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

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Carbon Dioxide Removal (CDR) strategies

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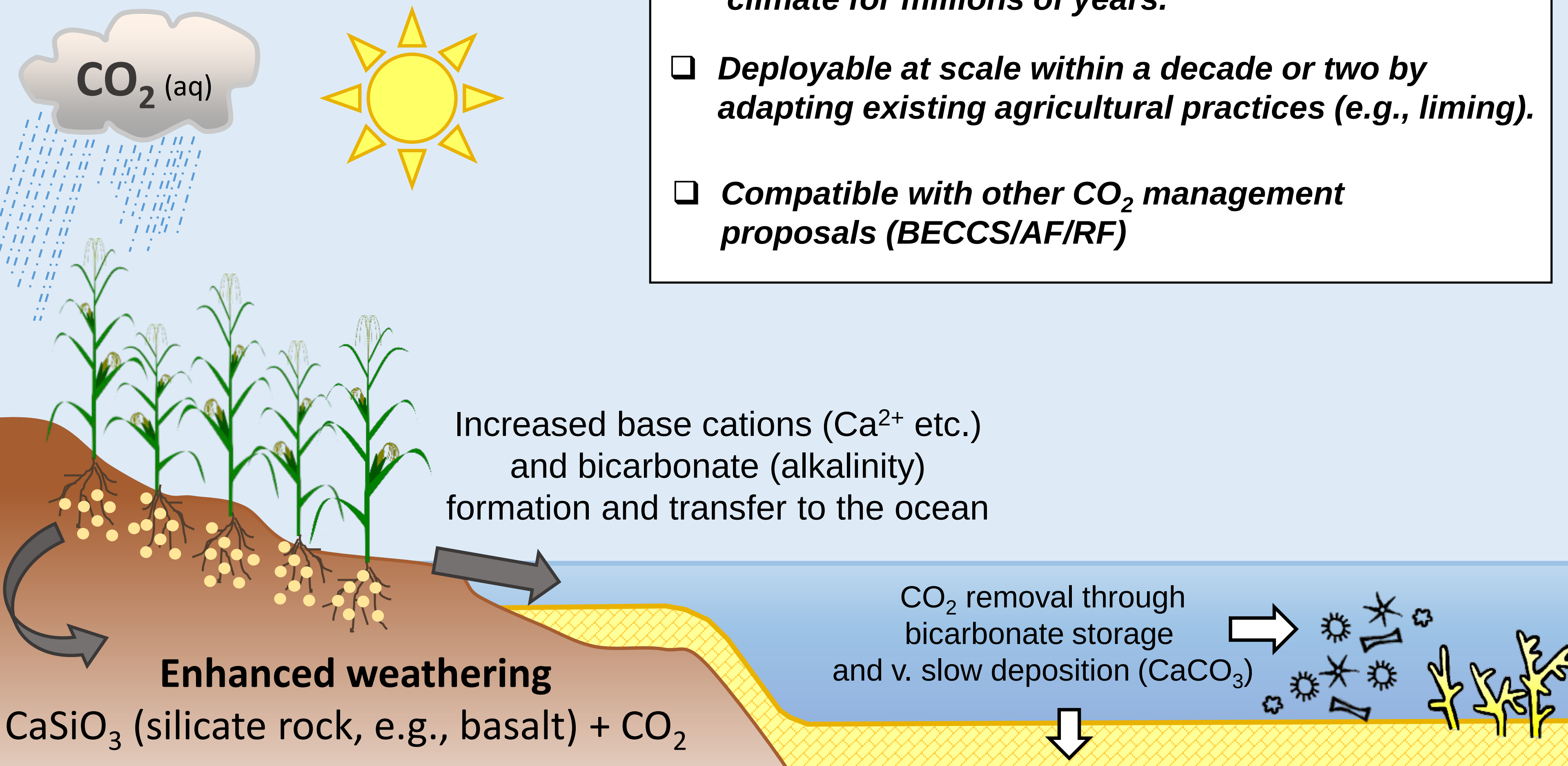
- ***Application of natural silicate rocks to croplands harnesses reactions that have been stabilizing climate for millions of years.***
- ***Deployable at scale within a decade or two by adapting existing agricultural practices (e.g., liming).***
- ***Compatible with other CO_2 management proposals (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

Leverhulme
Centre for Climate Change
Mitigation

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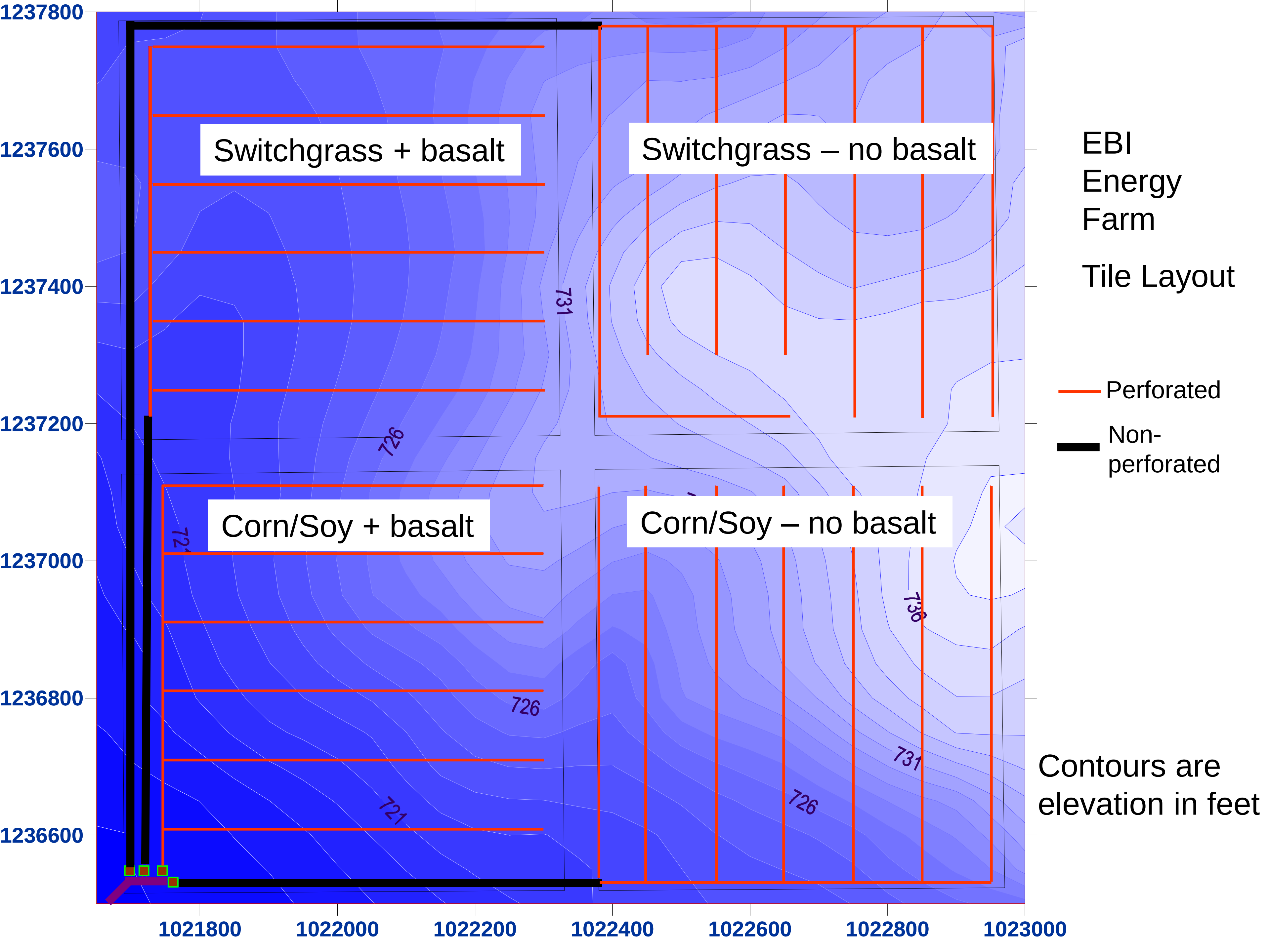
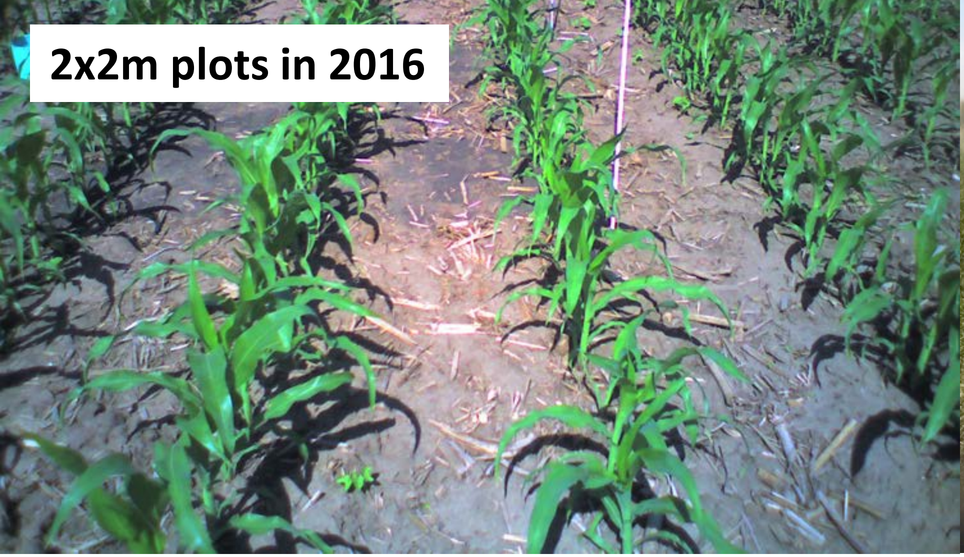
Catchment-scale field studies of CO_2 capture via enhanced weathering

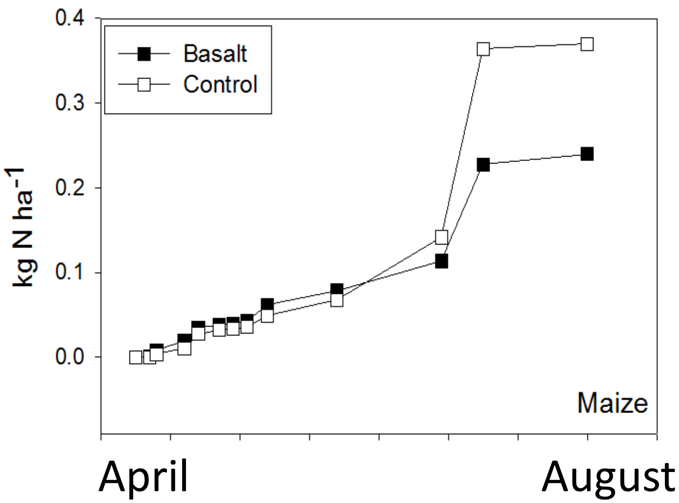
Leverhulme Centre for Climate Change Mitigation

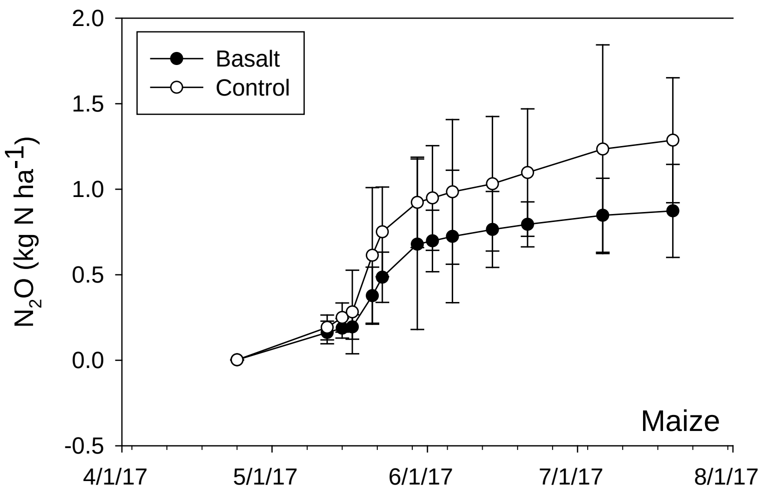
The 320 hectare Energy Farm facility; collaboration with Evan DeLucia and Steve Long (U. Illinois)

- 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.


1237800
1237600
1237400
1237200
1237000
1236800
1236600
1021800
1022000
1022200
1022400
1022600
1022800
1023000
Switchgrass + basalt
Switchgrass – no basalt
Corn/Soy + basalt
Corn/Soy – no basalt
731
726
721
726
721
736
731
726
EBI
Energy
Farm
Tile Layout
Perforated
Non-perforated
Contours are elevation in feet







Application of basalt to fertilized maize reduced N_2O 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.

ILLINOIS

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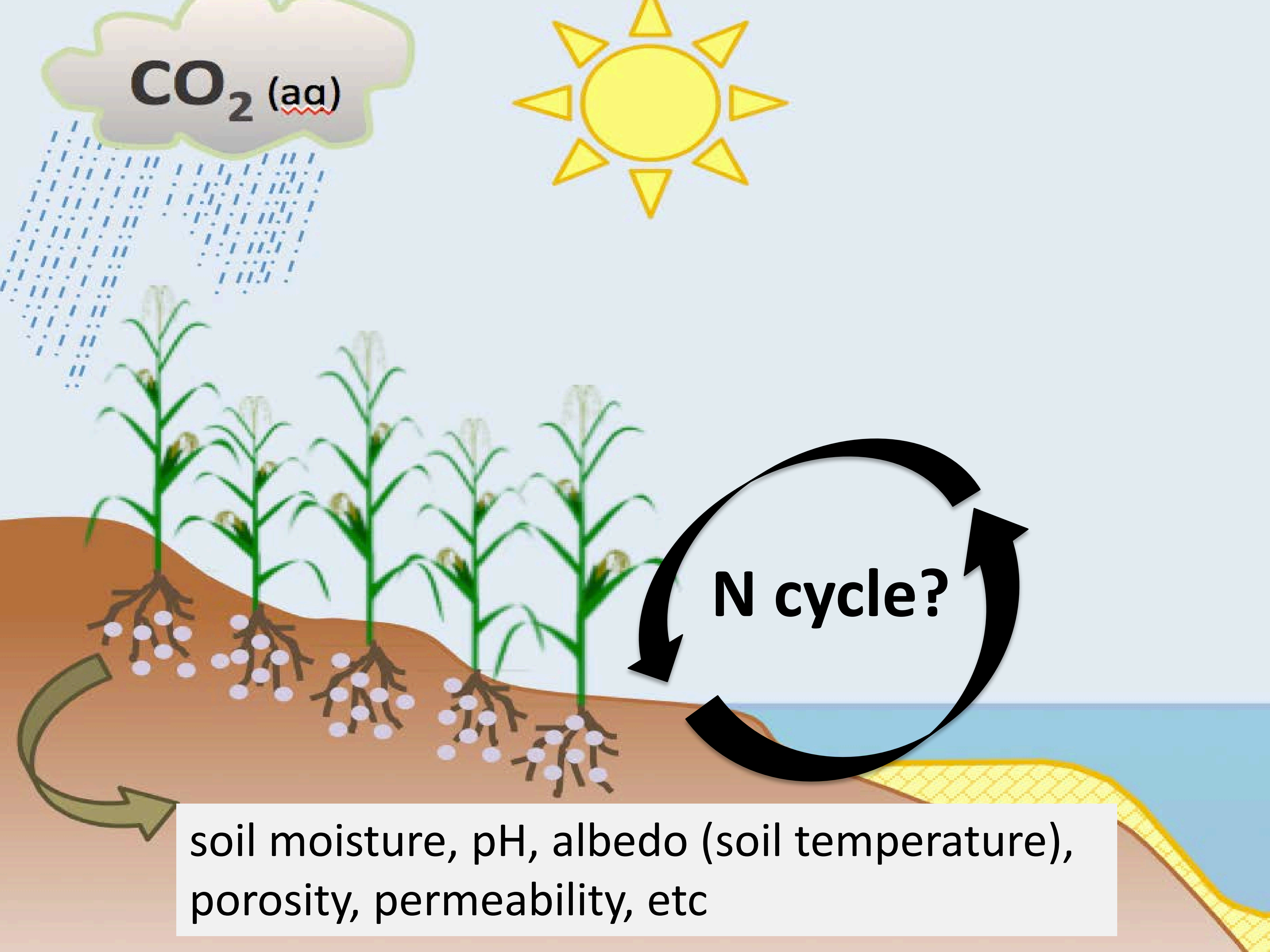
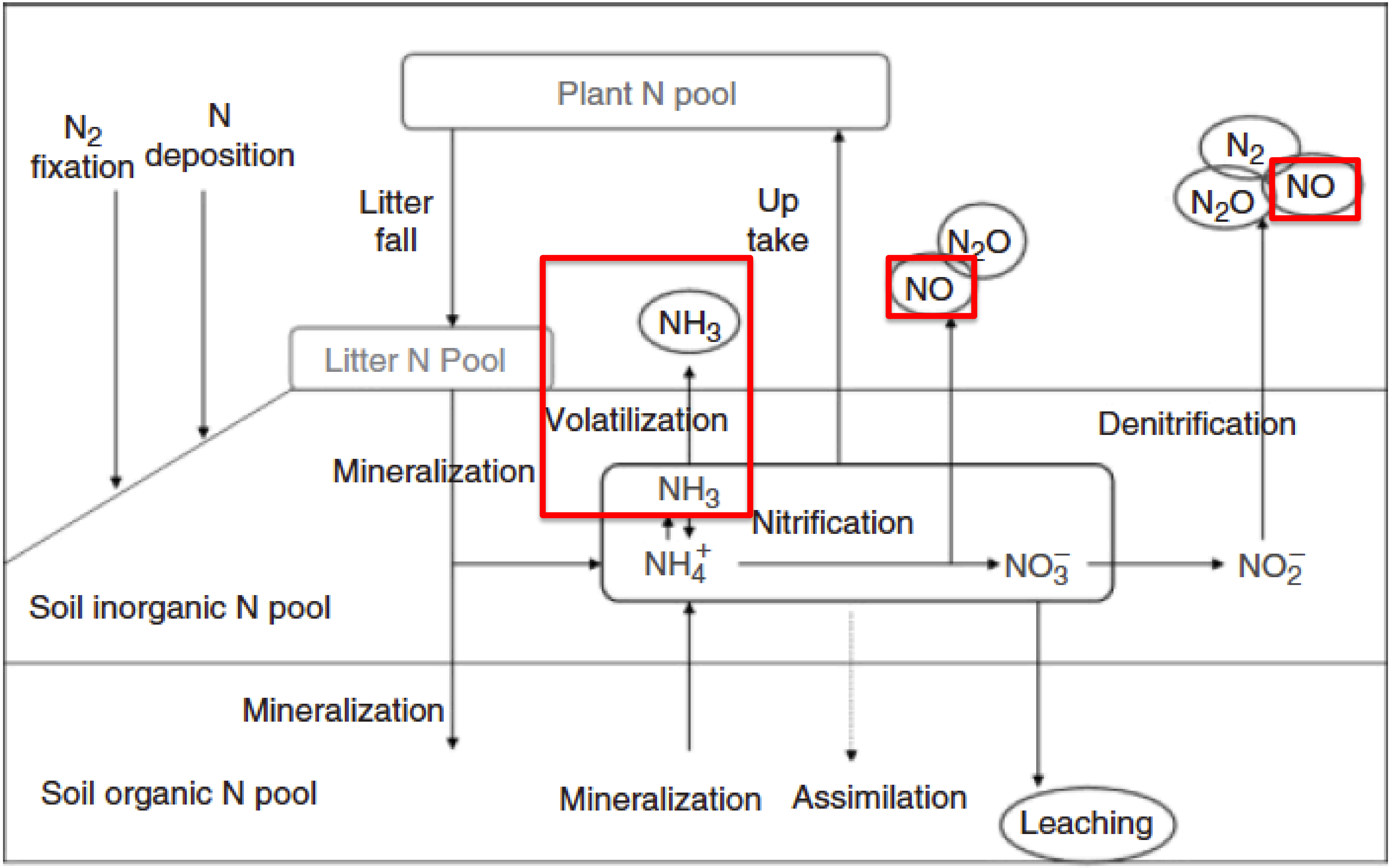


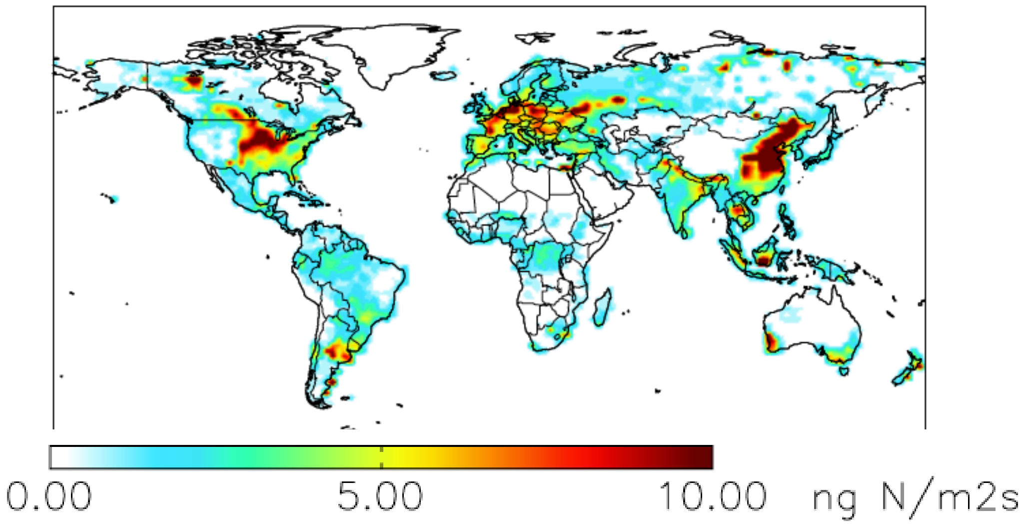
CO_2 (aq)
N cycle?
soil moisture, pH, albedo (soil temperature), porosity, permeability, etc

N Cycle Modeling Framework



Adapted from Xu-Ri and Prentice (2008)

Soil N_2O fluxes in CLM5

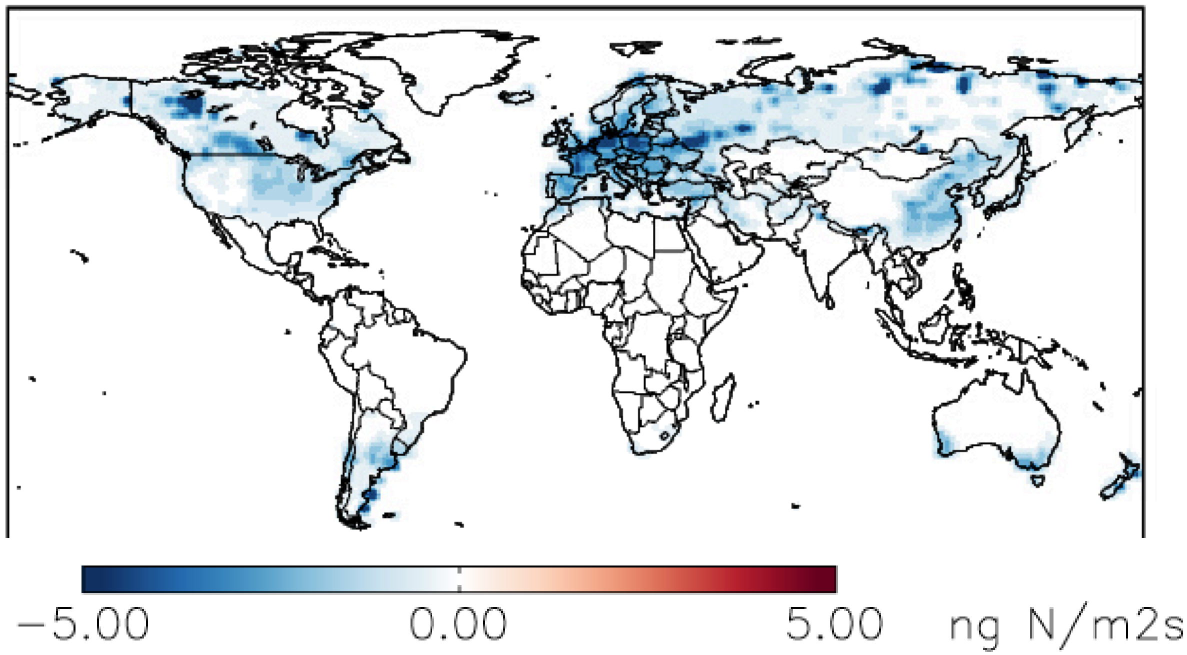


- CENTURY N Model (Parton et al., 1996, del Grosso et al., 2000)
- About 98 % denitrification and 2% nitrification

*Simulations with CLM5 BGC crops and GSWP3v1 forcing

Global N_2O (Tg N/yr)	Reference
9.8	**CLM5**
6±3	Seiler and Conrad (1987)
6.6-7	Bouwman et al (1995)
6.1	Potter et al (1996)
6.7	Kreileman and Bouwman (1994)
6.1	Schlosser et al (2007)
3.9-6.5	Hirsch et al (2006)
7.4-10.6	Saikawa et al (2013)
5.6-7.5	Huang et al (2015)

Temperature correction for soil N_2O flux



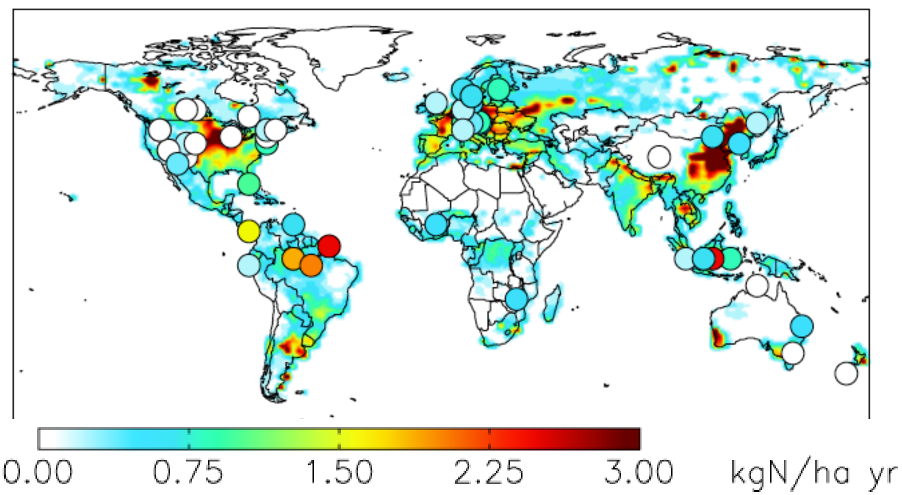
$$f\left(T_{\mathrm{soil}}\right) = \exp\left(308.56 \times \left(\frac{1}{68.02} - \frac{1}{T_{\mathrm{soil}} + 46.02}\right)\right)$$

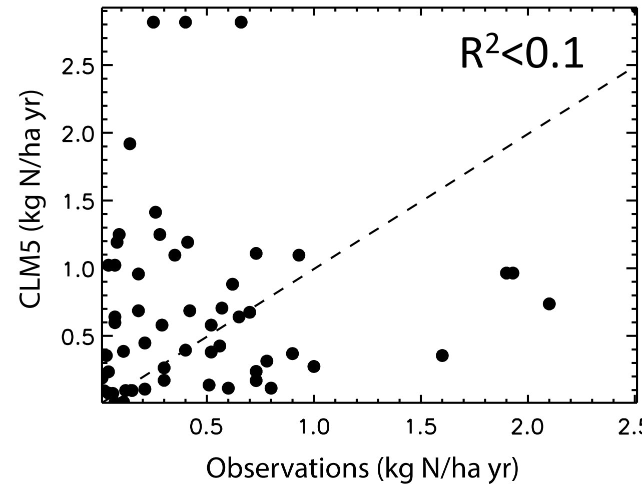
for denitrification

Xu-Ri and Prentice (2008)

It reduces the global annual N_2O flux to 7.1 Tg N

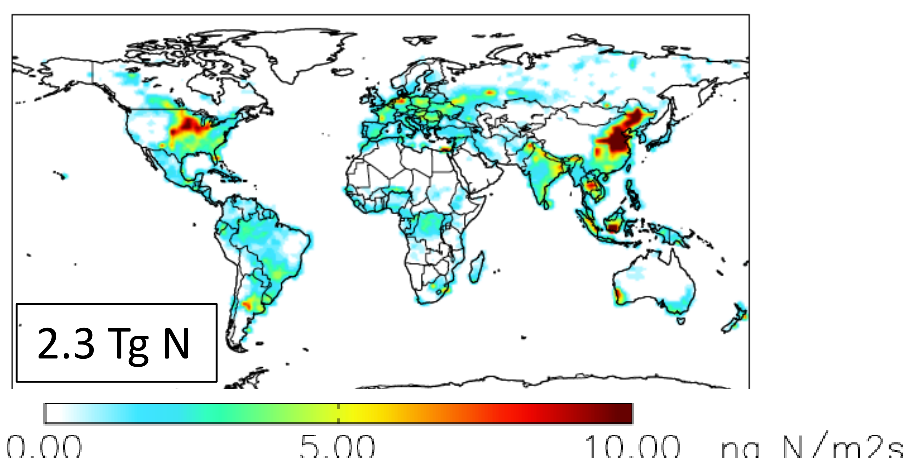
Are soil N_2O fluxes reasonable?



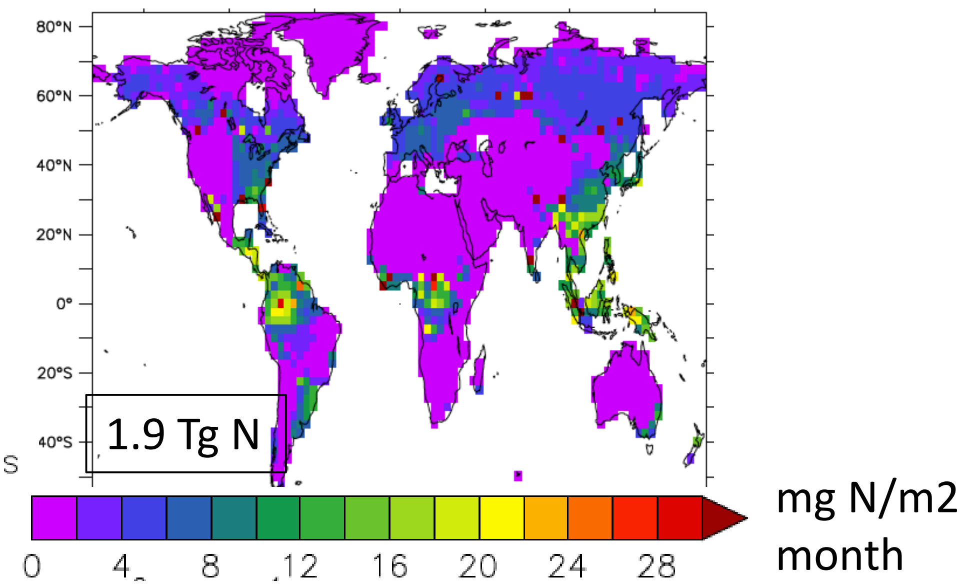


*Long-term means collected by Huang et al (2015)

CLM5 JJA



LM3V-N JJA



Implementing soil NO in CLM5

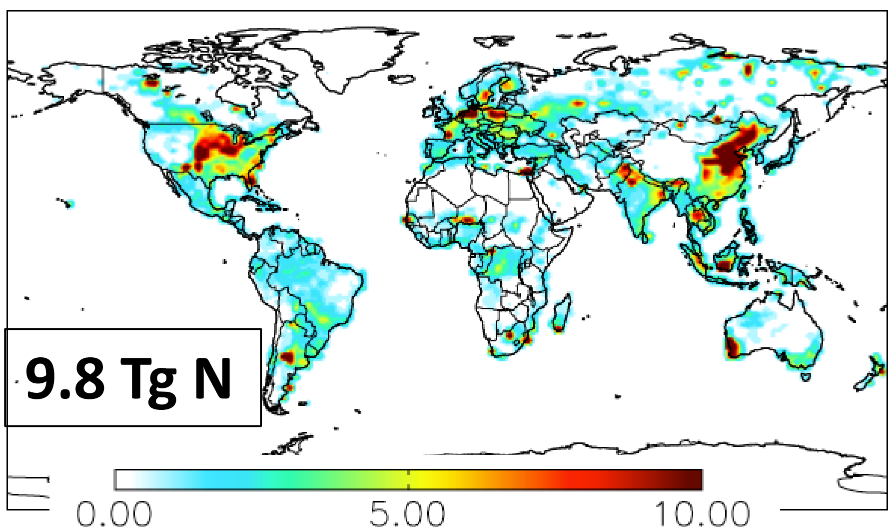
$$R_{\mathrm{NO}_x:\mathrm{N_2O}} = 15.2 + \frac{35.4 \times \mathrm{ATAN}\left[0.68 \times \pi \times \left(10 \times \frac{D}{D_0} - 1.86\right)\right]}{\pi}$$

$$\frac{D}{D_0} = 0.209 \times \mathrm{AFPS}^{\frac{4}{3}}$$

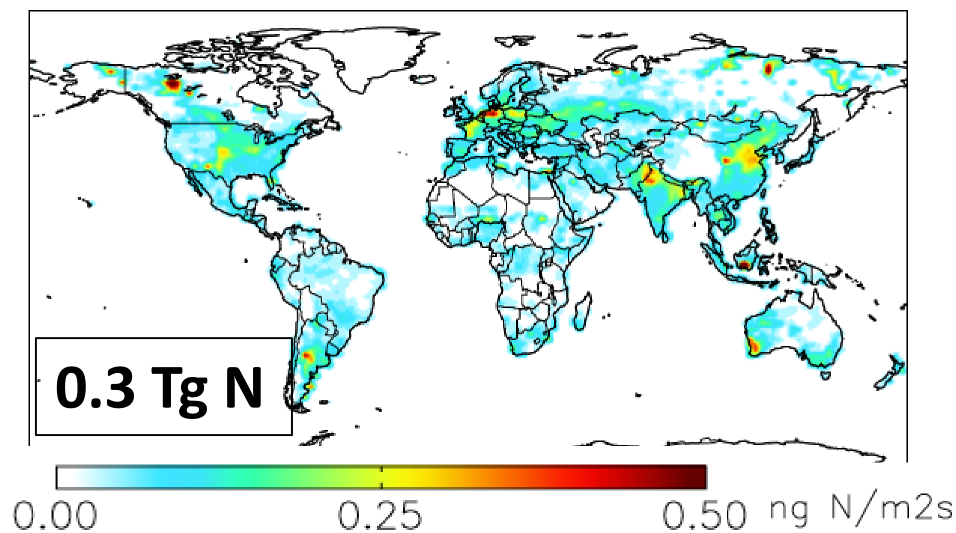
Parton et al., (2001)

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

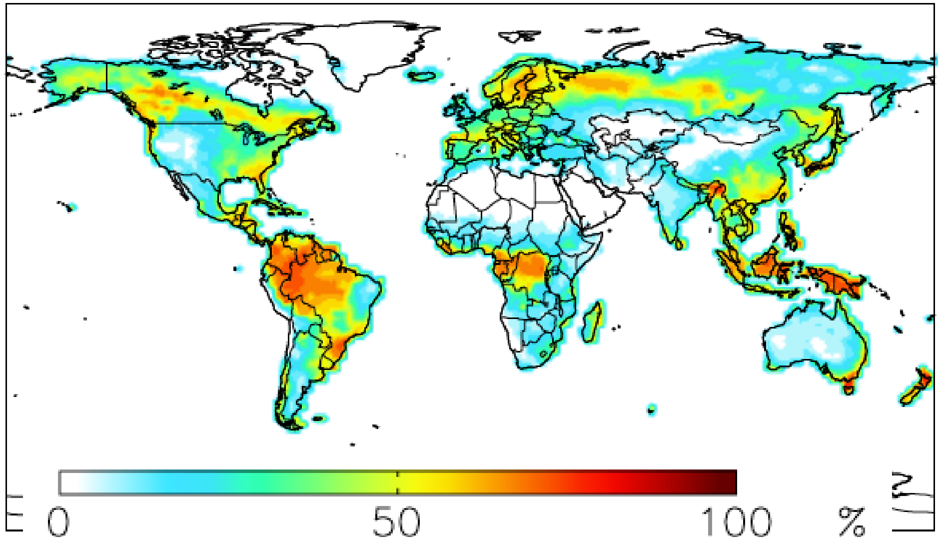
Soil NO from Denitrification



Soil NO from Nitrification



Above canopy soil NO emissions

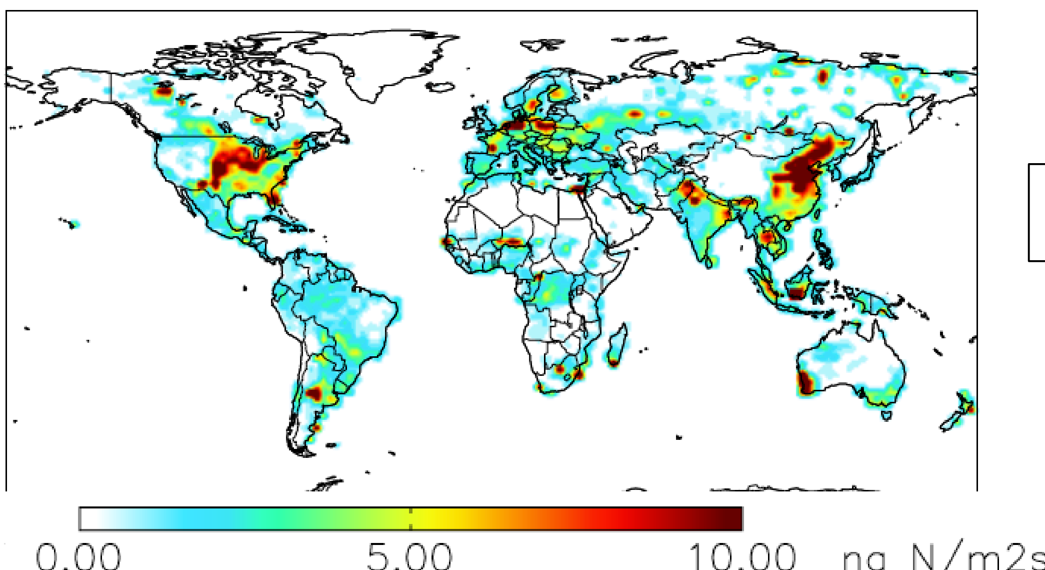


Canopy reduction factor

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

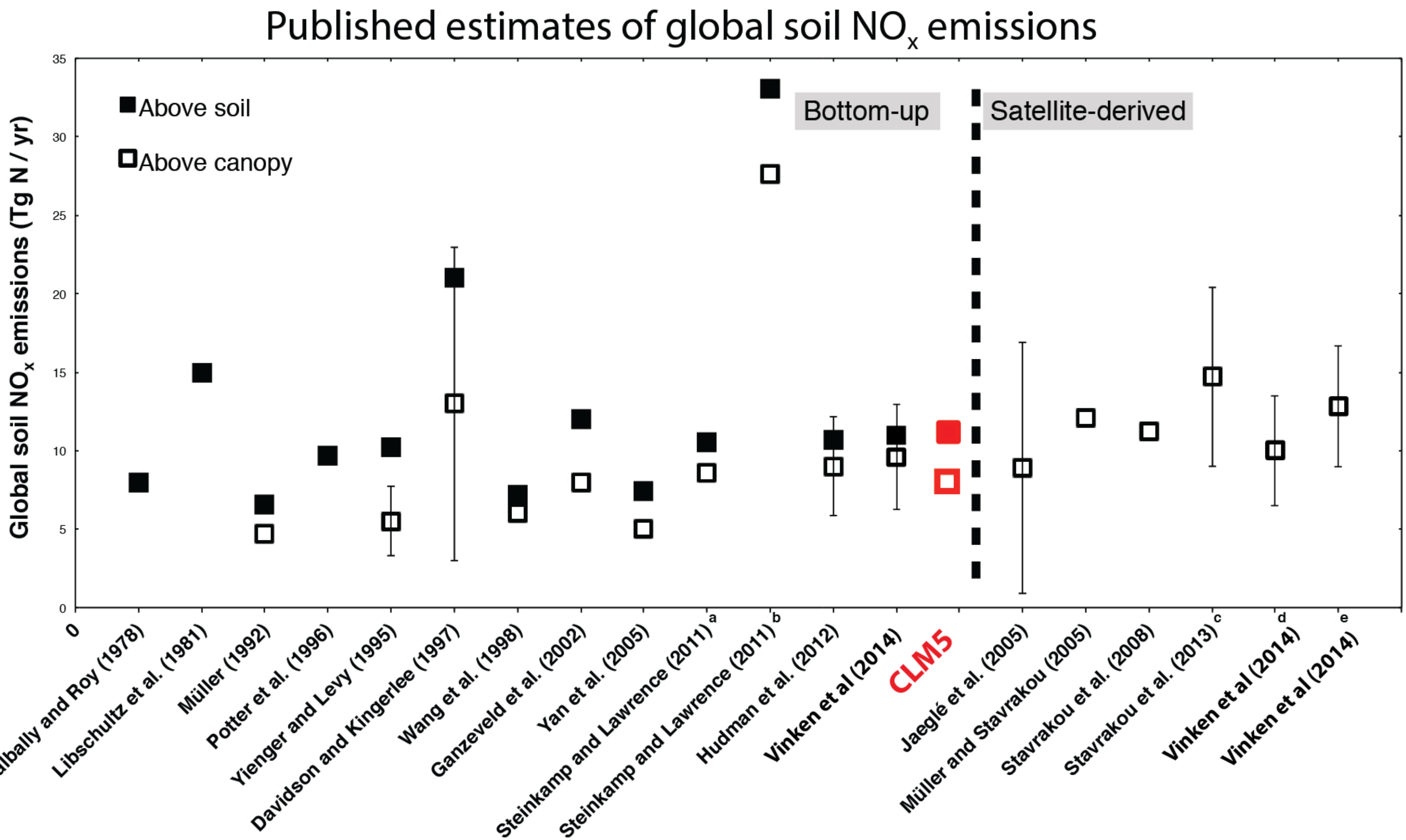
SAI-Stomata Area Index
LAI-Leaf Area Index

Yienger and Levy [1995]



6.5 Tg N/ yr

Soil NO emissions are within estimates



Adapted from Vinken et al (2014)

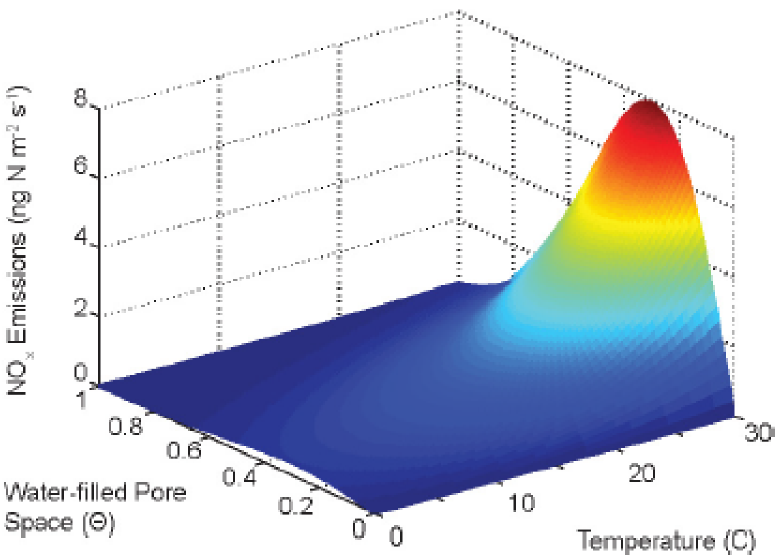
Future Work with CLM5

Soil NO flux for nitrification from rain pulses

Adding varying soil pH (surface file?)

Implementing NH_3 volatilization emissions

Coupling N_2O, NO and NH_3 to CAM-Chem



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

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