Nitrogen
and its role in agricultural resilience
to climate change

Robert Anex
University of Wisconsin, Madison
Resilient Agriculture 2014

This research is part of a regional collaborative project supported by the USDA-NIFA, Award No. 2011-68002-30190: Cropping Systems Coordinated Agricultural Project: Climate Change, Mitigation, and Adaptation in Corn-based Cropping Systems
Ammonia synthesis has changed the world

Nitrogen fertilizer responsible for feeding 48% of the world’s population in 2008

Erisman et al. 2008
Ammonia synthesis has changed farming

41% of U.S. corn yield attributable to nitrogen fertilizer

80% of nitrogen fixed by the Haber-Bosch process is used in fertilizer

Stewart et al. 2005  Erisman et al. 2008
Steam reforming over nickel oxide catalyst

Ammonia Synthesis by Haber-Bosch

8 lbs of Methane (CH₄)

10 lbs of Ammonia (NH₃)

16 lbs of CO₂
Making the N fertilizer used on U.S. corn in 2011 emitted GHGs equal to...

GHGs emissions from 1.7 million average American cars per year
Upstream effects of N-production

• 45% of life cycle energy use in corn production is in N fertilizer production
• 40% of life cycle GHG emissions are associated with N fertilizer production

The only way to reduce upstream effects is to reduce N use
Ammonia synthesis has changed farming

41% of U.S. corn yield attributable to nitrogen fertilizer

80% of nitrogen fixed by Haber-Bosch process is used in fertilizer

Of the 100 Tg N applied worldwide in 2005, only 17 Tg N was consumed by humans in crop, dairy and meat product.

Up to 70% of nitrogen applied to corn is harvested in grain

Stewart *et al.* 2005    Erisman *et al.* 2008
Nitrogen Cascade of Effects

Reactive Nitrogen Fertilizer

Terrestrial Ecosystem
- Soil acidification
- Biodiversity loss

Aquatic Ecosystems
- Surface & groundwater quality
- Eutrophication
- Biodiversity loss

Atmosphere
- Particulate matter & visibility
- Tropospheric ozone increase
- Stratospheric ozone loss
- Greenhouse effects
N Fertilization is (BIG) Global Change

Ammonium ion wet deposition, 2012

Atmospheric nitrogen deposition has increased from an average rate of $\sim 0.5 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ before Haber-Bosch to over $5 \text{ kg N ha}^{-1} \text{ yr}^{-1}$

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

SUSTAINABLE CORN.ORG
United States Department of Agriculture
National Institute of Food and Agriculture
Public domain image
How is nitrogen lost from the field?

- leaching
- denitrification
- ammonia volatilization
Changing Climate in Midwest

• Increase in atmospheric CO$_2$
• Increased atmospheric & soil temperatures

• Precipitation:
  – More in spring
  – More intense storms
Increasing rainfall when risk of nitrate loss is greatest.
Resilience through Nitrogen Management

• Side-dress
  – planned side-dress
  – reactive side-dress/top-dress
Resilience through Nitrogen Management

- Side-dress
  - planned side-dress
  - reactive side-dress/top-dress

- Nitrification inhibitors, urease inhibitors, coated urea
Other Management Practices

• Side-dress
  – planned side-dress
  – reactive side-dress/top-dress

• Nitrification inhibitors, urease inhibitors, coated urea

• Cover crops
Other Management Practices

• Side-dress
  – planned side-dress
  – reactive side-dress/top-dress

• Nitrification inhibitors, urease inhibitors, coated urea

• Cover crops

• Extended rotation
Other Management Practices

• Side-dress
  – planned side-dress
  – reactive side-dress/top-dress
• Nitrification inhibitors, urease inhibitors, coated urea
• Cover crops
• Extended rotation
• Drainage water management
Goal: Resilience & Nutrient Reduction

<table>
<thead>
<tr>
<th>Practice</th>
<th>Comments</th>
<th>% Nitrate-N Reduction*</th>
<th>% Corn Yield Change**</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Timing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moving from fall to spring pre-plant application</td>
<td>6 (25)</td>
<td>4 (16)</td>
</tr>
<tr>
<td></td>
<td>Spring pre-plant/sidedress 40-60 split Compared to fall-applied</td>
<td>5 (28)</td>
<td>10 (7)</td>
</tr>
<tr>
<td></td>
<td>Sidedress – Compared to pre-plant application</td>
<td>7 (37)</td>
<td>0 (3)</td>
</tr>
<tr>
<td></td>
<td><strong>Sidedress – Soil test based compared to pre-plant</strong></td>
<td>4 (20)</td>
<td>13 (22)**</td>
</tr>
<tr>
<td><strong>Source</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Liquid swine manure compared to spring-applied fertilizer</td>
<td>4 (11)</td>
<td>0 (13)</td>
</tr>
<tr>
<td></td>
<td>Poultry manure compared to spring-applied fertilizer</td>
<td>-3 (20)</td>
<td>-2 (14)</td>
</tr>
<tr>
<td><strong>Nitrogen Application Rate</strong></td>
<td>Nitrogen rate at the MRTN (0.10 N:corn price ratio) compared to current estimated application rate. (ISU Corn Nitrogen Rate Calculator – <a href="http://extension.agron.iastate.edu/soilfertility/nrate.aspx">http://extension.agron.iastate.edu/soilfertility/nrate.aspx</a> can be used to estimate MRTN but this would change Nitrate-N concentration reduction)</td>
<td>10</td>
<td>-1</td>
</tr>
<tr>
<td><strong>Nitrification Inhibitor</strong></td>
<td>Nitrapyrin in fall – Compared to fall-applied without Nitrapyrin</td>
<td>9 (19)</td>
<td>6 (22)</td>
</tr>
<tr>
<td><strong>Cover Crops</strong></td>
<td>Rye</td>
<td>31 (29)</td>
<td>-6 (7)</td>
</tr>
<tr>
<td></td>
<td>Oat</td>
<td>28 (2)</td>
<td>-5 (1)</td>
</tr>
<tr>
<td><strong>Living Mulches</strong></td>
<td>E.g. Kura clover – Nitrate-N reduction from one site</td>
<td>41 (16)</td>
<td>-9 (32)</td>
</tr>
<tr>
<td><strong>Extended Rotations</strong></td>
<td>At least 2 years of alfalfa in a 4 or 5 year rotation</td>
<td>42 (12)</td>
<td>7 (7)</td>
</tr>
<tr>
<td><strong>Drainage Water Mgmt.</strong></td>
<td>No impact on concentration</td>
<td>33 (32)</td>
<td></td>
</tr>
</tbody>
</table>

Lawrence (2013). Reducing Nutrient Loss. SP 0435
Nitrogen Resilience to Climate Change means:

- Maintaining flexibility in N fertilization so rate can be adjusted to match year (side-dress, top-dress, inhibitors in some places).
- Minimizing N release from field (cover crop, extended rotations, buffers and drainage water management).
References


