Management Practices to Mitigate N$_2$O Emissions from Agricultural Soils

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Nitrogen is Essential in Agriculture Production

- Optimizing Crop Yields
- Optimizing Economic Returns – keeping farmers in business
- Producing High Quality, Marketable Crops with Good Nutrition
Agriculture and GHG Emissions

- Agricultural soil management accounts for about 6.3% of all GHG emission in U.S.
- Addition of reactive N to soil and emission of N₂O via soil microbiological processes (Nitrification and Denitrification) makes U.S. agriculture the largest source (62%) of total U.S. N₂O emissions.
- Management controls over N₂O emissions are related to the size of substrate N pool and the addition of N in the presence of easily decomposable C.
- High degree of uncertainty in agriculturally derived N₂O estimates.

(a) **Nitrification** is an aerobic process where by $\text{NH}_4^+$ is transformed by *Nitrosomonas* spp. bacteria in soil to $\text{NO}_2^-$ which is transformed by *Nitrobacter* spp. bacteria to $\text{NO}_3^-$. (Follett, 2001).

(b) **Denitrification** is an anaerobic bacterial process, during which $\text{NO}_3^-$ or $\text{NO}_2^-$ are reduced to gaseous NO, $\text{N}_2\text{O}$, or $\text{N}_2$. (Follett, 2001).
Factors Affecting N$_2$O Emissions from Agricultural Systems:

- Soil temperature, water, and texture
- Anaerobic soil conditions (reduced oxygen supply)
- Microbial and fungal populations and type
- Legumes in crop rotation
- Crop residue type and amount (C:N ratio)
- Type of N fertilizer applied
- Fertilizer placement in soil
- Tillage system
- Year to year variations in climate – Temp. & Precip.
- Irrigation system – Furrow, Sprinkler, Drip

- Because of the above factors, N$_2$O emissions from soil are highly variable and unpredictable.
Walters (2005) also suggested that there is little difference in N$_2$O emission between fertilizer N sources, except for anhydrous ammonia (AA) which generally results in ~4 to 5 fold greater N$_2$O emissions than other N sources.
Irrigated Cropping System Effects on $N_2O$ Emissions in Colorado

CC = continuous corn; CSb = Corn-Soybean; NT = no-till; CT = Conv. Tillage
(adapted from Mosier et al., 2006, JEQ)

Walters (2005) also showed higher $N_2O$ emissions during the corn year following soybean in a corn-soybean rotation in Nebraska. Missouri research reported soybean had the highest $N_2O$ emissions when compared to non $N_2$-fixing crops (Nkongolo, 2007).

In California, Rolston et al. (2007) reported low $N_2O$ emissions prior to $N$ fertilization and irrigation, with slightly higher $N_2O$ emissions from minimum till system compared to standard tillage practices.
N$_2$O emissions from N fertilizer application increased linearly with increasing N rate each year from 2002 - 2006, but total emissions varied with year in irrigated cropping systems near Fort Collins, CO (Mosier et al., 2006; Halvorson & Del Grosso, 2007).

Estimated N$_2$O emissions, as a percent of N fertilizer applied, averaged 0.66, 0.60, and 0.63 % for the CT-CC, NT-CC, and NT-CSb rotations, respectively, from 2002 – 2006, varying from 0.3% to 1.53% depending on year. This is below the IPCC factor of 1% used in calculating the National GHG Inventories (IPCC, 2006).
Application of polymer-coated urea (ESN®) resulted in lower N₂O emissions than with UAN or Urea (Halvorson and Del Grosso, 2007).

Blaylock et al. (2004) reported reduced N₂O emissions with ESN® compared to other N fertilizer sources and improved N-use efficiency by the crop.

Research in Nebraska under irrigated crop production also found lower N₂O emissions when ESN® was used (Personal communications with Dan Walters, UNL, (2-6-07))

Polymer-Coated Urea

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Polymer coated urea

- N release controlled by diffusion
- Major factors affecting release
  - coating thickness
  - temperature
  - moisture

Figure courtesy of Dr. Mike Stewart, IPNI
Conclusions from Colorado Studies:

- Increased $\text{N}_2\text{O}$ emissions from N fertilization (UAN or Urea) occurs during the first 30-40 days following fertilization, with $\text{N}_2\text{O}$ fluxes declining to near background levels thereafter.

- No residual effects of N fertilization on $\text{N}_2\text{O}$ emissions late in the growing season or during the non-crop period.

- Total growing season $\text{N}_2\text{O}$ emissions vary with year, but are proportional to the amount of N applied.

- Tillage system does not appear to have much affect on $\text{N}_2\text{O}$ emissions, but inclusion of soybean or dry bean in the rotation increases $\text{N}_2\text{O}$ emissions.

- A polymer-coated urea (ESN®) shows potential for reducing $\text{N}_2\text{O}$ emissions in irrigated systems, but more research is needed to verify this observation.
Other Management Options

• Apply N through drip or sprinkler irrigation systems throughout growing season.

• Convert to reduced- and no-till production systems (reduce fossil fuel consumption, sequester SOC), offset N₂O emissions.
Irrigation Method vs N Needs of Onion

Examples:

Improved N use-efficiency by onion with drip irrigation in Colorado.

Drip vs furrow irrigation work with tomatoes in California shows less N$_2$O emissions with drip irrigation (Kallenbach et al., 2007).

Fertigation of corn with sprinkler irrig. system in Nebraska did not increase N$_2$O emissions (Ginting & Eghball, 2005).

Halvorson et al., 2006. GPSF Conf.
Converting to Conservation Tillage Systems to Offset N$_2$O Emissions

• Conventional intensive tillage practices results in the loss of soil organic carbon (SOC) and release of CO$_2$ to the air.

• Reduced-Till and No-Till Farming Systems can reduce CO$_2$ emissions and sequester SOC.

• Reduced- and No-Till systems can reduce soil erosion, fossil fuel consumption, and production costs.
No-till production: leaves crop residues on the surface – reducing soil erosion and enhancing soil organic C and N sequestration
Continuous Corn Production:

No-Till (NT):
- Plant
- Spray for pest control
- Harvest

Conventional Till (CT):
- Shred corn stalks
- Disk
- Moldboard plow
- Disk
- Roller Harrow
- Landplane (2 operations)
- Plant
- Spray for pest control
- Harvest

Adapted from Halvorson et al., 2005
Global Warming Potential Within NT and CT Irrigated Continuous Corn Systems Near Fort Collins, CO

Adapted from Mosier et al., 2006 JEQ
Managing $N_2O$ Emissions

- $N_2O$ emissions are proportional to the rate of $N$ fertilizer applied (reduce $N$ rate – reduce $N_2O$ emissions)

- Soil test to determine residual soil $N$ levels before applying $N$ fertilizer

- Apply only BMP $N$ dosages to crops that insure economic optimum return

- Source of $N$ fertilizer applied
  - Anhydrous Ammonia (~4 to 5 fold higher $N_2O$ emissions than other $N$ sources)
  - Change from AA to other $N$ sources: polymer-coated fertilizers, fertilizers treated with urease and nitrification inhibitors, controlled release $N$ fertilizers.
Managing \( \text{N}_2\text{O} \) Emissions

- Apply N in small quantities during the growing season through drip or sprinkler irrigation systems.

- Avoid very wet soil conditions when applying N fertilizer.

- Reduce soil area fertilized – put fertilizer in bands near plant row.

- Fertilizer N placement – surface, shallow, or deep in soil \((\text{Liu et al., 2005; Drury et al. 2006; Venterea, 2007})\)

- Convert to NT system to offset \( \text{N}_2\text{O} \) emissions by sequestering more SOC, reducing fossil fuel consumption, and reducing soil erosion.
Thanks for Listening!!!

Questions??