Long-term nitrous oxide in annual and perennial agricultural and unmanaged ecosystems in the upper Midwest USA

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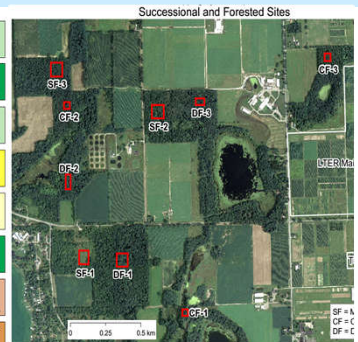
Background and objective

- Nitrous oxide (N_2O) plays a significant role in the greenhouse gas (GHG) balance of the atmosphere and stratospheric ozone depletion.
- Agricultural soils are the largest source of anthropogenic emissions of N_2O to the atmosphere.
- Understanding the controls and dynamics of emissions of N_2O is essential for: Developing mitigation opportunities, Predicting future climate impacts, and closing global N_2O budget, currently unbalanced.
- Sporadic nature of soil N_2O fluxes makes their evaluation and prediction difficult.

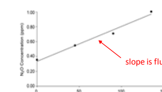
We've used 20 years of measurements of soil N_2O emissions, together with numerous environmental and soil variables to determine the effect of different agricultural and land management practices on soil N_2O emissions.

Study site and methods

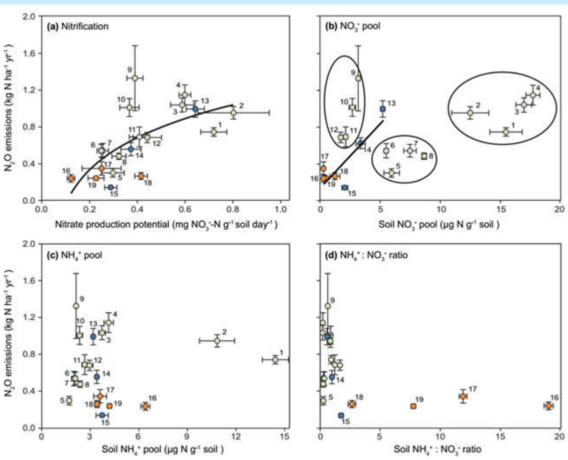
n = 3, 4, or 6



Bi-weekly measurements 1991 - 2011

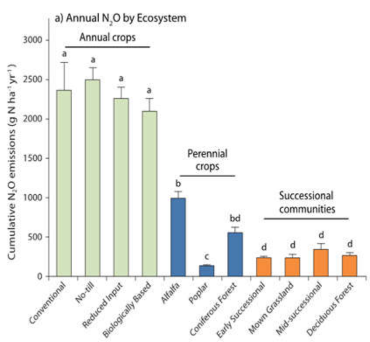


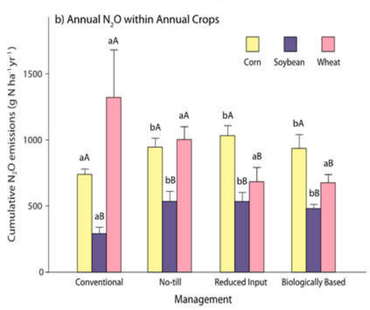
Results



Relationships between cumulative soil N_2O emissions and panel **a**) NO_3^- production potential, panel **b**) extractable soil NO_3^- pool, panel **c**) extractable soil NH_4^+ pool, and panel **d**) ratio between extractable soil pools of NH_4^+ and NO_3^-.

1 – CT corn, 2 – NT corn, 3 – RI corn, 4 – BIO corn, 5 – CT soybean, 6 – NT soybean. 7 – RI soybean, 8 – BIO soybean, 9 – CT wheat, 10 – NT wheat, 11 – RI wheat, 12 – BIO wheat, 13 – AA, 14 – CF, 15 – POP, 16 – NTG, 17 – SF, 18 – DF, and 19 – ES. Green circles represent perennial herbaceous vegetation (DF, ES, and NTG), blue circles represent perennial plantations (CF, AA, and POP), and brown circles represent annual ecosystems (CT, NT, RI, and BIO). Correlation between N_2O emissions and nitrification (**a**) is logarithmic $F = y0 + a \times \ln(abs(x)$; $a = 0.49 \pm 0.13$, $y0 = 1.15 \pm 0.14$; $R2 = 0.454$, $p = 0.0016$. Correlation between NO_3^- pool and soil N_2O emissions in perennial systems (**b**) is linear $F = y0 + ax$; $a = 0.14 \pm 0.04$, $y0 = 0.14 \pm 0.01$; $R2 = 0.7165$, $p = 0.016$. Circles on panel (**b**) identify the three rotation phases (corn, soybean, wheat) of the annual cropping systems.





Annual cumulative soil N_2O emissions

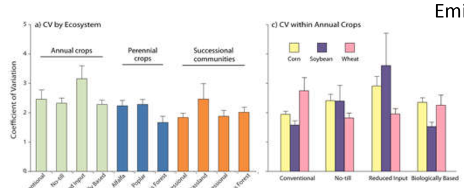
System	Measured*	Estimated IPCC‡	ΔEF§	Surplus†
	kg N_2O-N ha^{-1} yr^{-1}			
Conventional (CT)				
Corn	0.74 (0.04)	1.71 [0.25]	1.35	1.93
Soybean	0.39 (0.04)	0.39 [0.04]	0.33	2.14
Wheat	1.25 (0.36)	1.21 [0.17]	0.88	1.67
No-till (NT)				
Corn	0.91 (0.06)	1.64 [0.17]	1.36	1.95
Soybean	0.71 (0.07)	0.40 [0.03]	0.37	2.20
Wheat	0.92 (0.10)	1.20 [0.11]	0.93	1.77
Reduced input (RI)				
Corn	1.06 (0.08)	1.44 [0.1]	1.21	2.03
Soybean	0.62 (0.07)	0.48 [0.03]	0.50	1.93
Wheat	0.61 (0.12)	0.68 [0.05]	0.48	2.11
Biologically based (BIO)				
Corn	1.08 (0.10)	1.01 [0.08]	0.77	2.08
Soybean	0.62 (0.04)	0.40 [0.03]	0.36	2.02
Wheat	0.62 (0.05)	0.28 [0.04]	0.17	2.25

*Annual, not crop year, basis.
†Calculated according to van Groenigen *et al.* (2010).
‡Calculated according to IPCC Tier 1 emission factor (De Klein *et al.*, 2006): 1% of all of inputs; additional indirect emissions [in brackets] are based on leaching losses.
§Calculated according to Shcherbak *et al.* (2014).

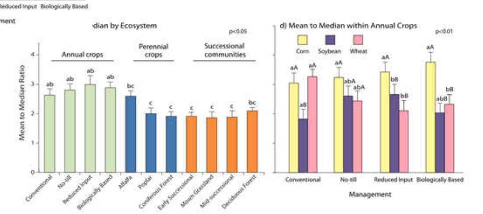
Comparison between different estimations of emission factors

Crop/management	Conventional (CT)	No-till (NT)	Reduced input (RI)	Biologically based (BIO)
	kg N_2O-N Mg^{-1} yield*			
Overall‡	0.213 (0.165–0.280)	0.202 (0.178–0.224)	0.209 (0.191–0.236)	0.263 (0.223–0.288)
By crop†				
Corn	0.102 (0.021)^{A}	0.103 (0.017)	0.120 (0.046)	0.165 (0.041)
Soybean	0.083 (0.029)^{Aa}	0.130 (0.050)^{b}	0.156 (0.044)^{b}	0.146 (0.024)^{b}
Wheat	0.229 (0.106)^{B}	0.165 (0.062)	0.168 (0.028)	0.230 (0.053)

Emission intensities in agricultural systems



Coefficient of variation (**a**, **b**) and mean to median ratio (**c**, **d**) of daily average soil N_2O emissions



Conclusions

- N_2O fluxes are substantially lower in non-legume perennial systems than in perennial systems, regardless of management intensity.
- Rotation phase (crop type) appears to matter greatly.
- Across all ecosystems N availability was the best predictor of N_2O fluxes only for systems with perennial vegetation – for annual systems management effects overrode the simple effects of N availability based on average soil nitrate pool sizes.
- No-till does not significantly affect N_2O emissions overall, but does interact with rotation phase
- Cover cropped systems also exhibited no overall emission differences from conventional systems.
- Emission intensities were similar among all annual cropping systems with the exception of two management × crop phase interactions.
- Both IPCC Tier 1 and ΔEF approaches provided reasonable estimates of overall emissions, on average either 11% over (IPCC Tier 1) or 11% under (ΔEF) measured emissions.

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