Effects of changes in climate and fire frequency on landscape-scale carbon cycling in coniferous forests

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The Yellowstone landscape

- Stand-replacing fires
- 100-300 year fire interval
- Large, “natural” landscape
- Mosaic of stand age and density

Questions:

- What key processes regulate carbon storage on landscapes?

- How sensitive is carbon storage of a landscape to changes in climate and/or disturbance regimes?

- How can we predict effects of changing disturbance regimes on landscape carbon storage?

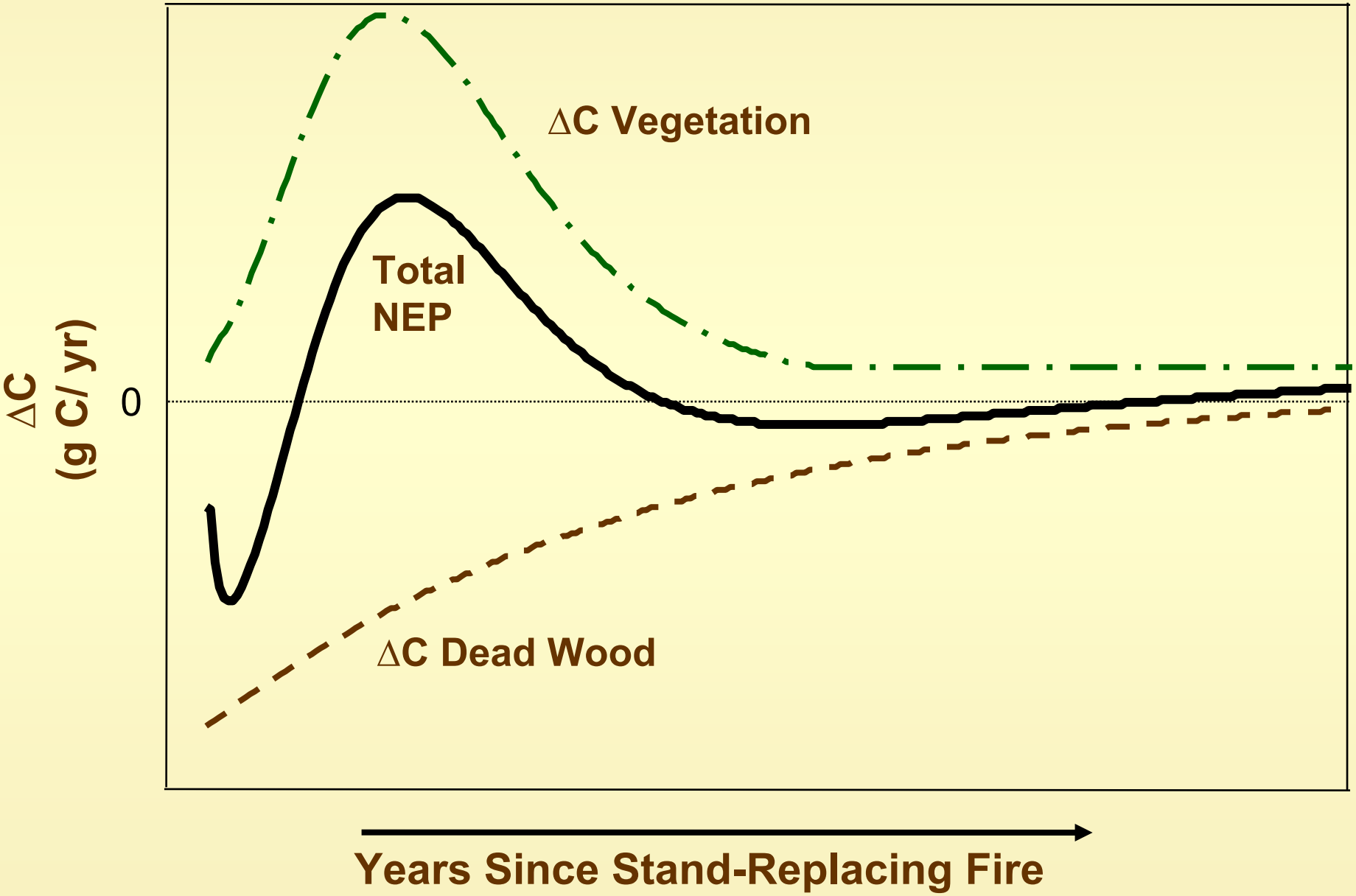
What affects landscape carbon storage?

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

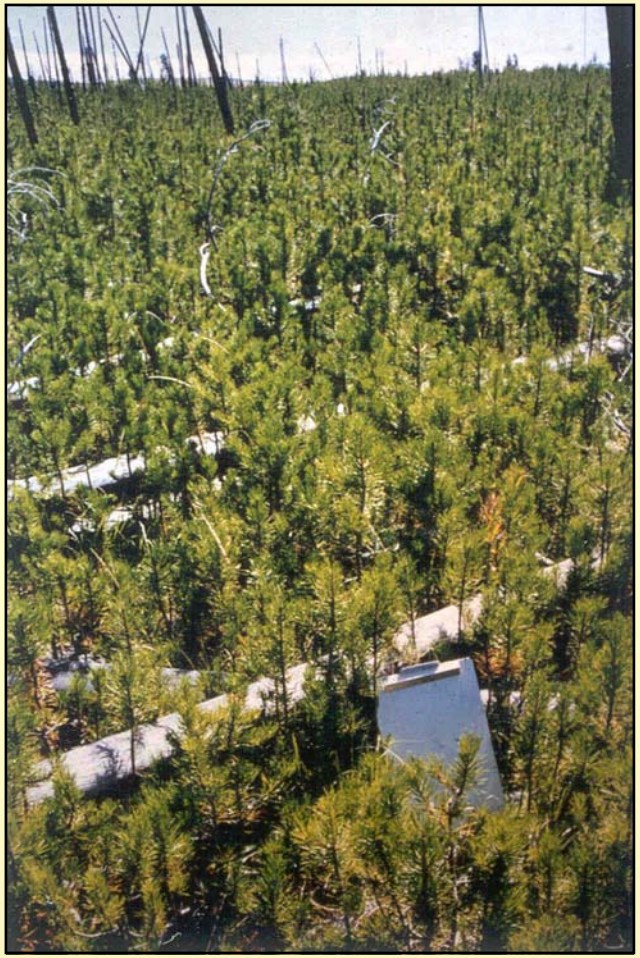
- Changes in the stand density distribution across the landscape following fires.

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

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



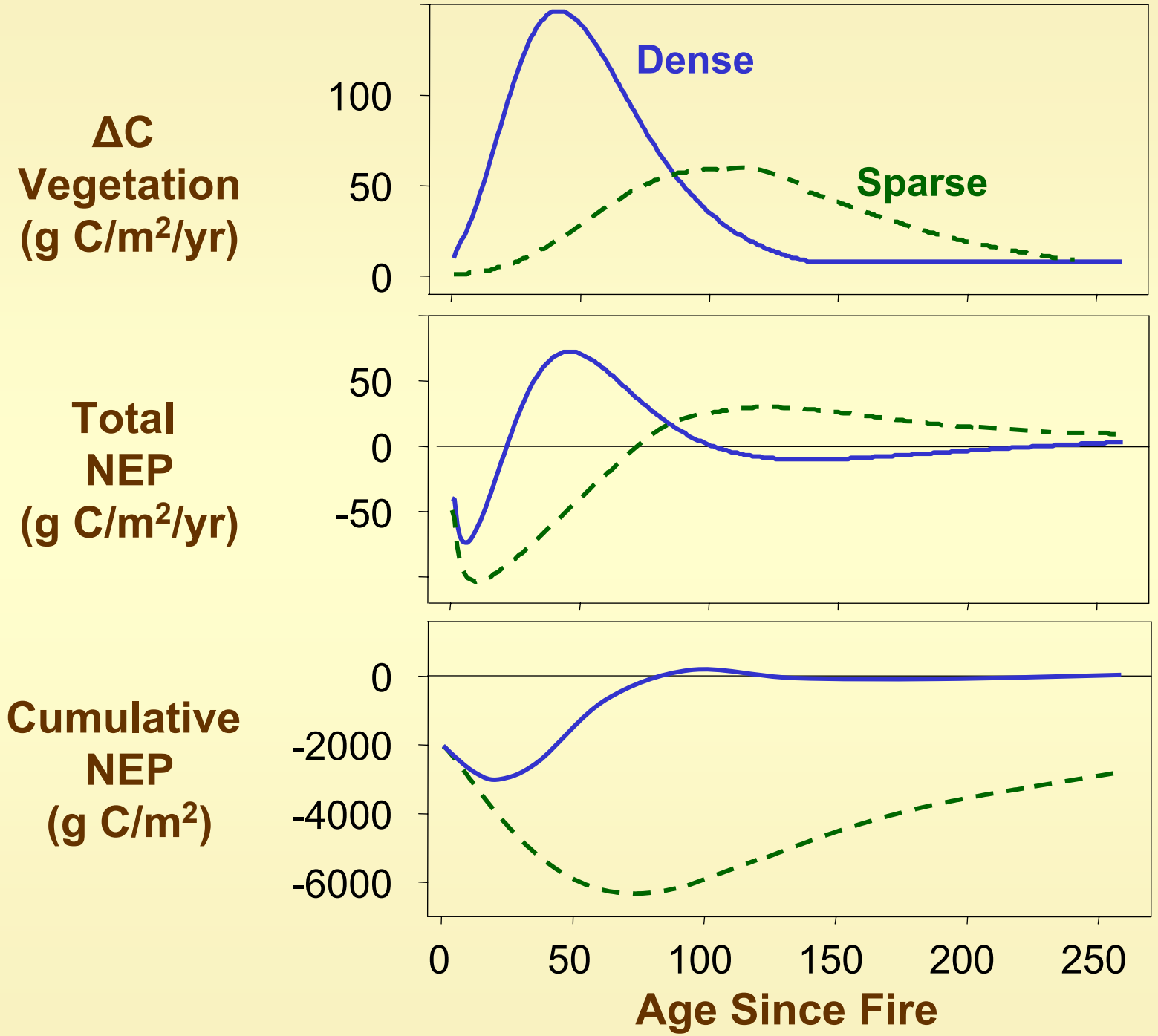
Variability in structure affects landscape NEP



>50,000 stems/ha

1,000 stems/ha

0 stems/ha


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

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

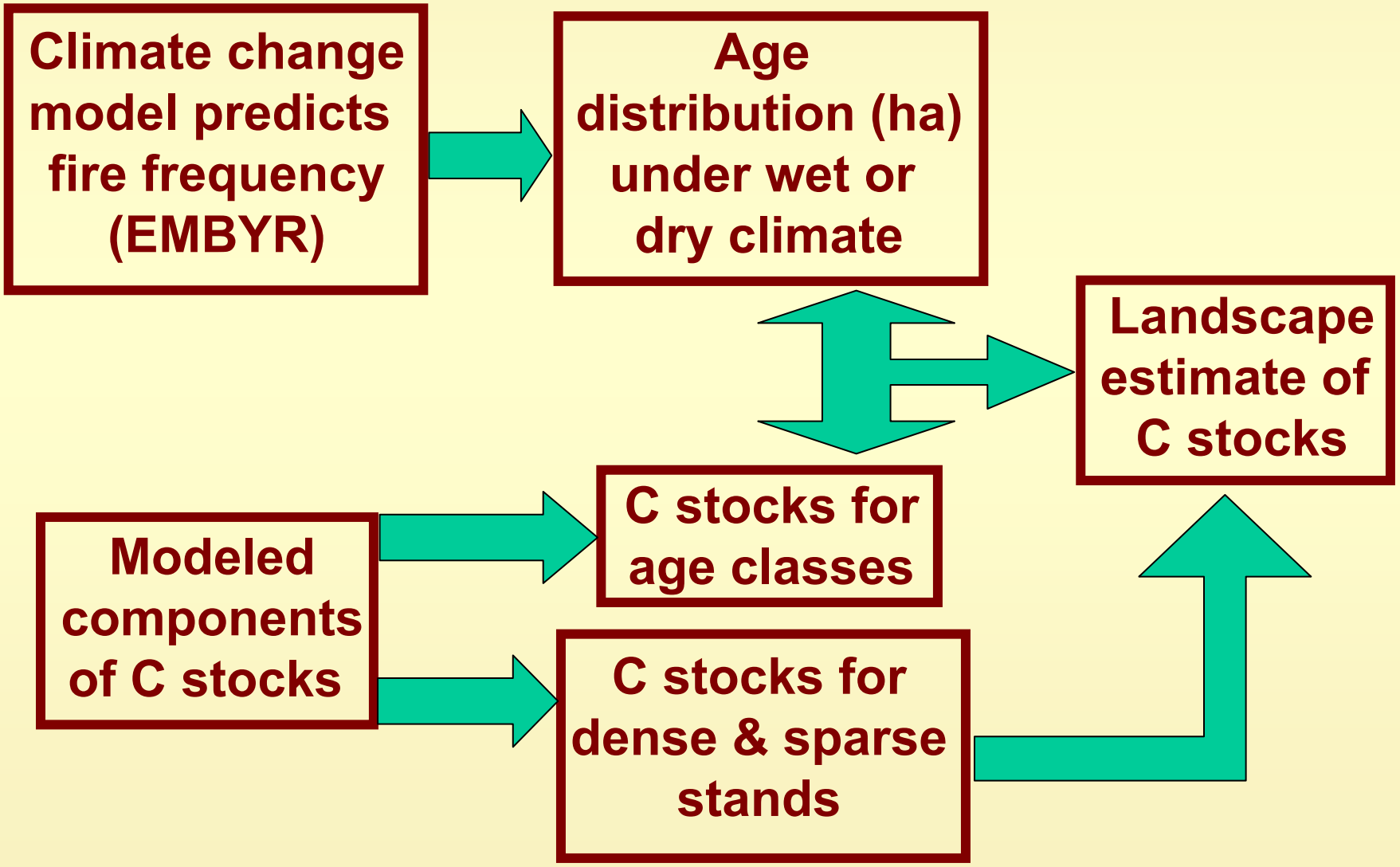
Dense pre-fire

Dense post-fire

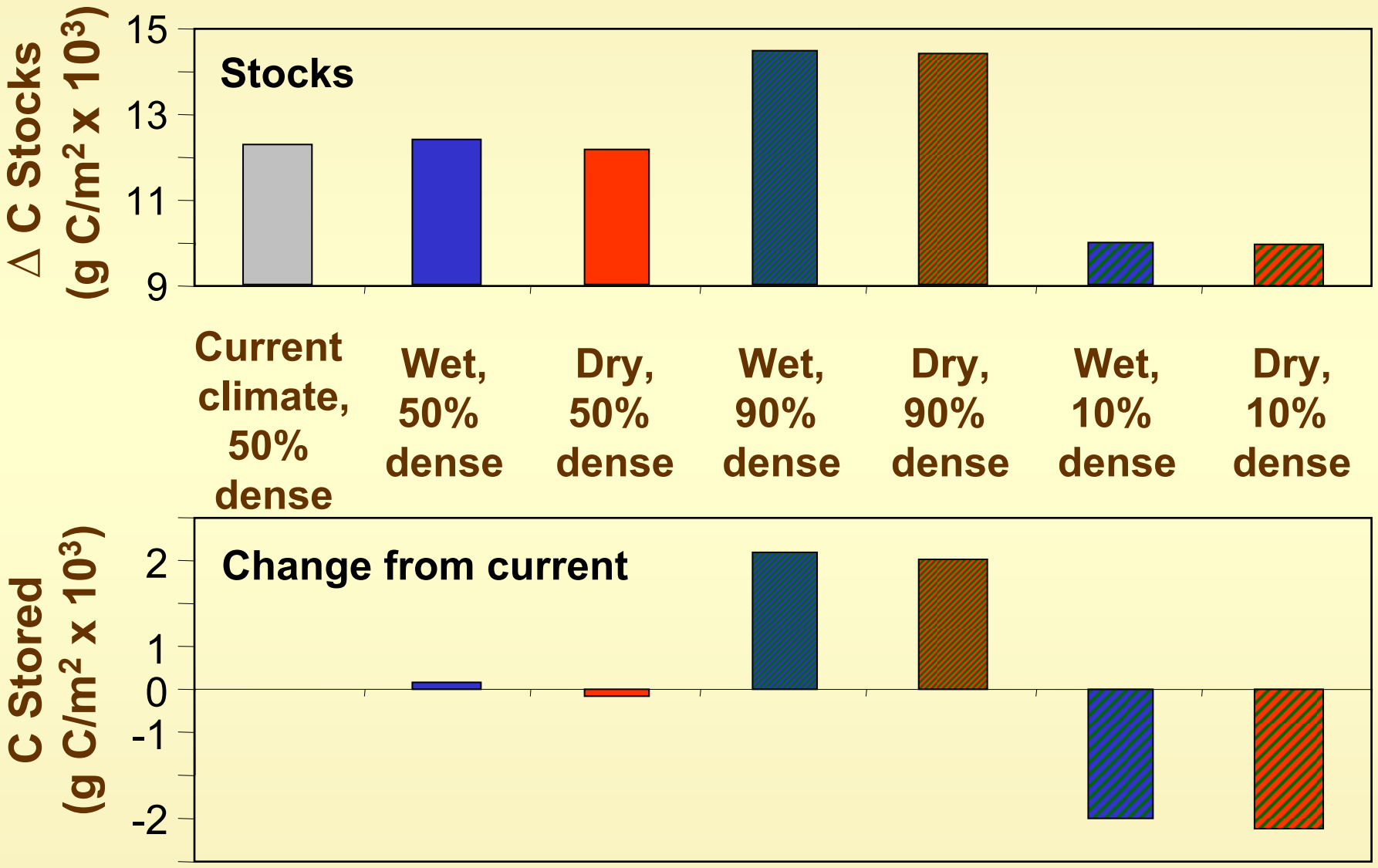
= C gained over fire cycle

Stand age distributions affect landscape NEP

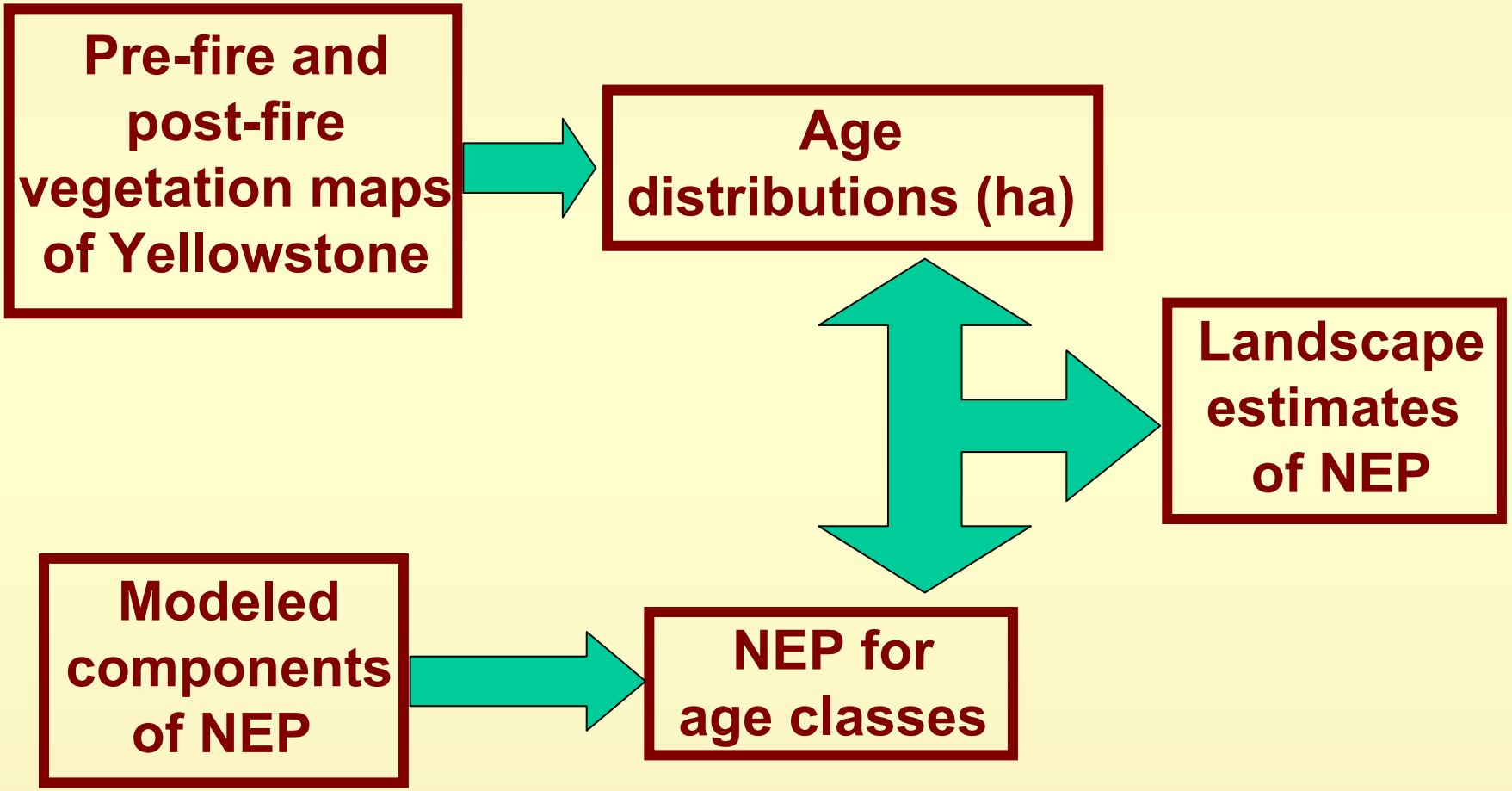
Modeling stand age and density effects on landscape C storage



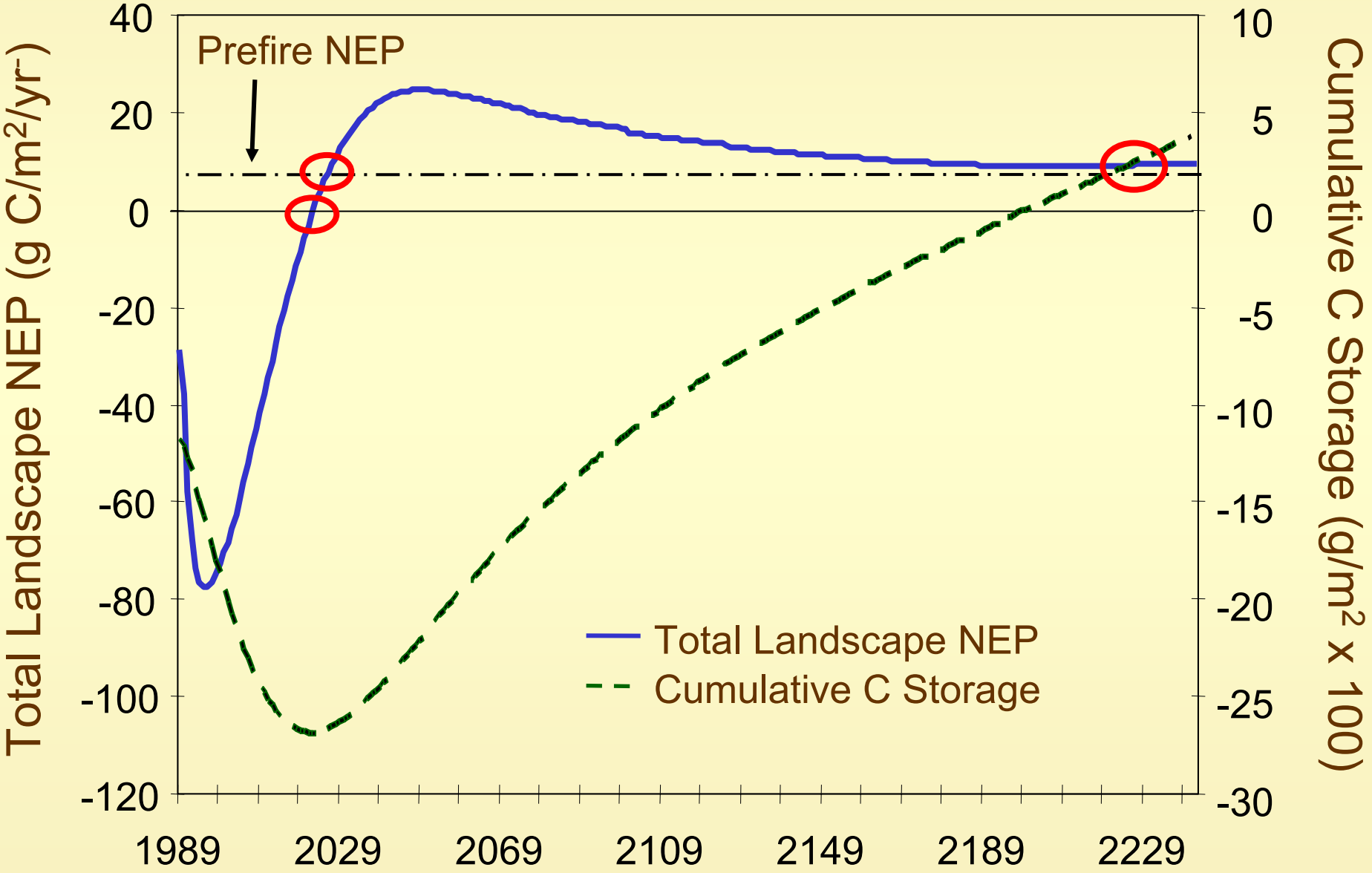
Stand age and density effects on C storage



Modeling future landscape C storage for Yellowstone



Long-term changes in C storage for Yellowstone



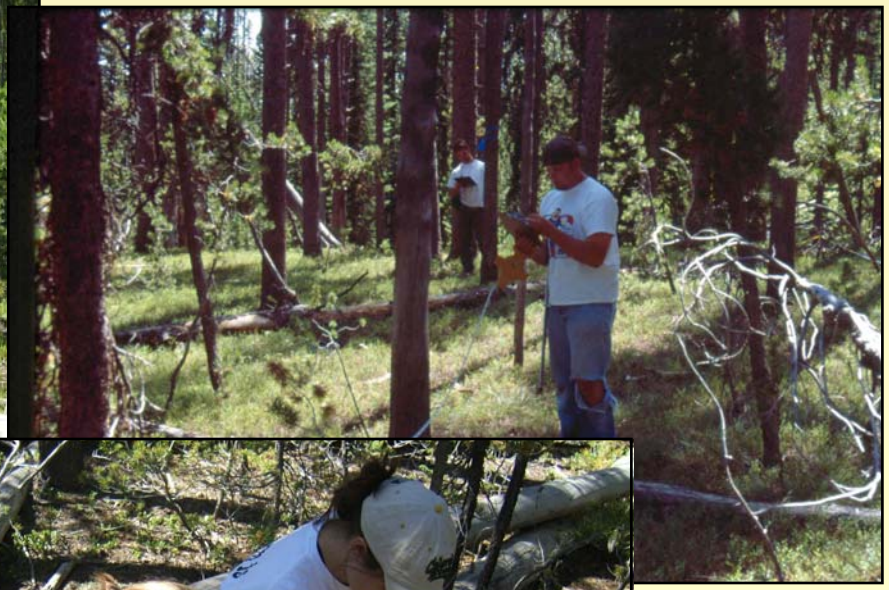
Key questions raised:

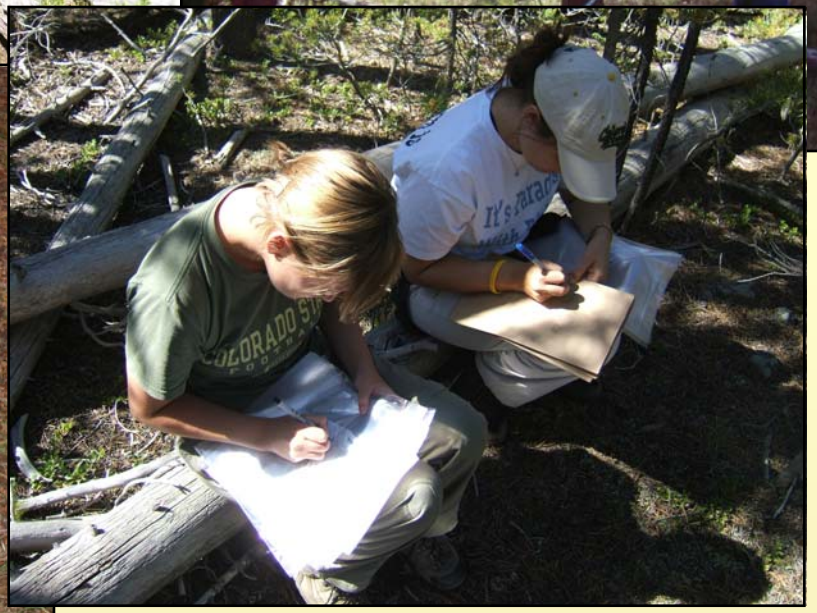
- Do stand structures replace themselves?

- How well can we estimate dead wood remotely, given stand age and density?

- How will climate change affect forest productivity?

- How is nitrogen related to carbon in these systems, and does it vary following fires?





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.

Modeling future C storage for Yellowstone

Area: **525,000 ha** of lodgepole pine forests

Prefire NEP:
~ **4.82 g C/m²/yr**

Carbon lost during 1988 fires:
1360 g C/m²

Post-fire carbon loss through decomposition:
1530 g C/m²