Recovery of carbon stocks after wildfires in boreal forests: a synthesis

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Background

- 10-15 million ha of boreal forests burn annually
- Climate warming has already increased and will increase the extent, intensity and frequency of forest fires in high-latitude boreal forests
- Fires decrease forest carbon (C) stocks and may cause long-term changes in C dynamics by altering forest regrowth, successional trajectories, litter production, organic matter decomposition and the fluxes of energy, water and nutrients

Quantifying the magnitude of post-fire C changes and the rate of recovery of C stocks is necessary for understanding how changing fire frequency and intensity influence regional and global C budgets and for predicting future changes in C budgets.
Research questions

• How quickly forest C pools recover after fire and how the recovery of C stocks vary across boreal zone?
• How fires change the distribution of C among different ecosystem components?
• To what extent time since fire and climatic conditions explain the variation in C accumulation rate?
• Data in total of **368 plots** from **15 fire chronosequence studies** from different parts of boreal zone (latitudes 44–67°N)
• Chronosequences covered at minimum the first 100 years after fire
• MAT varied from -9.5°C to +5.2°C and MAP from 295 mm to 824 mm.
• The mean annual GPP 0.31-0.94 kg m²
Schematic C dynamics after fire

- Living biomass accumulates over time until it stabilizes or even decline
- C increases linearly in O-horizon, mineral soil C remains quite unchanged
- Dead wood shows an U-shaped pattern
Carbon accumulation in living trees

Gompertz function
\[ y = (a_0 \times \text{Climate variable} + a_1)e^{b-c\times\text{Time}} \]

Potential evapotranspiration (PET) best explained the variation in C accumulation rate

<table>
<thead>
<tr>
<th>Model</th>
<th>AIC</th>
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</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>1674.542</td>
</tr>
<tr>
<td>Summer precipitation</td>
<td>1679.842</td>
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<tr>
<td>GPP</td>
<td>1679.583</td>
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<tr>
<td>Precipitation/PET ratio</td>
<td>1680.593</td>
</tr>
<tr>
<td>Drought index (pdi)</td>
<td>1681.594</td>
</tr>
<tr>
<td>Temperature</td>
<td>1675.959</td>
</tr>
<tr>
<td>PET</td>
<td><strong>1672.256</strong></td>
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<tr>
<td>Summer temperature</td>
<td>1675.075</td>
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<tr>
<td>Summer precipitation</td>
<td>1681.479</td>
</tr>
</tbody>
</table>
Carbon in the organic layer

- No clear trend, large variation
- Average C accumulation rate 6 g C m² yr⁻¹
C accumulation rates $< 5-30 \text{ g m}^{-2}\text{ yr}^{-1}$
Total ecosystem carbon (living trees + ground vegetation + dead trees + organic layer)

Time since fire and PET together explained 57% of the variation in total ecosystem C stocks
C accumulation rates < 5-60 g m$^{-2}$ yr$^{-1}$
Conclusions

• Annual C accumulation rates varied from < 5 to 60 g m\(^2\)
• PET is the most important factor explaining the C accumulation in trees and total ecosystem
• Accumulation pattern is not clear: linear vs. curved?
• O-horizon: several factors affect (climate→ biomass production and decomposition), changes in vegetation, successional trajectories, microbial communities, organic matter quality, the amount of dead trees and rhizosphere priming effect, the formation of pyrogenic compounds etc.
• Soil is naturally heterogenic, and during the fire, the severity of combustion is variable ranging from a light burning to an extensive combustion of surface soils layers which may further increase the spatial variation → adequate number of samples?
Methodological remarks

- Weaknesses of the chronosequence method:
- Assumption that only time since disturbance causes the differences
- Pre-fire structure and fire severity are very difficult to identify and may vary within the chronosequence (also the severity of previous fires may have varied between the sites)
  - Difficult to ascertain the similarity of plots within the chronosequence
    - Fertility, paludification, soil texture
    - Stochastic phenomena, history in pest and diseases
Thank you!

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