Reducing Nitrous Oxide Emissions Through Improved Nitrogen Stewardship: Balancing Crop Production Management and Environmental Protection

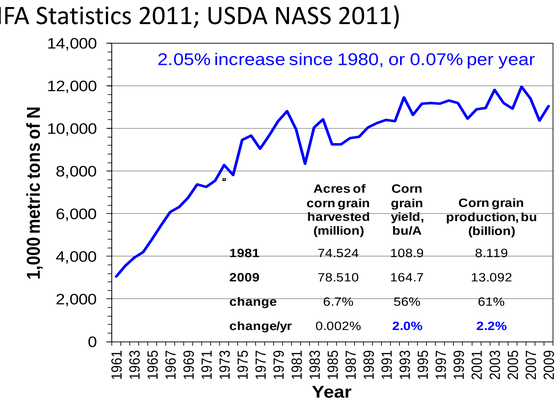
C.S. Snyder[1] and P.E. Fixen[2], International Plant Nutrition Institute

[1]Nitrogen Program Director, and [2]Senior Vice President Americas and Oceania Group and Director of Research

Background

- 40 to 60% of our population owes its existence to the food, feed, fiber and biofuel production made possible by nitrogen (N) fertilizers (Stewart et al. 2005, Erisman et al. 2008)
- Farmers are increasingly striving to improve crop and soil recovery of applied N, but in-season apparent N recovery often ranges < 40 to 50%. (Kitchen and Goulding 2001)
- Increased fertilizer N use in the U.S. (**Figure 1**) has contributed to increased production of corn and many other crops, yet corn yields have increased at a much higher rate than the fertilizer N consumption rate ; implying that the efficiency of N use has improved since 1980.
- N not taken up by crops is subject to different loss pathways from farm fields, including emissions as nitrous oxide (N_2O) a potent greenhouse gas (GHG); the IPCC roughly estimates 1% of applied N is emitted as N_2O.

Figure 1 - Fertilizer N consumption in the U.S. and corn production facts (IFA Statistics 2011; USDA NASS 2011)



U.S. N_2O Emissions and Corn Fertilizer N Applications

- Agricultural soil management, which includes fertilizer N use, accounts for 69% of the U.S. N_2O emitted, but less than 4% of the carbon dioxide equivalent (CO_2e) total net GHG emissions since 1990 (**Figure 2**).
- Corn is the largest fertilizer N consuming crop in the U.S.
  - -contrary to misperceptions, USDA ERS data indicate that farmers in leading corn-producing states do not apply more N than would be prescribed for the maximum economic return to N (MRTN), based on the Corn N Rate Calculator (**Table 1**).

Figure 2 - Net GHG emissions and N_2O associated with agricultural soil management (EPA, 2011)

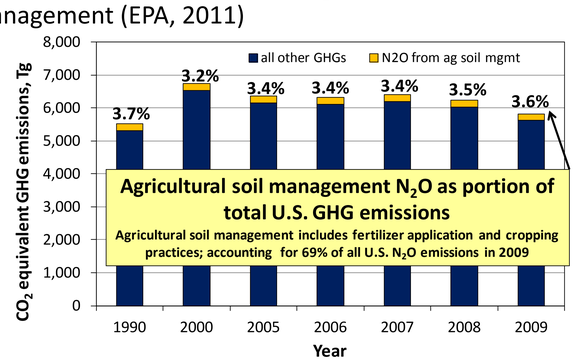


Table 1 - Corn N Rate Calculator and USDA ERS N Rate Comparisons
(http://extension.agron.iastate.edu/soilfertility/nrate.aspx & http://www.ers.usda.gov/Data/FertilizerUse/)

	2005 MRTN @ $0.36/lb N, corn @ $3.60/bu	2010 MRTN @ $0.30/lb N, corn @ $5.80/bu	On acres receiving fertilizer, actual N applied	
			2005	2010
State	kg of N/ha			
Illinois	188	220	164	187
Indiana	192	251	165	199
Iowa	140	170	158	159
Michigan	146	167	143	137
Minnesota	118	138	156	140
Ohio	195	224	180	140
6-state average	**164**	**195**	**161**	**164**

Increasing Crop N Uptake and Reducing N_2O Emissions

- Reductions in N_2O emissions ranging from 20 to 50% (or more) are possible in some cropping system environments, using appropriate N sources, rates, timing and place of application (**Figure 3**).
- Earlier work on cereal crops with nitrification inhibitors and polymer coated urea fertilizers showed reductions in N_2O emissions ranging from 35 to 82% (Bronson et al. 1992, Delgado and Mosier 1996, Shoji et al. 2001), while a recent meta-analysis showed no reductions in N_2O emissions with urease inhibitors (Akiyama 2010).
- A 2010 meta-analysis of N source, rate, time and place of application in eastern Canada (Bruulsema 2010) revealed significant effects of each in reducing N_2O emissions.
- Implementation of Best Management Practices (BMPs) that support 4R Nutrient Stewardship principles and their economic, social and environmental objectives can help improve crop N uptake and result in reduced N_2O emissions on a land area basis.
- While land area-scaled N_2O emissions are important, it is also vital to consider N management to reduce yield-scaled N_2O emissions (Snyder et al. 2009, van Groenigen et al. 2009; Venterea et al. 2011), because the net effect of ecologically intensive crop production is the avoidance of large GHG emissions (Burney et al., 2010), which can result from greater agricultural encroachment into natural areas (i.e. native forests, grasslands, wetlands) in producing more food.
- Appropriate N source, rate, time, and place of application helps to minimize the potential for "surplus" N in cropping systems , which has been shown to help reduce yield-scaled (based on total crop N uptake) N_2O emissions (**Figure 4**).

Figure 3 - Nitrogen source management effects on cumulative growing season N_2O emissions in an irrigated no-till corn-corn system in Colorado, averaged over 2007 and 2008 (Halvorson et al. 2009 and 2010).

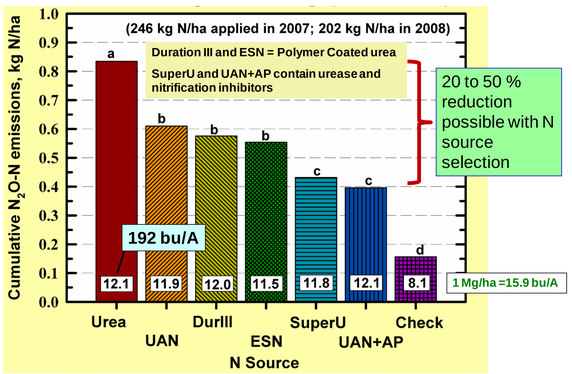
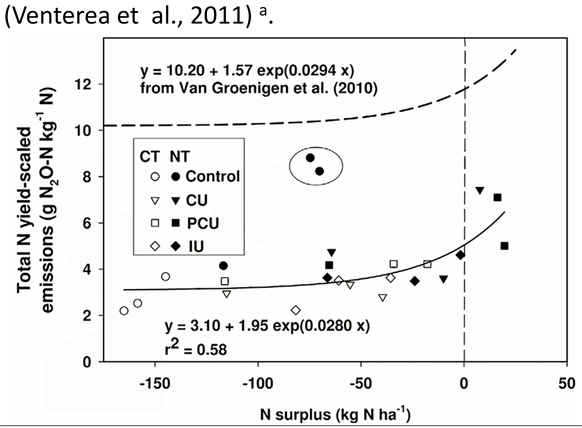


Figure 4 - Yield-scaled N_2O emissions associated with improved above-ground crop N uptake and lowered surplus N in cropping systems (Venterea et al., 2011) [a].



[a] CT=conventional tillage, NT=no-till; CU=conventional urea, PCU=polymer coated urea, and IU=enzyme inhibitor-impregnated urea. Circled treatments were considered outliers and not used in the regression analyses. Solid line is rainfed corn phase of a corn-soybean study in Minnesota (Venterea et al. 2011). Dashed line is from a review of multiple studies across multiple crops in North America, Europe, Asia, and Oceania (van Groenigen et al. 2010).

Sustaining Soil Organic Matter and Crop Production in an Economic Manner

- Proper fertilizer N management helps restore and maintain soil organic carbon (SOC) (**Figure 5**; Grove et al. 2009; Ladha et al., 2011). It can also help reduce the rate of SOC decline being observed around the world (Ladha et al. 2011).
- Deficit N fertilization, or a reduction in fertilizer N rates alone, to reduce agricultural nitrate-N loss via subsurface drainage could threaten long-term soil productivity and sustainability by causing the "mining" of total soil N and SOC (Jaynes and Karlen 2008). The same would be true for reductions in N rates to reduce direct N_2O emissions, or the indirect emissions associated with other N losses to water resources.
- Fertilizer N and cropping system tillage changes to reduce GHG emissions can substantially impact the net returns for farmers, as shown by Archer and Halvorson (2010) (**Figure 6**).

Figure 5 - Fertilizer N effects on profile soil organic carbon after 39 years of continuous corn with a winter cereal crop (Grove et al. 2010)

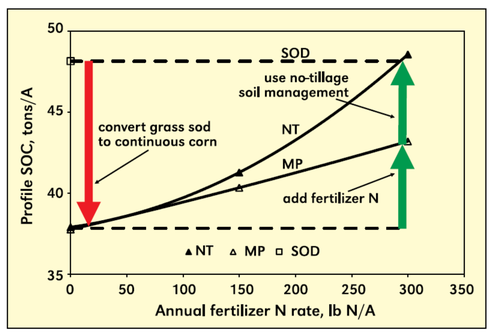
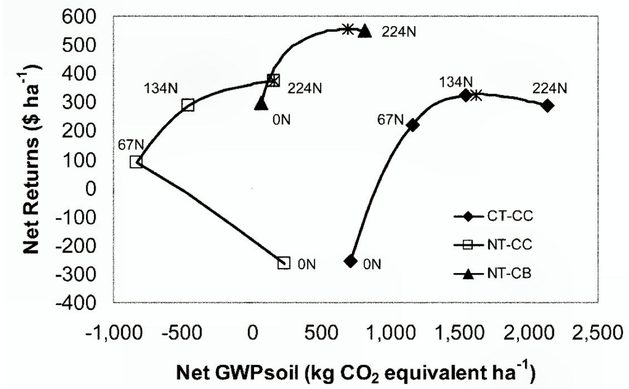


Figure 6 - Costs associated with reductions in carbon dioxide-equivalent greenhouse gas emissions in irrigated corn systems in Colorado (Archer and Halvorson 2010). [b]



[b] CT=conventional tillage, NT=no-till; CC=continuous corn, CB=corn-bean rotation. GWP=global warming potential determined by summing carbon dioxide-equivalent emissions of nitrous oxide, methane, and carbon dioxide. Values next to each point are kg N applied/ha.

Concluding Statements

- N_2O emissions vary according to N source, rate, time and place of application and will depend on site-specific conditions, weather, cropping and tillage systems.
- N management should support long-term soil fertility and productivity, and restoration and maintenance of soil organic carbon.
- Opportunities exist to enhance crop N uptake and to reduce N_2O emissions from productive cropping systems without sacrificing crop yields.
- Achieving significant N_2O emission reductions may require financial incentives for farmers.

References

✓*See sheets provided below on the table*

The mission of IPNI is to develop and promote scientific information about the responsible management of plant nutrients for the benefit of the human family.