PLAYING WITH FIRE:
Disturbances shaping Rocky Mountain Forest Landscapes and their Implications for Global Change

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Approach to Climate Change in Forests

How might climate (and potential changes) and disturbances interact to shape forests?

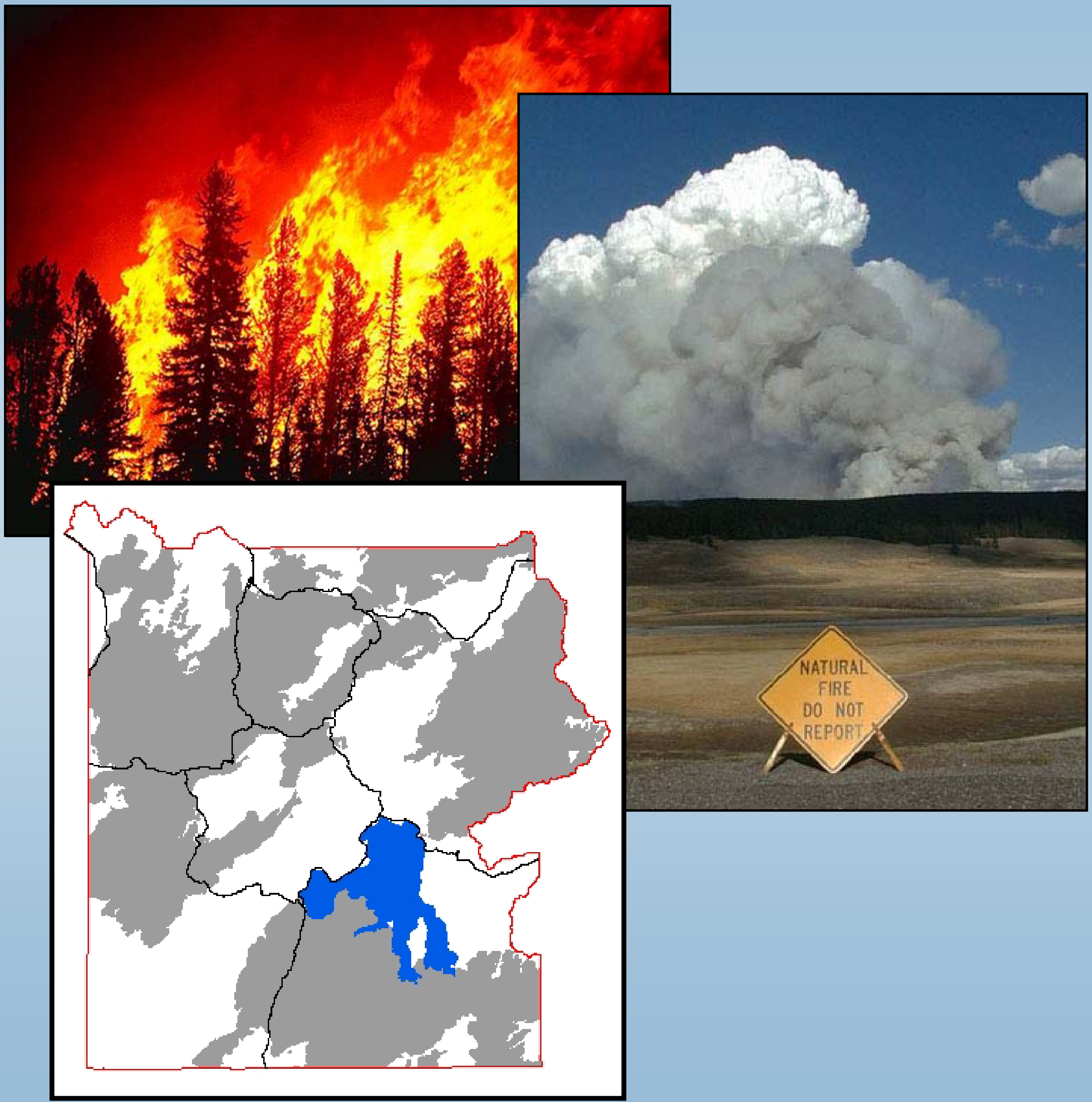
- "Most imminent and extensive"
- Succession creates changes in structure
- Structure directs carbon sequestration and storage.

Outline

Wildfires and lodgepole pine forests in Yellowstone National Park: The Long Story

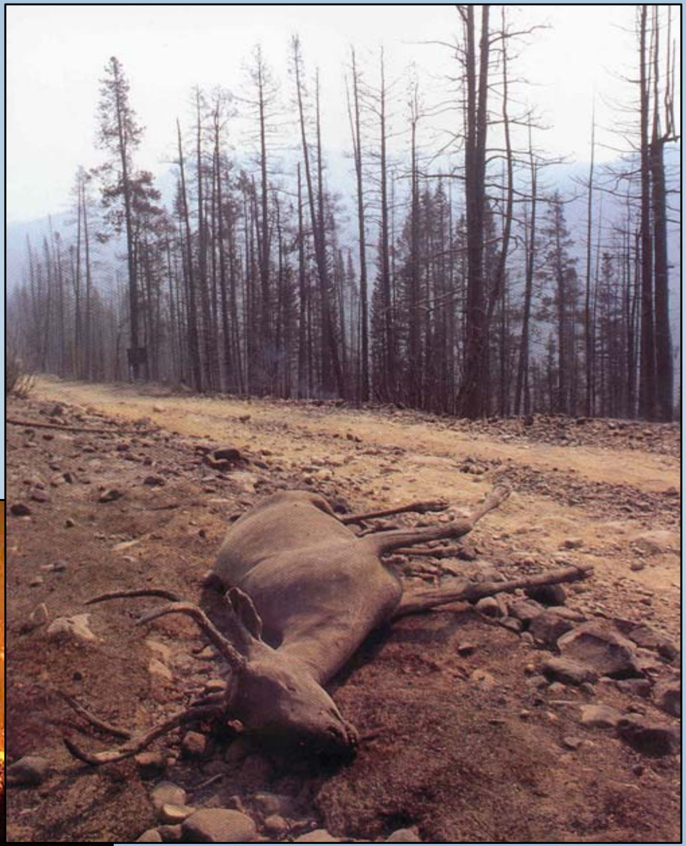
- Background: The 1988 Yellowstone fires
- Stand dynamics and convergence in forest structure: How do forest change?
- How might climate change affect forest structure?
- Landscape-level carbon cycling

The Yellowstone landscape

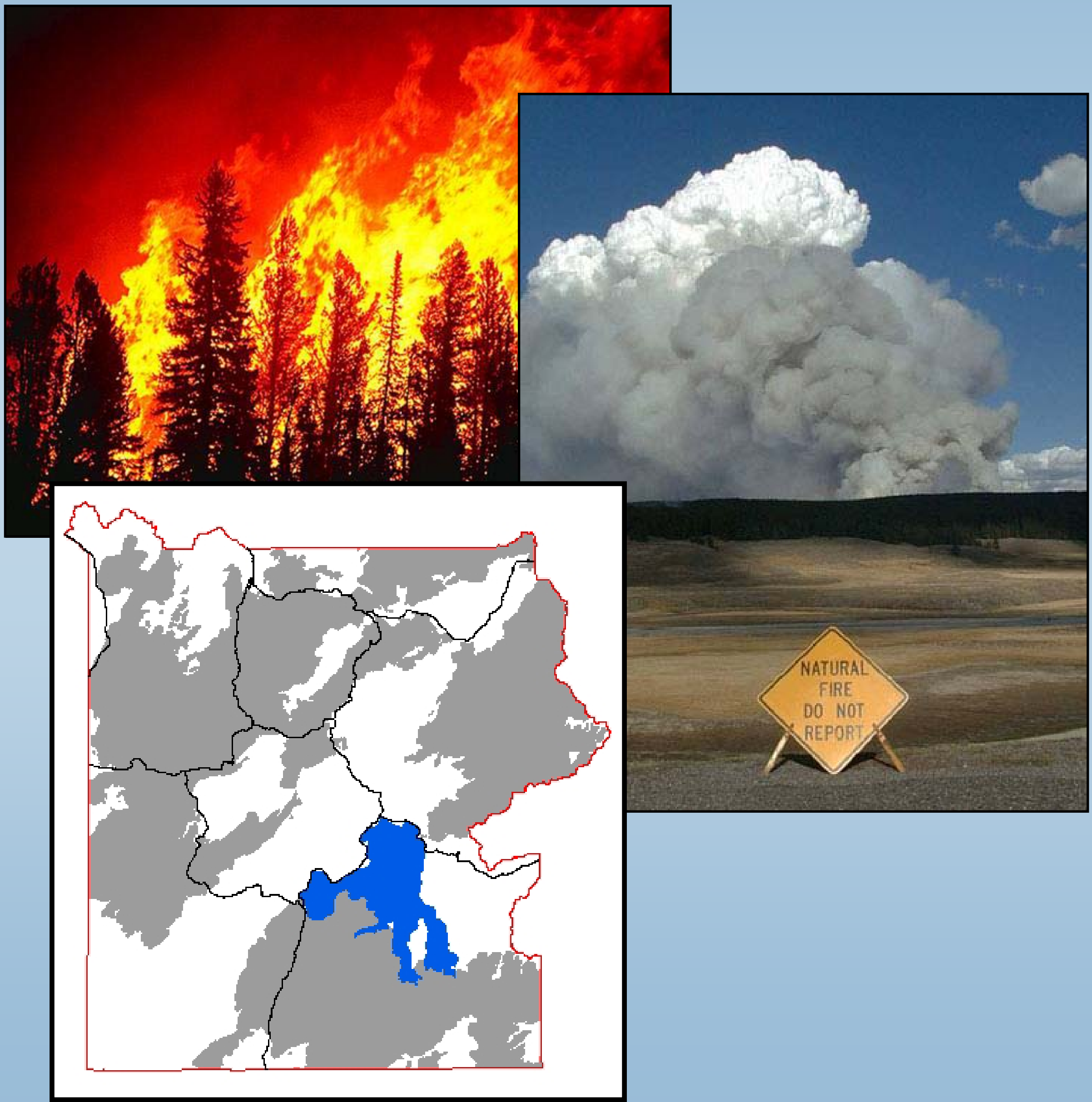


- Stand-replacing fires, climate-driven
- 100-300 year fire interval
- Large, “natural” landscape

Destruction and Death on the Yellowstone Landscape!



The Yellowstone landscape



- Stand-replacing fires, climate-driven
- 100-300 year fire interval
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Variation in burn severity

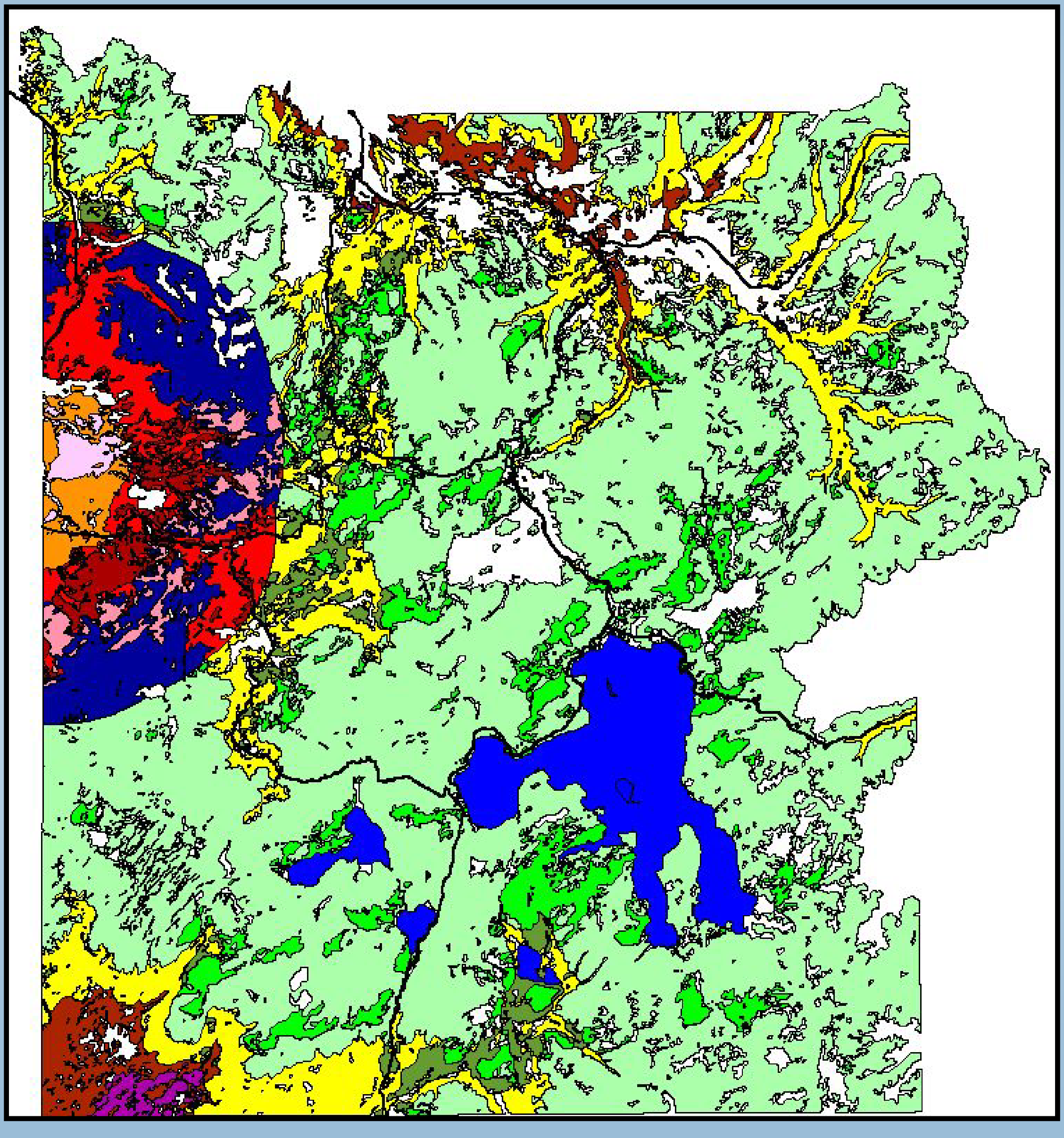
Yellowstone Burn Mosaic, 10/88

Light/Severe Surface Fire

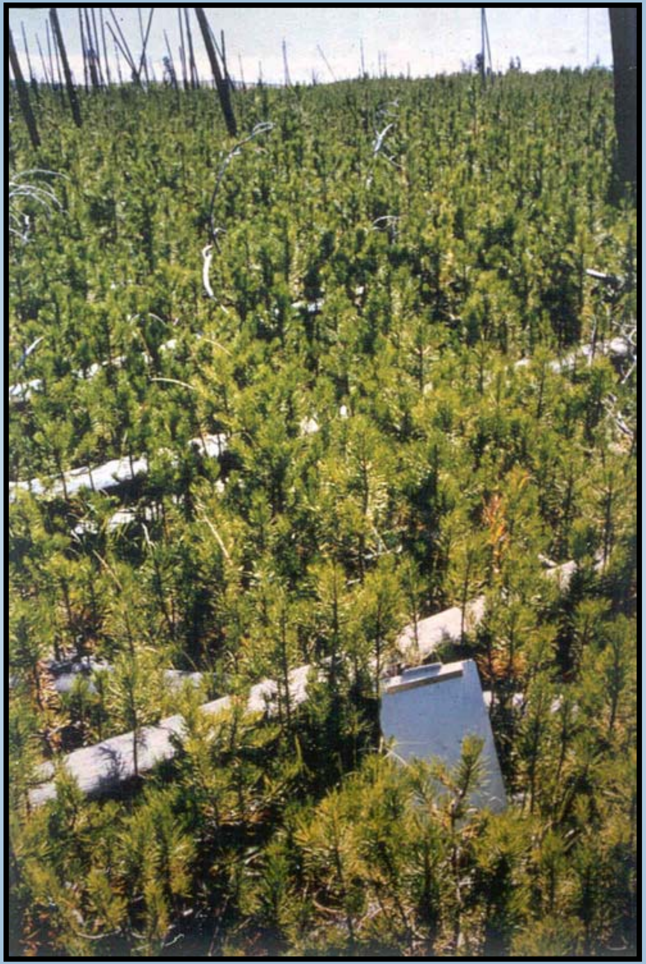
Severe Surface/Crown Fire

Serotiny in lodgepole pine

Variation in lodgepole pine serotiny



Variation in regeneration density



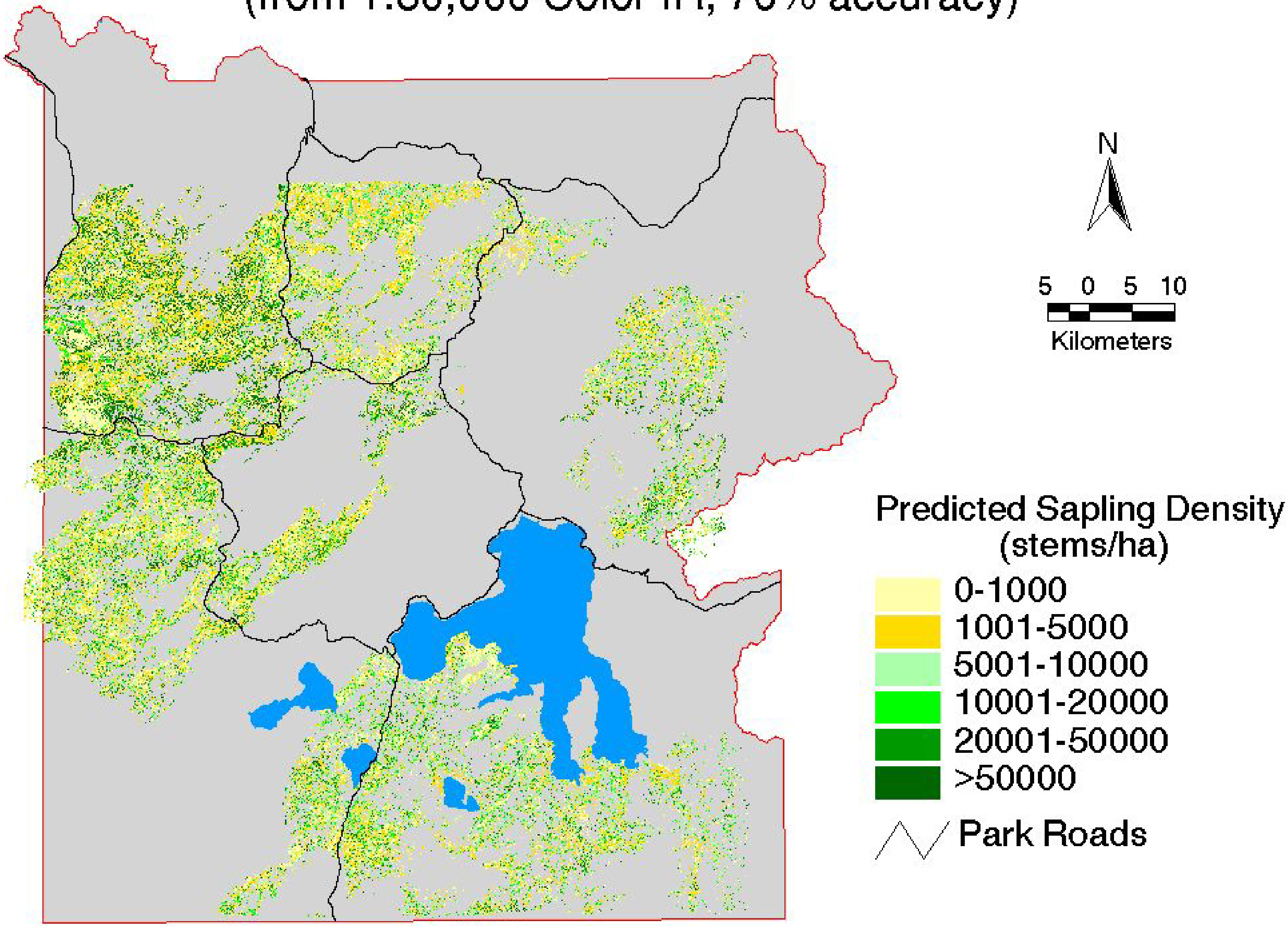
>50,000 stems/ha

1,000 stems/ha

0 stems/ha

1998 Lodgepole Pine Sapling Density

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



Variation in Stand Density

Stands shown are in the 50-100 year age class

3,000 stems/ha

1,100 stems/ha

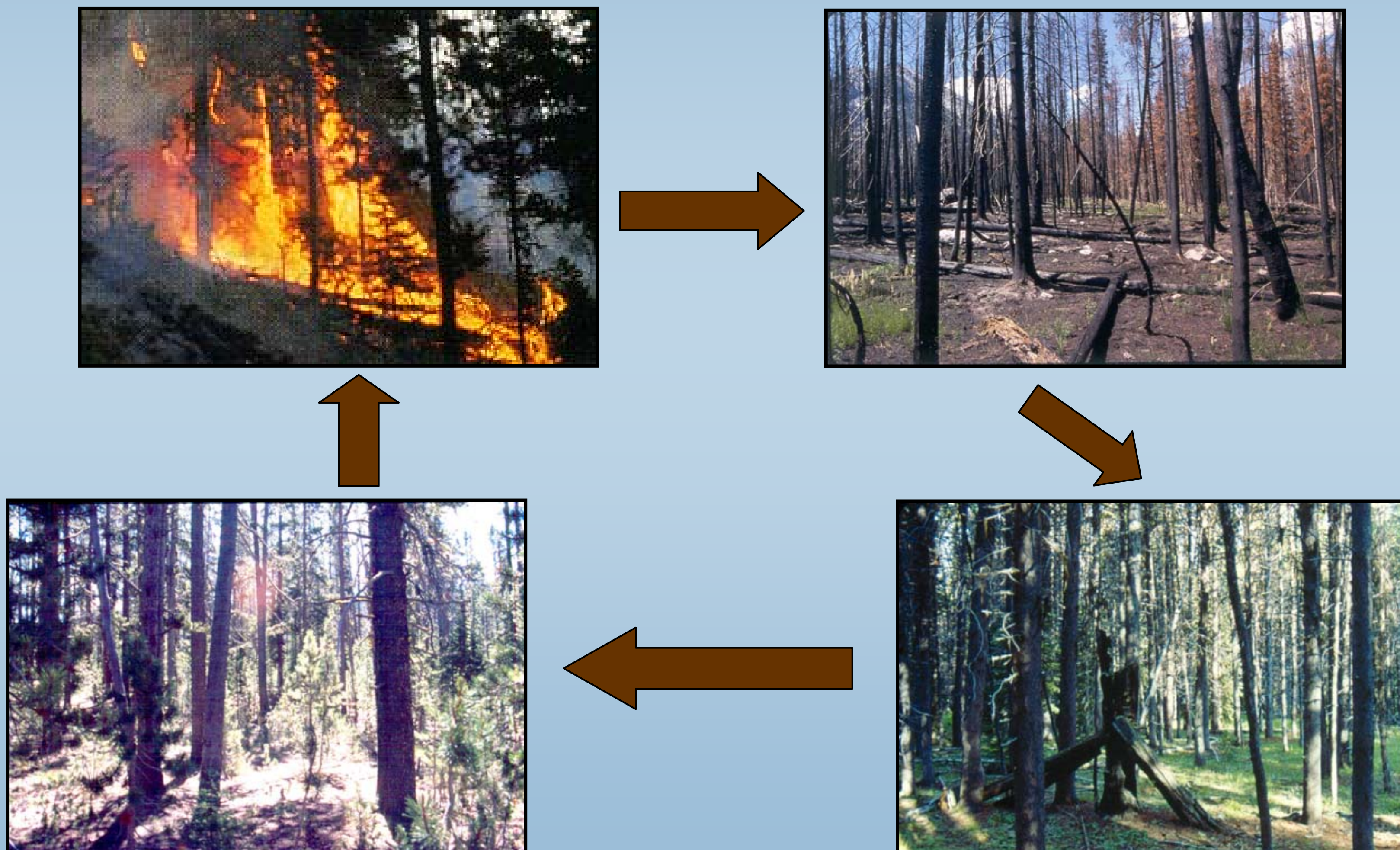
11,000 stems/ha

Do initially dissimilar stand structures eventually converge?

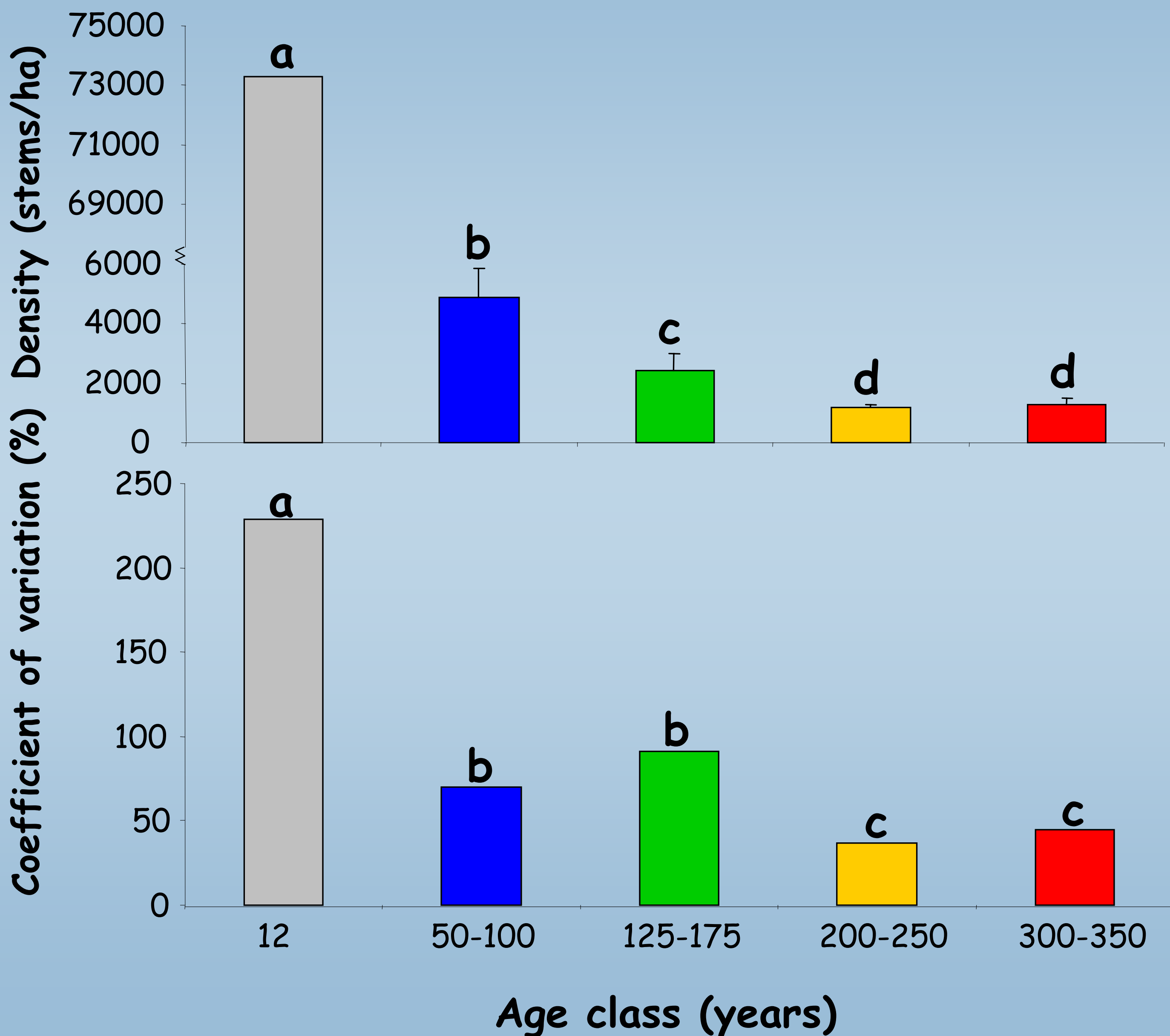
???

???

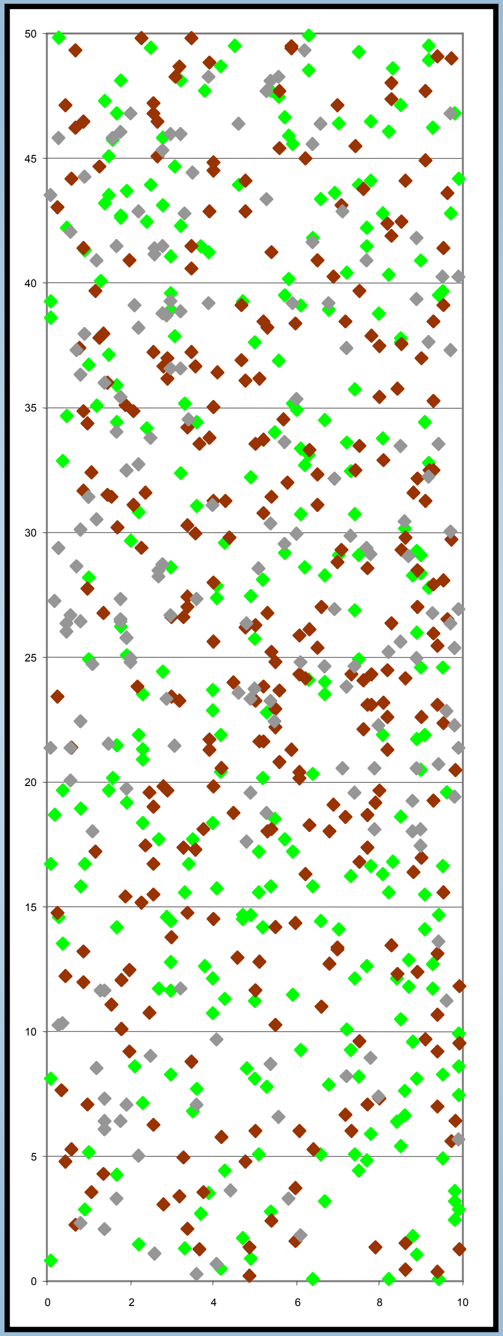
During succession, stand structure strongly affects carbon storage (and thus the global carbon cycle)



Variation and change in stand density with age



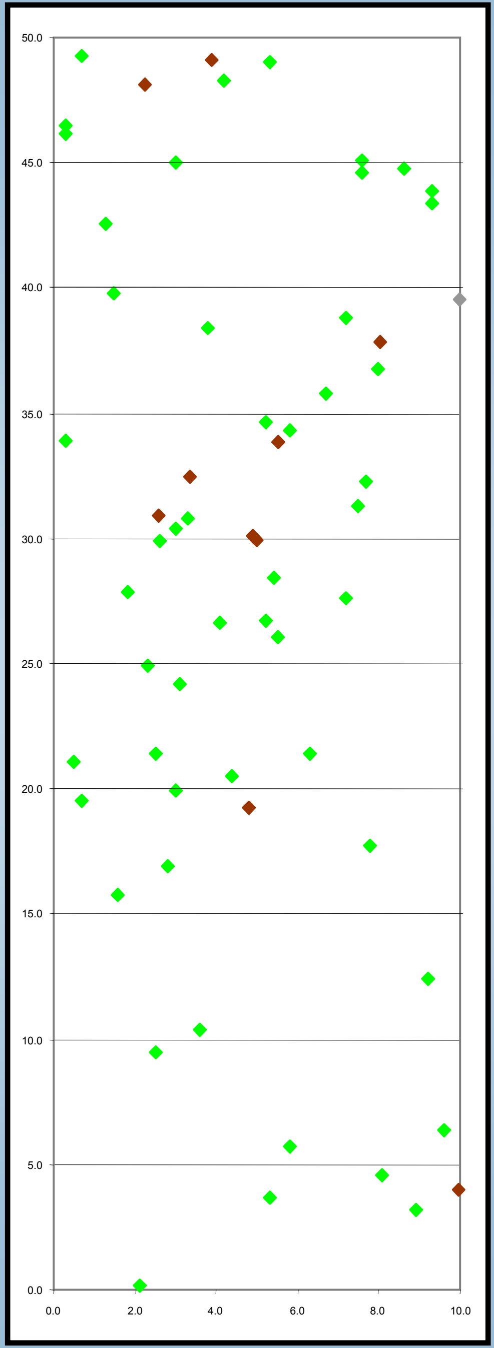
Stand A: Initially dense

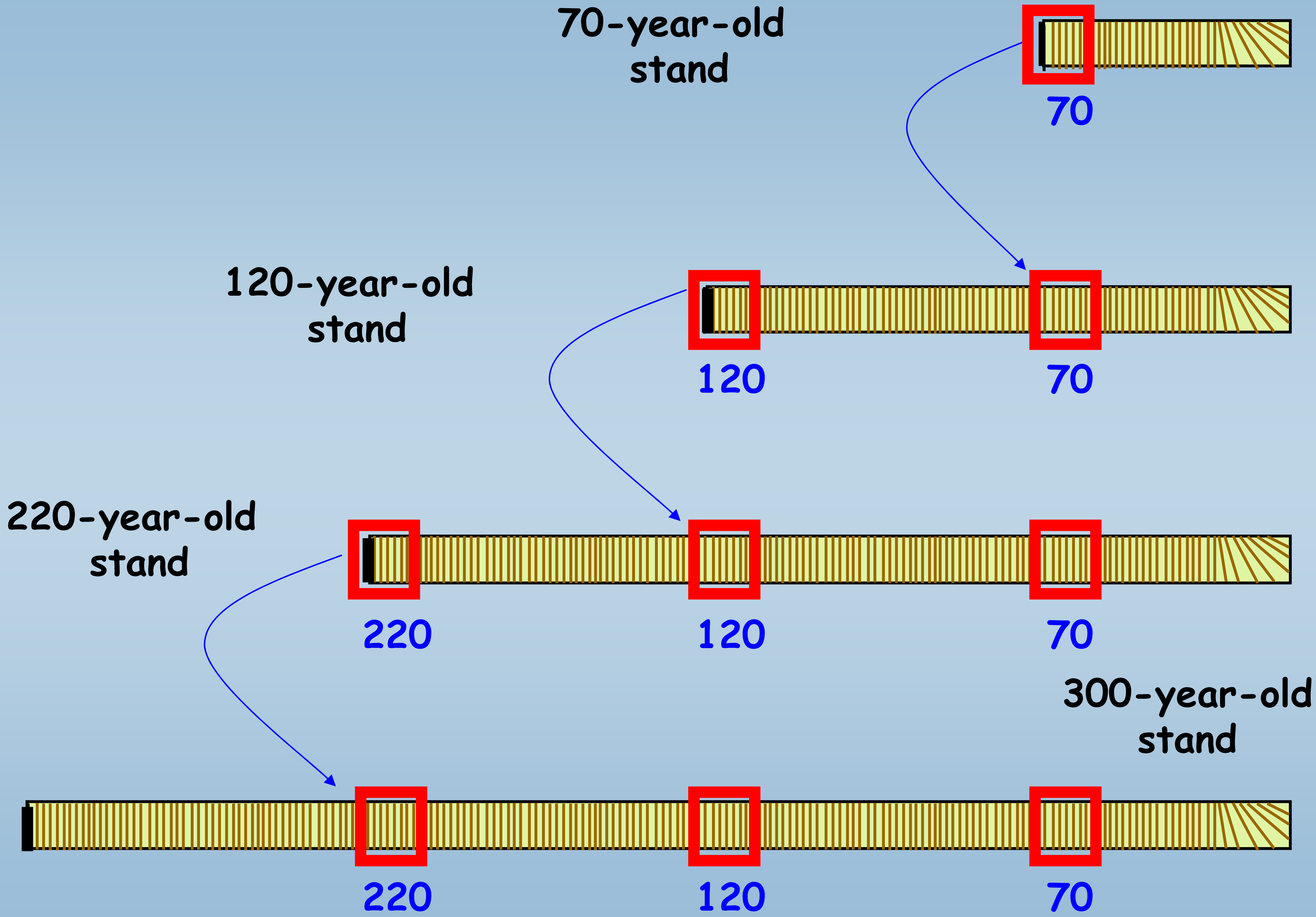


Age: 130 years
Density: 5,400 stems/ha

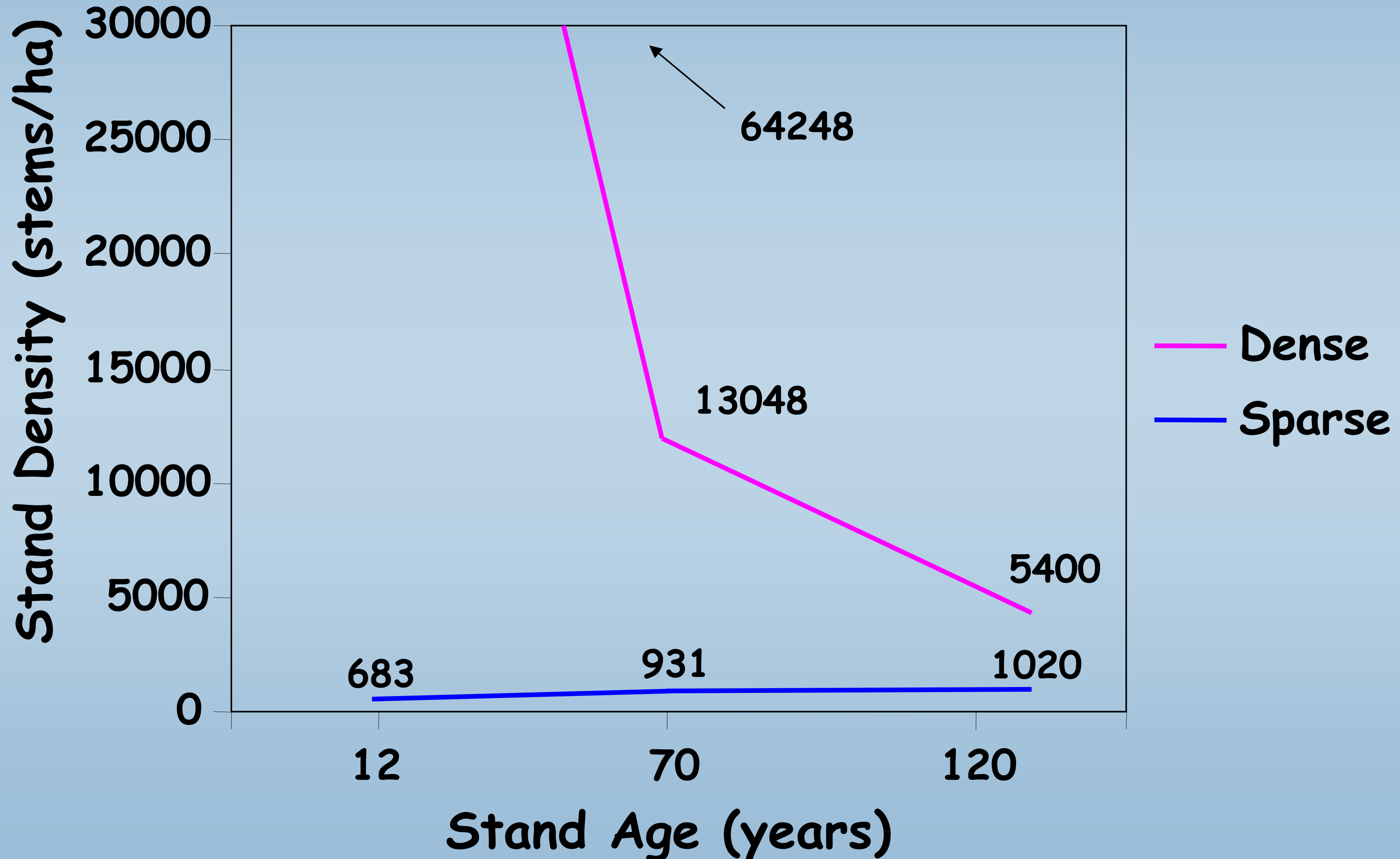
Stand B: Initially sparse

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

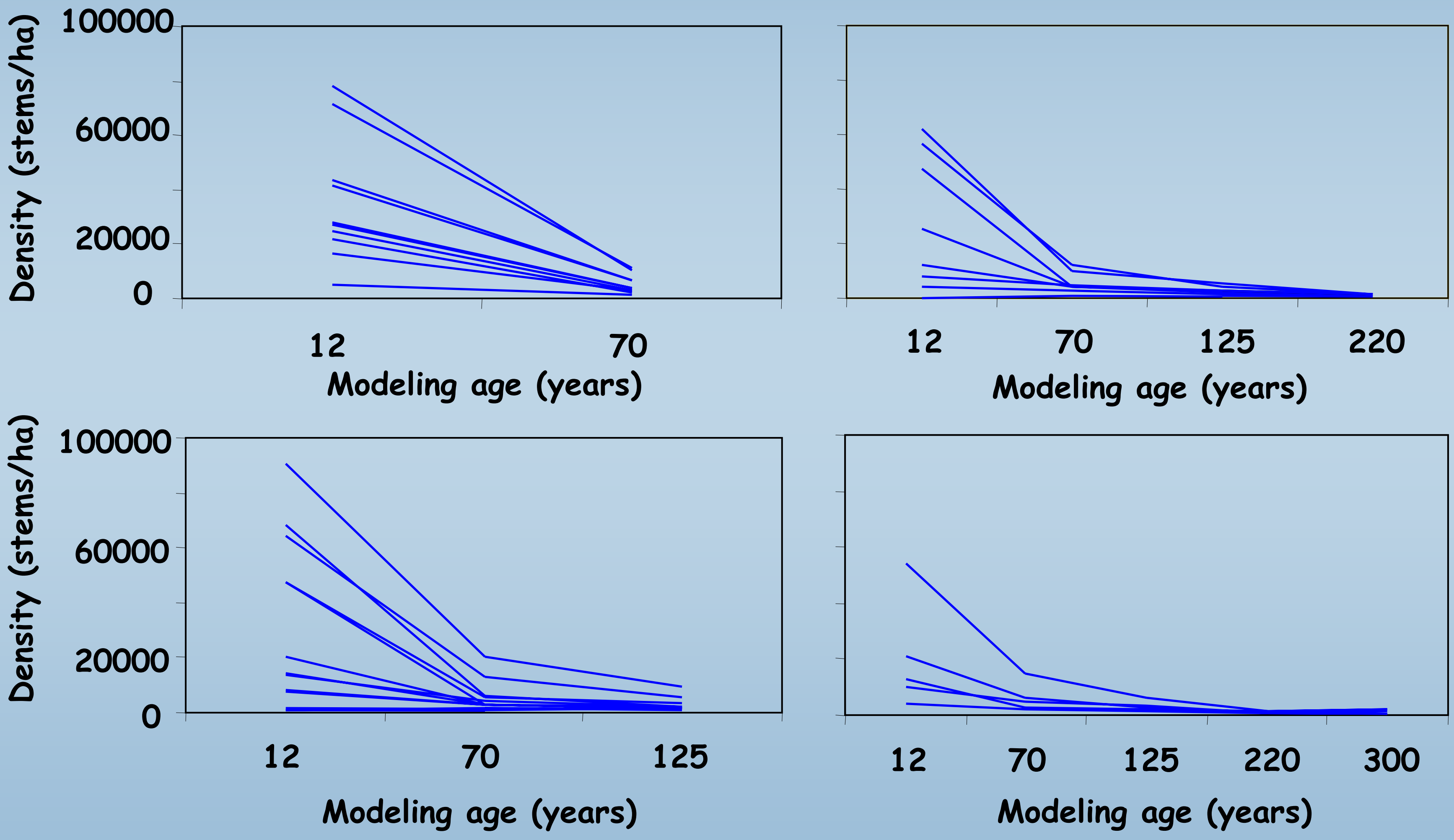


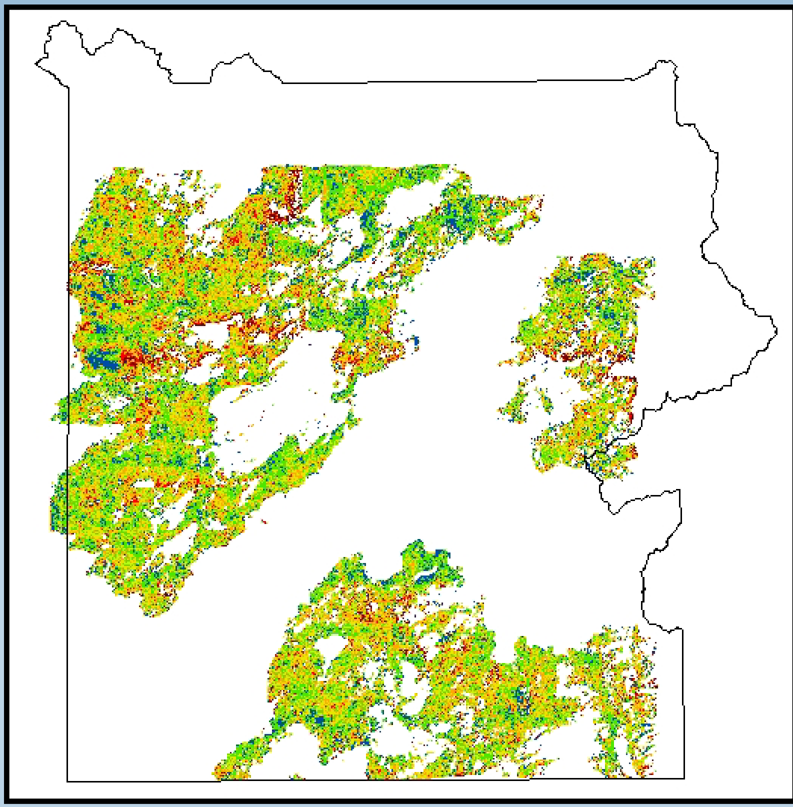

70-year-old stand
70
120-year-old stand
120
70
220-year-old stand
220
120
70
300-year-old stand
220
120
70

Stand Density Trajectory Reconstruction

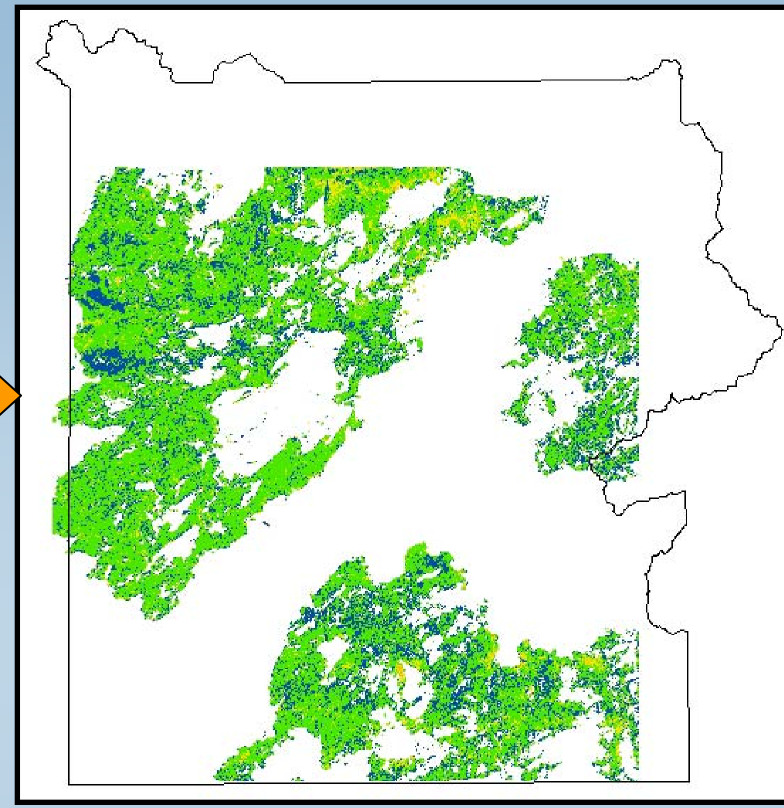


Stand Density Trajectory Reconstructions





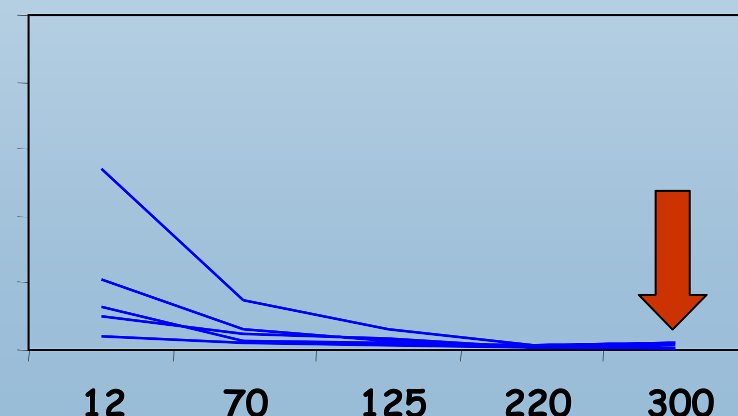
10 years after fire



300 years after fire

Relative deviation from median density

- -1 – -0.25
- -0.25 – 0.25
- 0.25 – 1
- 1 – 3
- 3 – 5
- >5



How might a changing climate affect forest structure on landscapes?

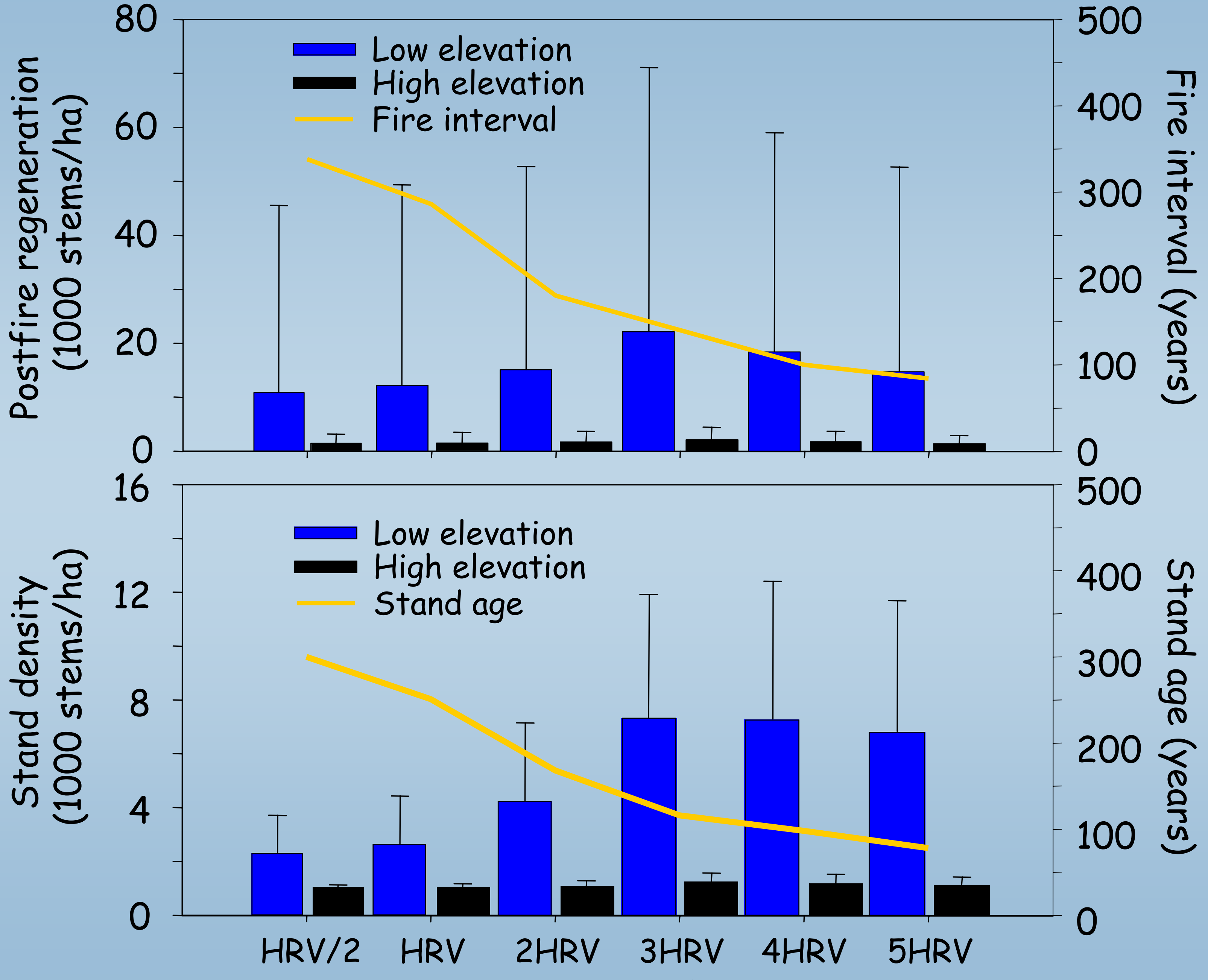
- Probabilistic, cell-based model in SELES based on empirical data (YNPFIRE; Schoennagel et al.).

- Models the response of stand age and density to alterations in frequency of large fires (>10,000 ha).

- Climate scenarios defined by the probability of large fire occurrence.

YNPFIRE Climate Scenarios

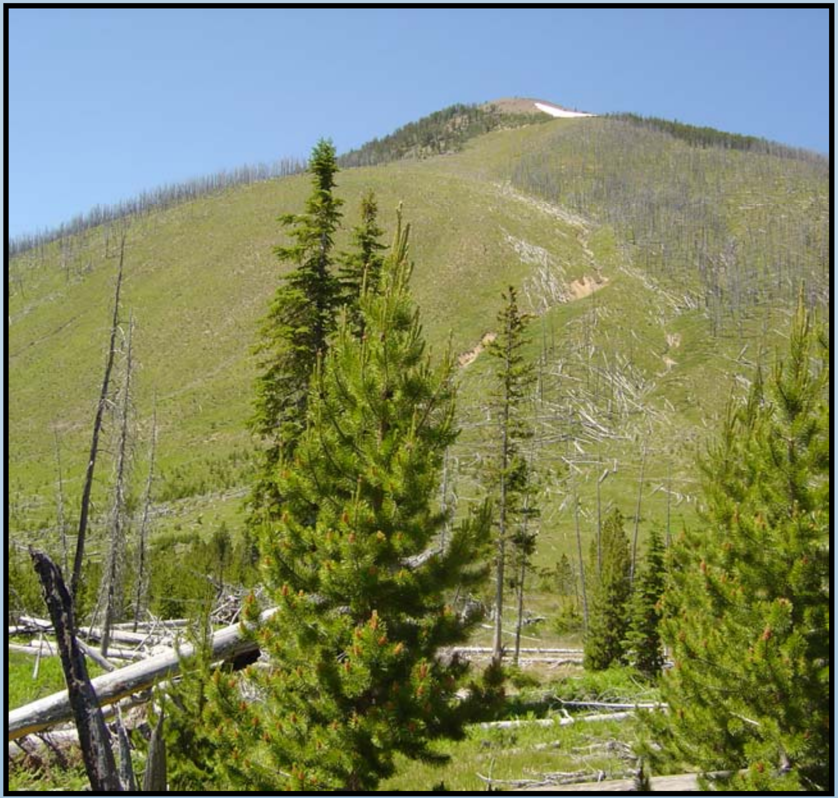
Scenario	Prob. Extremely Dry Year	# Large Fires per 1,000 years
Less Extreme (HRV/2)	0.003	3
Nominal (HRV)	0.006	6
More Extreme (2HRV)	0.012	12
More Extreme (3HRV)	0.018	18
More Extreme (4HRV)	0.024	24
More Extreme (5HRV)	0.030	30



Low elevation
High elevation
Fire interval
Postfire regeneration (1000 stems/ha)
Fire interval (years)
80
60
40
20
0
500
400
300
200
100
0
Low elevation
High elevation
Stand age
Stand density (1000 stems/ha)
Stand age (years)
16
12
8
4
0
500
400
300
200
100
0
HRV/2
HRV
2HRV
3HRV
4HRV
5HRV
Scenarios

Implications for the geographic distribution of lodgepole pine forests

- Serotiny would increase with increasing fire frequency
- Post-fire regeneration would increase with fire frequency
- Upper timberline would rise, but lower timberline would be maintained
- Alpine species may be extirpated



Structure Conclusions

- Structural variability is likely related to initial variation in postfire density.

- Under the current climate, variation in stand structure across the landscape decreases with time and converges near 200 years.

- Climate scenarios that reduce the fire interval are likely to increase stand density and heterogeneity on the landscape.

What are the implications of changing climate for landscape carbon storage?

- How do large fires affect landscape carbon storage?

- How sensitive is carbon storage of a landscape to changes in disturbance regimes?

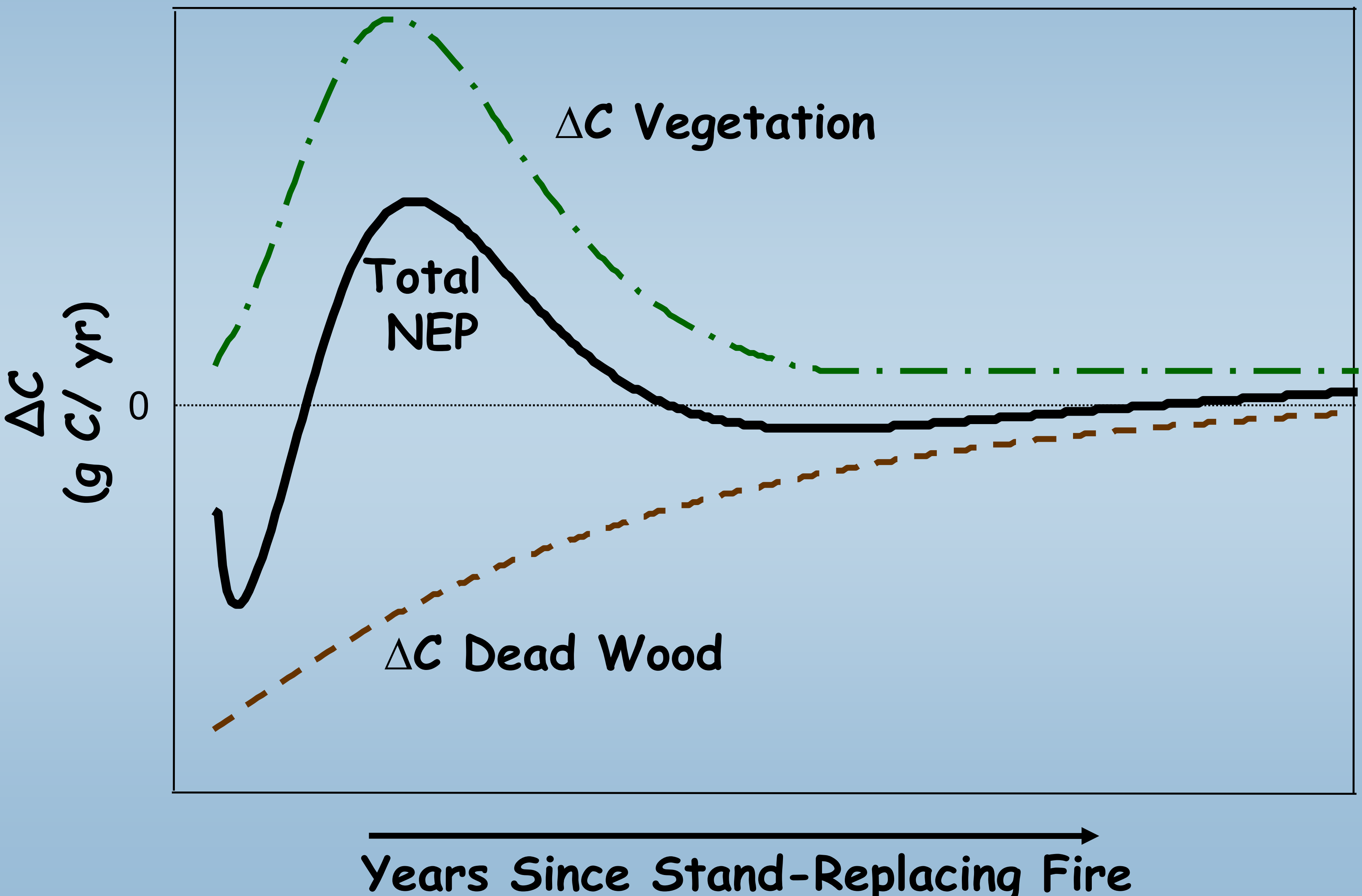
Landscape carbon storage is affected by:

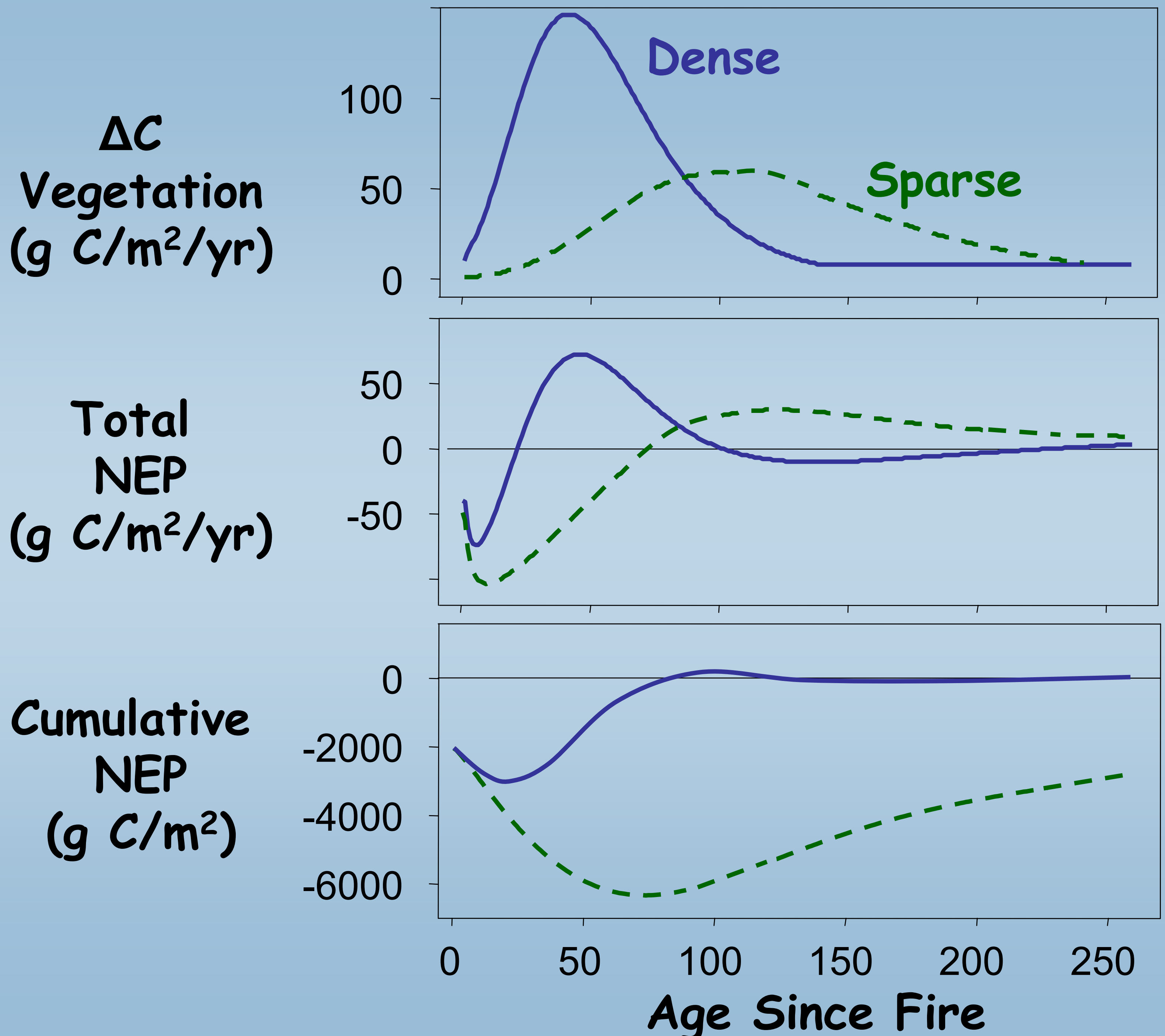
- Balance between carbon accumulating in vegetation/forest floor and carbon lost through decomposition of dead wood.

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

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

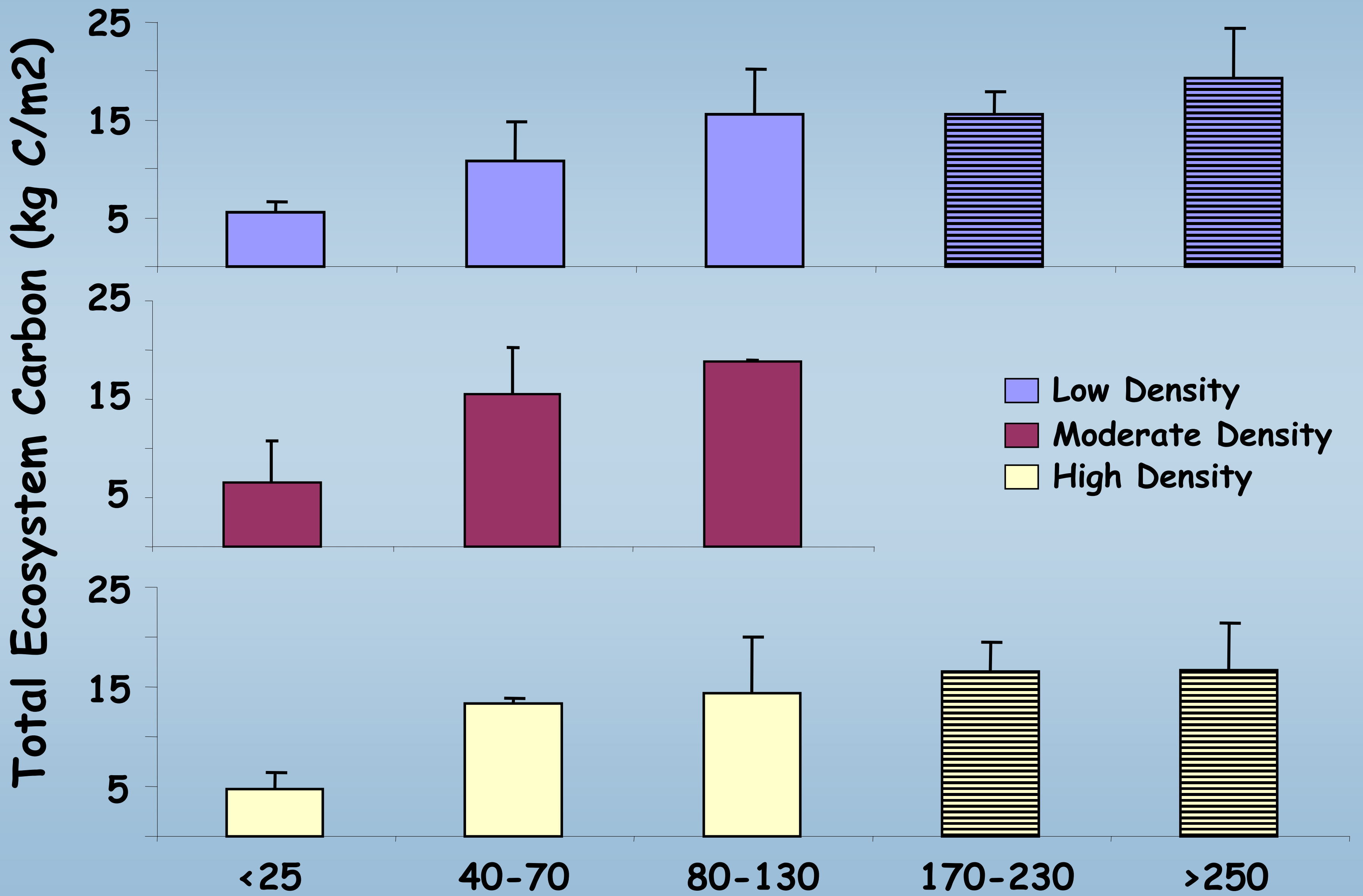
NEP = C gained (NPP) – C lost (decomposition)



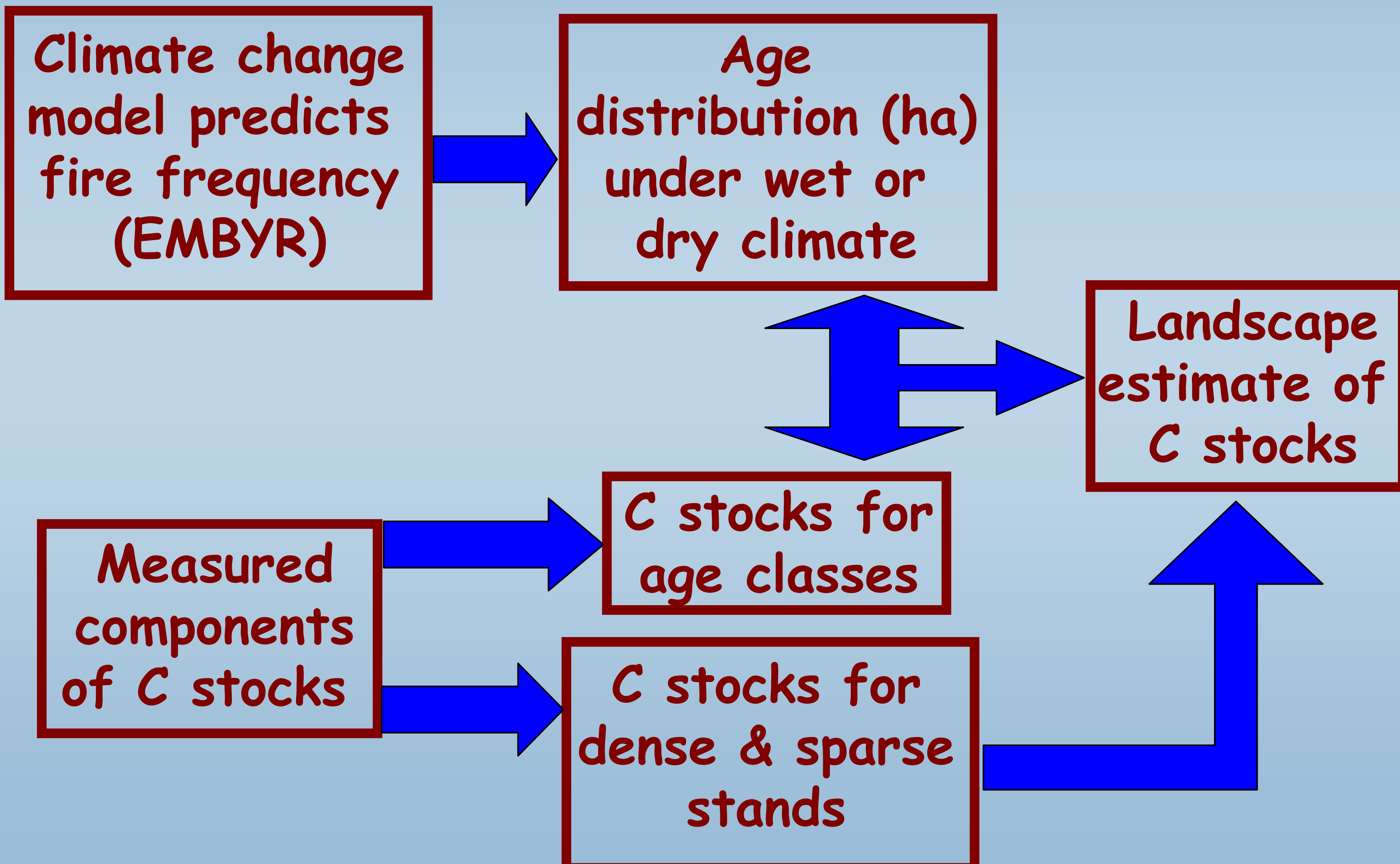

ΔC Vegetation (g C/m²/yr)
Total NEP (g C/m²/yr)
Cumulative NEP (g C/m²)
Dense
Sparse
100
50
0
50
0
-50
0
-2000
-4000
-6000
0
50
100
150
200
250
Age Since Fire

Stand age distributions affect landscape NEP

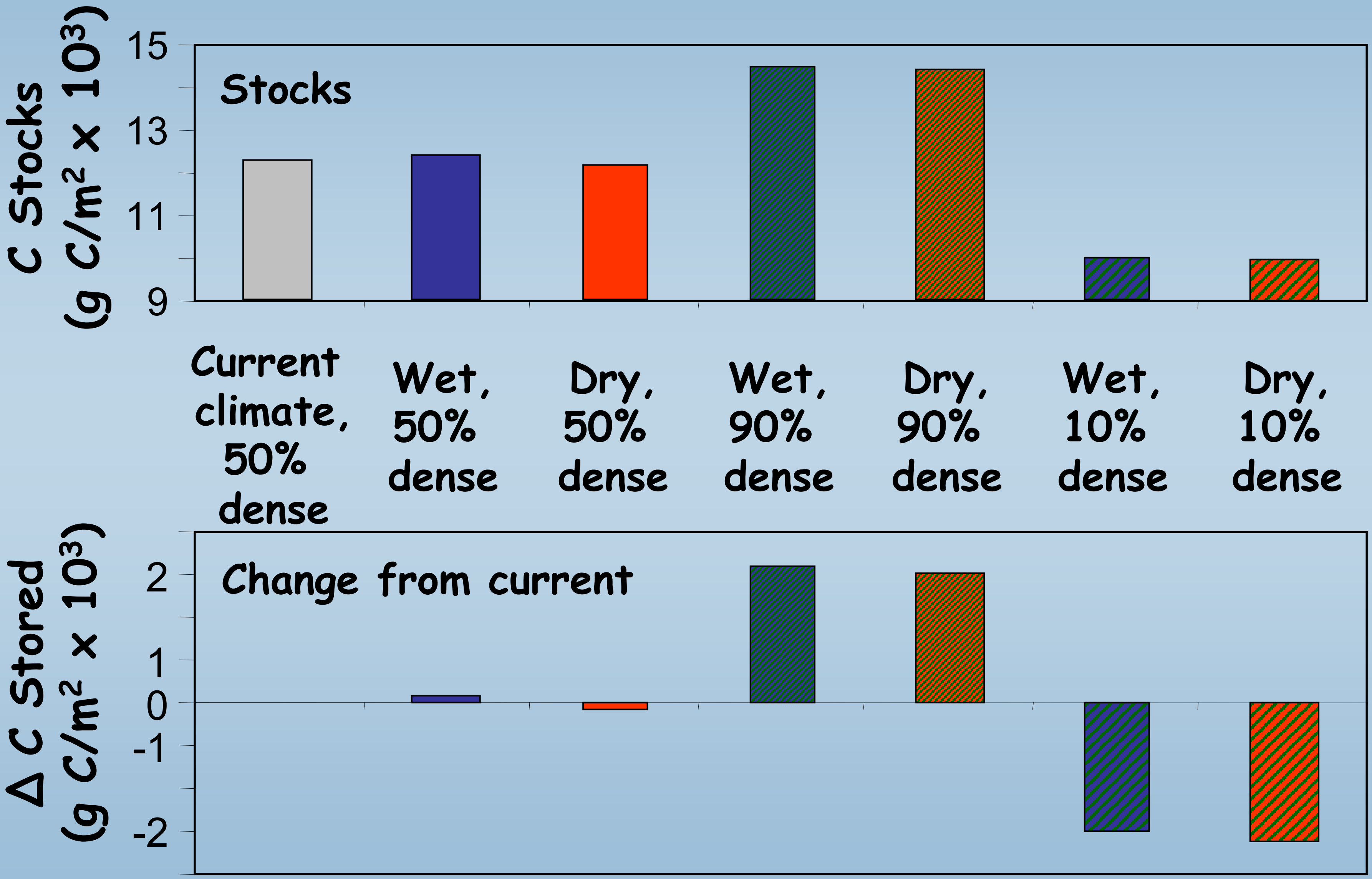
Total Ecosystem Carbon Stocks (Measured)



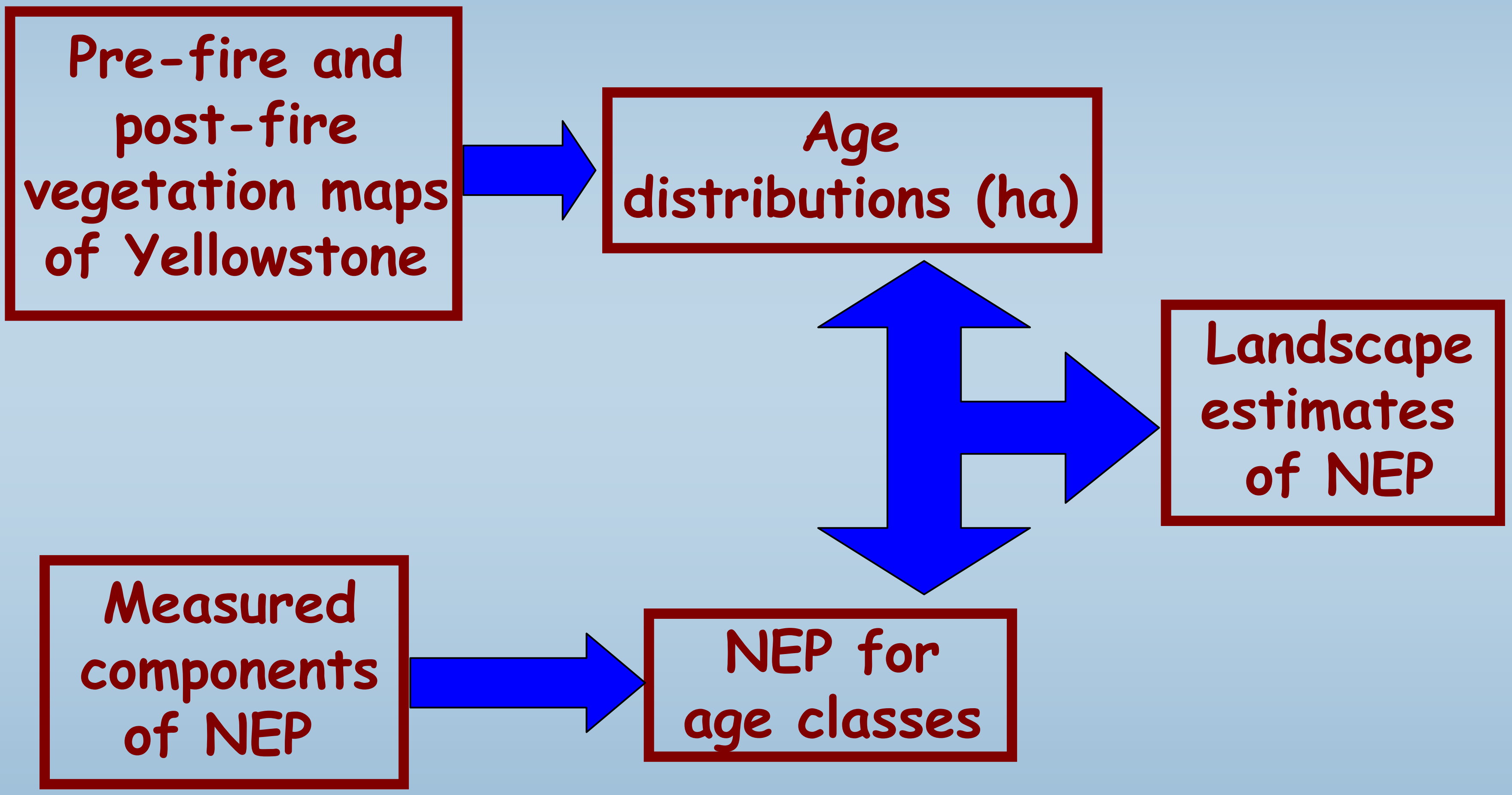
Stand age and density effects on landscape C storage



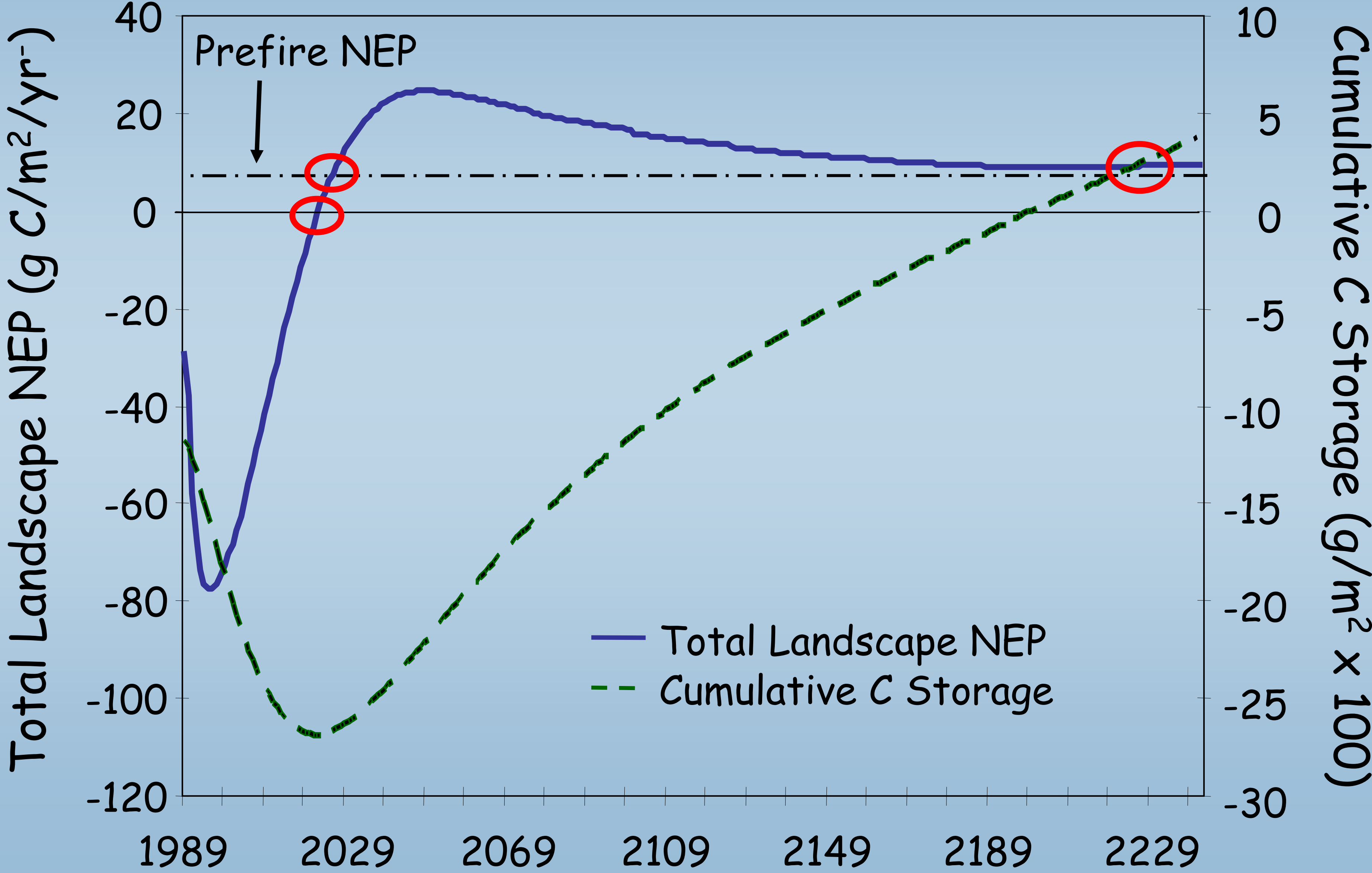
Stand age and density effects on C storage



Predicting future landscape C storage for post-1988 Yellowstone



Long-term changes in C storage for Yellowstone



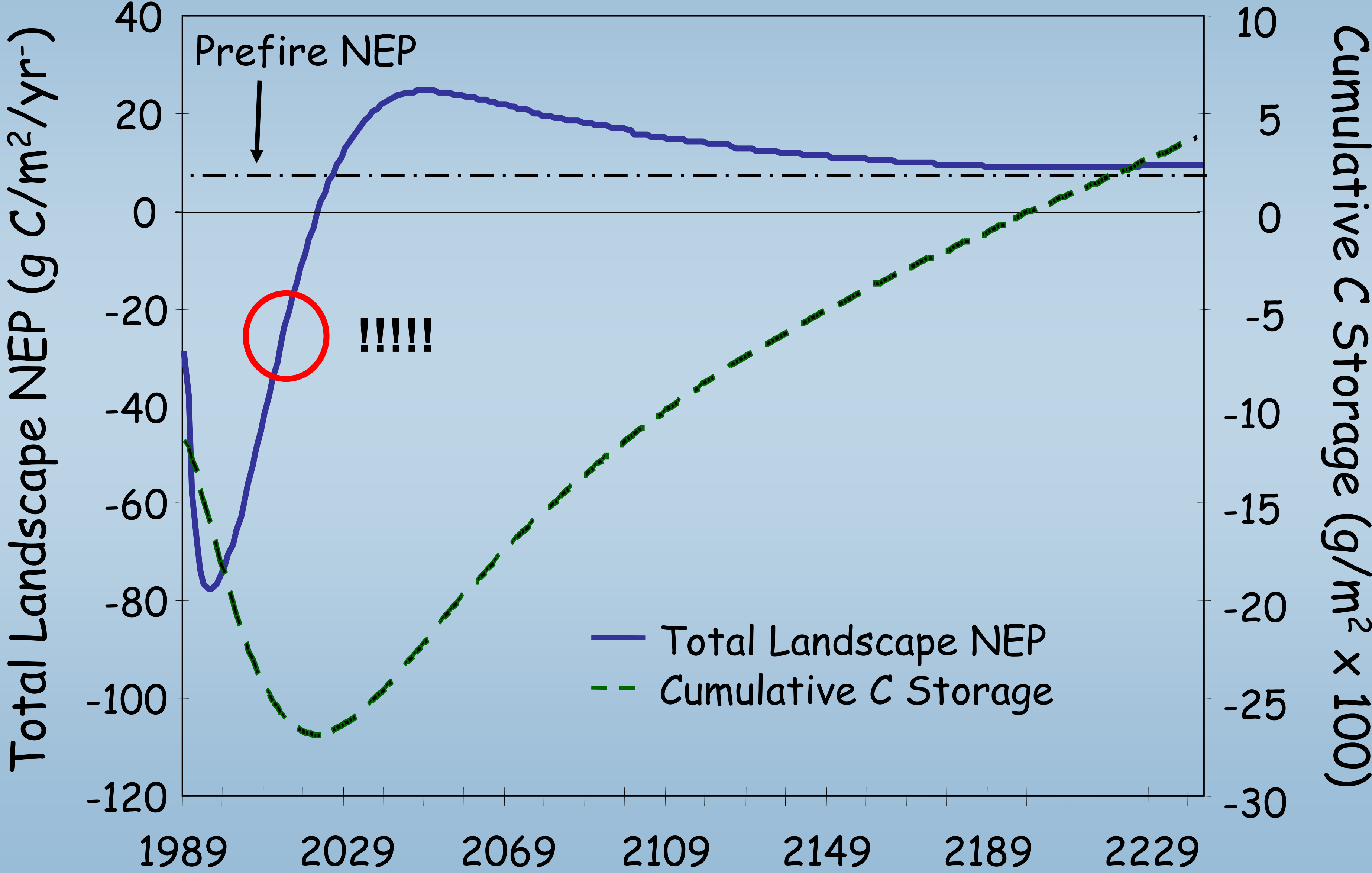
Carbon Storage Conclusions:

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

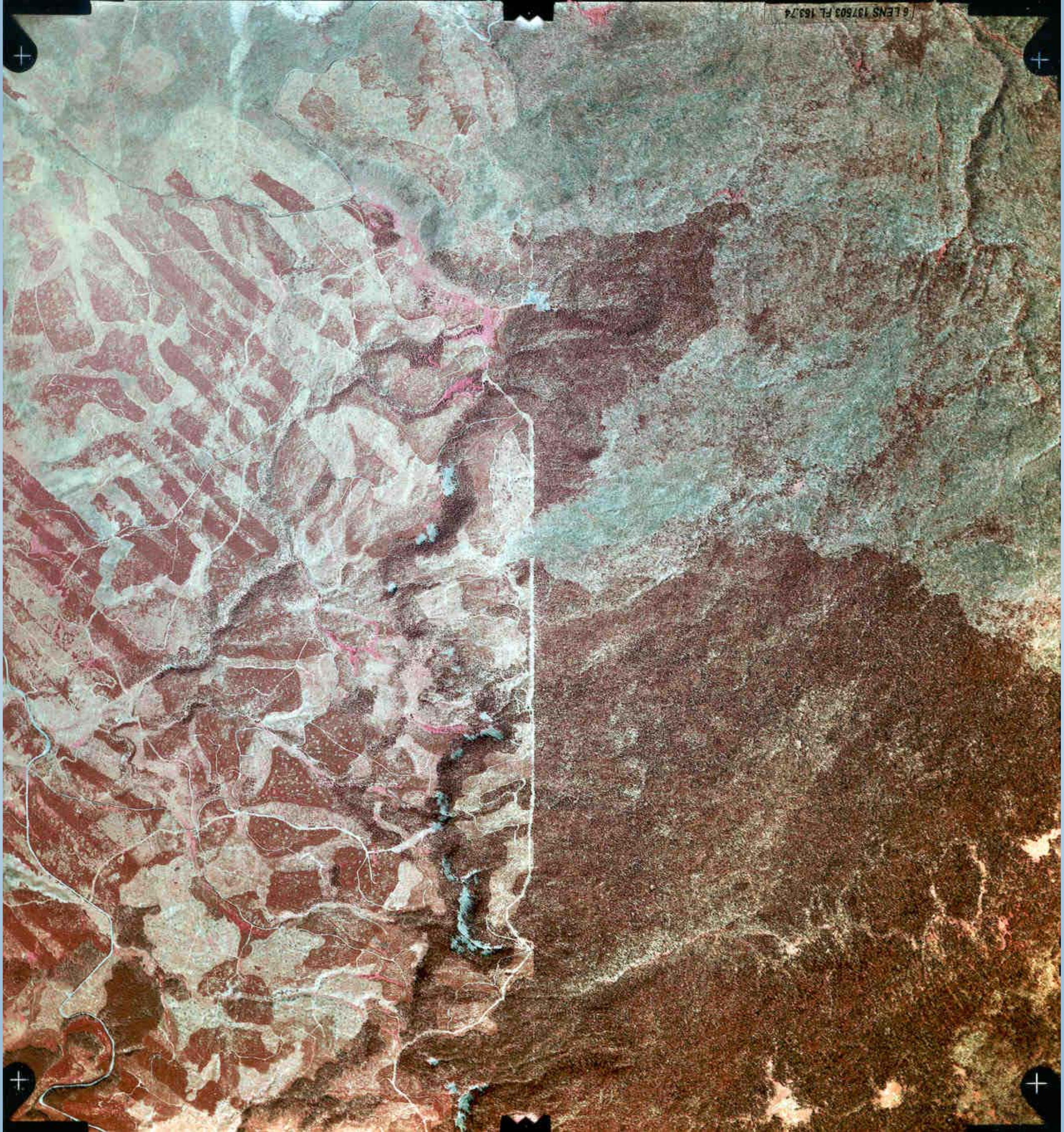
- Large changes in the distribution of stand densities on the landscape are necessary to shift its ability to store carbon.

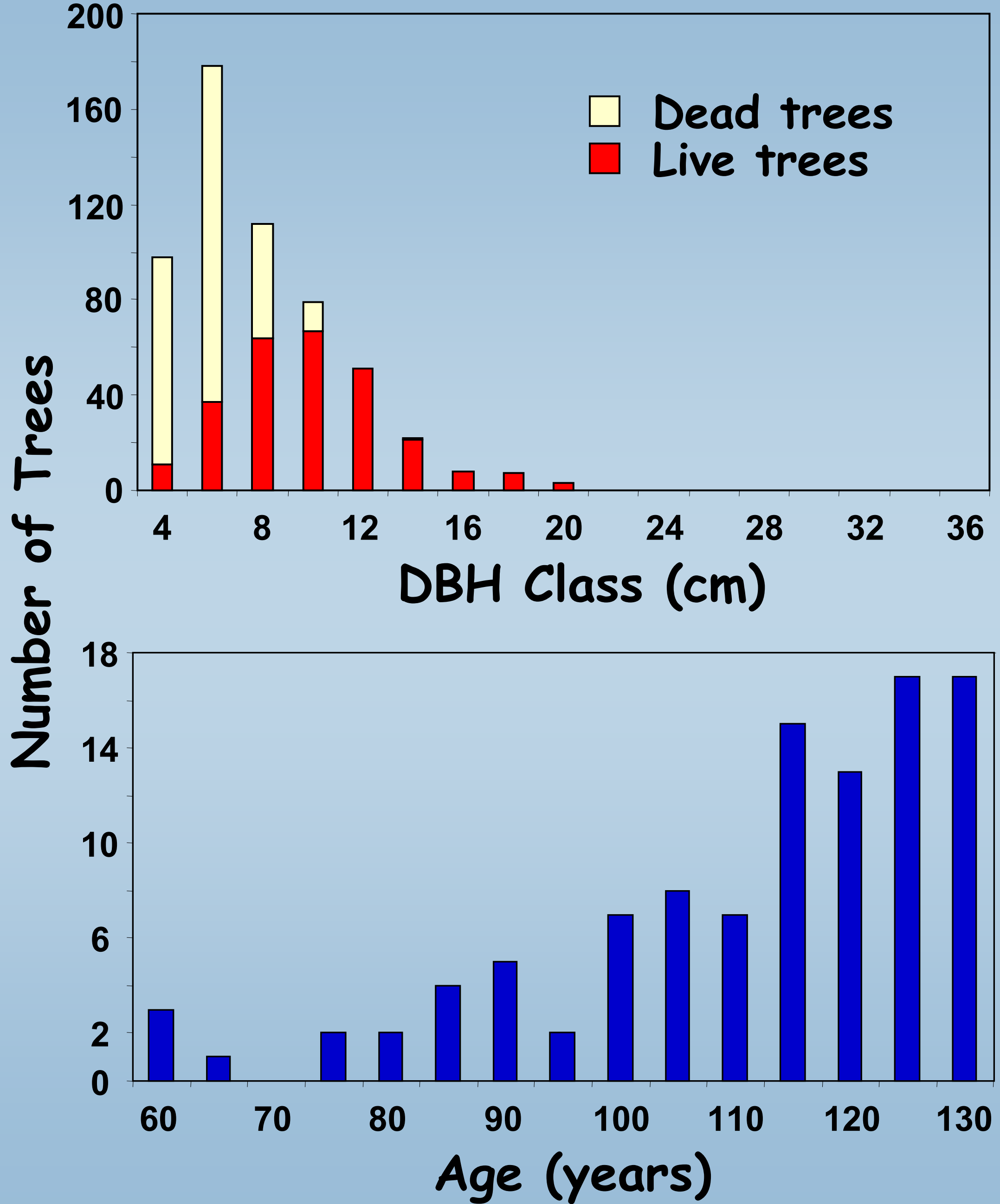
- The post-1988 Yellowstone landscape will recover all carbon lost within the fire cycle (~230 years).

Long-term changes in C storage for Yellowstone



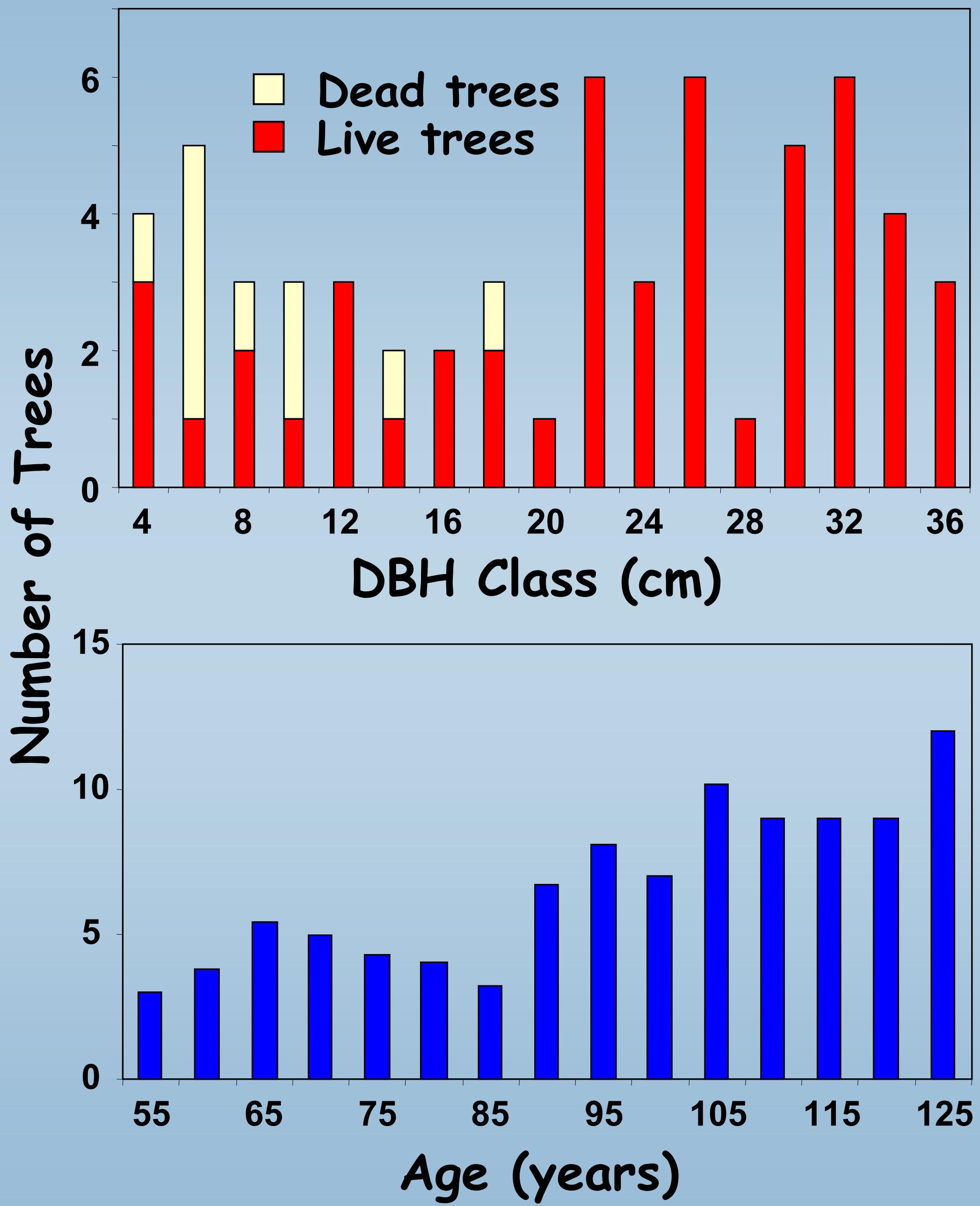
How 'bout them bugs?





Initially dense stand

- Unimodal, steep distributions
- Dead trees common and small



Initially sparse stand

- Bimodal or wide distributions
- Dead trees much less common

Location of Carbon Stocks (Measured)