Can we predict C and N cycling based from soil physical properties in a northern hardwood forest?

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Outline

- Background
  - Particle size distribution
  - Study Sites: Hydro-Pedological Units

- Results
  - C, N chemistry by particle size
  - Nitrification

- Next steps
Context

- Climate change
  - C dynamics
  - C sequestration
- N saturation
  - Predict N retention or loss
  - C and N interactions
Relating soil particle size distribution to function

Overall study objectives:

- Characterize particle size distribution in soils → pore size distribution → soil moisture
  - Pipette method (gravitational sedimentation)
  - Laser Diffraction
  - Thin section
  - Field soil moisture and tensiometers
Relating soil particle size distribution to function

**Overall study objectives (cont’d):**

- **C and N availability**
  - Directly: %C and N by particle size
  - Directly: lability of C and N by particle size
  - Indirectly: linking soil moisture to N mineralization/nitrification

Relevant for climate change models
Background

- C age increases with depth
- Microbial transformations increase $\delta^{15}N$ and $\delta^{13}C$ of remaining organic matter
- Soil $\delta^{15}N$ and $\delta^{13}C$ increases with depth/age
- Mineral soils have surface-associated C and N
- Factors affecting C and N isotope signature
  - microbial transformations
  - DOM of varying isotopic signatures
Soil $\delta^{15}$N with Depth
HBEF W5

Pardo et al., CJFR, 2002
Hypotheses I

1. $\delta^{15}$N and $\delta^{13}$C will increase with decreasing particle size

2. **Organic horizons:**
   a. %N will decrease with decreasing particle size

**Mineral horizons:**

b. %N will increase with decreasing particle size
• Humid, continental climate
• Mixed northern hardwood/spruce-fir forest
  • *Fagus grandifolia*, *Betula allegheniensis*, *Acer saccharum*
  • *Picea rubens*, *Abies balsamea*
• Crystalline granitic/metasedimentary bedrock
• Acidic soils developed in sandy to loamy glacial till
Hydro-pedological Units
in W3 at the Hubbard Brook Experimental Forest

PIs: Scott Bailey, Kevin McGuire, Don Ross
Schematic showing representative pedons from each HPU. Redrawn from Brousseau et al. (unpublished)

Hydropedologic Units:
Type 1: E-Podzols
Type 2: Bhs-Podzols
Type 3: Typical Podzols
Type 4: Bimodal Podzols
Type 5: Bh-Podzols
Type 6: Seep Inceptisols

Slide courtesy of R. Bourgault
Variation in Soil Morphology

Typical podzol

O
--- 8 cm
E
---- 16 cm
Bhs
---- 25 cm
Bs
---- 47 cm
BC
---- 63 cm
C

Pedon I1

Podzol

E podzol

Oa
---- 15 cm
E₁
---- 45 cm
E₂
---- 75 cm
Cd

Pedon A6

Bhs podzol

A
---- 7 cm
Bhs₁
---- 19 cm
Bhs₂
---- 41 cm
BC
---- 64 cm
Cd

Pedon N2

Photos: Scott Bailey
<table>
<thead>
<tr>
<th>Upslope</th>
<th>H5 Bimodal podzol</th>
<th>N3 E podzol</th>
<th>K9 Typical podzol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Down-slope</td>
<td>H6 Riparian Bh podzol</td>
<td>N4 Bhs podzol</td>
<td>K10 Hillslope Bh podzol</td>
</tr>
</tbody>
</table>
Additional Hypothesis

3. Horizons with lateral flow will have higher rates of N mineralization and nitrification.
<table>
<thead>
<tr>
<th>Size Fraction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2,000μm</td>
<td>bulk soil (sand, silt, clay)</td>
</tr>
<tr>
<td>&gt;500μm</td>
<td>very coarse sand, coarse sand</td>
</tr>
<tr>
<td>&gt;250μm</td>
<td>medium sand</td>
</tr>
<tr>
<td>&gt;125μm</td>
<td>fine sand</td>
</tr>
<tr>
<td>&gt;63μm</td>
<td>very fine sand</td>
</tr>
<tr>
<td>&lt;63μm</td>
<td>some very fine sand, silt, clay</td>
</tr>
<tr>
<td>2-50μm</td>
<td>silt</td>
</tr>
<tr>
<td>&lt;2μm</td>
<td>clay</td>
</tr>
</tbody>
</table>
%N by particle size
W3 H5

Particle size fraction (\(\mu m\))

- >500
- >250
- >125
- >63
- <63

%N

0.0
0.1
0.2
0.3
0.4
0.5

E
Bhs1
Bhs2
BC
Cd
C:N by particle size
W3 H5

Particle size fraction (μmol):

- >500
- >250
- >125
- >63
- <63

C:N values:

- >500: 10
- >250: 12
- >125: 14
- >63: 16
- <63: 18

Legend:

- E
- Bhs1
- Bhs2
- BC
- Cd
$^{13}$C by particle size
W3 H5

<table>
<thead>
<tr>
<th>Particle size fraction (μm)</th>
<th>d$^{13}$C (per mil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;500</td>
<td>-27.5</td>
</tr>
<tr>
<td>&gt;250</td>
<td>-27.0</td>
</tr>
<tr>
<td>&gt;125</td>
<td>-26.5</td>
</tr>
<tr>
<td>&gt;63</td>
<td>-26.0</td>
</tr>
<tr>
<td>&lt;63</td>
<td>-25.5</td>
</tr>
<tr>
<td>&lt;63</td>
<td>-25.0</td>
</tr>
<tr>
<td>&lt;63</td>
<td>-24.5</td>
</tr>
<tr>
<td>&lt;63</td>
<td>-24.0</td>
</tr>
</tbody>
</table>

![Graph showing $^{13}$C by particle size with different symbols for different categories: E, Bhs1, Bhs2, BC, and Cd.]
$^{15}$N by particle size

W3 H5

Particle size fraction ($\mu m$)

- $>$500
- $>$250
- $>$125
- $>$63
- $<$63

$^{15}$N (per mil)

![Graph with particle size fraction on the x-axis and $^{15}$N (per mil) on the y-axis. Different symbols represent different samples: E, Bhs1, Bhs2, BC, Cd.]
%N by particle size
W3 N3

Particle size fraction (μm)

- >500
- >250
- >125
- >63
- <63

%N

0.25

0.20

0.15

0.10

0.05

0.00

E1
E2
Bhs
Bsm

Particle size fraction (μm)
15N by particle size
W3 N3

Particle size fraction (μm)

>500
>250
>125
>63
<63

$^{15}$N (per mil)

0.00
0.05
0.10
0.15
0.20
0.25

E1
E2
Bhs
Bsm

Particle size fraction (μm)
C:N by particle size
W3 N3

Particle size fraction (µm)

- >500
- >250
- >125
- >63
- <63

C:N

Particle size fraction (µm)

- E1
- E2
- Bhs
- Bsm

C:N by particle size fraction

E1
E2
Bhs
Bsm
Summary

1. $\delta^{15}$N and $\delta^{13}$C increase with decreasing particle size
2. %N increases with decreasing particle size (except A, E-podzol E1)
3. N mineralization and nitrification are high in some lateral flow horizons
Next Steps

- Isotopic analysis of 2011 soil extracts (t=0 and 10 day): $\delta^{15}$N in NH$_4^+$ and NO$_3^-$

- Re-incubation of different particle size fractions
  - $\delta^{15}$N in NH$_4^+$ and NO$_3^-$
  - Evaluate the DOM compounds associated w/ mineral surfaces
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N mineralization and Nitrification
W3 2011
Further Variation in Soil Morphology
Fig. 2. Variation in $\delta^{15}$N of plant and soil fractions: inorganic N at day 0 ($\triangle \cdots \triangle$), inorganic N mineralized over 55 days (□---□ ), plant extractable N after 55 days growth (○---○), and total N in soil (▲---▲) (points denote means for the depth intervals). Bars represent standard errors.
