Implementation of soil NO fluxes in CLM5: An enhanced rock weathering application

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Carbon Dioxide Removal (CDR) strategies
Enhanced weathering

CaSiO₃ (silicate rock, e.g., basalt) + CO₂

Increased base cations (Ca²⁺ etc.) and bicarbonate (alkalinity) formation and transfer to the ocean

CO₂ removal through bicarbonate storage and very slow deposition (CaCO₃)

- Application of natural silicate rocks to croplands harnesses reactions that have been stabilizing climate for millions of years.
- Deployable at scale within a decade or two by adapting existing agricultural practices (e.g., liming).
- Compatible with other CO₂ management proposals (BECCS/AF/RF)

Enhanced weathering in managed cropland soils – how does the concept work?
Leverhulme Centre for Climate Change Mitigation

Earth system science

Field-scale investigations

Experimental science

Sustainability and Society
Catchment-scale field studies of CO₂ capture via enhanced weathering
The 320 hectare Energy Farm facility; collaboration with Evan DeLucia and Steve Long (U. Illinois)

- Four 3.8ha plots.
- Equipped with eddy-covariance for crop measuring carbon balance.
- Instrumented field drains for measuring flow and leachate chemistry from each of the four plots.
EBI Energy Farm

Tile Layout

- Switchgrass + basalt
- Switchgrass – no basalt
- Corn/Soy + basalt
- Corn/Soy – no basalt

Contours are elevation in feet
Application of basalt to fertilized maize reduced N$_2$O emissions from soil by 50% linked to increased soil pH (no effect on soil CO$_2$ emissions)

Ilsa Kantola, Evan DeLucia, Steve Long  et al. unpublished.
soil moisture, pH, albedo (soil temperature), porosity, permeability, etc
N Cycle Modeling Framework

Adapted from Xu-Ri and Prentice (2008)
Soil $\text{N}_2\text{O}$ fluxes in CLM5

- CENTURY N Model (Parton et al., 1996, del Grosso et al., 2000)
- About 98% denitrification and 2% nitrification

*Simulations with CLM5 BGC crops and GSWP3v1 forcing

<table>
<thead>
<tr>
<th>Global $\text{N}_2\text{O}$ (Tg N/yr)</th>
<th>Reference</th>
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<tbody>
<tr>
<td>9.8</td>
<td>CLM5</td>
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<tr>
<td>6±3</td>
<td>Seiler and Conrad (1987)</td>
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<td>6.6-7</td>
<td>Bouwman et al (1995)</td>
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<tr>
<td>6.7</td>
<td>Kreileman and Bouwman (1994)</td>
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<td>6.1</td>
<td>Schlosser et al (2007)</td>
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<td>7.4-10.6</td>
<td>Saikawa et al (2013)</td>
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<tr>
<td>5.6-7.5</td>
<td>Huang et al (2015)</td>
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Temperature correction for soil $\text{N}_2\text{O}$ flux

It reduces the global annual $\text{N}_2\text{O}$ flux to 7.1 Tg N

$f (T_{\text{soil}}) = \exp \left(308.56 \times \left(\frac{1}{68.02} - \frac{1}{T_{\text{soil}} + 46.02}\right)\right)$

for denitrification

Xu-Ri and Prentice (2008)
Are soil N\textsubscript{2}O fluxes reasonable?

Implementing soil NO in CLM5

\[ R_{\text{NO}_x: \text{N}_2\text{O}} = 15.2 \]

\[
35.4 \times \text{ATAN} \left[ 0.68 \times \pi \times \left( 10 \times \frac{D}{D_0} - 1.86 \right) \right] + \frac{\pi}{\pi} \]

\[
\frac{D}{D_0} = 0.209 \times \text{AFPS}^{\frac{4}{3}}
\]

*Already implemented in CLM4.5 by Zhao et al., (2017)*

Parton et al., (2001)

**Soil NO from Denitrification**

9.8 Tg N

**Soil NO from Nitrification**

0.3 Tg N
Above canopy soil NO emissions

Canopy reduction factor

\[
CRF = \frac{e^{-k_s \times SAI} + e^{-k_c \times LAI}}{2}
\]

SAI - Stomata Area Index
LAI - Leaf Area Index

Yienger and Levy [1995]

6.5 Tg N/yr
Soil NO emissions are within estimates

Adapted from Vinken et al (2014)
Future Work with CLM5

Soil NO flux for nitrification from rain pulses
Adding varying soil pH (surface file?)
Implementing NH₃ volatilization emissions
Coupling N₂O, NO and NH₃ to CAM-Chem

\[ P(l_{dry}, t) = [13.01 \ln(l_{dry}) - 53.6] \times e^{-ct} \]

Yan et al., (2005); Hudman et al (2012)