Importance of Gaseous N Losses

- Can be a significant loss of N from the plant soil system (>50%)
- Environmental impact of emitted N gases (N$_2$O, NO, NO$_2$)
- N$_2$O is one of the most important of the non-CO$_2$ greenhouse gases
  (i) In the troposphere, potent greenhouse gas (GWP = 298 CO$_2$)
  (ii) the single most important ozone-depleting substance
- Fertilized agricultural soils are the major anthropogenic source of N$_2$O (70% from agricultural soils)
Gaseous N losses in Soils

\[ \text{NH}_4^+ \rightarrow \text{NH}_3 \rightarrow \text{N}_2\text{O} \rightarrow \text{NO} \rightarrow \text{N}_2\text{O} \rightarrow \text{N}_2 \]

- **NITRIFICATION**
  - Aerobiosis
  - Fert or Organoc N

- **DENITRIFICATION**
  - Anaerobiosis
  - CHO
  - LEACHING

- NITROGEN USE EFFICIENCY

Increasing Nitrogen Use Efficiency

• N losses can be reduced by:
  - Matching fertilizer N supply with plant N demand (Timing).
  - Reducing conventional N rates by taking into account residual soil N, mineralization of SOM and residues (e.g. green manures).
  - Increased use of Enhanced Efficiency Fertilisers (EEFs) to slow the production of nitrate.
National Agricultural Nitrous Oxide Research Program

- Sugarcane
- Dairy
- Cotton
- Horticultural
- Grain

Research activities

1. Automated gas monitoring network
2. Manual chamber monitoring network
3. Define nitrogen response curves
4. Determine $^{15}$N mass balance
5. Estimate $N_2O$ and $N_2 = \text{total } N$ gas loss
6. Crop-soil modelling
   - 23 projects in total (5 cropping systems)
   - Total investment ($50M$) 2012-2016

<table>
<thead>
<tr>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>No data/uncertain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugarcane</td>
<td>Dairy</td>
<td>Cotton</td>
<td>Horticultural</td>
</tr>
<tr>
<td>Grain</td>
<td></td>
<td></td>
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</tbody>
</table>
STUDY SITE WA (Buntine)

- 296 km north-east of Perth
- Rainfall: 285 mm/yr
- Basic Regolithic Yellow-Orthic Tenosol (deep yellow sand)
- Study site established in 2003 by Liebe Group

(Louise Barton, UWA)

Liebe Long-Term Soil Biology Trial: Soil Carbon Stocks

- Does increasing soil organic C in sandy soils increase soil nitrous oxide emissions from grain production?

Model Assumptions:
60% water-use efficiency, 80% stubble retention, Current rotation maintained

(Louise Barton, UWA)
INCREASING SOC INCREASED N₂O EMISSIONS

- Emission factors are still low (0.09-0.12%).
  International default value: 1.0%; Australian value: 0.3%

![Cumulative N₂O flux graph](image)

(Louise Barton, UWA)

Annual N₂O Losses in Australia

![Annual N₂O Losses graph](image)
N₂O emissions as indicator for total denitrification losses

Gympie N₂: N₂O ratios

Losses of applied N from northern grains region
Summer sorghum
**N₂O emissions typically 0.5-1.5% of applied N**

Losses increase exponentially with N rate, so getting N rate right is NB

\[
\begin{align*}
\text{a)} & \quad y = 0.1088x^{2.3016} \\
\text{R}^2 &= 0.9996 \\
2013/14 \text{ Kingaroy}
\end{align*}
\]

\[
\begin{align*}
\text{b)} & \quad y = 0.2135x^{2.2011} \\
\text{R}^2 &= 0.999 \\
2013/14 \text{ Kingsthorpe}
\end{align*}
\]

This is dwarfed by total N losses, especially on Vertosols. Typically 20-40% of applied N!

Ferrosols have much higher plant recovery and lower total losses
Enhanced Efficiency Fertilizers can reduce $N_2O$ emissions
Most work with Entec (Urea with nitrification inhibitor DMPP)

![Benefits of EEF](chart.png)

Economics of DMPP use don’t stack up on Vertosols – the main cropping soil

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Urea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y0</td>
<td>2260 (+223)</td>
<td>1100 (+180)</td>
<td>2710 (+222)</td>
<td>6485 (+140)</td>
<td>6850 (+195)</td>
</tr>
<tr>
<td>Ymax</td>
<td>4790 (+350)*</td>
<td>6820 (+500)*</td>
<td>8000 (+500)*</td>
<td>7543</td>
<td>7010</td>
</tr>
<tr>
<td>N rate for Y0</td>
<td>120</td>
<td>125</td>
<td>100</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Urea+DMPP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y0</td>
<td>2260 (+223)</td>
<td>1100 (+180)</td>
<td>2710 (+222)</td>
<td>6485 (+140)</td>
<td>6850 (+195)</td>
</tr>
<tr>
<td>Ymax</td>
<td>4870 (+660)*</td>
<td>6910</td>
<td>7875 (+2420)*</td>
<td>7564</td>
<td>7120</td>
</tr>
<tr>
<td>N rate for Y0</td>
<td>110</td>
<td>100</td>
<td>95</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Net benefit of using urea+DMPP ($Urea-N minus $urea+DMPP-N) *</td>
<td>$-18.70/ha</td>
<td>$+0.50/ha</td>
<td>$-20.15</td>
<td>$34.45</td>
<td>NA</td>
</tr>
</tbody>
</table>

*Yields still increasing at highest N rates. Highest yield recorded for each N product used as $Y_{max}$.

*Urea-N valued at $1.10/kg, with a 25% price premium on the urea+DMPP product.
Nitrogen Use **Inefficiency** / $^{15}$N Losses

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>Medium</th>
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<th>No data/uncertain</th>
</tr>
</thead>
</table>

**Vertosols**: 40% Dairy, 20-50% 
**NSW sorghum**: 12-45% 
**Wimmera**: 20-40% 
**HRZ Grains**: 20-40%

---

**Total N Applied National Basis – (IFIA, 2013)**

<table>
<thead>
<tr>
<th>Commodity</th>
<th>N applied (kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>367</td>
</tr>
<tr>
<td>Pasture etc</td>
<td>161</td>
</tr>
<tr>
<td>Sorghum etc</td>
<td>154</td>
</tr>
<tr>
<td>Cotton</td>
<td>97</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>86</td>
</tr>
<tr>
<td>Sugar</td>
<td>61</td>
</tr>
<tr>
<td>Fruit</td>
<td>23</td>
</tr>
<tr>
<td>Vegetables</td>
<td>17</td>
</tr>
<tr>
<td>Roots/tubers</td>
<td>8</td>
</tr>
<tr>
<td>Rice</td>
<td>6</td>
</tr>
<tr>
<td>Maize</td>
<td>2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>982</td>
</tr>
</tbody>
</table>

**FERT N LOSS = $400 M / annum**
Summary

The NANORP (2012-2015) found that on average 40% of applied nitrogen is permanently lost from agricultural soils of Australia, double previous estimates. Growers continue to apply excess N due to timing restrictions, poor N budgeting and lack of accurate information on N mineralisation and N losses in their systems.

This is double previous estimates and confirms that increasing NUE is vital for:

• Improved productivity and profitability
• Improved sustainability and environmental outcomes
• Continued social license to farm

Future direction

• Recent advances in fertilizer technology (EEFs) have considerable potential to deliver a step change in NUE in many cropping regions – (high rainfall zones).
• Improved knowledge on SOM mineralisation, the use of legumes, along with improved irrigation management are the key strategies for major increases in NUE, productivity and profitability.
• Reducing N application rates through legume rotations and/or nitrification inhibitors will reduce emissions and maintain productivity.
• Better understanding of EEF performance on different soil types and on total denitrification losses (i.e. the ratio of N₂:N₂O) needed.
Acknowledgements

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  Department of Agriculture, Incitec Pivot Ltd., GRDC

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• Colleagues from NANORP (Peter Grace, Mike Bell, Louise Barton, David Rowlings)