Synthetic N Application in Agriculture: Some things we need to know to get it 'just right'

Presentation to ND Stakeholders and Focus Group
ARS Research Station
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How well have we quantified…

- The amount of added N transformed to N_2O, the duration of this response, and how this response changes with rate of addition
- The extent to which added N mixes or exchanges with resident soil N
- How N addition and rate of N addition influences soil respiration

What do we think happens following N addition?

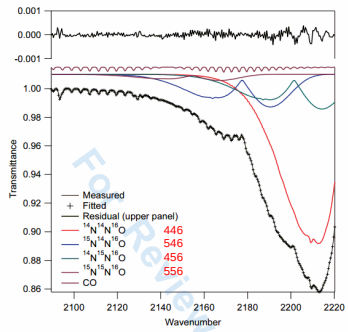
- The duration added N will stimulate N_2O is ~2 to 10 weeks
- The percentage of N applied transformed to N_2O is ~1 to 2% but could be more or less
- With irrigation or rainfall, added N should mix well with resident N in soil, but this is rarely quantified
- Added N could 'prime' respiration, but it is unclear at what rate of N application this might occur

Field Experiment Questions:

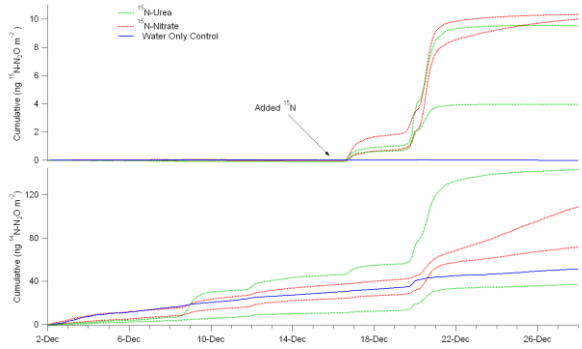
1. Can we quantify fluxes of 28-N_2O, 29-N_2O, 30-N_2O, and CO_2 continuously in the field?
2. What percent of applied N is transformed to N_2O and what is the duration of this response?
3. Do fluxes track peaks in soil moisture for all isotopologues?
4. What fraction of added N mixes with resident N to form N_2O, and how does this change with time?
5. Does addition of 4 kg N ha^{-1} N 'prime' soil respiration?

Two Trials Performed- Dec 2011 and Jan 2012

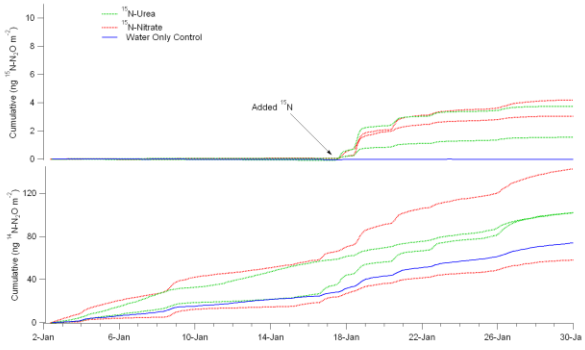
Question 1: Can we quantify fluxes of $28N_2O$, $29N_2O$ and $30N_2O$, and CO_2 continuously in the field?



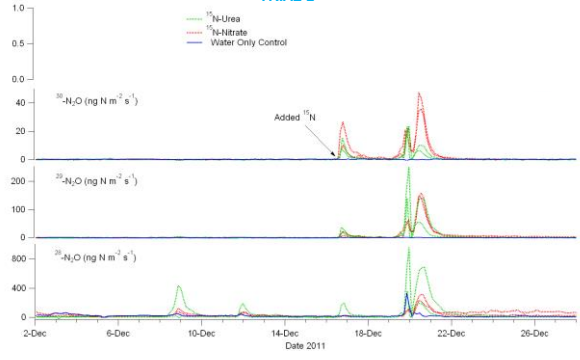
Question 2: What percentage of applied N is transformed to N_2O and what is the duration of this response?
TRIAL 1



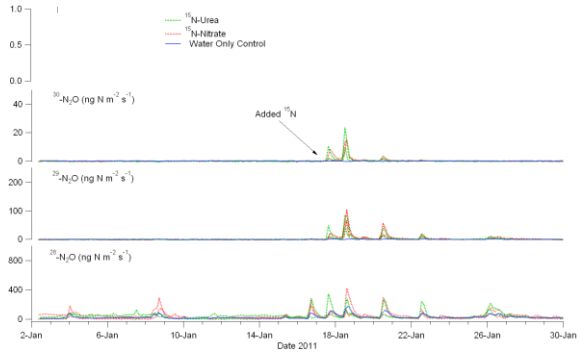
Question 2: What percentage of applied N is transformed to N_2O and what is the duration of this response?
TRIAL 2



Question 3: Do fluxes track peaks in soil moisture for all isotopologues?
TRIAL 1



Question 3: Do fluxes track peaks in soil moisture for all isotopologues? TRIAL 2



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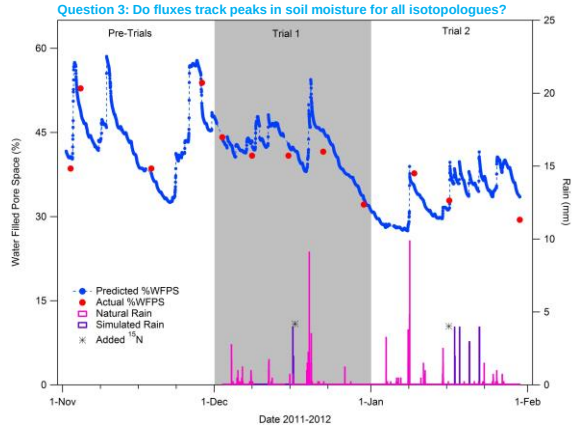


What was the distribution of isotopologue cumulative flux?

Chamber ID	Percentage of Cumulative N_2O Emitted by Isotopologue		
Trail 1	^{30}- N_2O	^{29}- N_2O	^{28}- N_2O
T1 Nitrate-1	6.6%	21.6%	71.8%
T1 Nitrate-2	4.1%	15.3%	80.6%
T1 Urea-1	1.3%	14.8%	83.9%
T1 Urea-2	3.7%	18.5%	77.8%
Average	3.9%	17.6%	78.5%
Trial 2			
T2 Nitrate-1	2.0%	11.7%	86.3%
T2 Nitrate-2	0.7%	8.4%	90.9%
T2 Urea-1	1.1%	8.3%	90.6%
T2 Urea-2	0.5%	5.5%	94.1%
Average	1.1%	8.5%	90.4%

Question 4: MIXING OF ADDED AND RESIDENT N

Pool substitution can only occur if added ^{15}N and resident ^{14}N occupy the same pool, so the ^{15}N added in these experiments needed to mix with soil ^{14}N to facilitate this substitution

Theoretical Statistical Distribution of N_2O Isotopologues if Well-Mixed

446: $^{14}N^{14}N^{16}O$ 456: $^{14}N^{15}N^{16}O$ 546: $^{15}N^{14}N^{16}O$ 556: $^{15}N^{15}N^{16}O$

Atom fraction (x) of ^{15}N relative to soil ^{14}N pool in well-mixed media:

$x^2 = C_{556}$
$x(1-x) = C_{546}, C_{456}$
$(1-x)^2 = C_{446}$

$C_{446} / C_{456} = 1-x/x$

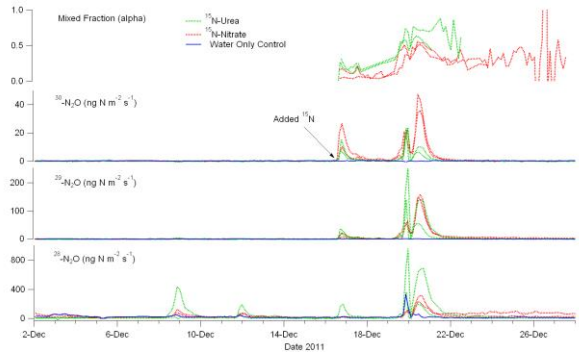
$C_{456} / C_{556} = 1-x/x$

If well-mixed, $C_{446} / C_{456} = C_{456} / C_{556}$

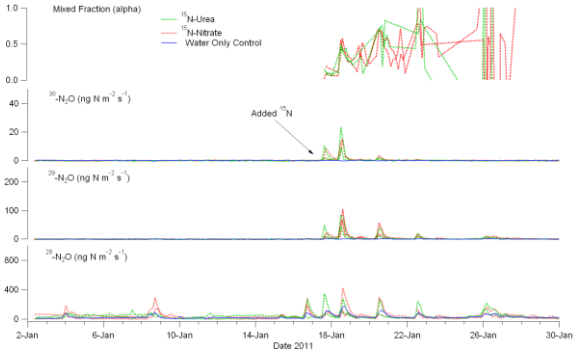
If not well-mixed, $C_{446} / C_{456} > C_{456} / C_{556}$
Additional N from unmixed pool ⬆

$\alpha = C_{456} * C_{546} \; / \; C_{446} * C_{556}$

Question 4: What is the fraction of added N that is mixed? TRIAL 1



Question 4: What is the fraction of added N that is mixed? TRIAL 2



Is there evidence that agricultural N addition increases soil respiration?

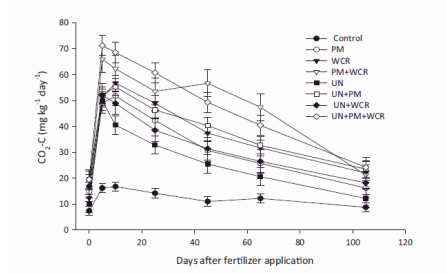
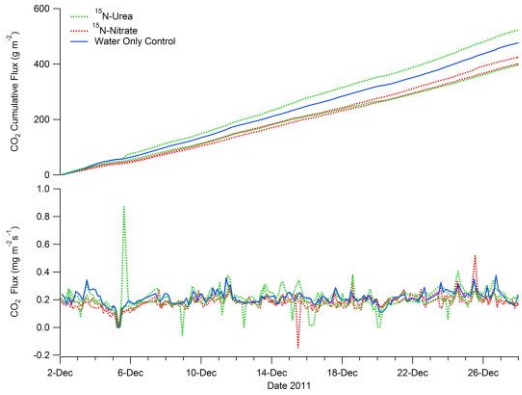


Fig. 1. Rates of CO_2 evolution (mg kg^{-1} soil day^{-1}) in soil amended with organic and inorganic N sources and measured at different incubation periods. Vertical lines on each bar represent the LSD ($P \leq 0.05$) at different timings.
From Abassi and Khizar, 2012

Question 5: Did we find addition of 4 kg N ha^{-1} N 'primed' soil respiration?
TRIAL 1



Question 5: Did we find addition of 4 kg N ha^{-1} N 'primed' soil respiration?
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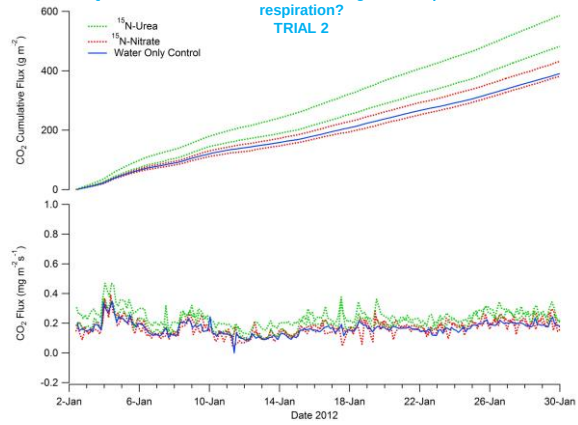
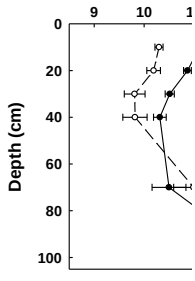
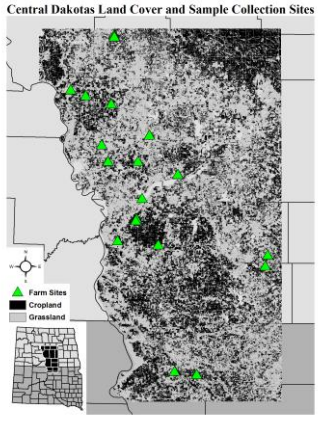


What if N addition prime
this substantively affec





Phillips et al. 2013. Soil organic matter and la
Manuscript in prep.

Summary

1. We can measure N_2O isotopologues continuously in the field
2. An average of 1% of the added N was emitted as N_2O and this response lasted 7 to 10 days
3. Soil moisture and N_2O isotopologue peaks tracked each other
4. Greatest mixing of added N with the resident N occurred during and after high rainfall events, and this varied with time
5. Adding 4 kg N ha^{-1} did not prime respiration but soil N pool substitution was evident

Possible directions

Design experiments to test effect of N addition to better constrain 'optimum' application rates, times, irrigation, etc.

- -Quantify N_2O emission factors
- -Find how added N and resident N mixing affects the N cycle
- -Find how N addition alters the carbon cycle with $\delta^{13}C$ in CO_2
- -Find how nitrification inhibitors affect isotopologue fluxes