dense post-fire

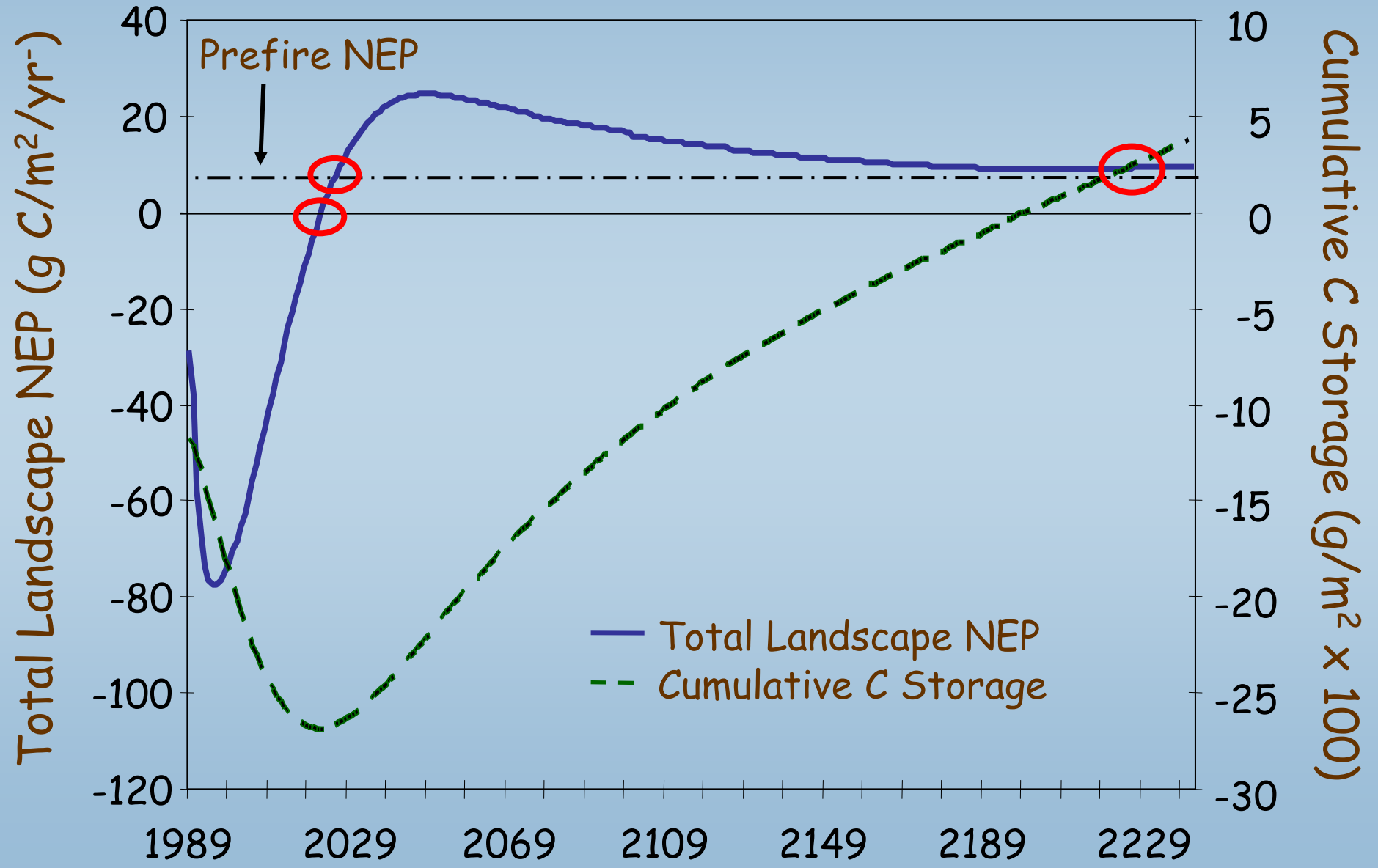
= C gained over fire cycle

Stand age distributions affect landscape NEP

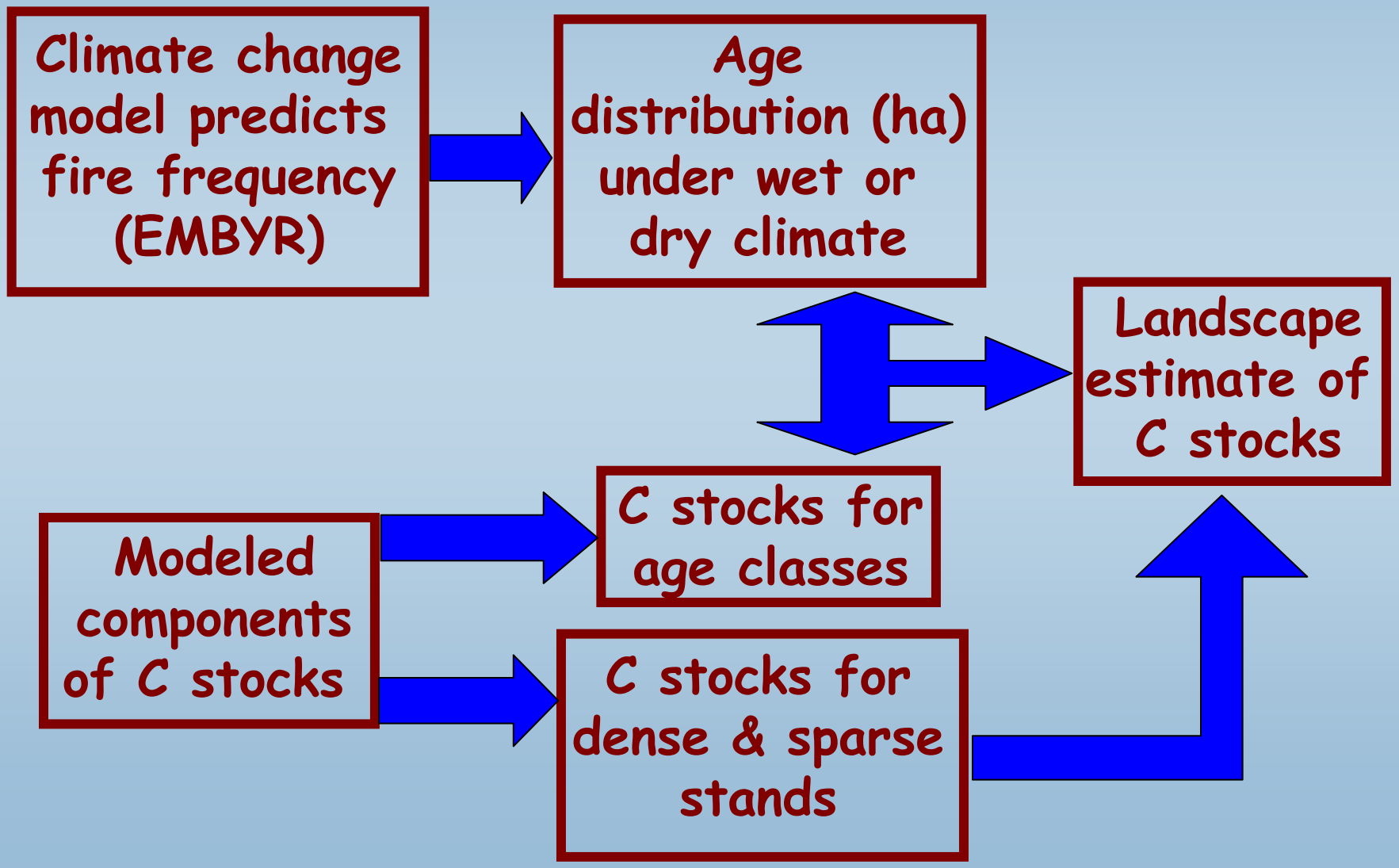
Modeling future landscape C storage for Yellowstone



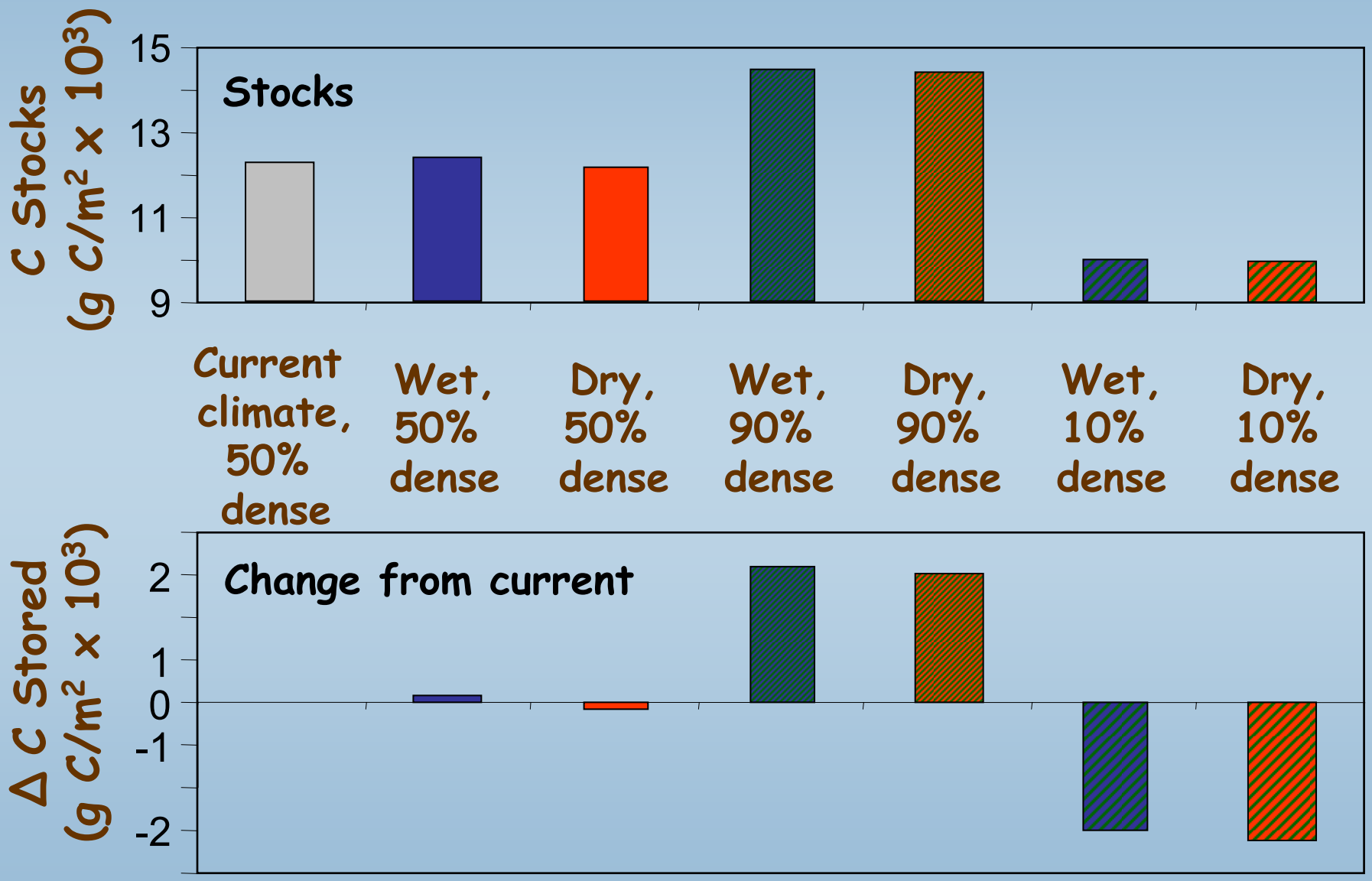
Post-fire changes in C storage for Yellowstone



Modeling stand age and density effects on landscape C storage



Stand age and density effects on C storage



Landscape Conclusions:

- Equilibrium C storage is resistant to changes in disturbance regimes at landscape scales.

- Large changes in the distribution of stand densities on the landscape are necessary to shift its ability to store carbon.

- The post-1988 Yellowstone landscape will recover all carbon lost within the fire cycle (~230 years), but it is currently a large source of C to the atmosphere.

What are the implications of dissimilar stand structures for carbon storage?

- How closely related are carbon stocks (esp. live biomass and dead wood) to stand age?

- How do carbon stocks vary with stand density?

Methods:

- Replicated chronosequences (n=77 stands);

Age classes:
< 25 years
40-70 years
80-130 years
170-230 years
> 250 years

Methods:

- Replicated chronosequences (n=77 stands);

High density

Density classes:

< 25	>50,000 st/ha
40-70	> 5,000 st/ha
80-130	> 5,000 st/ha
170-230	Beetle killed
> 250	Beetle killed

Methods:

- Replicated chronosequences (n=77 stands);

Moderate density

Density classes:

< 25	7-40,000 st/ha
40-70	1,300-5,000 st/ha
80-130	1,300-5,000 st/ha

Methods:

- Replicated chronosequences (n=77 stands);

Low density

Density classes:

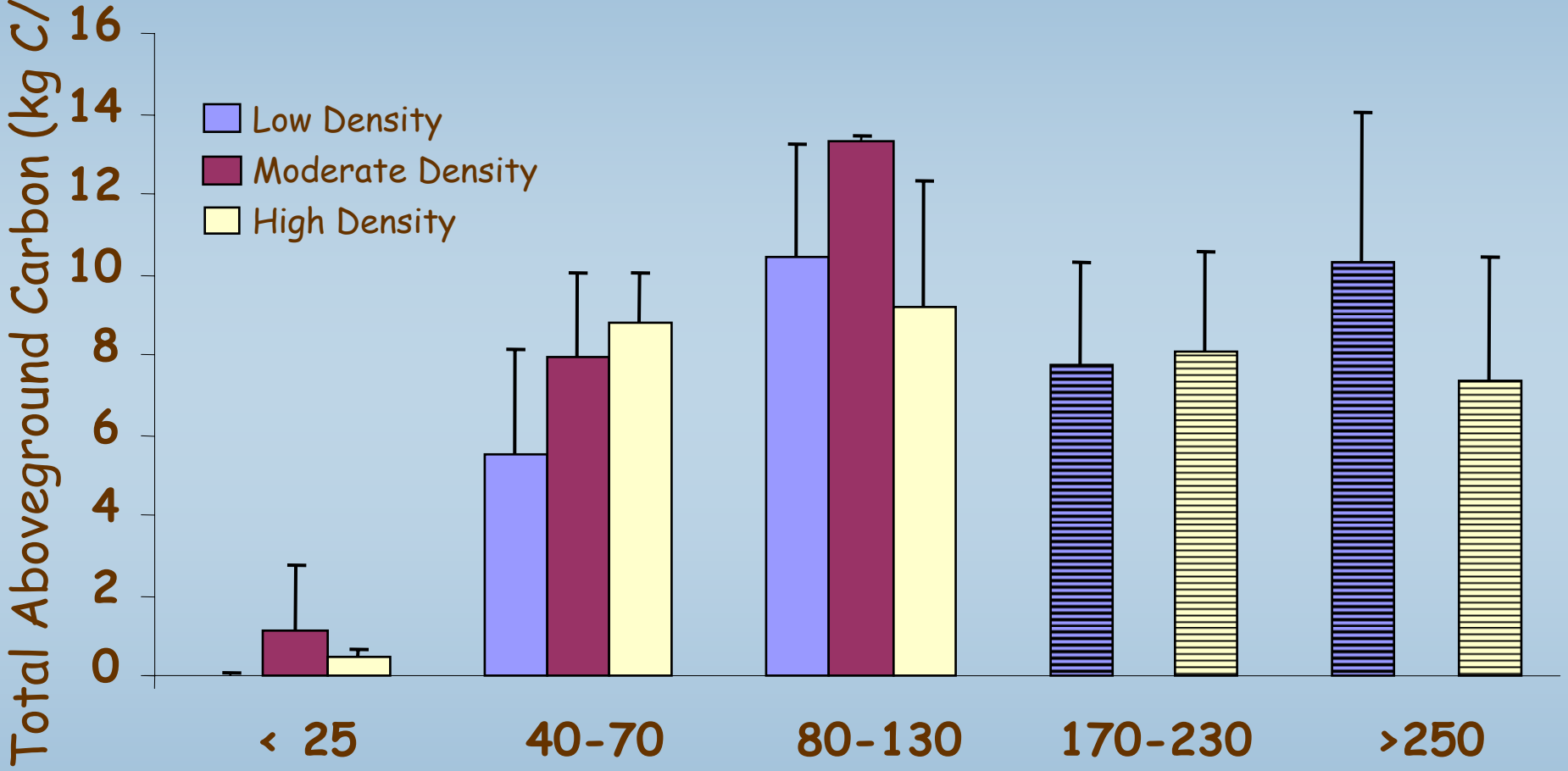
< 25	< 1,000 st/ha
40-70	< 1,300 st/ha
80-130	< 1,300 st/ha
170-230	Not beetle killed
> 250	Not beetle killed

Methods:

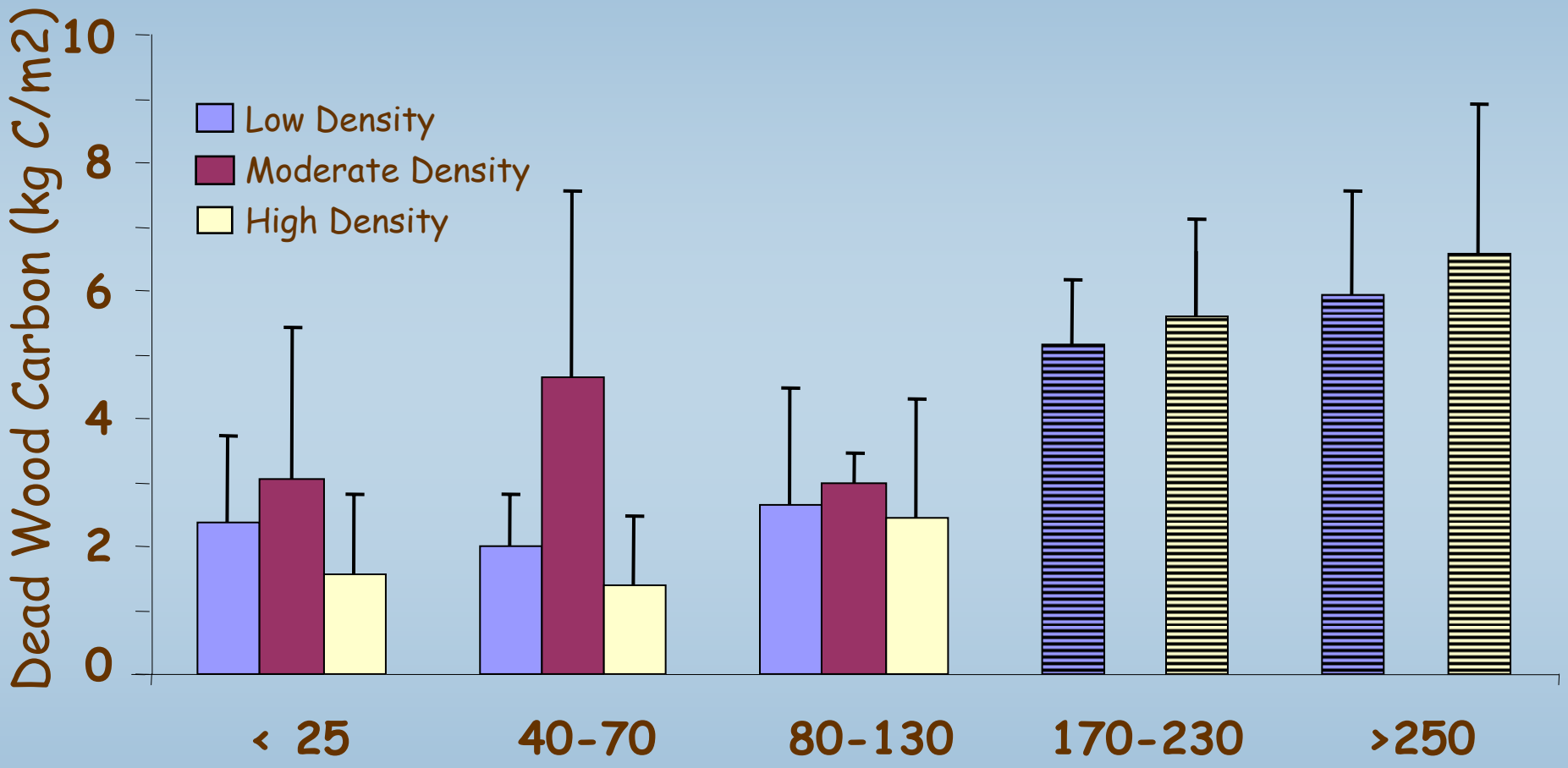
- Mass balance approach using field measurements of all C pools in 77 stands:

Above and belowground biomass
(on-site allometrics)
Standing and down dead wood
Stumps and dead coarse roots
Forest floor and mineral soil

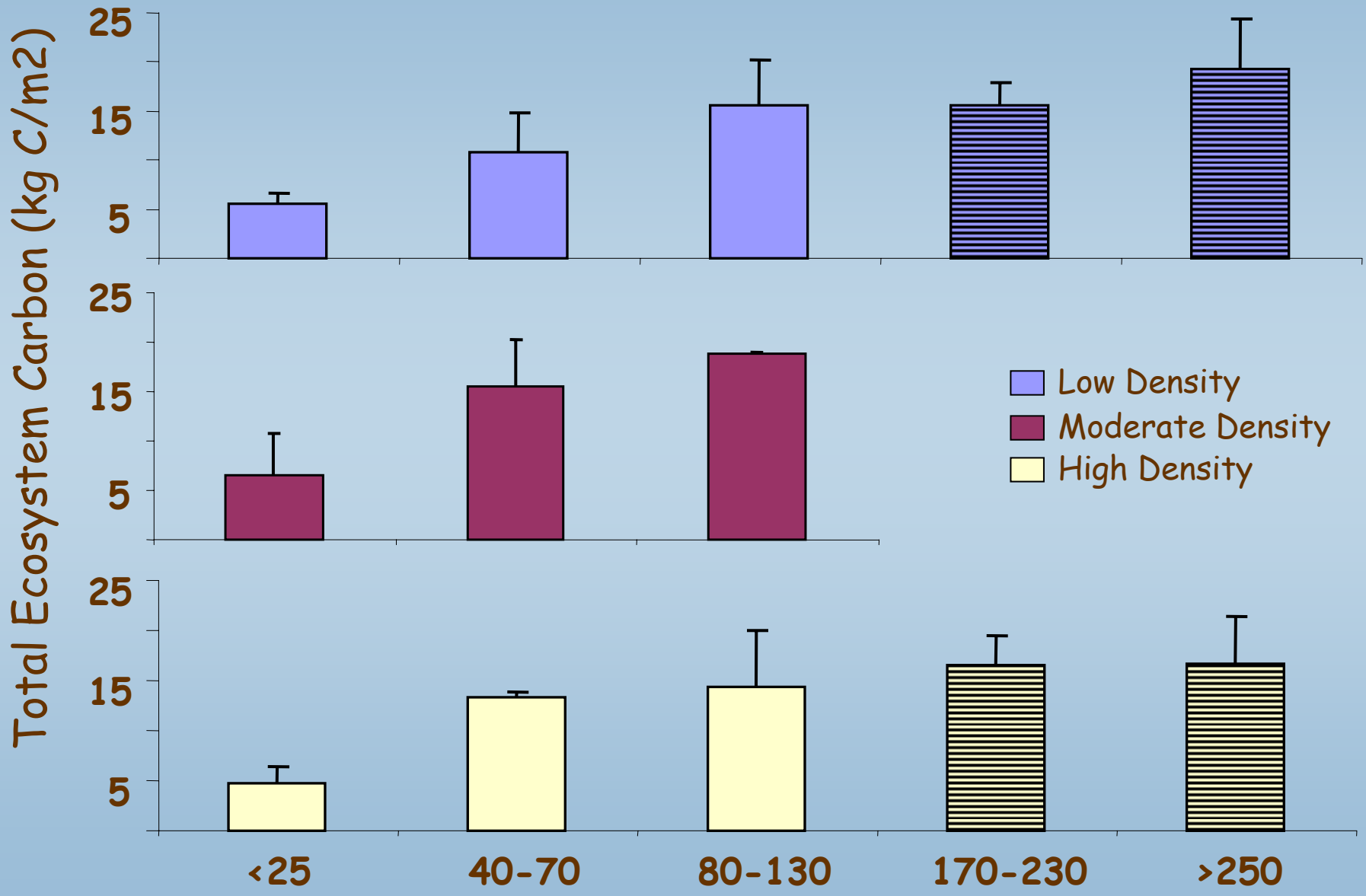
Aboveground Live Carbon



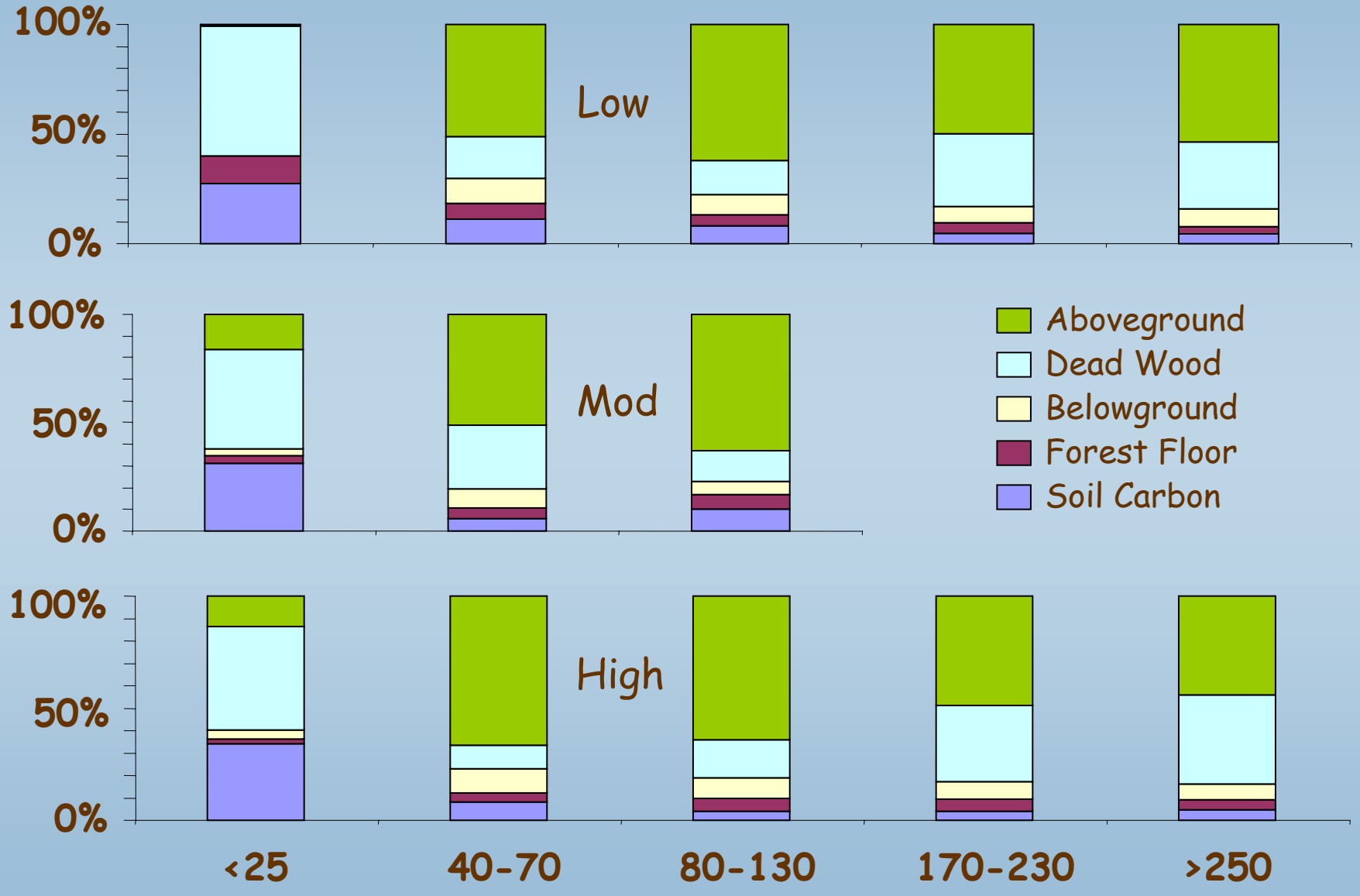
Dead Wood Carbon



Total Ecosystem Carbon Stocks



Location of Carbon Stocks



Conclusion: *C* storage

- Initial post-fire stand densities are probably not important for *C* storage in this system.

- This is for a single fire cycle and does not consider temporal changes in dead wood between cycles.

Yellowstone: an exciting place!