What factors control post-fire ecosystem processes in burned forest?

Examining the influences of wildfire severity, forest type, and soil organic matter composition on carbon & nitrogen dynamics

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Fire is an important ecological process in forests around the globe
Predictions of increased fire risk (Liu et al. 2013), size and severity (Miller et al. 2009) raise concerns about the ability of forests to recover after extreme fire events (Breshears et al. 2005, Van Mantgem et al. 2009)
Pagami Creek Fire, Minnesota, 2011

Research questions

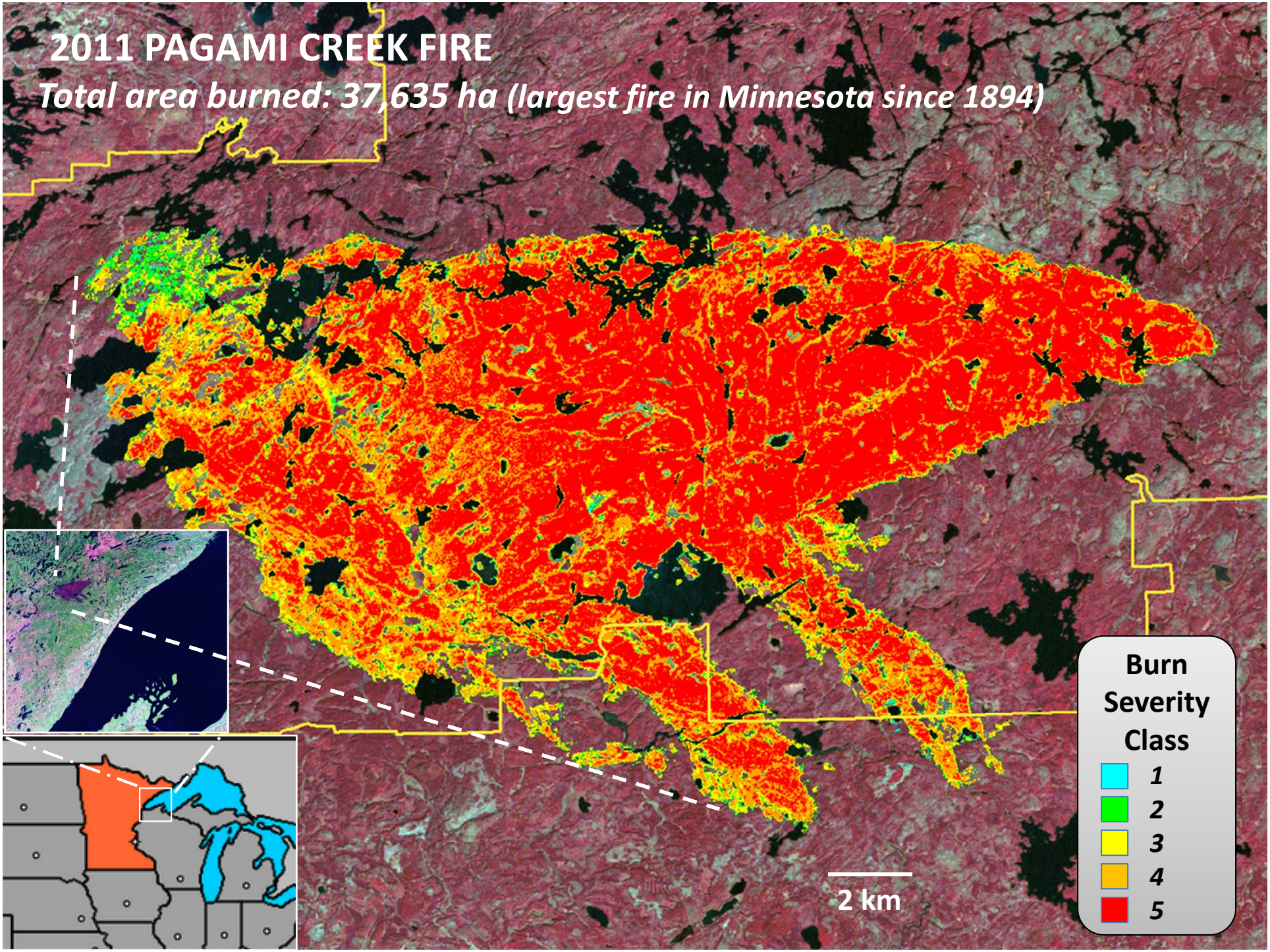
- ***How does wildfire severity affect forest ecosystem recovery? And, how do effects differ between contrasting forest cover types?***
- ***How does soil organic matter composition (especially pyrogenic C content) influence soil C & N dynamics?***

  - SOM composition
  - Carbon (C) and Nitrogen (N) mineralization rates
  - Relationships between PyC content & ecosystem processes

Study area: southern boreal forest

Boundary Waters Canoe Area Wilderness, Minnesota, USA

- Mean annual temperature: **4° C**
- Mean annual precipitation: **650 mm** *(Recently: prolonged regional drought)*
- Soils: **Entisols**


2011 PAGAMI CREEK FIRE
Total area burned: 37,635 ha (largest fire in Minnesota since 1894)
Burn Severity Class
1
2
3
4
5
2 km

In 2011 we installed permanent research plots across a gradient of fire severity, in multiple forest cover types

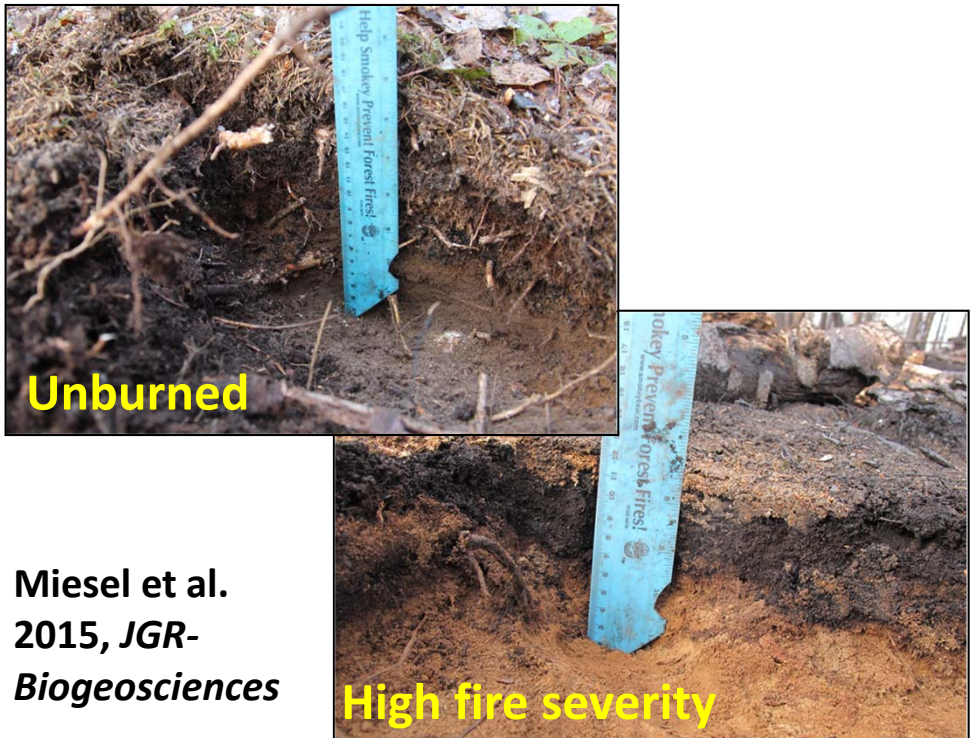
- **Unburned (Control) = 0**
- **Low severity = 2**
- **Moderate = 3**
- **High severity = 4**

↑ Conifer-dominated forest (2014)

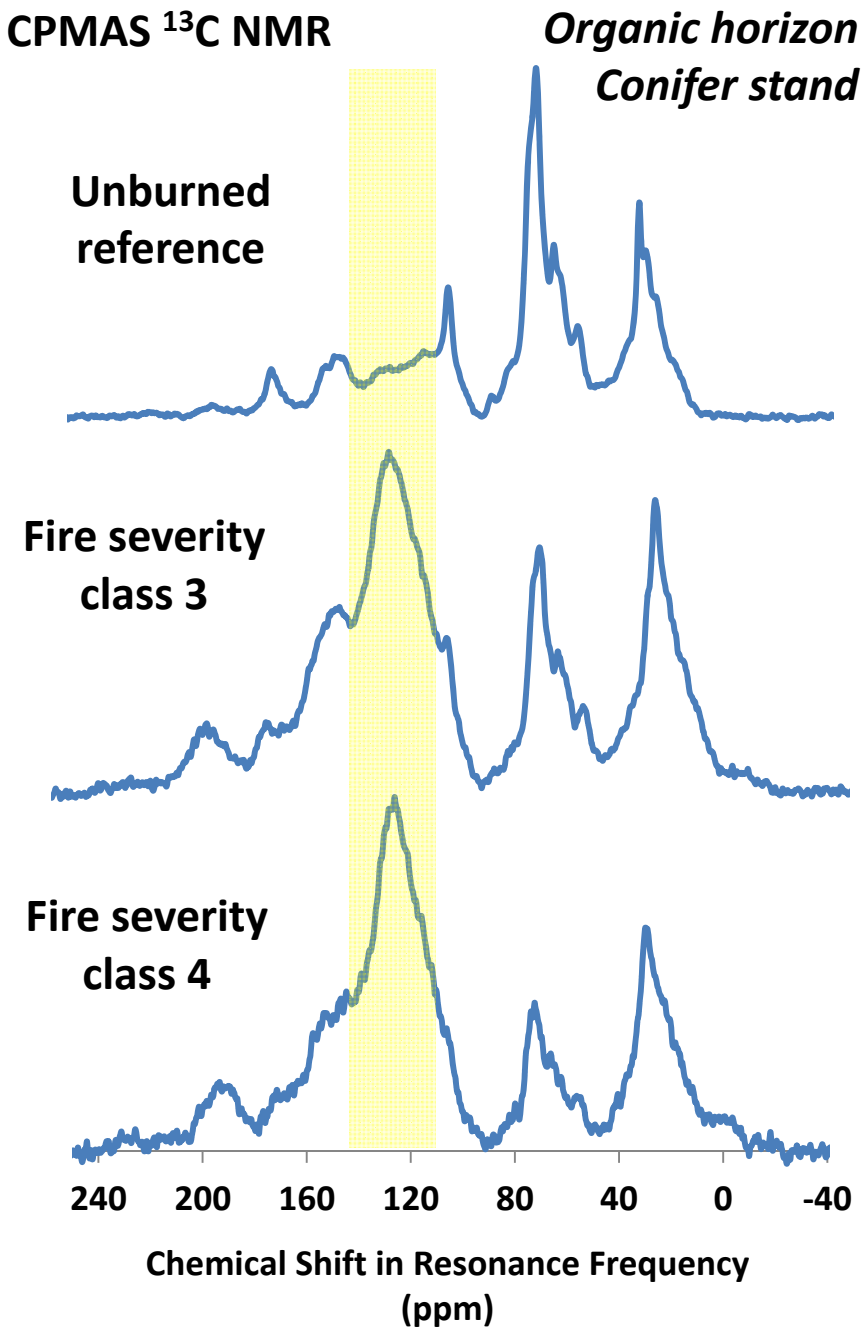
Deciduous-dominated forest (2014) →

1. Immediate changes to SOM composition

- Initial (2011) samples showed that fire and severity level influenced soil organic matter (SOM) composition
- The contribution of the aromatic region (^{13}C NMR) increased with fire severity in the forest floor layer

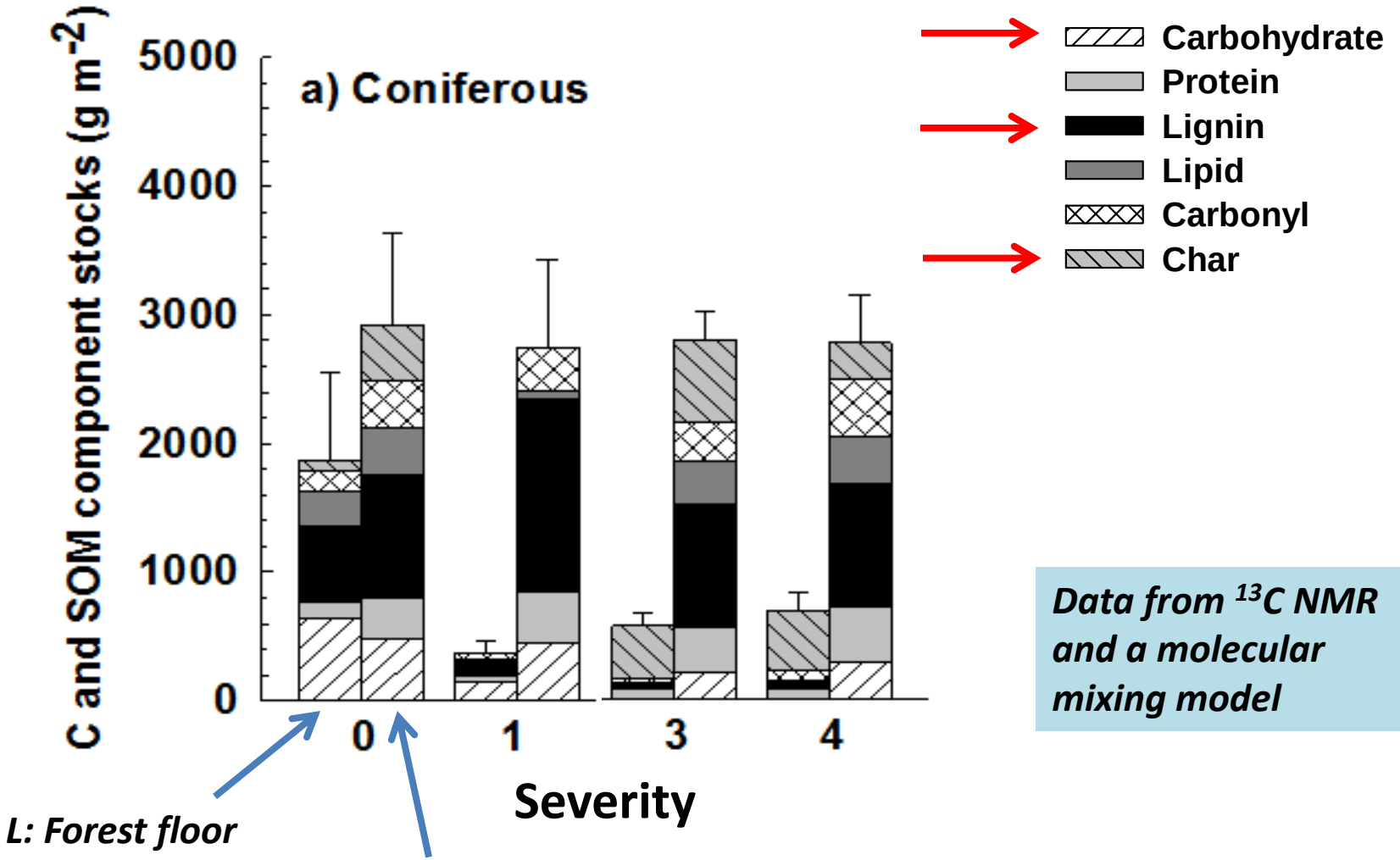


Miesel et al. 2015, *JGR-Biogeosciences*



1. Immediate changes to SOM composition

- In the forest floor layer, carbohydrate & lignin stocks decreased with severity, whereas PyC (char) stocks increased with severity



Data from ^{13}C NMR and a molecular mixing model

Miesel et al. 2015, *JGR-Biogeosciences*

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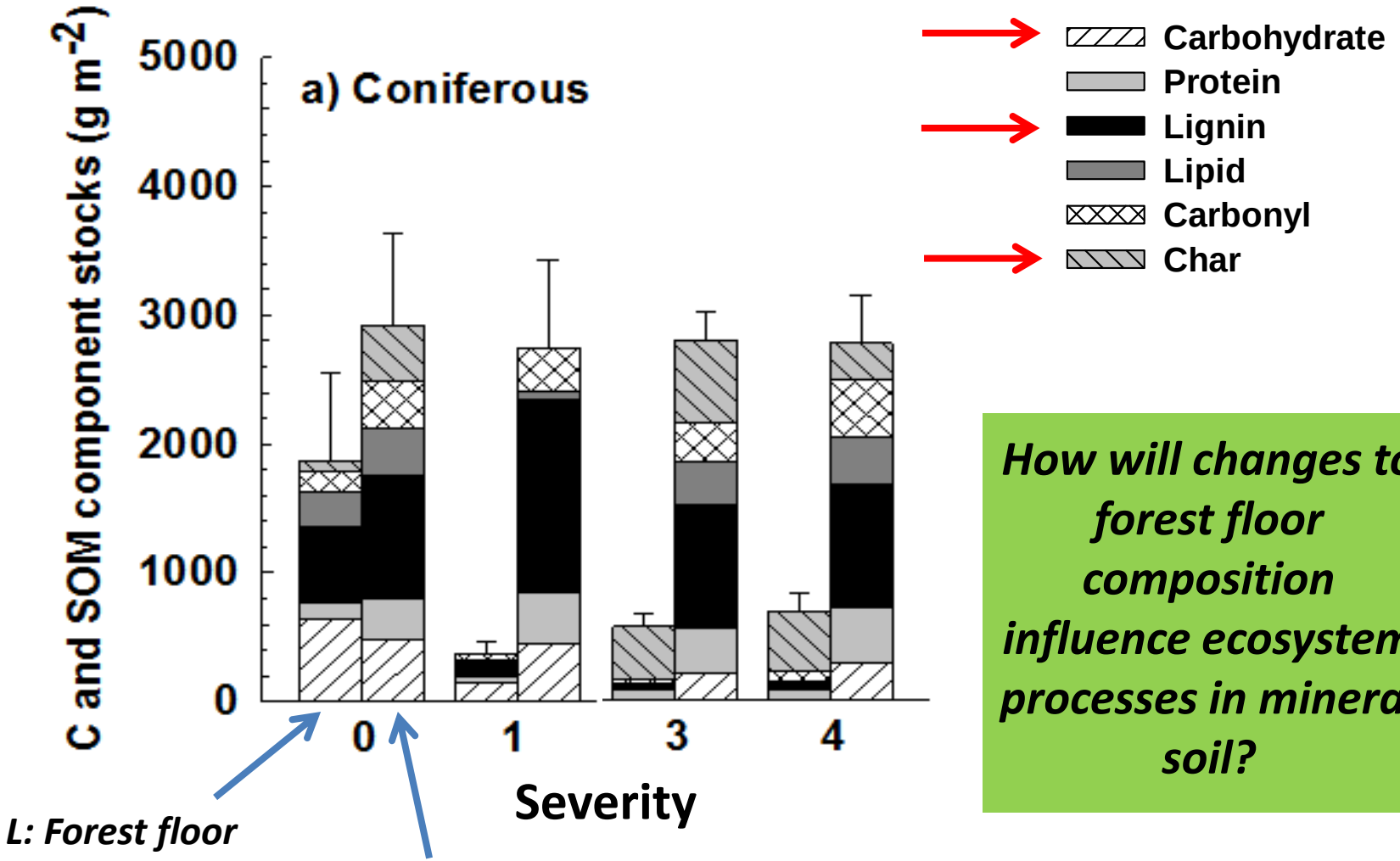


How will changes to forest floor composition influence ecosystem processes in mineral soil?

Miesel et al. 2015, *JGR-Biogeosciences*

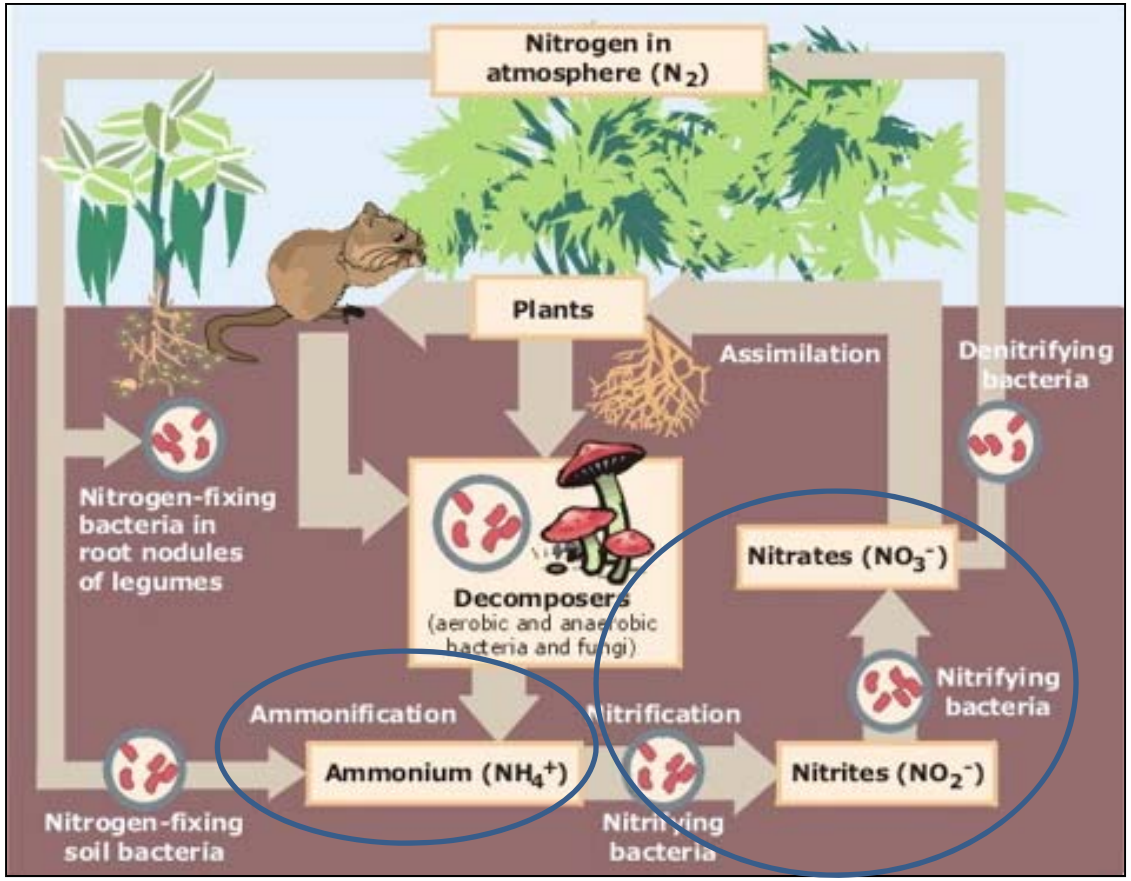
2. Nitrogen mineralization rates

First, a brief review of the N cycle...

- **N "mineralization" = the process by which N_2 or organic N is transformed into plant-available N**

- **Performed by microbes in soil**

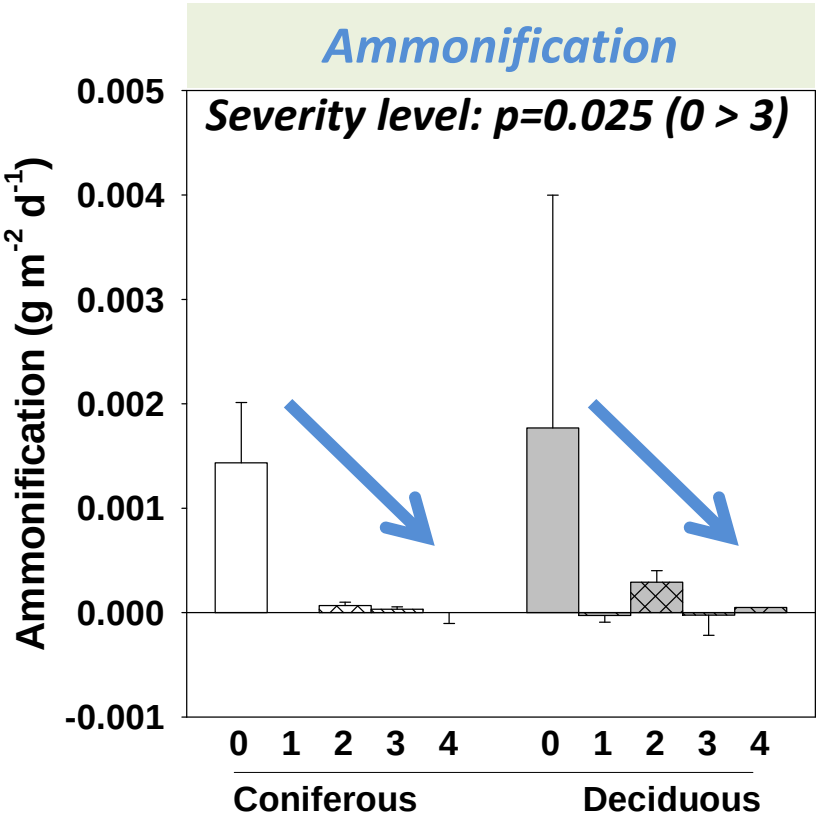
- **Focus on rates of *ammonification*** (organic N → NH_4^+) **and *nitrification*** (NH4 → NO_3^-)

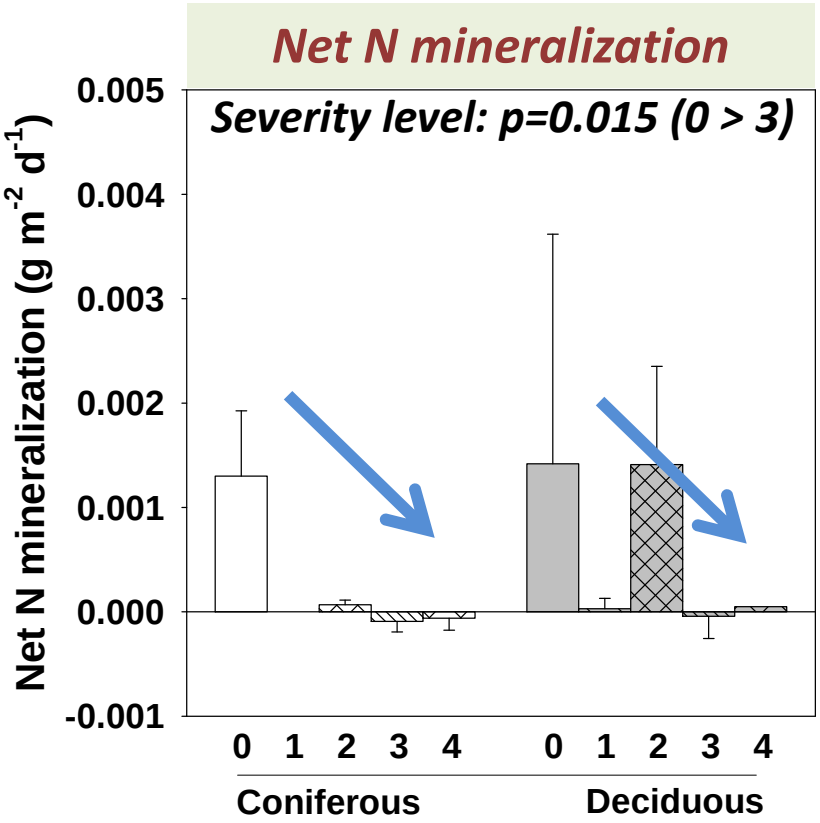


2. Nitrogen mineralization rates

- Our data show a trend towards **decreasing ammonification** and **net N mineralization rates** with fire severity, in mineral soil samples collected three years post-fire (2014)

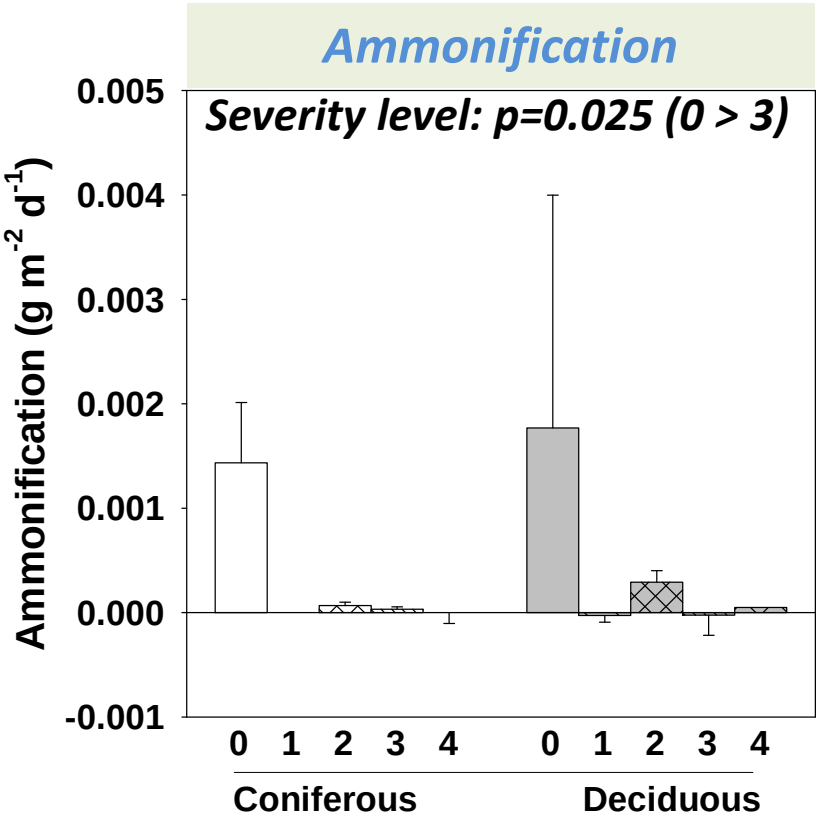
Data from a 68-day field incubation: 0-10 cm mineral soil

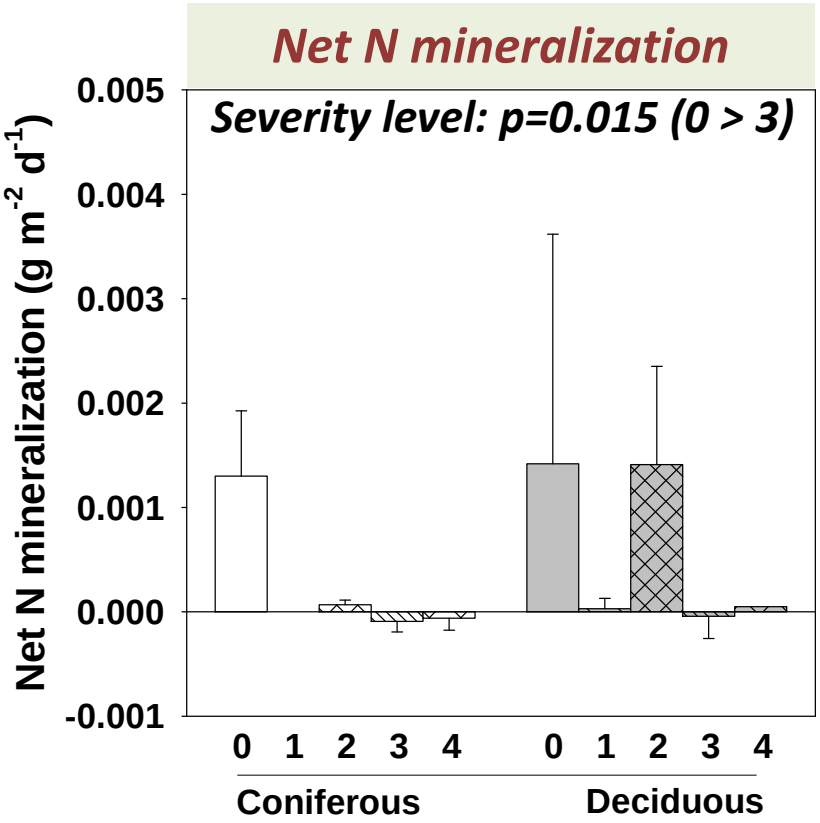




2. Nitrogen mineralization rates

- Fire may slow rates of microbial processes responsible for converting organic N into N available for uptake by forest plants
- Microbial communities in burned areas may be less diverse, less active, or more resource-limited relative to control areas

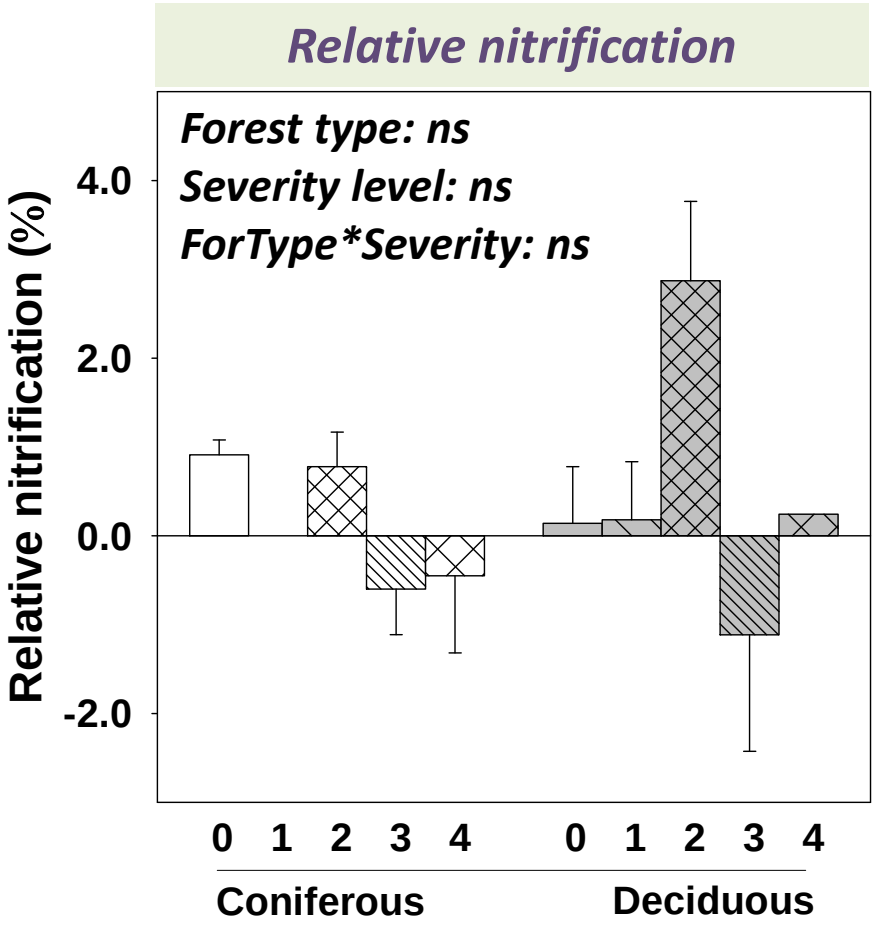




2. Nitrogen mineralization rates

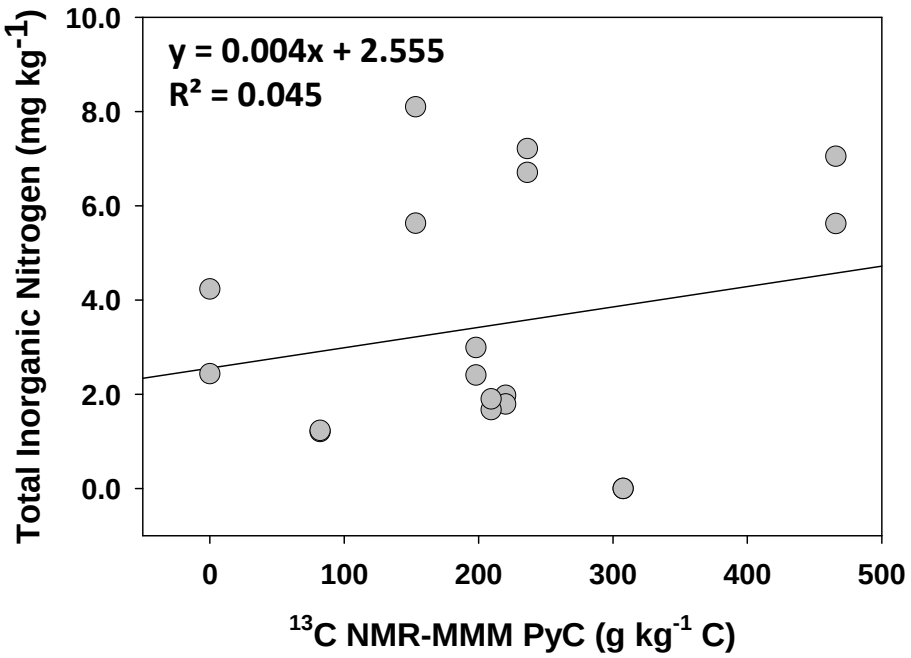
- **Relative nitrification evaluates the effectiveness of nitrifier microbes at converting $NH_4^+ \rightarrow NO_3^-$**
- **In general, <1% of NH_4^+ was converted to NO_3^-**
- **Negative nitrification rates suggest microbial immobilization of N**

Loosely capped PVC tubes prevented N loss from leaching



3. How does the presence of pyrogenic C in mineral soil influence nutrient availability & cycling?

- **We observed weak *negative* relationships between N mineralization rates and PyC concentrations** *(data not shown)*
- **There is a weak *positive* relationship between the concentration of Total Inorganic N (NH_4^+ + NO_3^-) and PyC concentration**



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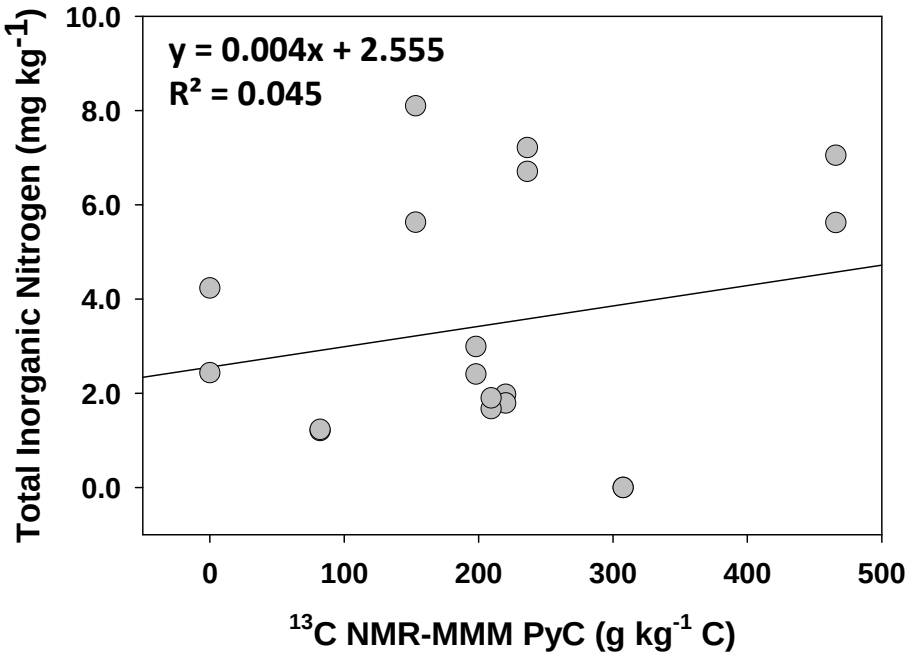
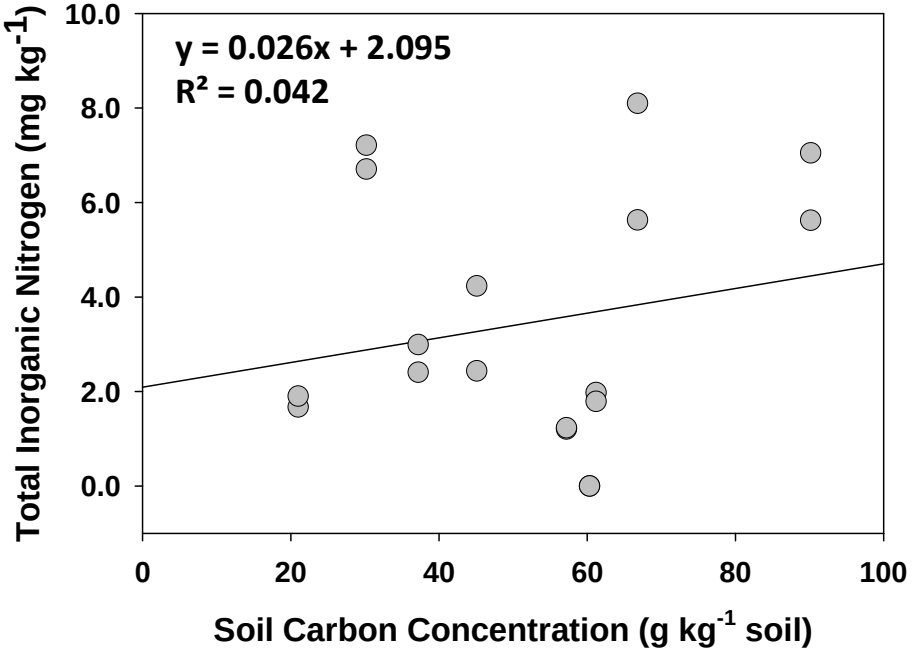


However, we observe a similar relationship with total C concentration!



Conclusions: part I

How does wildfire severity affect forest ecosystem recovery? And, how do effects differ between contrasting forest cover types?

- **Fire changed OM composition in the forest floor**
  - Loss of carbohydrate and lignin, & gain of PyC with severity.
  - Long-term nutrient depletion?

- **Fire may slow nitrogen mineralization rates in mineral soil (?)**
  - Microbial communities may be less diverse, less active or more resource-limited in burned areas

- **Ecosystem response to fire severity is not linear, and forest type was not a significant factor**

Conclusions: part II

How does soil organic matter composition (especially pyrogenic organic matter content) influence soil C & N dynamics?

- **The relationships between PyC concentrations in mineral soil and N mineralization rates or total inorganic nitrogen (TIN) concentrations were weak**
  - Analysis of additional samples may help resolve the relationships for southern Boreal forest
  - Results contrast with laboratory incubations of PyC-amended mineral soil *(Michelotti & Miesel 2015, Forests **6**:1325-1342)*

Thank you!

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Field, laboratory and logistical support:
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