Managing nitrogen for climate change mitigation and adaptation in agriculture

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German chemist Fritz Haber developed a chemical process in which nitrogen and hydrogen gas are combined to form gaseous ammonia.

Ammonia can be used directly as fertilizer, but most of it is further processed to urea and ammonium nitrate (NH₄NO₃).

Coupled with irrigation, N fertilizer revolutionized agriculture by increasing crop yield.
Global Fertilizer Nitrogen Consumption

Year | N consumption (Million t) | Ave. yearly increase rate: 5.4% | Increased by 6.4 times in 39 years
--- | --- | --- | ---
1950 | 0 | 1960 | 40
1970 | 60
1980 | 80
1990 | 100
2000 | 120
2010 | 140

Source: (FAO, 2002)
Nitrogen fertilizer is a major driver of food production in India

Pathak (2011)
Environmental Challenge...

Global pools of N in pre- and post-industrial era

N₂
Unreactive Pool
4 x 10⁹ Tg

Reactive Pool of N
(N₂ Fixation Tg/year)

Preindustrial

Biotic
90-130

Industrial

Human activities
130-150
(60%)

Accumulation of reactive N in

- Atmosphere
- Soils
- Groundwater
- Land vegetation
- Oceans
- Marine sediments
Impact of reactive N (Nr) in global heat balance

**Warming effects of Nr:**
- Emission of $N_2O$
- Production of $O_3$
- Reduction in the biospheric CO$_2$ sink by tropospheric $O_3$.

**Cooling effects of Nr:**
- Increasing biospheric CO$_2$ sink by atmospheric Nr deposition
- C sequestration due to N fertilization
- Light scattering effects of Nr containing aerosol
- Effect of $O_3$ in reducing the atmospheric lifetime of CH$_4$. 
Key processes involved

Atmospheric processes eg. O₃ chemistry, aerosols, CH₄-lifetime

Plant processes and C sequestration

Butterbuck et al. (2011)
Nitrogen in soil-crop-animal-atmosphere continuum

N inputs:
- N fertilizer
- BNF
- N deposition

N outputs:
- harvested crop
- milk, meat, egg
- Atmosphere: NH₃, N₂O, NOₓ, N₂

Crop production:
- Crop type
- Cropped area
- Management

Animal production:
- Animal species
- Animal number
- Management

Groundwater & surface waters:
- NH₄⁺, NO₃⁻, DON, Npart

Oenema et al. (2009)
Greenhouse gas emission from Indian agriculture

<table>
<thead>
<tr>
<th>Source</th>
<th>CH$_4$ (Mt)</th>
<th>N$_2$O (Mt)</th>
<th>CO$_2$ eq. (Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice cultivation</td>
<td>3.33</td>
<td>-</td>
<td>83.25</td>
</tr>
<tr>
<td>Agricultural soil</td>
<td>-</td>
<td>0.14</td>
<td>41.72</td>
</tr>
<tr>
<td>Crop residue burning</td>
<td>0.23</td>
<td>0.006</td>
<td>7.54</td>
</tr>
<tr>
<td>Total</td>
<td>3.56</td>
<td>0.146</td>
<td>132.51</td>
</tr>
</tbody>
</table>

Pathak et al. (2010)
Emission of N$_2$O-N from different sources in agricultural soils (Total emission 0.14 Mt)

- Soil mineralization: 7%
- Crop residue: 10%
- Green manure: 6%
- Animal manure: 7%
- Fertilizer: 70%

Pathak et al. (2010)
Trends in GHG emission from Indian agricultural soil

GWP = Methane \times 25 + \text{Nitrous oxide} \times 298
Trend in GHG emission intensity in Indian agriculture

GHG intensity = GWP / Ag-GDP

GWP (kg/ha)
GWP (kg/t)
GWP (kg/10000 Rs)

Global warming potential


GHG intensity = GWP / Ag-GDP
Estimate of annual inputs and outputs of N in the rice-wheat systems in the Indo-Gangetic Plain

N annual budget (2000-01) in Indian and World (in parentheses) agriculture (in million tons)

Pathak et al.
Net effect of $N_r$ on European GHG balance

Butterback et al. (2011)
Nitrogen management for climate change adaptation

• N fertilizer enhances crop yield and acts as an insurance of climatic risks.
• Compensating quality of crop with additional N application under elevated CO$_2$.
Approaches for enhancing the N use efficiency

Strategic options
- Improving supply and demand synchrony
- Improvement in soil health
- Improvements in varieties

Management options
- Site-specific nutrient management
- Integrated nutrient management
- Improving application methods
- Improving the fertilizer formulations
- Integrated crop management

Tools and technologies
- Leaf colour chart
- Decision support system
- Remote-sensing
- Geographic information system
- Precision farming

Policy options
- Communication and dissemination of the technologies
- Improving management skills of farmers
- Private/public partnerships
- Infra-structure, subsidy, crop insurance
How to Improve N Use Efficiency and Minimize Leakage of N into Environment?

Synchronize

Plant N Demand

Soil N Supply

Mineral Fertilizer

Organic Residue

GM
Leaf colour chart

Urea tablet/
Nitrification inhibitor

Smart Nitrogen Management for $\text{N}_2\text{O}$ Mitigation

Adaptation of late planted rice with demand-driven N management

Demand-driven N use can help in adaptation

But it requires 30 kg ha\(^{-1}\) extra N fertilizer
## Nitrous oxide mitigation with nitrification inhibitor

<table>
<thead>
<tr>
<th>Nitrification inhibitor</th>
<th>Mitigation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dicyandiamide (DCD)</td>
<td>13-42</td>
</tr>
<tr>
<td>Neem cake</td>
<td>10-21</td>
</tr>
<tr>
<td>Neem oil</td>
<td>15-21</td>
</tr>
<tr>
<td>Nimin</td>
<td>25-30</td>
</tr>
<tr>
<td>Coated Ca-carbide</td>
<td>12-29</td>
</tr>
<tr>
<td>Thiosulphate</td>
<td>15-20</td>
</tr>
</tbody>
</table>

Source: Pathak et al. (2011)
# Fertilizer N Management tools/ tactics - a comparison

<table>
<thead>
<tr>
<th>Tool</th>
<th>Benefit / cost</th>
<th>Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart N Timing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blanket splits</td>
<td>High</td>
<td>Tendency to overuse</td>
</tr>
<tr>
<td>LCC-aided real time mgt</td>
<td>High</td>
<td>None</td>
</tr>
<tr>
<td>Soil-test</td>
<td>Medium</td>
<td>Facilities</td>
</tr>
<tr>
<td>Remote-sensing (NDVI )</td>
<td>Low</td>
<td>Not perfected &amp; high cost</td>
</tr>
<tr>
<td>GIS / GPS</td>
<td>Low</td>
<td>Not perfected</td>
</tr>
<tr>
<td>Smart N Supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placement</td>
<td>High</td>
<td>Machines</td>
</tr>
<tr>
<td>CRF</td>
<td>Low</td>
<td>High cost and not reliable</td>
</tr>
<tr>
<td>Inhibitors</td>
<td>Low</td>
<td>High cost and not reliable</td>
</tr>
<tr>
<td>Foliar</td>
<td>Low</td>
<td>Equipment, risk</td>
</tr>
</tbody>
</table>
Implementation of Mitigation Options

- Cost effectiveness
- Enhanced production
- Resource availability of the farmers
- National and international policy environment
Mitigation of GHG by improved N management

- Emission of GHG can be mitigated with improved N management.
- But, in most cases, cost of mitigation is more than the cost of N.
- Incentives and policy support, therefore, are required to popularize these technologies.

Pathak (2010)
Climate Change and Agriculture

Greenhouse gas emission
- Carbon dioxide
- Methane
- Nitrous oxide

Climate Change

Impact on agriculture
- Adaptation
- Mitigation
- Vulnerability

Nitrogen management plays a crucial role
Conclusions

- N influences climate change.

- Efficient N management can help in adaptation and mitigation while reducing other environmental threats such as eutrophication, acidification, air quality, and human health.

- Complex and important effects of Nr on climate change processes need more attention.
Publications from ING Workshops

2005
NAAS Policy Paper

2007
Edited Book

2008
IGBP-WCRP-SCOPE Report 3, INSA

2008
Journal Spl. Issue on N in India

For copies, email: raghuram98@hotmail.com
Most recent publications from ING

REACTIVE NITROGEN: GOOD, BAD AND UGLY

V. BALASUBRAMANIAN
International Agricultural Consultant and Trainer

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