Assessing Baseline N_2O Emissions in Response to Nitrogen Fertilizer Application Rates in Corn Systems

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Nutrient Management:
Challenges and Opportunities

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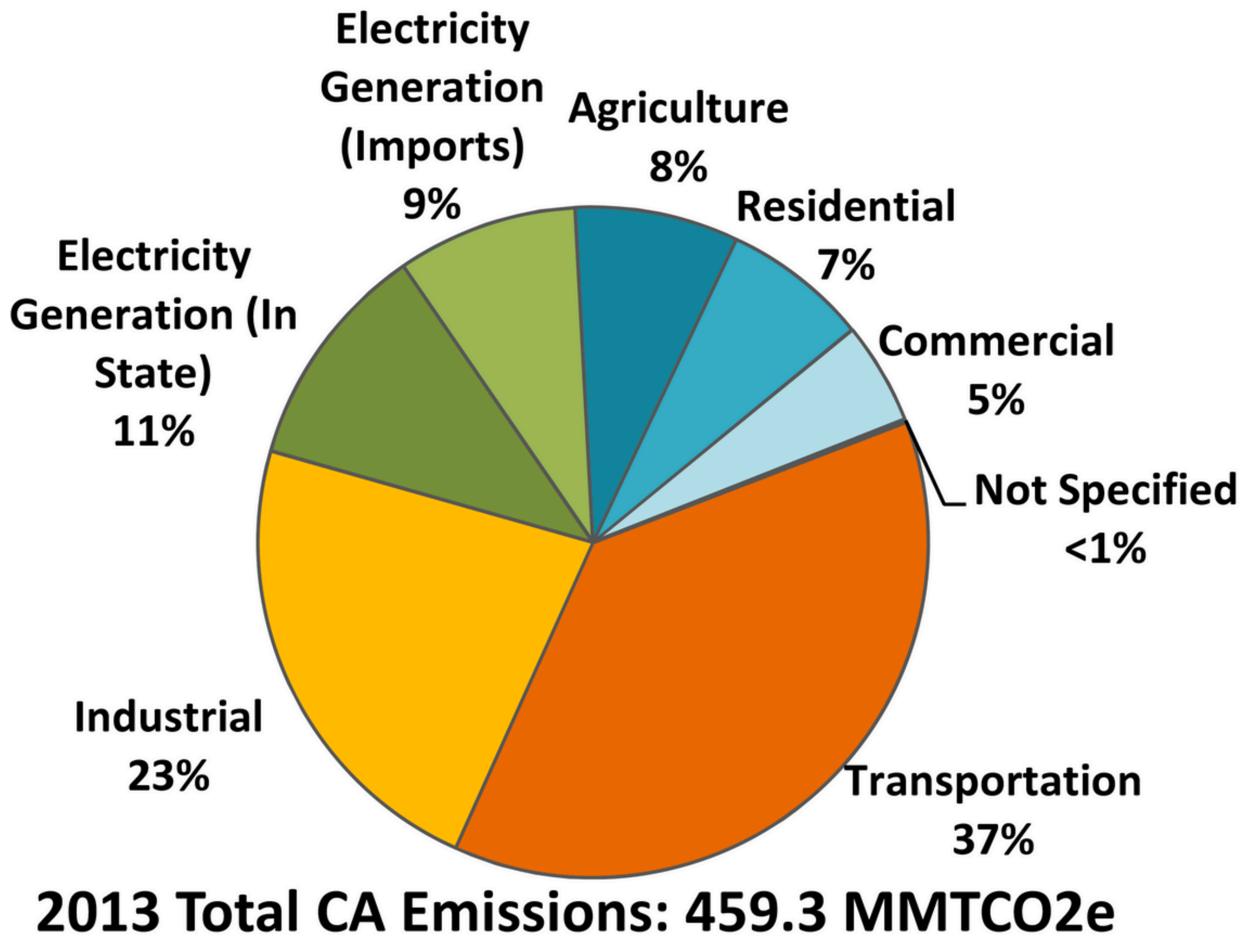
California Greenhouse Gas Emissions



3% of all greenhouse gas emissions are N_2O

Source: CA ARB 2015

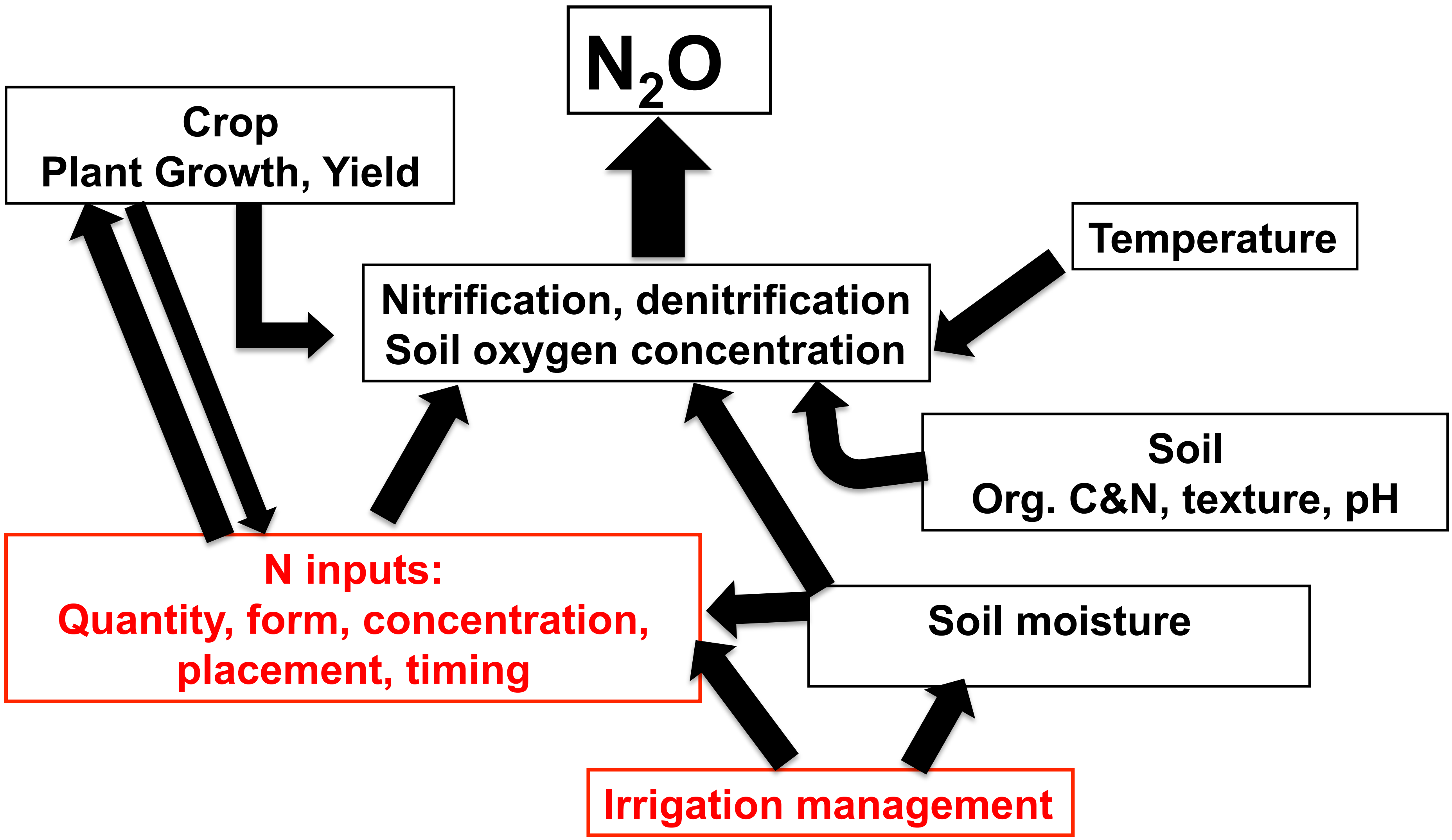
CA statewide N_2O emissions

Agricultural sector:

- Fertilizer & crop residue: 40%
- Manure: 35%

Transportation:	13%
Industrial:	8%
Electricity generation:	2%
Other:	2%

Controls on N_2O Emissions from Agricultural Soil



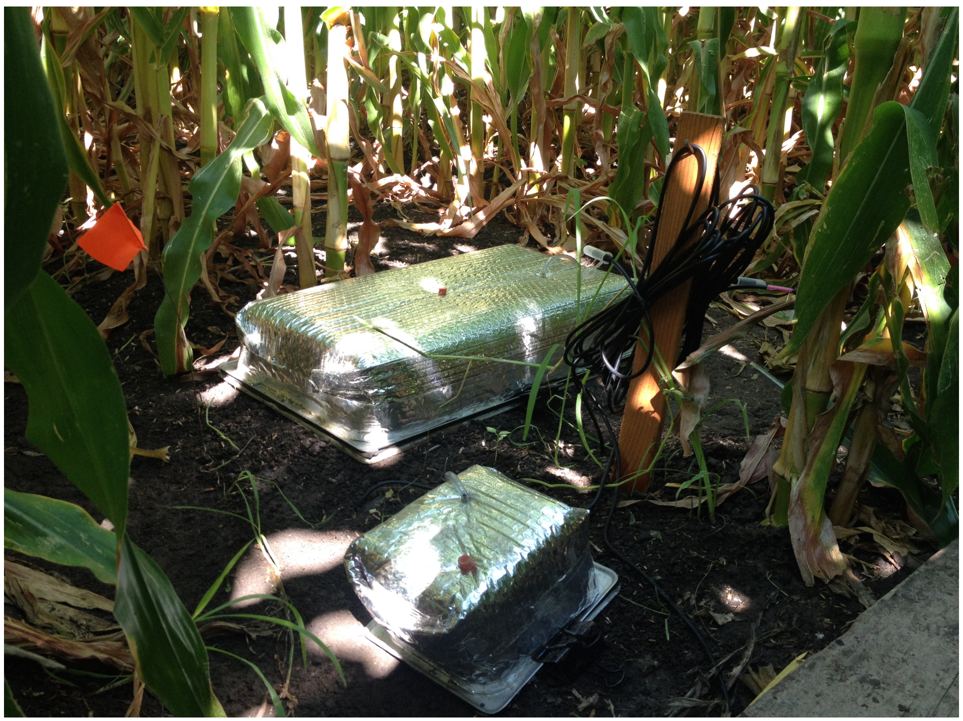
Field Measurements

Furrow-irrigated corn field site near Stockton

Soil parameters:

2013: 35% clay, 30% sand (clay loam); 1.04% carbon

2014: 43% clay, 19% sand (clay); 1.12% carbon



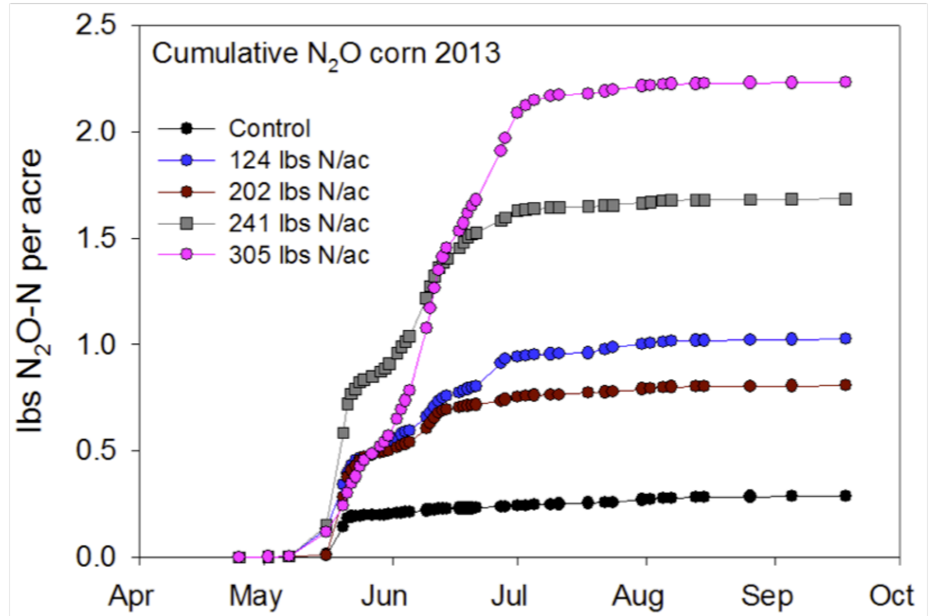
Gas flux measurements:

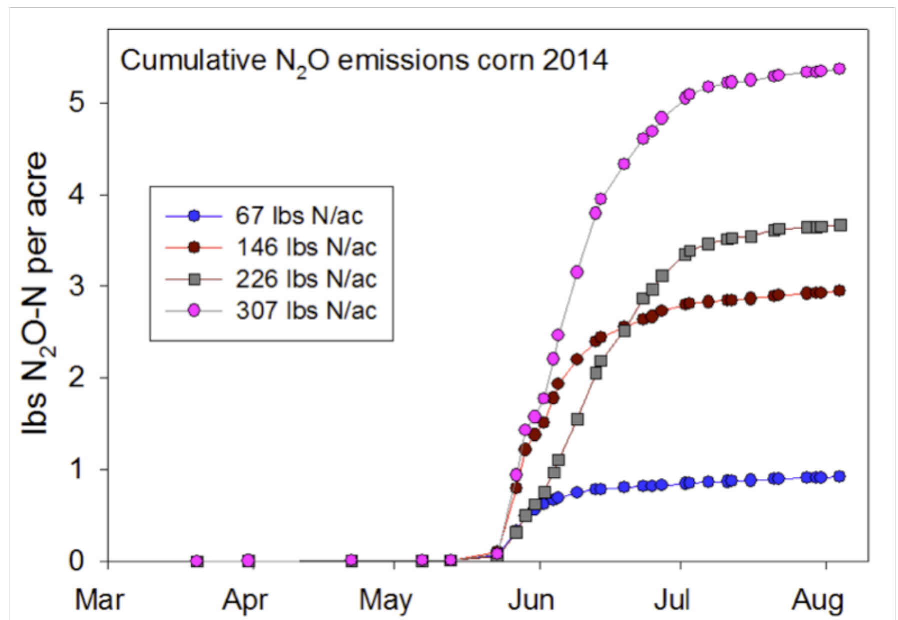
- Static chamber technique
- 3 different chamber locations within each replicate plot (n=3):
  - Furrow
  - Shoulder
  - Bed

Liquid N fertilizer (urea ammonium nitrate) placement

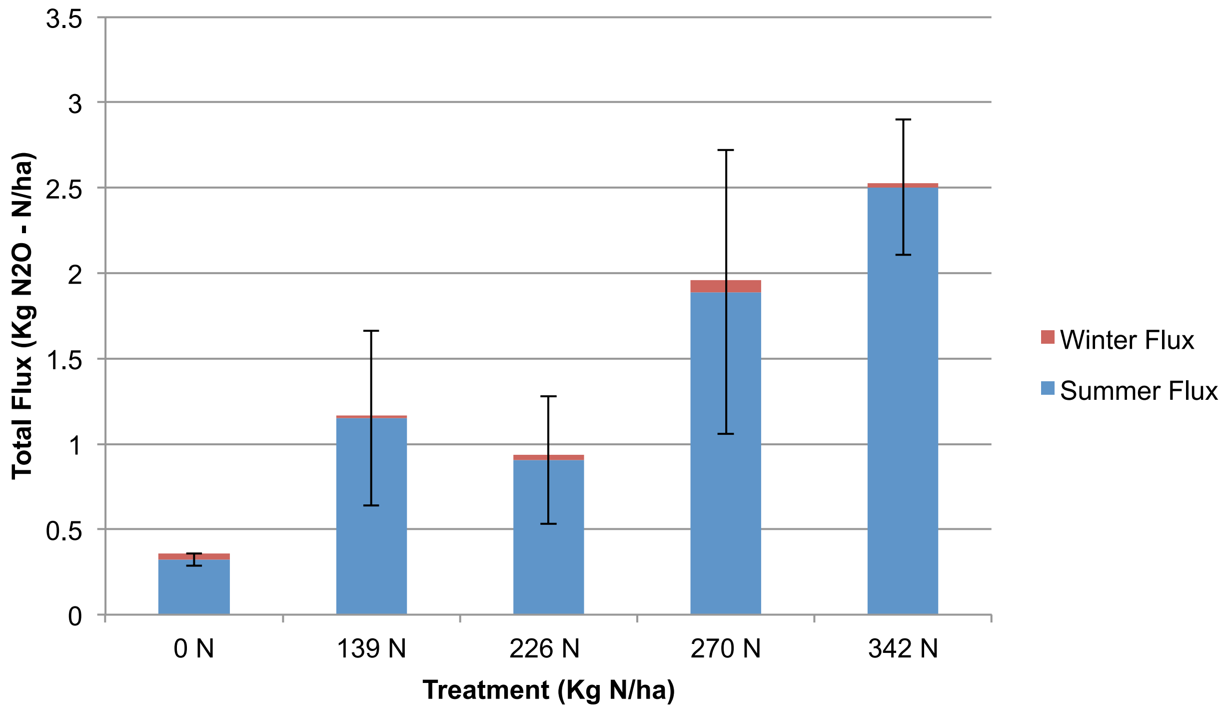
Nitrogen inputs and cumulative N_2O emissions

Fertilizer N treatments	Pre-plant NO_3^-
lbs N / acre	
2013	
11	64
124	64
202	64
241	64
305	64
2014	
67	77
146	77
226	77
307	77





Small contribution of post-harvest season N_2O fluxes to total annual N_2O emissions



Fertilizer recommendation based on yield potential

- 36 - 45 lbs N per ton corn grain*
- Assumed yield potential 6.3 tons /acre at this site: 227-283 lbs N / acre

Fertilizer N	Pre-Plant N	Total N inputs	Corn N uptake	Yield
lbs N/acre				(tons/acre)
2013				
8	64	72	103	1.7 (c)
124	64	188	187	4.3 (ab)
202	64	266	176	3.9 (b)
241	64	305	204	4.1 (b)
305	64	369	257	5.5 (a)
2014				
67	77	144	233	5.6 (a)
146	77	223	287	6.3 (a)
226	77	303	301	5.9 (a)
307	77	384	377	6.3 (a)

**Source: Alley et al., 2009; Beegle & Durst, 2003 (FREP Fertilization Guidelines)*

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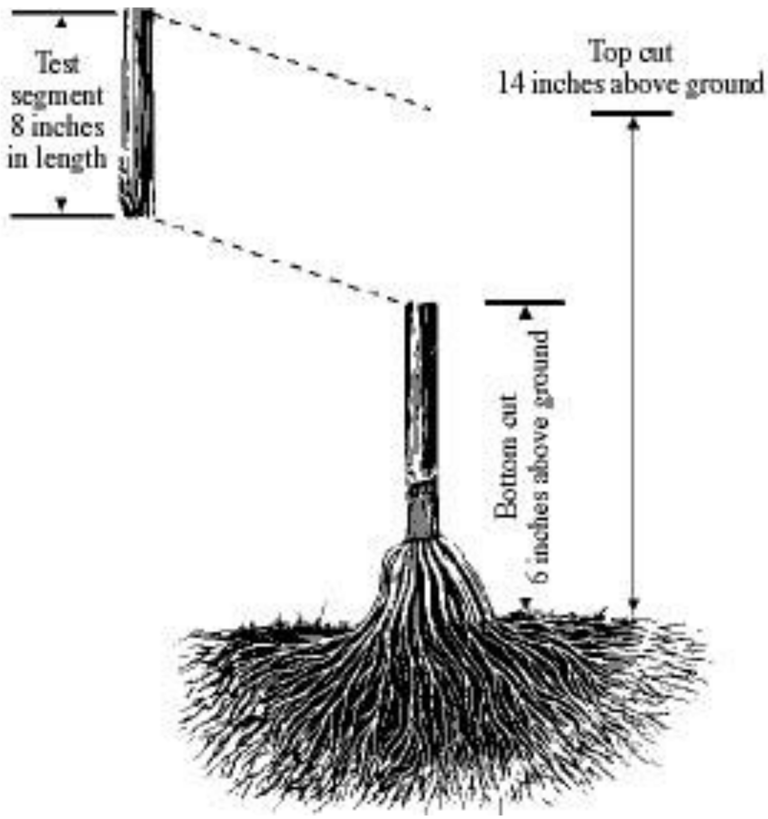
Corn Stalk Nitrate Test



https://www.agry.purdue.edu/ext/corn/news/articles.03/stalknitratetest-0915.html

http://msue.anr.msu.edu/news/a_report_card_on_corn_n_management

Corn Stalk Nitrate Test

- Deficient (0-250 ppm) → increase fertilizer rate
- Marginal (250-700 ppm) → increase rate if multiple years result in marginal levels
- Optimal (700-2000 ppm) → continue current application rate
- Excess (>2000 ppm) → reduce application the following year

Murdock and Schwab (2004), U. Kentucky Coop. Ext.

Corn Stalk Nitrate Test Results

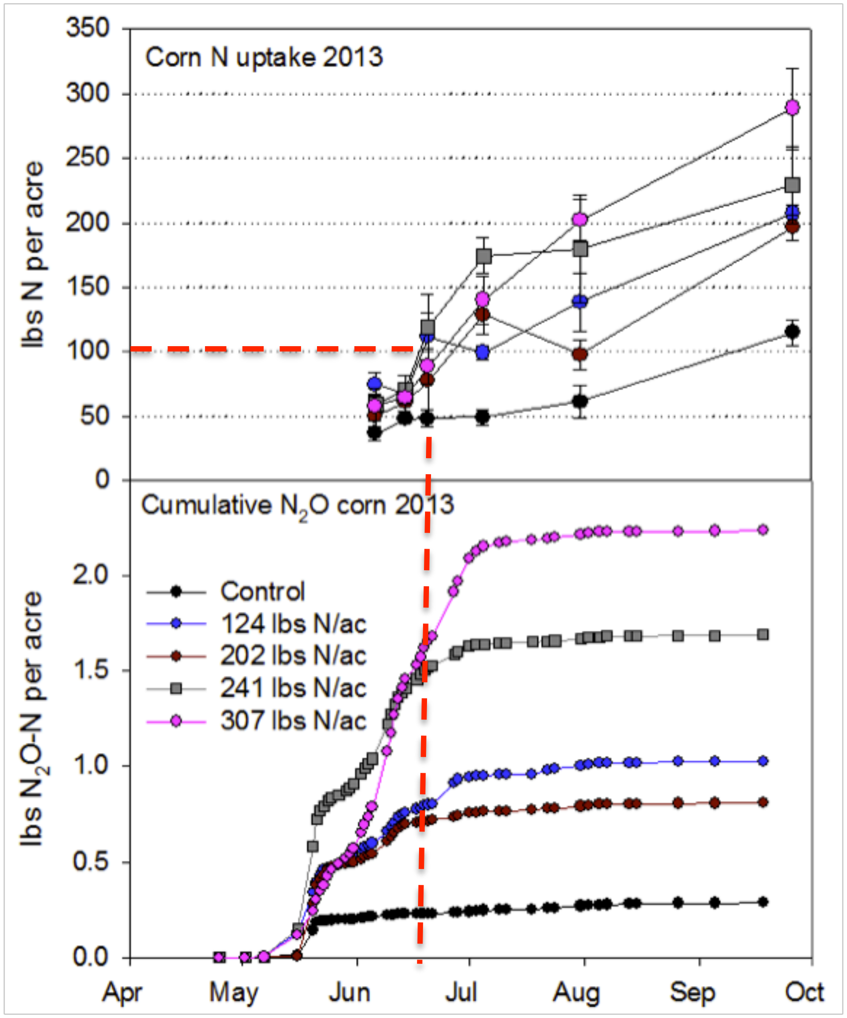
Treatment	Pre-Plant NO_3^-	Total N inputs	Yield	Corn Stalk NO_3^-	Status
(lbs N/ acre)	(lbs N/acre)	(lbs N/acre)	(tons/acre)	(ppm)	
2014					
67	77	144	5.6 (a)	371	Marginal
146	77	223	6.3 (a)	684	Sufficient
226	77	303	5.9 (a)	8339	Excess
307	77	384	6.3 (a)	8418	Excess

Comparison of Results with Other Studies

	N_2O	**Applied fertilizer N**	**Yield-scaled N_2O**
	lbs N2O-N/acre	lbs N/acre	lbs CO_2 equiv. / ton grain
2013	0.7	202	40
2014	3.0	146	113
*Midwest	3.4	123 - 140	n.d.
**Worldwide	2.7	136	185

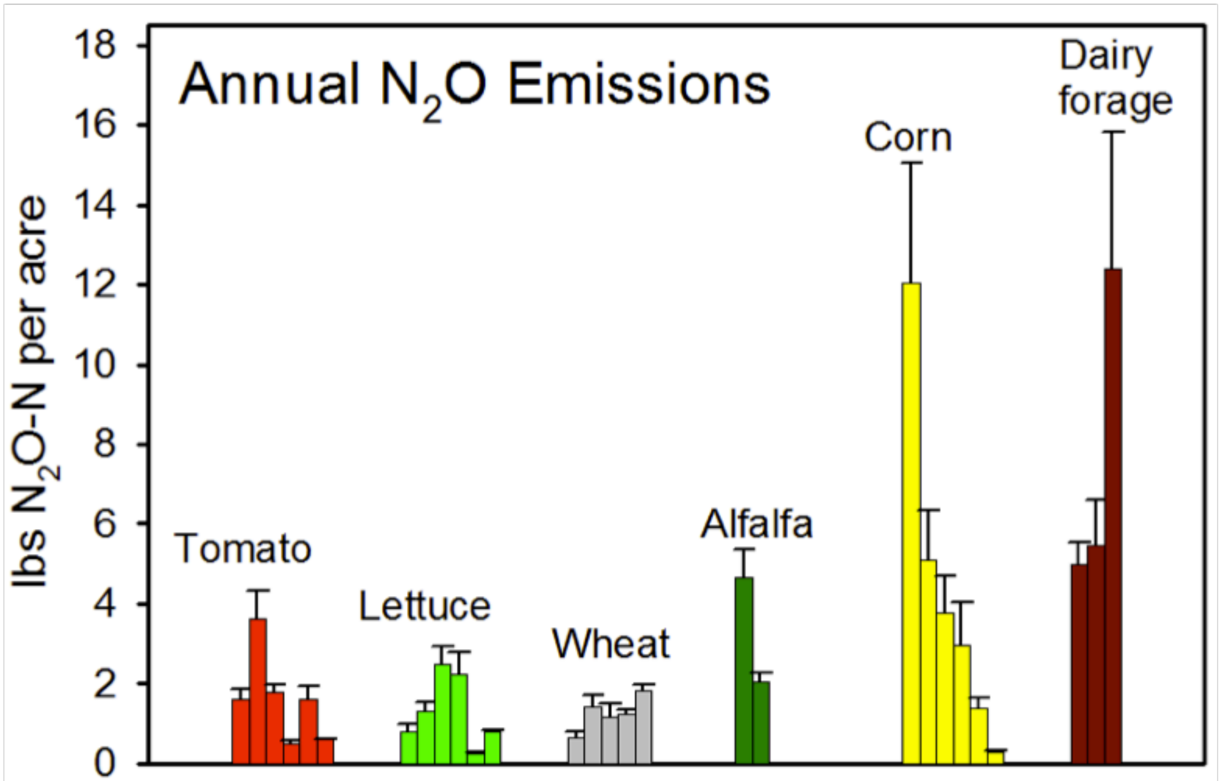
**DeCock, 2014, Environ. Sci. & Technol.*
***Linquist et al., 2012, Global Change Biol.*

How are fertilizer N rates, crop N uptake, and N_2O emissions related?



- N_2O emissions increase with increasing N fertilizer rates
- Most N_2O emissions occur in the first 4-6 weeks following fertilizer applications
- Nitrification is an important source of N_2O emissions
- The higher the N rate, the longer the elevated N_2O fluxes persist

N_2O emissions vary among and within CA cropping systems



Differences in emissions are due to management practices:

- N inputs
- Fertilizer formulations & placement
- Irrigation systems

Nitrification Inhibitors

- Slow down nitrification (conversion of ammonium to nitrate).

$$NH_4^+ \xrightarrow{\text{Nitrosomonas}} NO_2^- \xrightarrow{\text{Nitrobacter}} NO_3^-$$

- Nitrification inhibitors applied with N fertilizers partially inhibit nitrification for 3-4 weeks.
- Allow plants to take up more N in the ammonium form

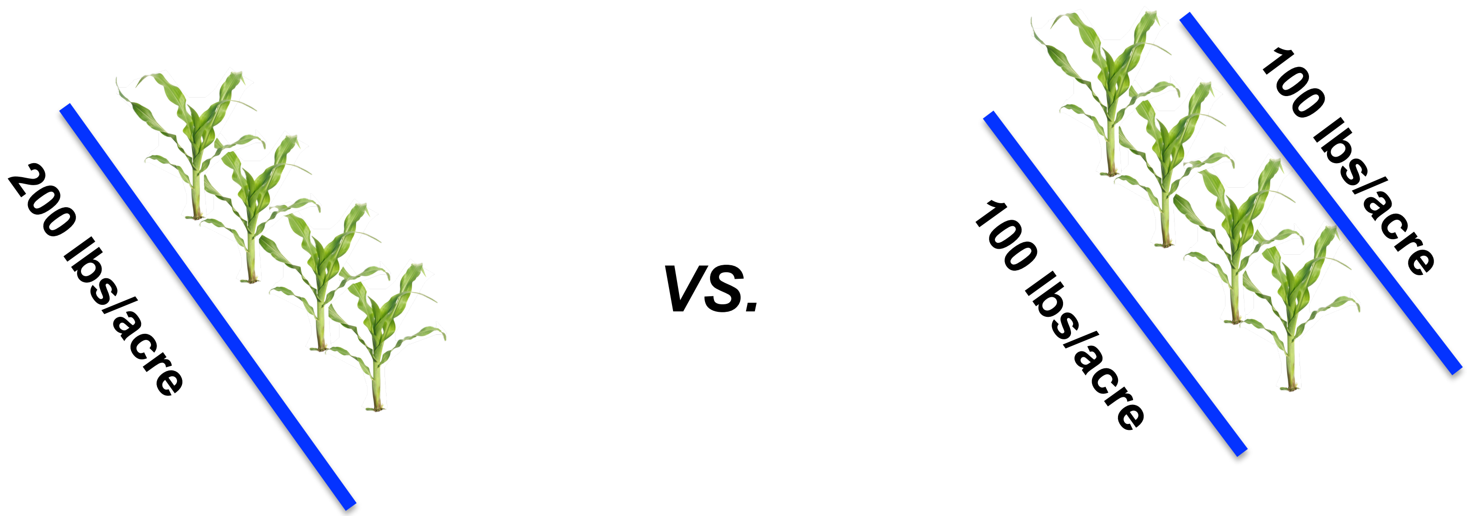
- Results:
  - Reductions in emissions were between 0 and 63% (6 full growing season experiments).

Concentration of N substrate affects N_2O emissions

Examples:

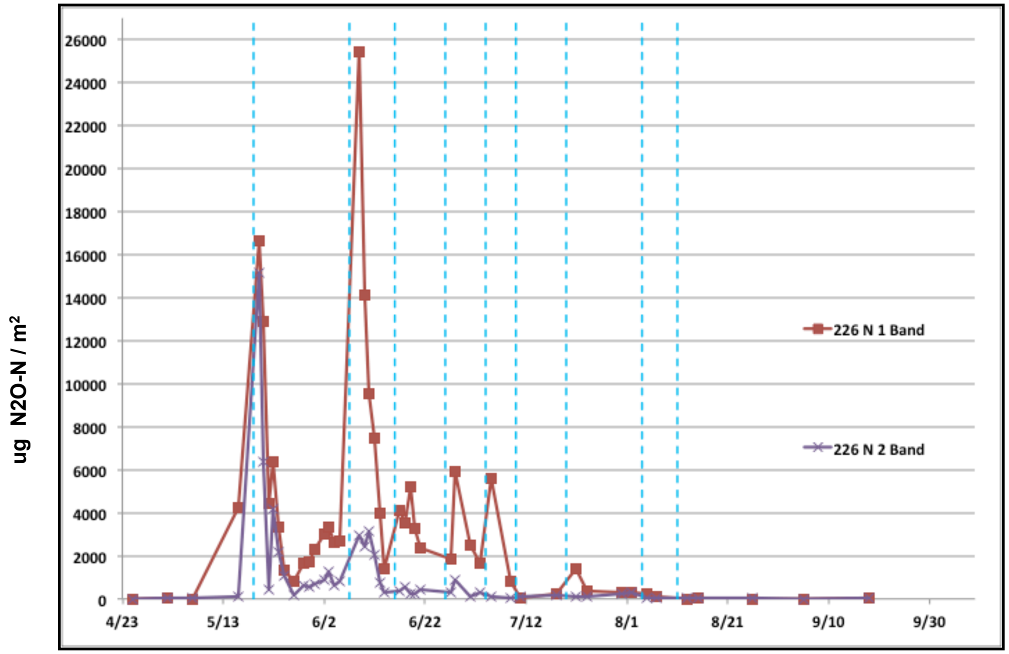
- Fertilizer N formulation (e.g. Anhydrous ammonia *vs.* less concentrated fertilizers)
- Fertilizer N placement (banding *vs.* broadcast)
- Multiple small *vs.* single large applications

- **One-band vs. two-band application of UAN fertilizer**



One-band *vs.* two-band application

Daily N_2O flux in furrow-irrigated corn fertilized with UAN



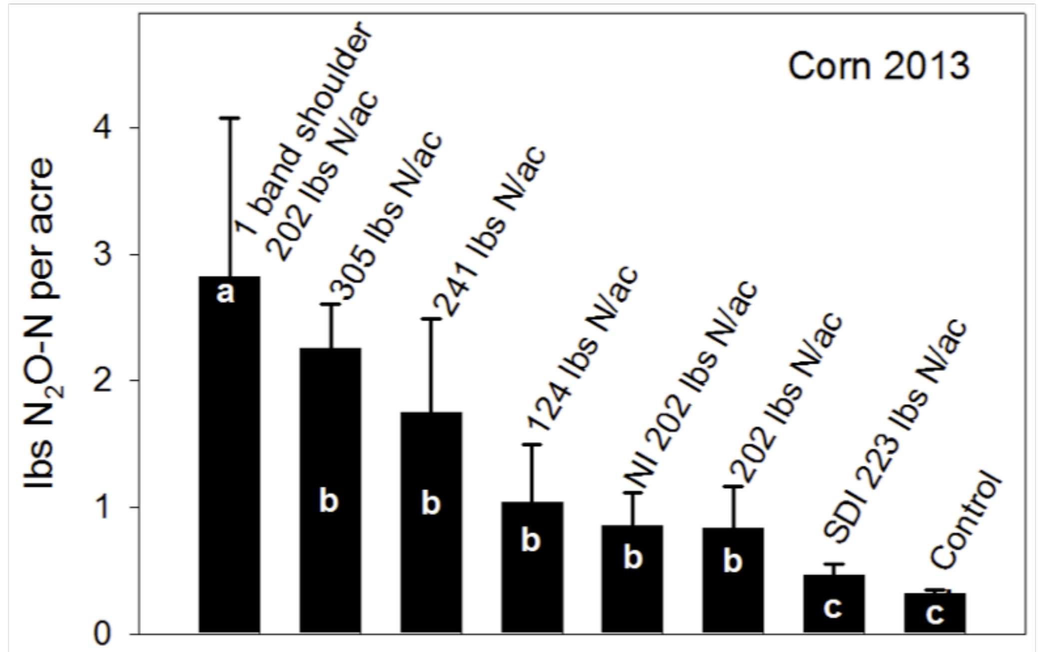
Daily N_2O fluxes were elevated for weeks when side-dress N was applied in one band (red symbols), rather than in two bands.

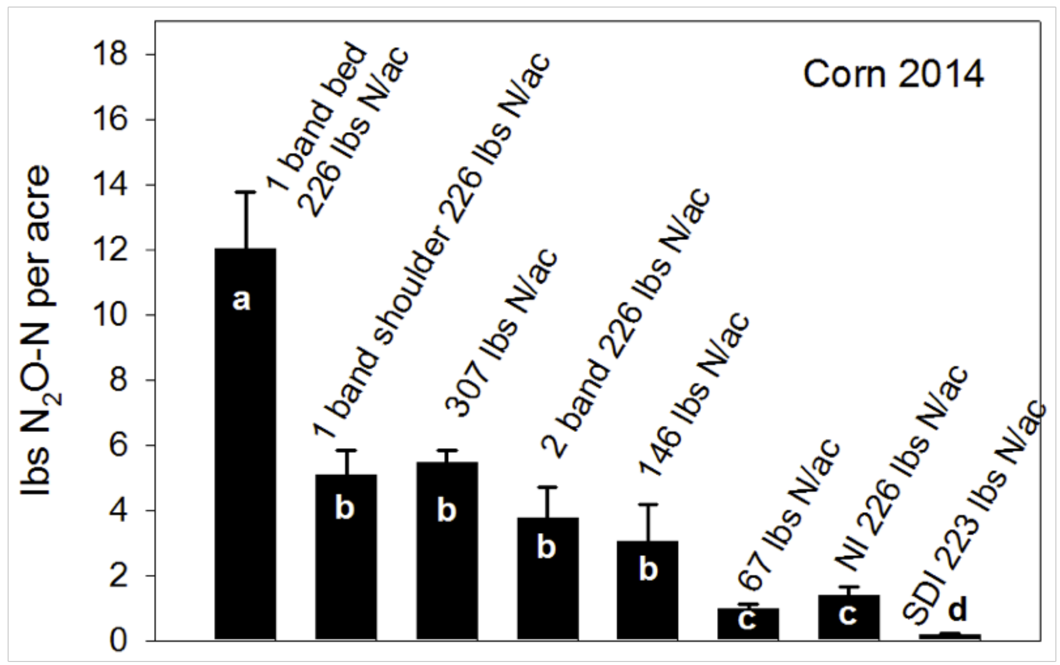
Subsurface drip irrigation

- Large reductions in N_2O emissions
- Yield increases

Results of corn trials in commercial field

- Subsurface drip irrigation most reliably mitigates N_2O emissions.
- If applied at the right crop stage, nitrification inhibitors can reduce N_2O emissions.
- One-band N fertilizer applications increased N_2O emissions compared to two-band applications.
- N_2O emissions increase with increasing N rates; at the recommended N rates, N_2O emissions can be significantly further reduced through the use of nitrification inhibitors or SDI.





Conclusions

- This research showed in multiple ways how concentrating soil inorganic N, especially ammonium, increases the potential for N_2O emissions:
    - N_2O emissions increase with increasing N fertilizer rates
    - N fertilizer formulation, e.g. ammonium does not disperse until it is nitrified
    - Placement of N fertilizer (one-band vs. two-band N fertilizer applications)

- Nitrification inhibitors showed potential as mitigation practice:
    - More information on time of efficacy, crop N uptake rates needed to take full advantage of this technology.

- To minimize N_2O emissions, N fertilizer guidelines, combined with regular pre-plant testing of soil inorganic N levels, must be implemented and can be combined with other technologies, such as nitrification inhibitors and drip irrigation.

Thank You!

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