Agricultural Sustainability and Nitrous Oxide (N_2O) Markets

How Long-Term Ecological Research Informs Sustainability Science and Action

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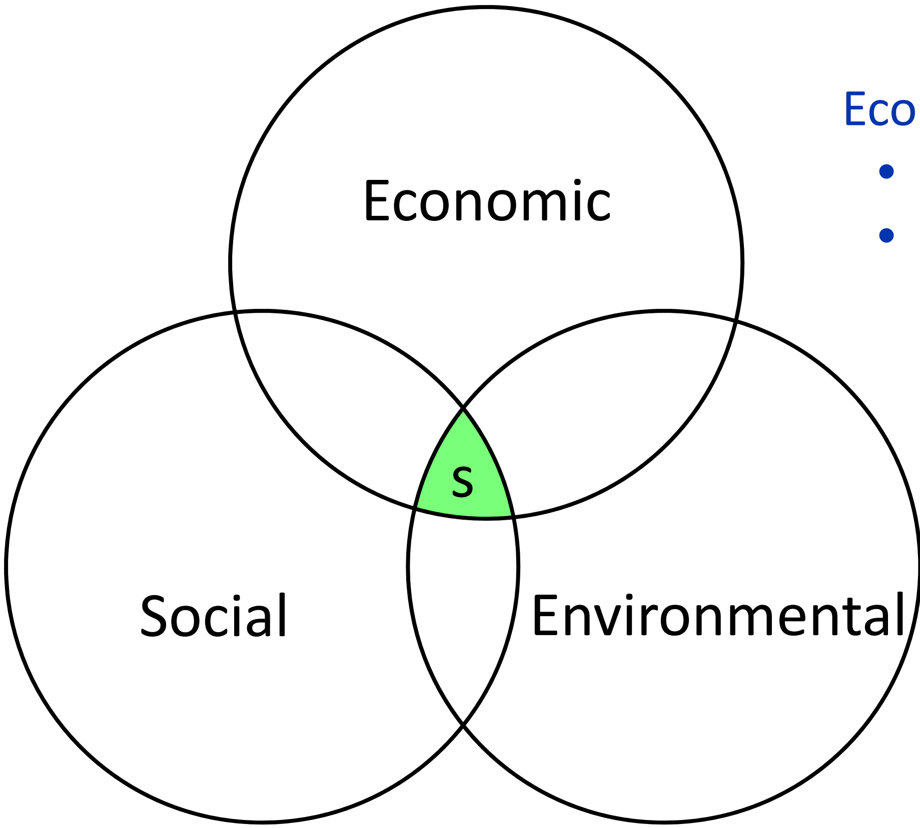
Interacting Dimensions of Sustainability for Agriculture



Sustainable Agricultural Practices require

Economic incentives for producer acceptance
- Profitability
- Economic well-being (wealth)

Social benefit for public acceptance
- Food and energy security
- Rural community health
- Human health & nutrition

Environmental benefit to mitigate burdens
- Climate security
- Biogeochemical health
- Biodiversity benefits

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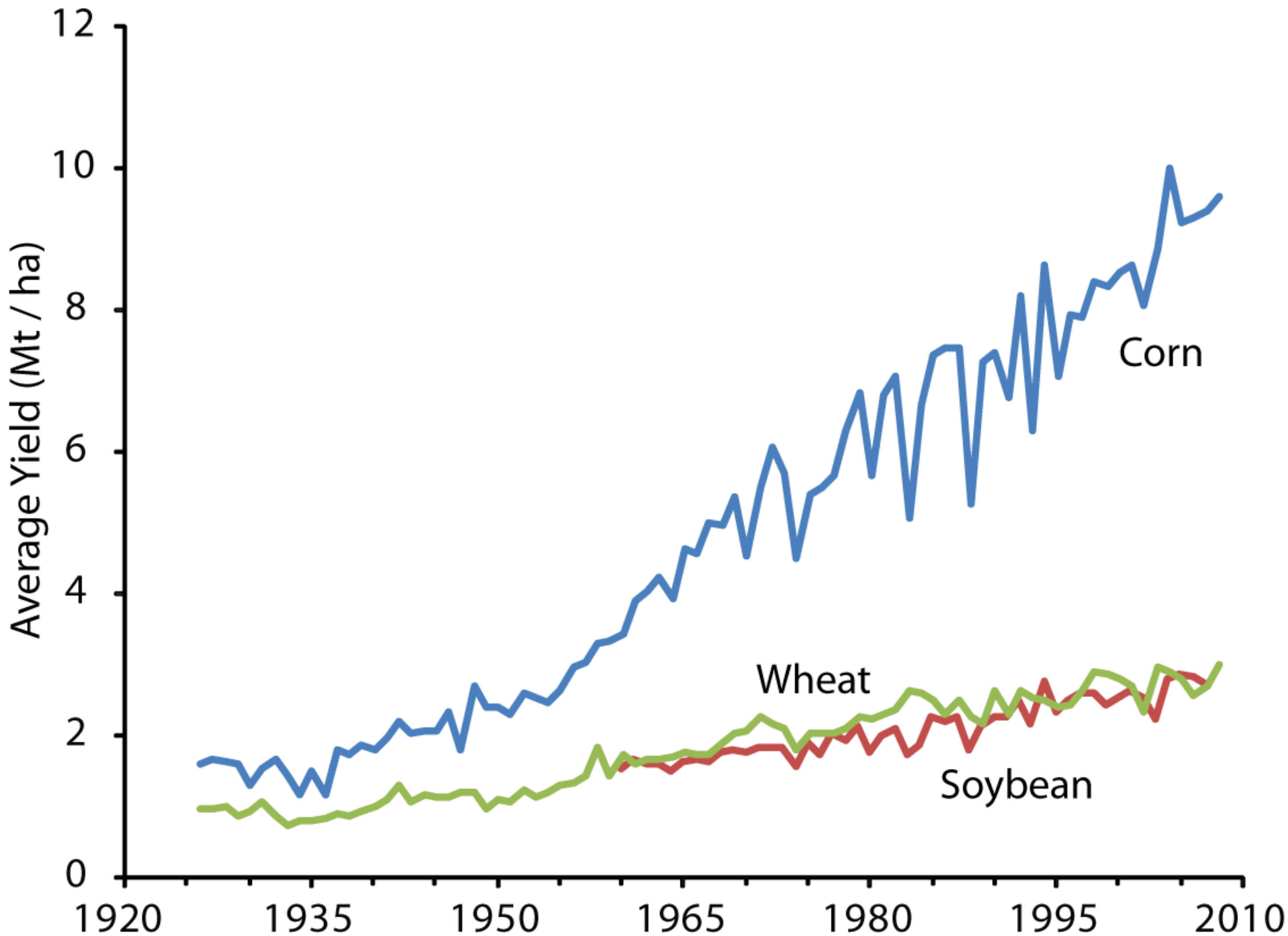
U.S. Average Yields for Major Grain Crops from 1930



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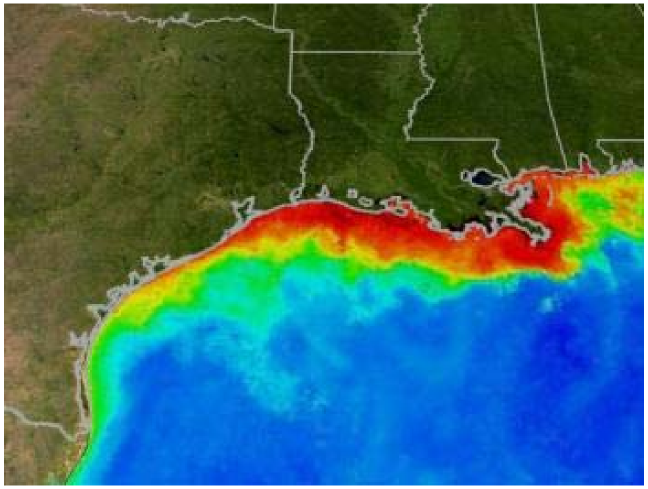
Environmental Signals of Agricultural Intensification

Inland Phosphorus



Coastal Nitrate

Habitat loss

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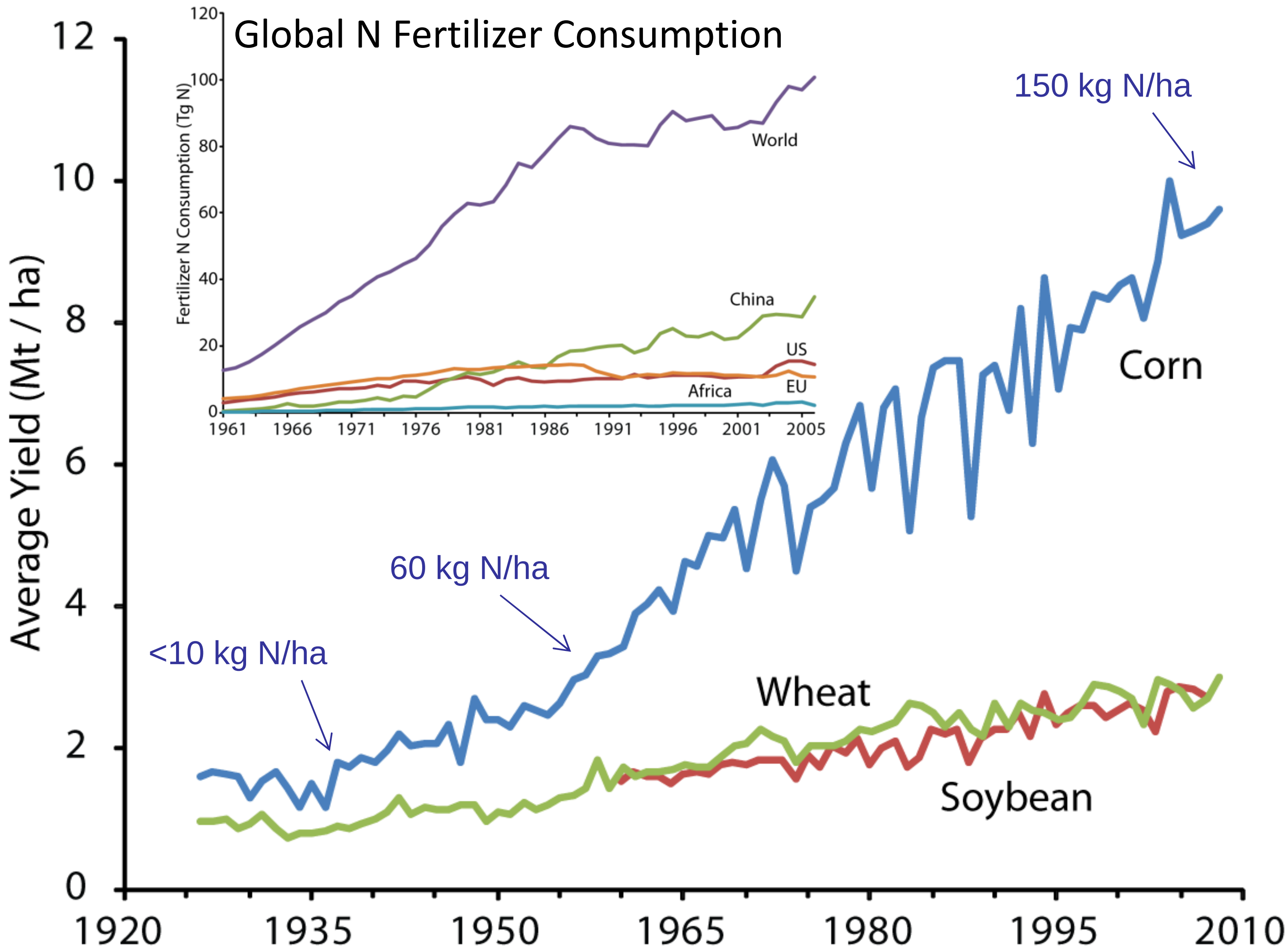
U.S. Average Yields for Major Grain Crops from 1930



From USDA ERS (2011), FAO (2011), Robertson & Vitousek 2009 Ann .Rev.

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Sources of information used by Michigan farmers to determine nitrogen fertilizer application rates to corn

	% Getting Information From Source	% Using as Most Important Source
Fertilizer dealers	69.6	36.5
Seed company agronomist	44.7	17.9
University recommendations	31.1	15.8
Other farmers	33.1	7.9
Magazines	23.3	3.4
Private consultant	18.7	7.4
Other	12.9	10.2

D. Stuart et al. 2012 (submitted)

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MSU-EPRI Nitrous Oxide Reduction Protocol

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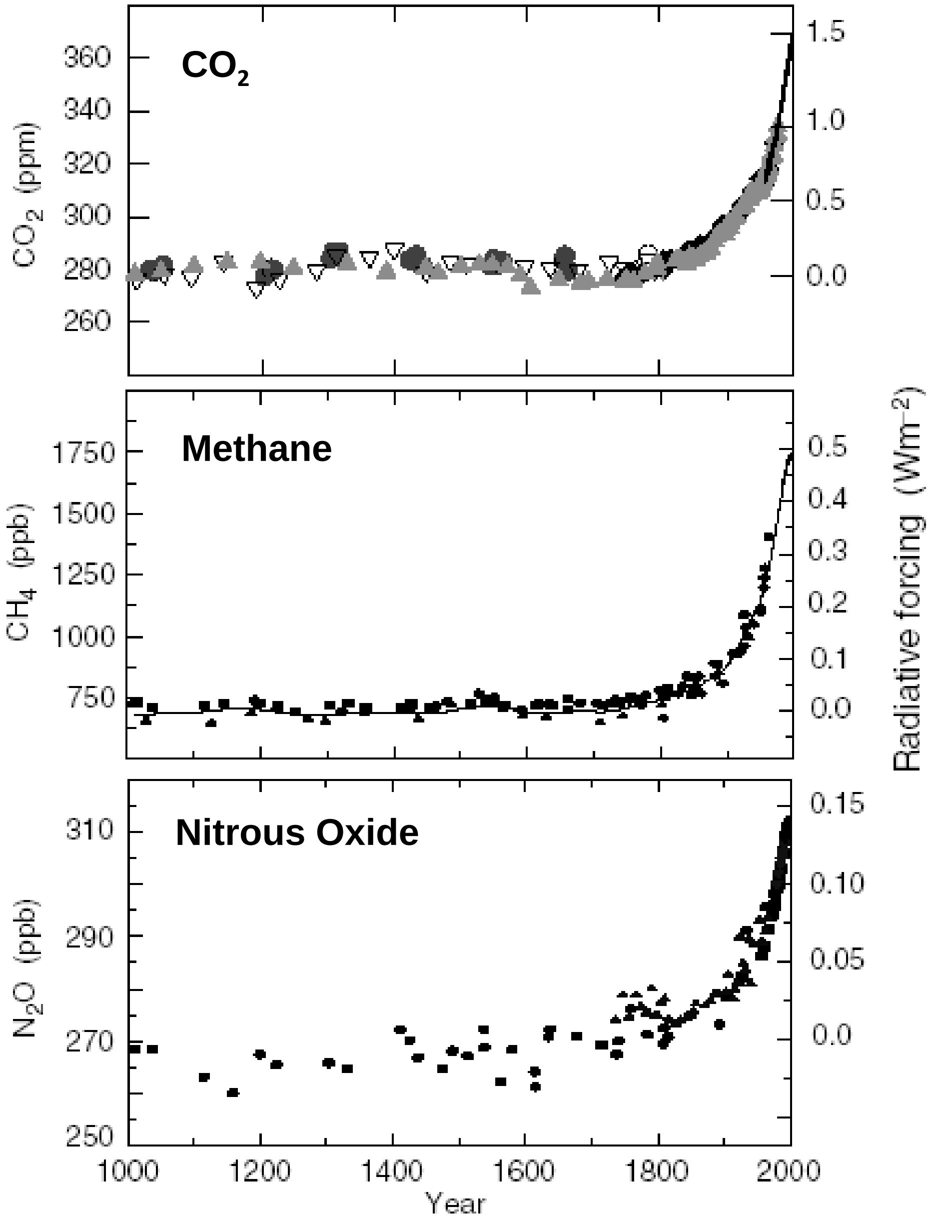
Partner Utilities

- American Electric Power
- Detroit Edison Co.
- Duke Energy
- Hoosier Energy Rural Electric Coop
- Oglethorpe Power Corporation
- PNM Resources Inc.
- Salt River Project
- Southern California Edison
- Tri-State Generation and Transmission Coop

Atmospheric Concentrations from 1000 C.E.



Atmospheric N_2O is increasing at rates similar to the other 2 major biogenic gases

N_2O

From IPCC (2001, 2007)

Global Warming Potential (GWP)
Biogenic Gases

	Lifetime yr	Global Warming Potential 20 yr	100 yr	500 yr
CO_2	variable	1	1	1
CH_4	12	62	23	7
N_2O	114	275	296	156

Source: IPCC 2002; 2007

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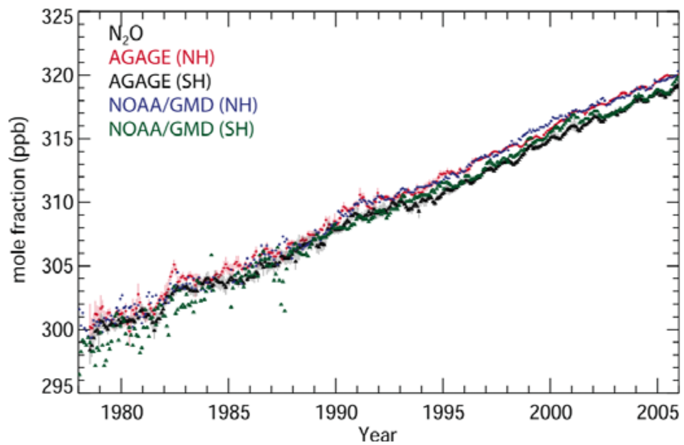
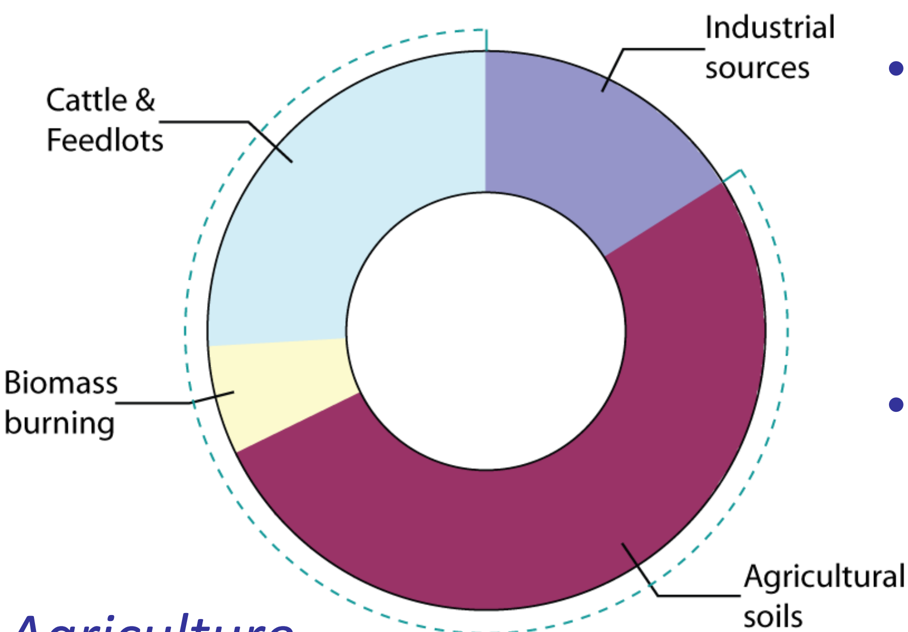
Atmospheric N_2O from 1976



The contemporary N_2O increase is largely due to agricultural intensification

- with a total annual impact ~ 1.2 Pg C_{equiv}

(compare to fossil fuel CO_2 loading = 4.1 PgC per year)



- Industry is responsible for ~16% of the anthropogenic source
    - Agriculture for the remainder
- with most of the agricultural increase (~60%) from cropped soils

Agriculture

Source IPCC 2001, 2007; Prinn 2004; Robertson 2004

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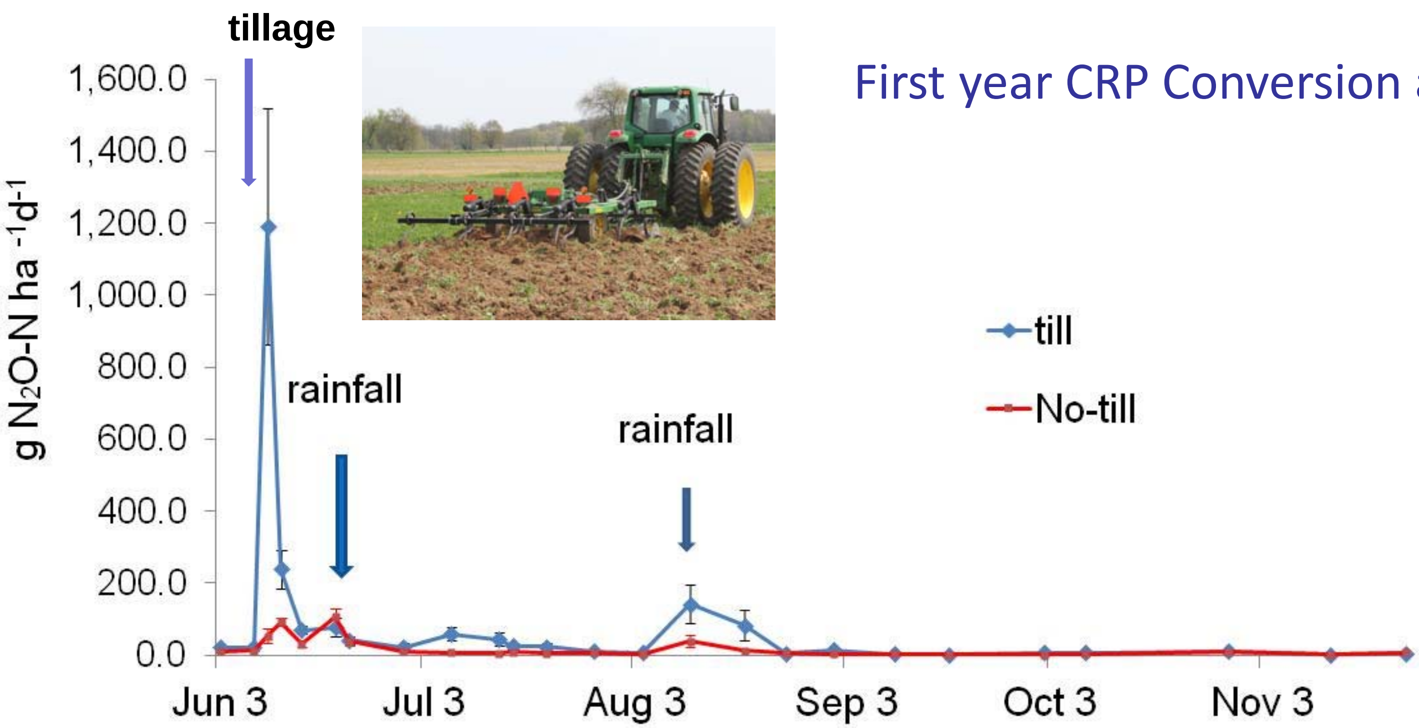
KBS Long-Term Ecological Research (LTER) Site

Ecosystem Type	Management Intensity
Annual Grain Crops (Corn - Soybean - Wheat)	
Conventional tillage	High
No-till	↓
Low-input with legume cover	
Organic with legume cover	
Perennial Biomass Crops	
Alfalfa	
Hybrid poplars	
Unmanaged Communities	
Early successional old field	
Mid successional old field	
Late successional forest	Low

N_2O Measurements are relatively simple but labor intensive

- Seasonality and environmental **events** are important



First year CRP Conversion at KBS

Ruan and Robertson 2011

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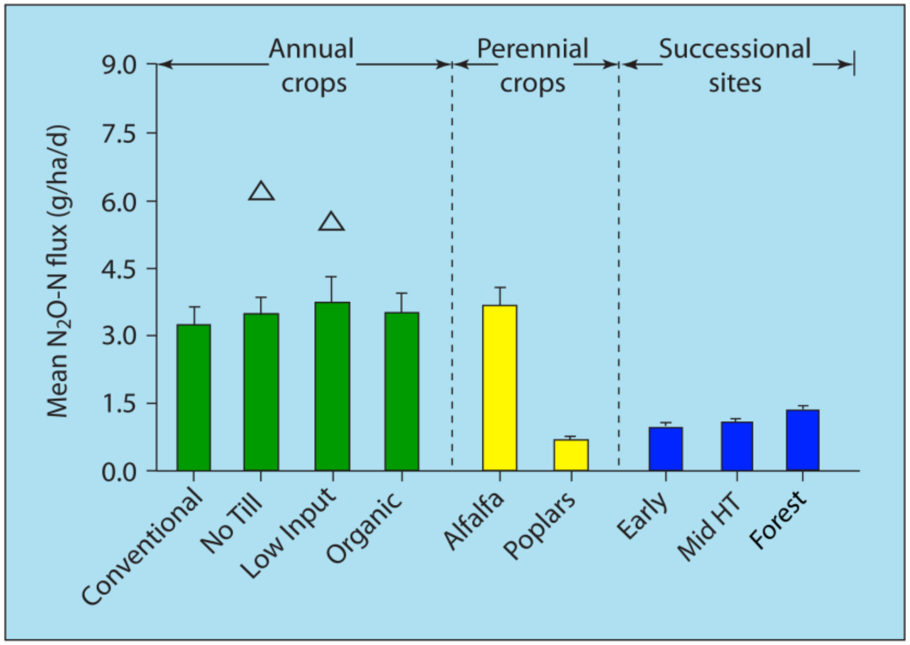
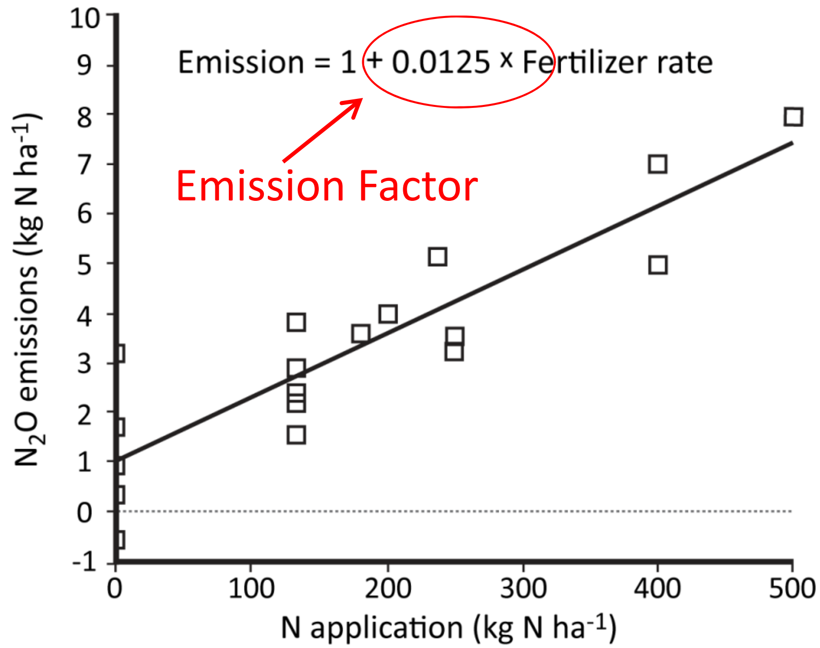
Nitrous Oxide Fluxes at KBS are related to the amount of N cycling in the system



IPCC N_2O Tier 1 Emission Factor



Bouwman et al. 1996

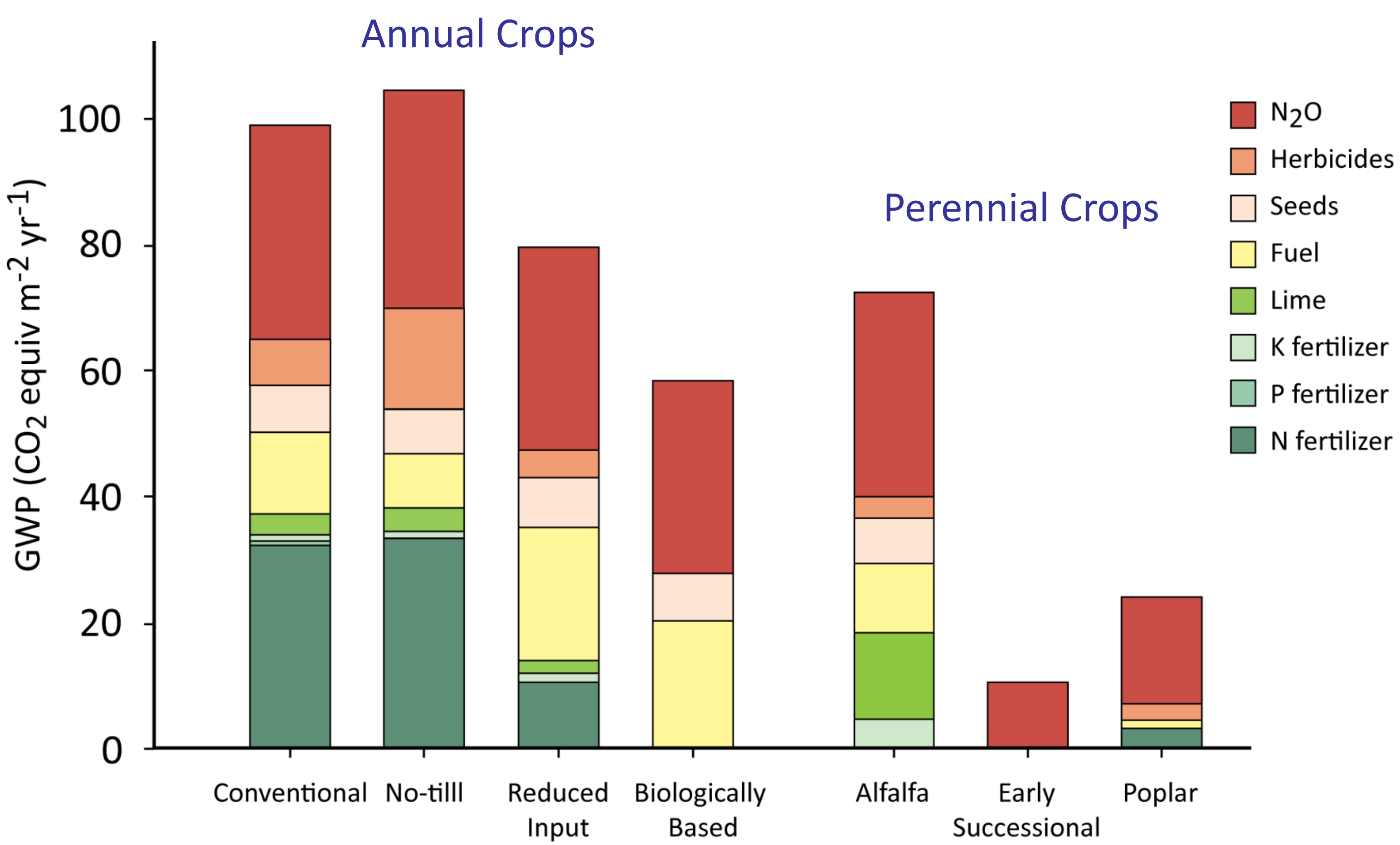
- IPCC 2006

  Tier 1 Linear Emission Factor

  EF = 1.0% (0.25 – 2.25%)

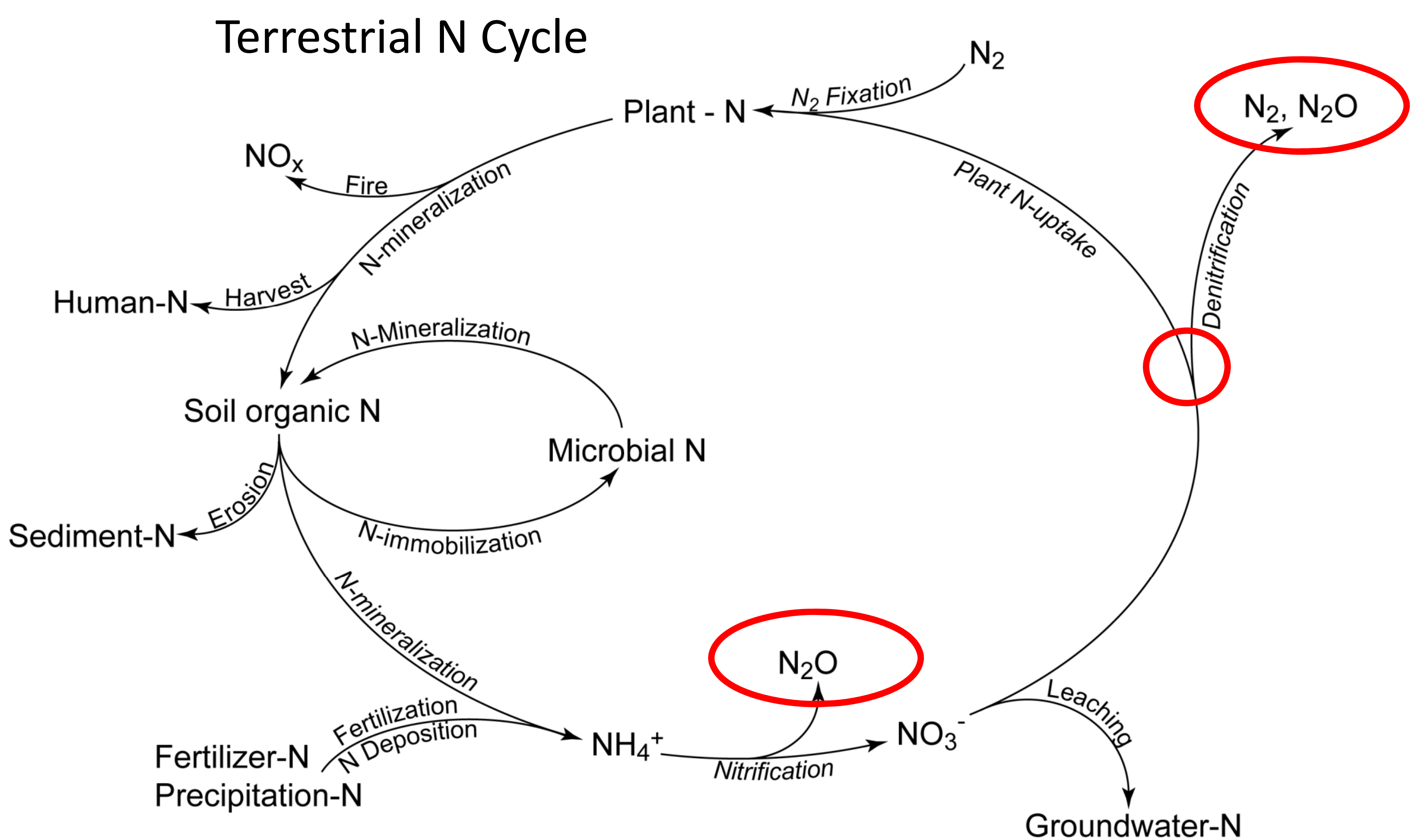
Robertson et al. 2000; Bouwman et al. 1996; IPCC 2006

Sources of Global Warming Impacts in KBS Cropping Systems (1992-2010)



Gelfand *et al. in prep.*

Sources of N_2O in soil



Robertson & Groffman 2007

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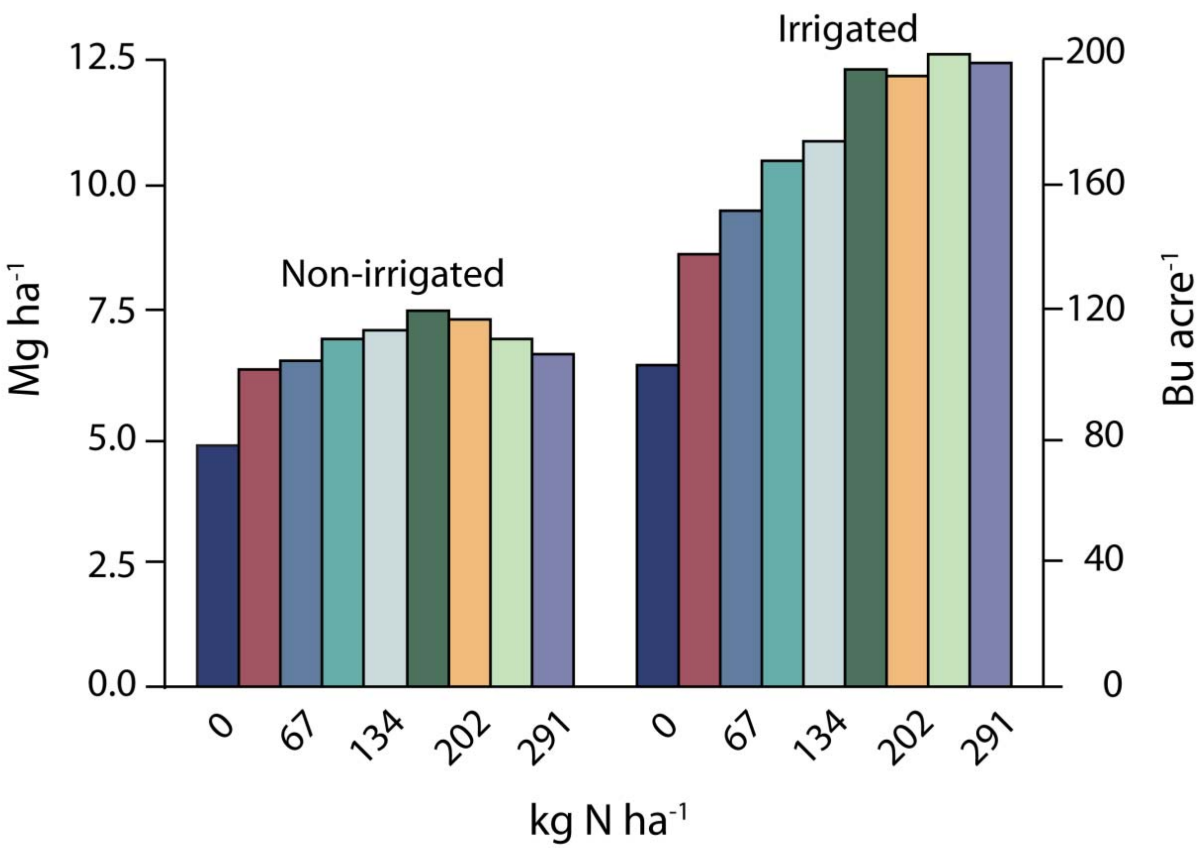
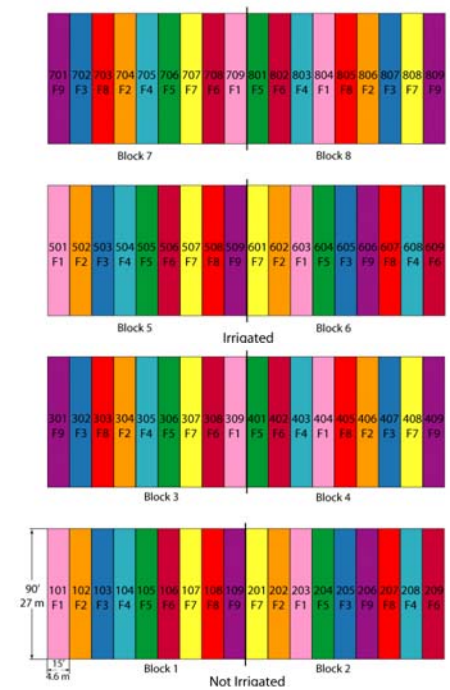
KBS corn yields at different N rates (2008)





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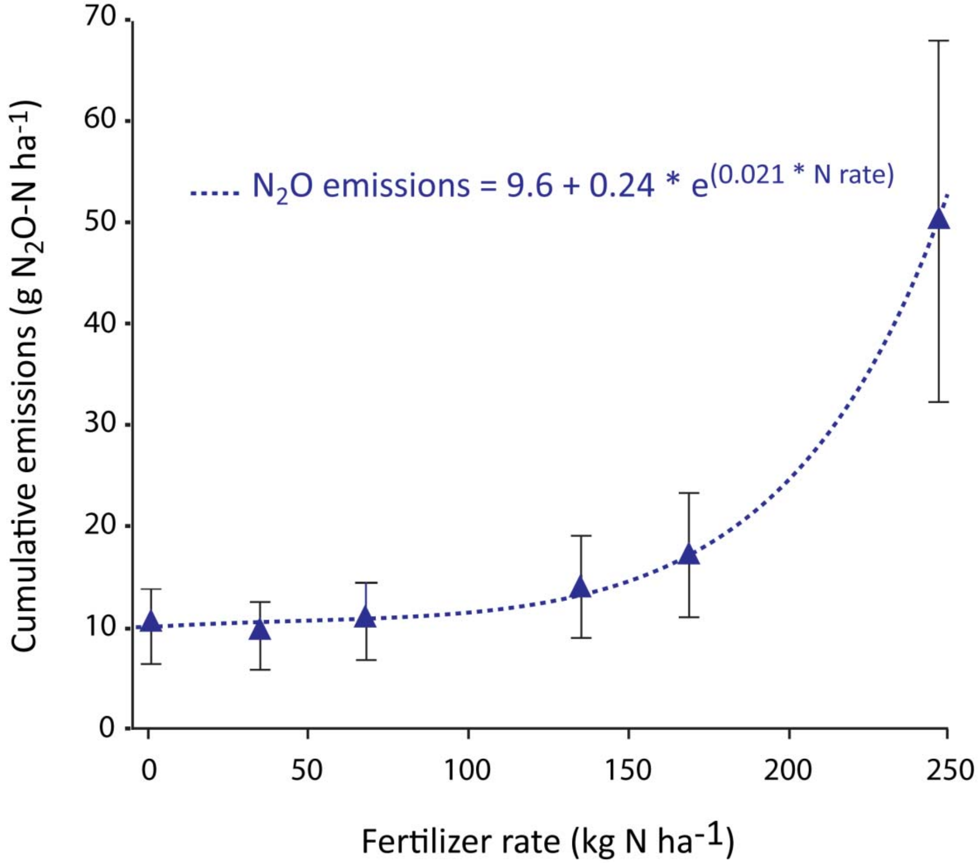
N_2O fluxes across different N rates (KBS 2010 wheat)



- Emissions factors vary with N-rate – especially above crop optimum

Millar et al., submitted

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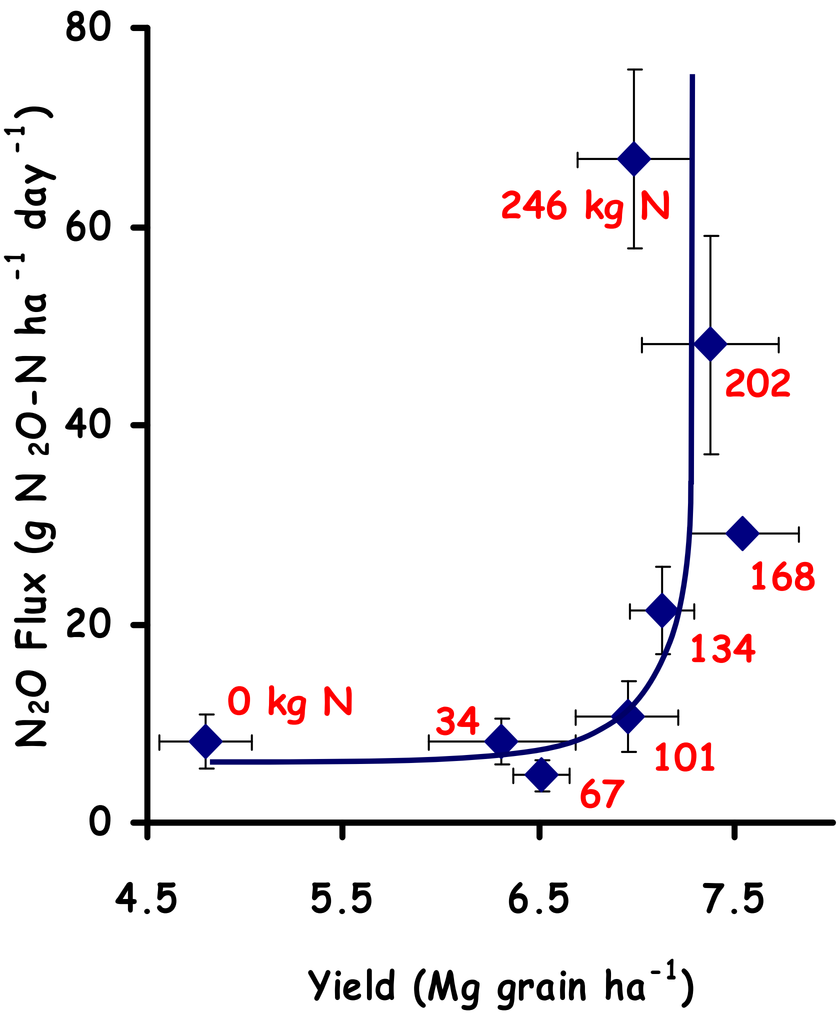
N_2O flux × crop yield



- N_2O fluxes accelerate at N-fertilizer rates greater than yield response
- Implication – N_2O savings can be substantial where fertilizer rate exceeds crop needs

Millar et al. 2012; McSwiney & Robertson, *Global Change Biology*, 2005.

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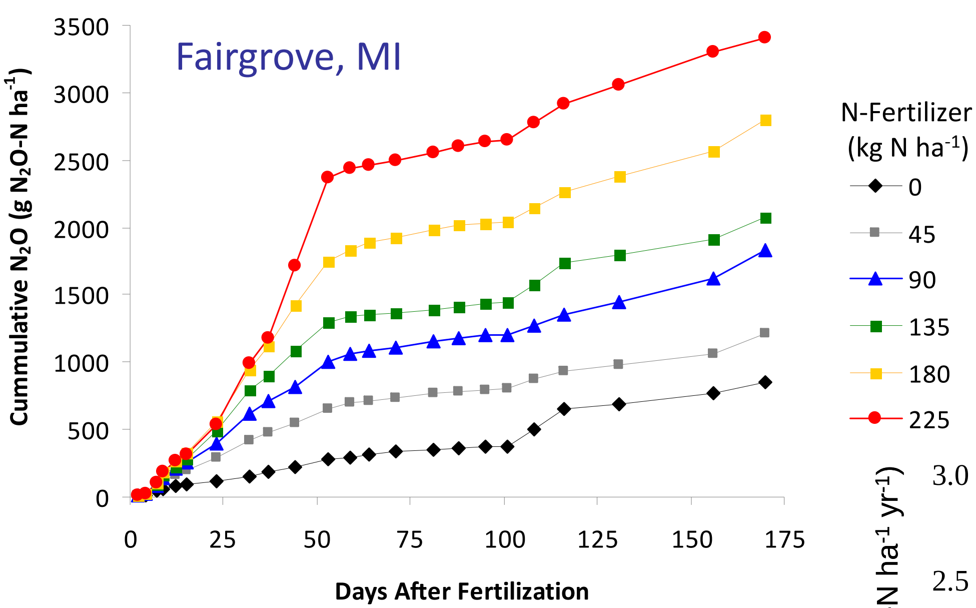
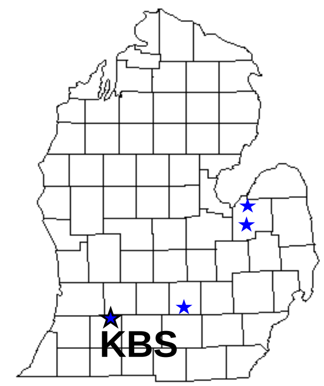
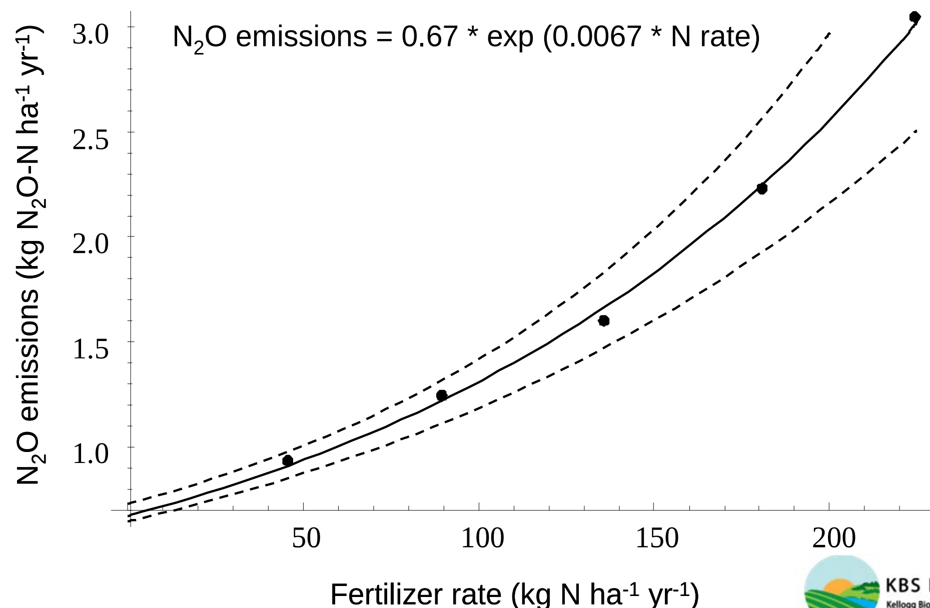
Cross-state test of non-linear N_2O response to N-fertilizer

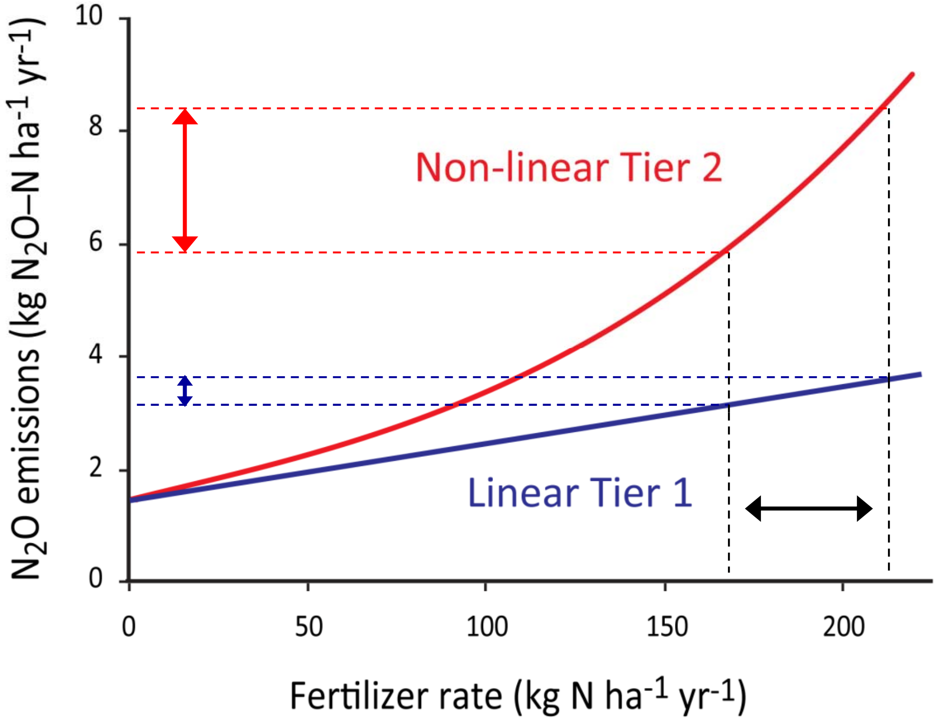






Hoben et al., 2011, Global Change Biology

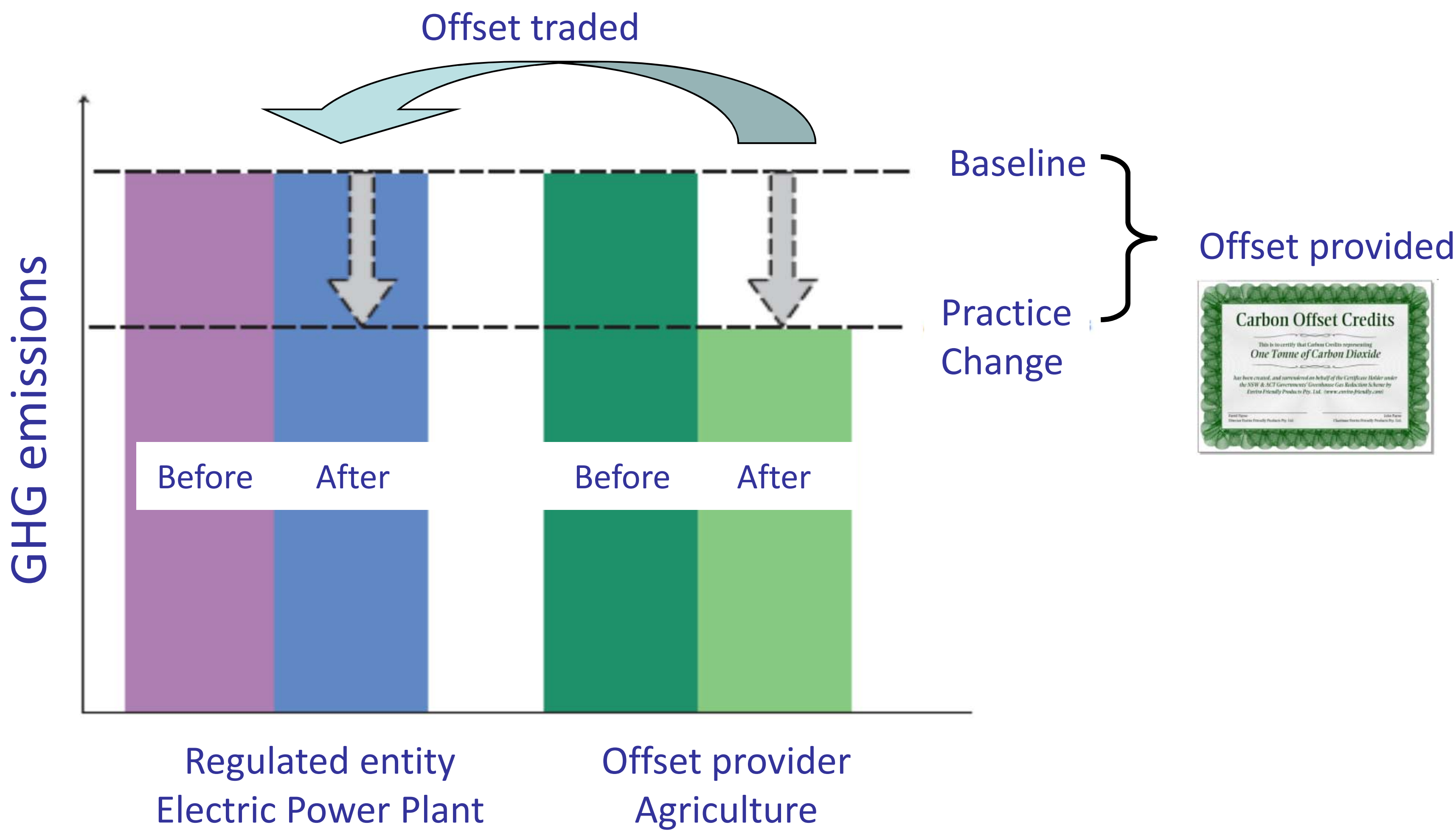
Implications for N_2O reductions for a given N rate reduction



N rate reduction (50 kg N)

For a given N rate reduction, very different N_2O outcomes

Trading and Offsets



Emerging Offset Opportunities

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Benefits

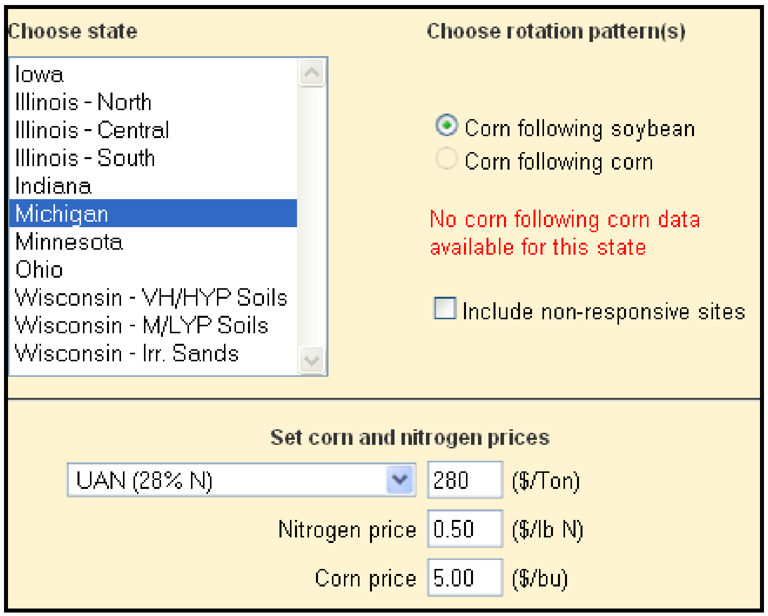
- Reduce agricultural GHGs
- Reduce reactive N release to the environment
- Incentivize conservation using current technology
- Incentivize new technology

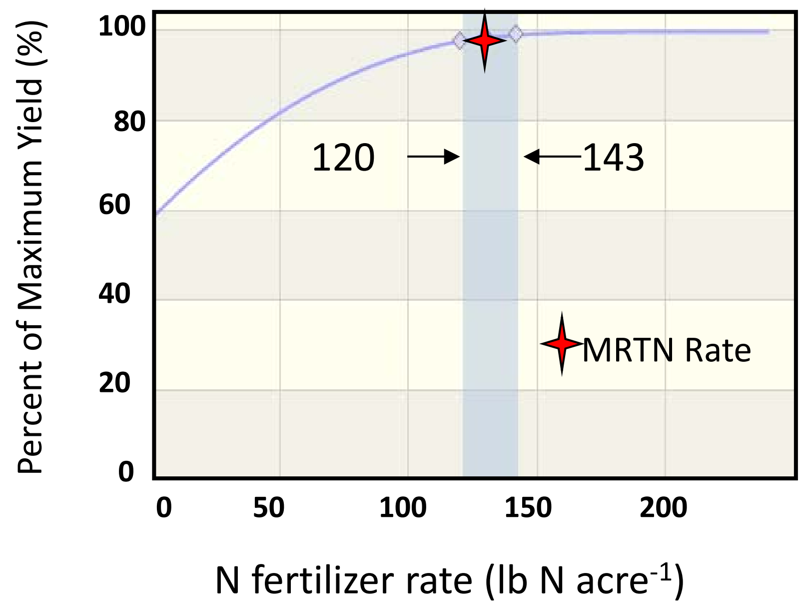
Market Issues

- Baseline establishment
- Permanence
- Additionality
- Leakage

How to reduce N-fertilizer rates without affecting yields

Calculators are available for better economic estimates





Mean Return to Nitrogen (MRTN) Calculator

http://extension.agron.iastate.edu/soilfertility/nrate.aspx

Conclusions

1. Reactive nitrogen escaping to the environment is a major and recalcitrant problem challenging the sustainability of row-crop agriculture

2. Nitrous oxide is the most important source of greenhouse gas impact in fertilized crops
   - Fluxes can be reduced with closer attention to crop needs and adoption of technology that maximizes crop uptake
   - Carbon market payments may be sufficient to incentivize conservation efforts

3. Reducing N_2O loss through better fertilizer management will provide co-benefits related to the loss of other forms of nitrogen – nitrate, ammonia, and nitric oxides, in particular

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