Nitrous oxide mitigation in UK agriculture

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MARCO Workshop on Technology Development for Mitigating Greenhouse Gas Emissions from Agriculture
16-17th November 2011
Global $\text{N}_2\text{O}$ emissions

Global $\text{N}_2\text{O}$ emissions in the 1990's (Tg $\text{N}_2\text{O}$-N/y)

- 62% natural
- 38% anthropogenic

**Total emissions**

17.7 (8.5-27.7) Tg N/y

Denman et al 2007, IPCC
Growth in emissions

Direct soil NO emissions relative to 1970 emissions

USA
UK
Japan
China
India

05/12/2011
Edgar database
## Regional projections

<table>
<thead>
<tr>
<th>Region</th>
<th>Population</th>
<th>Current (N_2O) emission (Gg)</th>
<th>Current per capita emission of (N_2O) (g)</th>
<th>Projected population growth 2000-2050</th>
<th>Projected (N_2O) emission 2050 (Gg)</th>
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<tbody>
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<td>Africa</td>
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</tbody>
</table>

05/12/2011
Government targets for greenhouse gas mitigation

- 2007 emissions:
  - International aviation & international shipping: 42 Mt CO₂e
  - UK non-CO₂ GHGs: 94 Mt CO₂e
  - Other CO₂:
    - Industrial CO₂ (heat & industrial processes): 109 Mt CO₂e
    - Residential, public & commercial heat: 97 Mt CO₂e
    - Domestic transport: 135 Mt CO₂e
    - Electricity generation: 178 Mt CO₂e

- 2050 objective: 159 Mt CO₂e

76% cut (= 80% vs. 1990)

* bunker fuels basis

DEFRA 2009
Driving factors of $\text{N}_2\text{O}$ production

- Anaerobicity (moisture)
- Mineral N
- Available C
- pH

$\text{N}_2\text{O}$ production vs Factor
UK \( \text{N}_2\text{O} \) emission inventory

U. Dragosits, CEH
Annual $N_2O$ emission vs Climate

Management

Site
Variability in N$_2$O emissions between arable sites

![Box plot showing variability in N$_2$O emissions between arable sites](image-url)

Ln N$_2$O (kg N ha$^{-1}$ y$^{-1}$)
Management options

• Adopt non-intensive input regimes
• Improve soil fertility
• Use soil amendments
• Apply soil conditioners
• Fertiliser redistribution
• Nitrogen management
• Fertilisation regime
• Precision farming
• Land use change
• Regionally optimised plant and animal production
• Improved timing of mineral fertiliser N application
• Land drainage

• Loosen compacted soils / Prevent soil compaction
• Burying biochar
• Enhancing feed protein quality
• Peat and Organics providing alternative N sources
• Re-locate high N input cropping to drier, cooler areas

What are the current baseline conditions?

How do you upscale mitigation potential?

What are the affects on food production?

How do they affect profitability?
Cheap option, big emission savings

Expensive options, small emission savings

Financial savings
Management as a mitigation tool

• Nitrogen input
  – Form/rate
  – Biological inputs
  – Timing
  – Inhibitors
  – Slurries and manures

• Soil and water management
  – Tillage
  – Irrigation/drainage

• Crop rotation/agronomy
  – System changes
NITROGEN INPUT
Reducing N applications

DEFRA project ‘ Min-No ‘
Pappa & Rees, SAC
**Spring barley**

Cumulative values of \( \text{N}_2\text{O} \) per fertiliser treatment

Cumulative values of \( \text{N}_2\text{O} \) (g) per grain yield of production (t) per fertiliser treatment

**Economic Optimum**

DEFRA project ‘Min-No’
Pappa & Rees, SAC
Biological N fixation

- Direct emission factor for N\(_2\)O release from legumes reduced from 1.25% to 0 in 2006
- Emissions now restricted to residue inputs

Legumes and nitrous oxide emissions

Two mechanisms:

- Rhizobium sp can produce $\text{N}_2\text{O}$ directly
- Decomposition of plant residues can increase $\text{N}_2\text{O}$ emissions
• A 4 year FP7 programme – 18 partners, 18 experimental sites (~ €4M)

• Assess the wider role of legumes in farming systems
  - Agronomic & environmental criteria
  - Use of experimental and modelling approaches

• Design novel legume-based cropping systems for Europe

• Deliver productive, environmentally-friendly legume-based farming

• Use a carefully selected network of research staff and experiments

www.legumefutures.eu
Nitrification inhibitors

- Nitrification inhibitors demonstrate significant mitigation potential
- Can contribute to lower overall loss, therefore reducing fertiliser input
- Costs remain high, which limit wider current use

Controlled release fertilisers

- Reduce release of available N
- Can contribute to significant mitigation
- High costs

Ball et al, *Soil Use and Management*, 20, 287-295
Manure management and storage

• Manure management has a major impact on emissions
• Method of application can significantly reduce NH$_3$ emissions but increase N$_2$O emissions

Fertilised grasslands receiving organic manures

Organic N application

$g \text{ N}_2\text{O-N ha}^{-1} \text{ d}^{-1}$

- NPK
- cattle
- poultry
- sewage

Jones et al 2007. Agriculture Ecosystems and Environment, 12174-83
Timing

Fertiliser application

Jones et al 2007. Agriculture Ecosystems and Environment, 12174-83
SOIL AND WATER MANAGEMENT
Drainage

- Impeded drainage increases the water filled pore space and denitrification
- Regional assessments of drainage efficiency are difficult

Dobbie and Smith 2006. Soil Use and Management, 22, 22-28
Reduced tillage

Rainfall: May-August 321 mm

Cumulative N₂O flux (g N₂O-N ha⁻¹)

- No-till
- Min-till
- Normal plough
- Deep plough
- Normal plough compacted

James Hutton Institute
CROP ROTATION AND AGRONOMY
Low input systems

Inputs vs. Outputs

- N2O
- Leaching
- Livestock
- Off-take
- Seed N
- BNF
- Fertilizer N
- Manure total N
- Atm. deposition

Inputs vs. Outputs

- Denmark
- Scotland
- Sweden

Ngodzi et al., In preparation.
Improved plant varieties

Beans

- Ben
- Betty
- Fuego
- Tattoo

Peas

- Crackerjac
- Nitouche
- Prophet
- Ragtime

Cumulative N₂O-N (kg/ha)

Graphs showing the cumulative N₂O-N emissions for different plant varieties over time.
Species introduction

Pappa et al 2011. Agriculture Ecosystems and the Environment 141, 153-161
Changing behaviour

• Rational analysis of mitigation potential does not necessarily lead to change in behaviour

• Barriers
  – Economic
  – Cultural
  – Educational
Improving national inventory reporting of emissions

Agricultural Greenhouse Gas Inventory Research Programme

A 5-year research programme (2010-2015) has been funded by the UK government to generate new country-specific measured and modelled Emission Factors for methane (CH₄) and nitrous oxide (N₂O) from agriculture. This will build on previous research, combining field experimentation, modelling and scoping of data sources to fill knowledge gaps.

The main objective of the research programme is the development of an Improved Agricultural Greenhouse Gas Inventory reporting tool for the UK, that uses appropriate country- and practice-specific emission factors and that will reflect the adoption of mitigation practices by the agricultural industry, enabling forecasting and monitoring of performance against target emissions reductions set by the UK Climate Change Act 2008.

Field measurements will be conducted at a number of sites across the UK and will include:
- Nitrous oxide emissions from soils, focusing on nitrogen source (fertiliser, manure, urine) and application management (rate, timing, method) across representative soil and climatic regions.
- Methane emissions from farm livestock, from the animals (enteric fermentation) and their manures. The focus of measurements will be on sheep, beef and dairy cattle of different breeds and sizes, ages, and production systems (indoor and outdoor), across a range of diets and assessing different manure storage systems.
- Activity data, including farm practices and spatial agri-environment data, are key to improved reporting. Existing and potential new data sources and methods for their interpretation will be assessed and applied with enhanced emission factors for CH₄ and N₂O.

Modelling will be used to estimate emissions at field and farm scale, and to interpolate to the national scale taking account of local climate and soil conditions and management practices.

The structure of the Improved Inventory will allow for reporting by individual sector and regionally. Close engagement with agricultural industry bodies will be an important part of this programme.

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Conclusions

• Technologies are available that can contribute significantly to lowering emissions of N₂O
• In the UK this could result in GHG savings of between 1.6-10.2 Mt CO₂e y⁻¹ by 2022
• Much of this is achieved by increased efficiency
• We need to understand more about farmer behaviour
• We urgently need better reporting systems that reflect actual emissions and are sensitive to changes in management
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