Knowledge gaps in soil C and N interactions – From molecular to global scale

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Objective

To identify, address and rank 5 knowledge gaps for their importance for soil-climate interactions.

‘To (let) know that we know what we know, and that we do not (pretend to) know what we do not know that is true knowledge’ Confucius (551 – 479 BC) after Thoreau, H., D, 1895.

Picture: Ola Borin
Five soil C-N interactions

i) N control of soil emissions of GHG CO₂, CH₄ and N₂O
ii) Quantification of plants’ use of organic N
iii) Impact of rhizosphere priming on C and N cycling
iv) Black N - SOM stability
v) Adequate representation of different fractions of SOM in models at various scales

Picture: Ola Borin
Carbon cycling in a terrestrial ecosystem

(Phil Ineson, UK)
1a. N control of soil CO$_2$ emissions

+N


$\textit{lb}$. N control of $\text{N}_2\text{O}$ and $\text{CH}_4$ emissions

$+N$

$\text{N}_2\text{O} = f(\text{N-fertilizer, C:N ratio and drainage level})$

Measurements limitations, contradicting results

Davidson 2009, Noll et al. 2008
II. quantification plant uptake of Organic N

Keys for quantification:
A) Diffusion rate of DON
B) Life time of DON-compounds
C) Distinction symbiotic and other uptake

III. Rhizosphere priming impact on C-N interactions

Rhizosphere priming is a short-term change of decomposition rate in the vicinity of roots (Kuzyakov, 2002)

from – 50 to + 380 %
Key questions - rhizosphere priming (RP)

A) Does it effect C and N mineralization differently?

B) Are some functional groups of microorganism more important for RP?

C) What will be the net impact of climate change?
IV. Black N – SOM stabilization

Charred organic matter

$^{15}$N NMR,

Courtesy of H. Knicker

Key limitation:
Analytic techniques
Oxidizable groups

<table>
<thead>
<tr>
<th>Pyridine</th>
<th>Nitrile</th>
<th>Amide</th>
<th>Pyrrole</th>
<th>Amino</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh grass</td>
<td>C:N = 8.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burnt grass (2 min, 350°C)</td>
<td>C:N = 7.3</td>
<td></td>
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</tbody>
</table>

< Young fertilization Black N Old > immobilization
V. Adequate representation of different fractions of SOM in models at various scales

Discrete

- Extractives
- Celluloses
- Lignin-like compounds
- Humus 1
- Humus 2

Continuum

- Leaf
- Old leaf
- Stem
- Old stem
- Seed
- Old roots
- Litter
- Roots
- Humus
- Microbes
- Plant uptake
- NH₄⁺
- NO₃⁻

Measurable
Yasso07
Liski et al. 2005;2007

Conceptual
CoupModel
Jansson & Karlberg 2004,2010

Principal
Ågren & Bosatta 1998
Key questions in adequate representation of SOM fractions

- A) The plant utilisation of various sources of N like organic, mineral and black N.

- B) The interaction between soil C and N should go beyond fixed C:N ratios in different pools.

- C) When does the vertical variation in SOM and its decomposition rates in the whole profile matter?
Knowledge level at different scales

Manzoni & Porporato 2009
Unidentified Ecosystem model
Criteria for importance

- Direct effect on soil-climate interactions
- Indirect effect on soil-climate interactions through plant available N, and thereby Net Ecosystem Productivity

Knowledge level

Very high

Very low

Importance

molecular organism ecosystem global

GHG emissions Organic N Priming Black N Modelling
Conclusions

- We found most important for improving soil-climate representations in GSMs:
  - Reliable quantifications of GHG-emissions at the ecosystem scale
  - Impact of different N species for temperature sensitivity of SOM decomposition, and consequences for plant available N
- Multi-approaches and dual-isotopes techniques could narrowing knowledge gaps
Thank you for your attention!

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Graduate school Focus on Soils organized the workshop and the NL-faculty of SLU financed it. All participants are kindly acknowledged for their contributions to the discussions.

Key reference
Gärdenäs A.I., Ågren G.I., Bird J.A., et al. 2011. Knowledge gaps in soil carbon and nitrogen interactions - From molecular to global scale. SBB 43, 702-717. e-mail: Annemieke.Gardenas@slu.se
• In mineral soils, elucidating the physio-chemical processes involved in mineral-OM interactions, across submicron to aggregate scales, offers the best way forward towards reconciling measurable and modelable pools or gradients.
• Accounting for ‘near inert’ components (e.g. some BC) is needed for initializing SOM models. Standardized methods are needed to separate semi-charcoal from highly stable forms.
• Establishment of permanent soil monitoring sites/networks with carefully designed protocols – ‘on the landscape’ – where land use/management are recorded, are crucial for selection and deployment of models for decision-making and policy applications.
How to describe rhizosphere priming in a model at ecosystem scale?

Plant-fine root biomass + stage

=f(Mineral N)

A triangular drama