Stand-replacing fires and carbon storage:

Effects of stand age and density on carbon storage in lodgepole pine ecosystems

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The Yellowstone landscape

• Stand-replacing fires

• 100-300 year fire interval

• Large, “natural” landscape

• Mosaic of stand ages and densities
In directing succession, stand-replacing wildfires strongly affect carbon storage
Carbon balance = $C$ gained – $C$ lost

$\Delta C$ Vegetation

$\Delta C$ Dead Wood

Years Since Stand-Replacing Fire

$\Delta C$ (g C/yr)
Variability in structure follows fires

- >50,000 stems/ha
- 1,000 stems/ha
- 0 stems/ha
Questions:

• How closely related are carbon stocks (esp. live biomass and dead wood) to stand age?
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• How do carbon stocks vary with stand density?
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• How closely related are carbon stocks (esp. live biomass and dead wood) to stand age?
• How do carbon stocks vary with stand density?
• How variable are carbon pools within age and density classes?
**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 > 25
- 40-70 > 5,000 stems/ha
- 80-130 > 5,000 stems/ha
- 170-230 Beetle killed
- > 250 Beetle killed
Methods:

• Replicated chronosequences (n = 77 stands);

Moderate density
Density classes:
< 25  7 - 40,000 stems/ha
40-70 1,300 - 5,000 stems/ha
80-130 1,300 - 5,000 stems/ha
**Methods:**

- Replicated chronosequences (n = 77 stands);

**Low density**

**Density classes:**

- < 25 < 1,000 stems/ha
- 40-70 < 1,300 stems/ha
- 80-130 < 1,300 stem/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

<table>
<thead>
<tr>
<th>Density</th>
<th>Total Aboveground Carbon (kg C/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Density</td>
<td>40-70</td>
</tr>
<tr>
<td>Moderate Density</td>
<td>80-130</td>
</tr>
<tr>
<td>High Density</td>
<td>170-230</td>
</tr>
</tbody>
</table>

CV=42%

CV=49%
Dead Wood Carbon

Dead Wood Carbon (kg C/m²)

- Low Density
- Moderate Density
- High Density

Density Ranges:
- < 25
- 40-70
- 80-130
- 170-230
- > 250
Dead Wood Carbon

Dead Wood Carbon (kg C/m²)

Low Density
Moderate Density
High Density

CV = 76%
CV = 79%
Total Ecosystem Carbon Stocks

Low Density

High Density

Moderate Density

Total Ecosystem Carbon (kg C/m²)

<25  40-70  80-130  170-230  >250

Low Density

Moderate Density

High Density
Location of Carbon Stocks

- **Low**: <25, 40-70, 80-130, 170-230, >250
- **Mod**: <25, 40-70, 80-130, 170-230, >250
- **High**: <25, 40-70, 80-130, 170-230, >250

Legend:
- Green: Aboveground
- Light Blue: Dead Wood
- Light Yellow: Belowground
- Purple: Forest Floor
- Blue: Soil Carbon
Conclusions:

- Carbon stocks for most important pools vary with age, but less with density.
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- Most change in carbon storage occurs in the first 100 years following the fire.
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- Carbon stocks for most important pools vary with age, but less with density.
- Most change in carbon storage occurs in the first 100 years following the fire.
- Dead wood component varies more than live biomass within age and density classes.
Take-home Point:

For a single fire cycle, initial post-fire stand densities are probably not important for carbon storage on these landscapes; even the age effect is relatively short-lived.
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Belowground Live Carbon

Total Belowground Carbon (kg C/m2)

- Low Density
- Moderate Density
- High Density

Belowground Live Carbon concentrations for different density ranges:

- < 25 kg C/m²: Limited data, CV=57%
- 40-70 kg C/m²: Moderate concentration, CV=33%
- 80-130 kg C/m²: High concentration
- 170-230 kg C/m²: High concentration
- >250 kg C/m²: High concentration

Note: CV values indicate variability coefficients.
How important are stand age and density for carbon storage?

(Kashian et al. 2006, Bioscience)

• Stand age is less important than stand density in affecting landscape carbon storage; large changes in fire intervals (< 100 years) are necessary.

• Large (?) changes in the stand density distribution are necessary to shift landscape carbon storage.