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Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Non-CO_2 greenhouse gas sources from managed and natural soils -fluxes and mitigation

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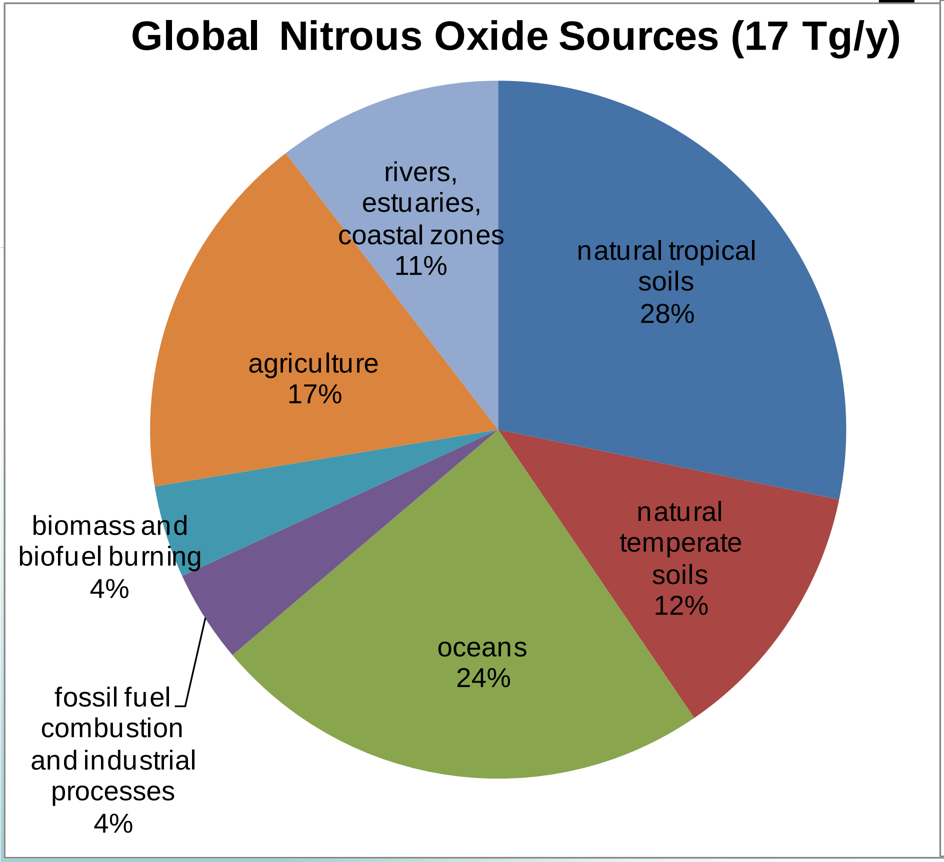
Centre for Ecology and Hydrology

CEH is the UK's Centre of Excellence for integrated research in terrestrial and freshwater ecosystems and their interaction with the atmosphere.
It is part of the Natural Environment Research Council (NERC).

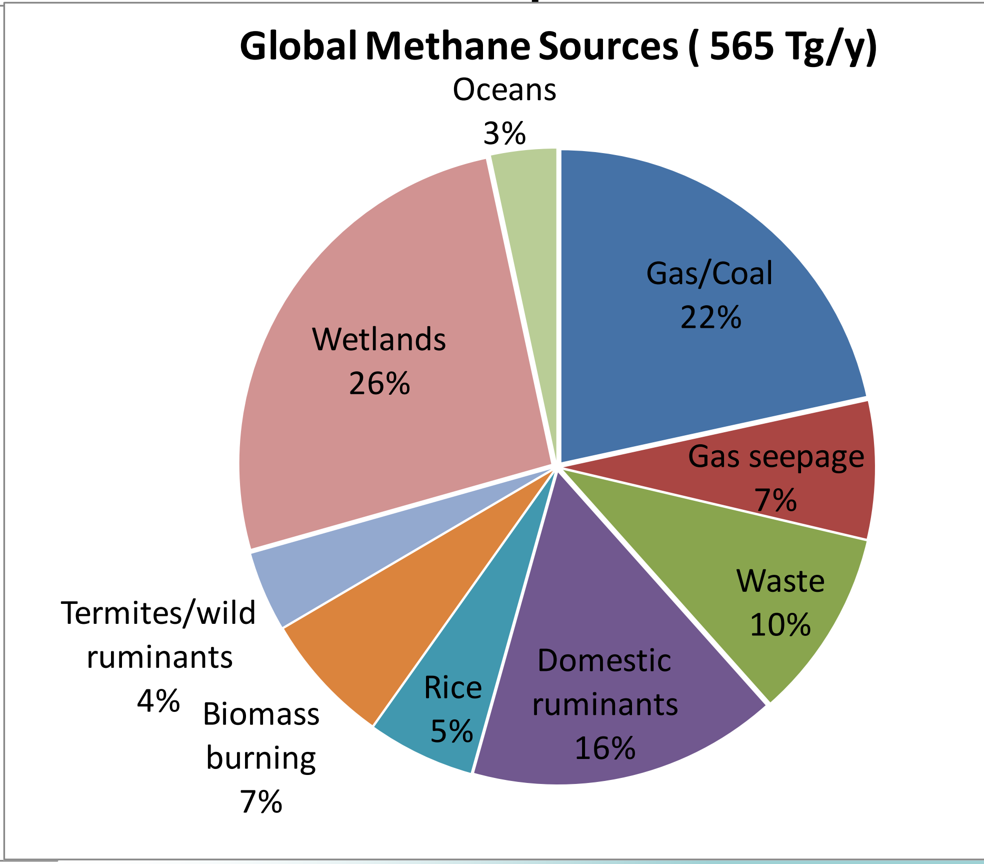
Biodiversity
Biogeochemistry
Freshwaters

Why are we interested in N_2O and CH_4 emissions from soils?

Soils are important sources and sinks of N_2O and CH_4



Global Nitrous Oxide Sources (17 Tg/y)

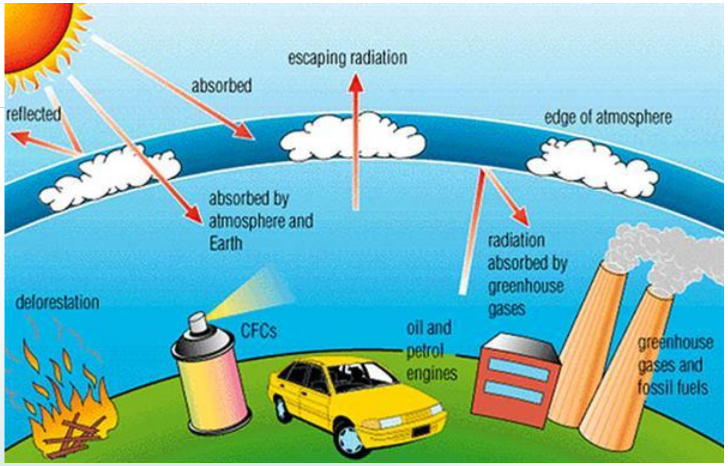


Global Methane Sources (565 Tg/y)

Soil is responsible for >60% of global N_2O emissions

Wetlands are responsible for 30% of global CH_4 emissions. Dry soils are a sink for CH_4 (30 Tg/y)

Global warming potential of N_2O and CH_4 is larger than for CO_2



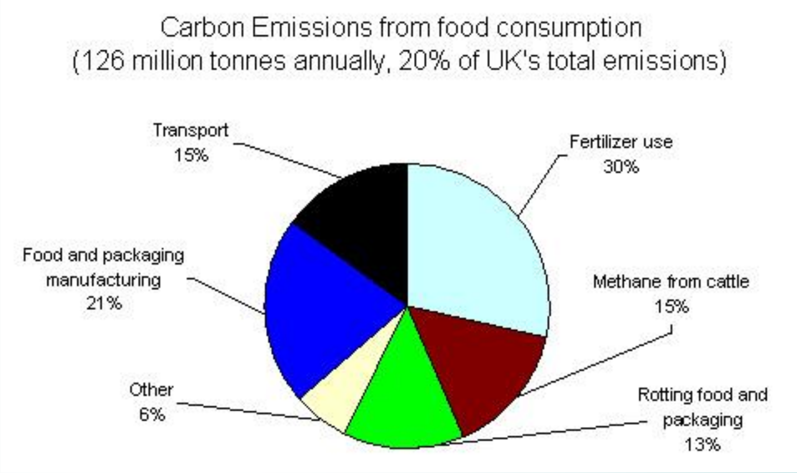
Global warming potential over a 100 year period

CO_2 = 1
CH_4 = 25
N_2O = 298

CH_4 increase is responsible for 20% and N_2O for 6% of the GHG effect

GHG reporting requirements

- International reporting requirements
  - Kyoto Protocol: The signatories must submit annual reports to the UNFCCC.
  - Reduce EU emissions by > 50% - 2050 of 1990 levels
- Carbon footprints for biofuel production, food…



Monitoring Reporting

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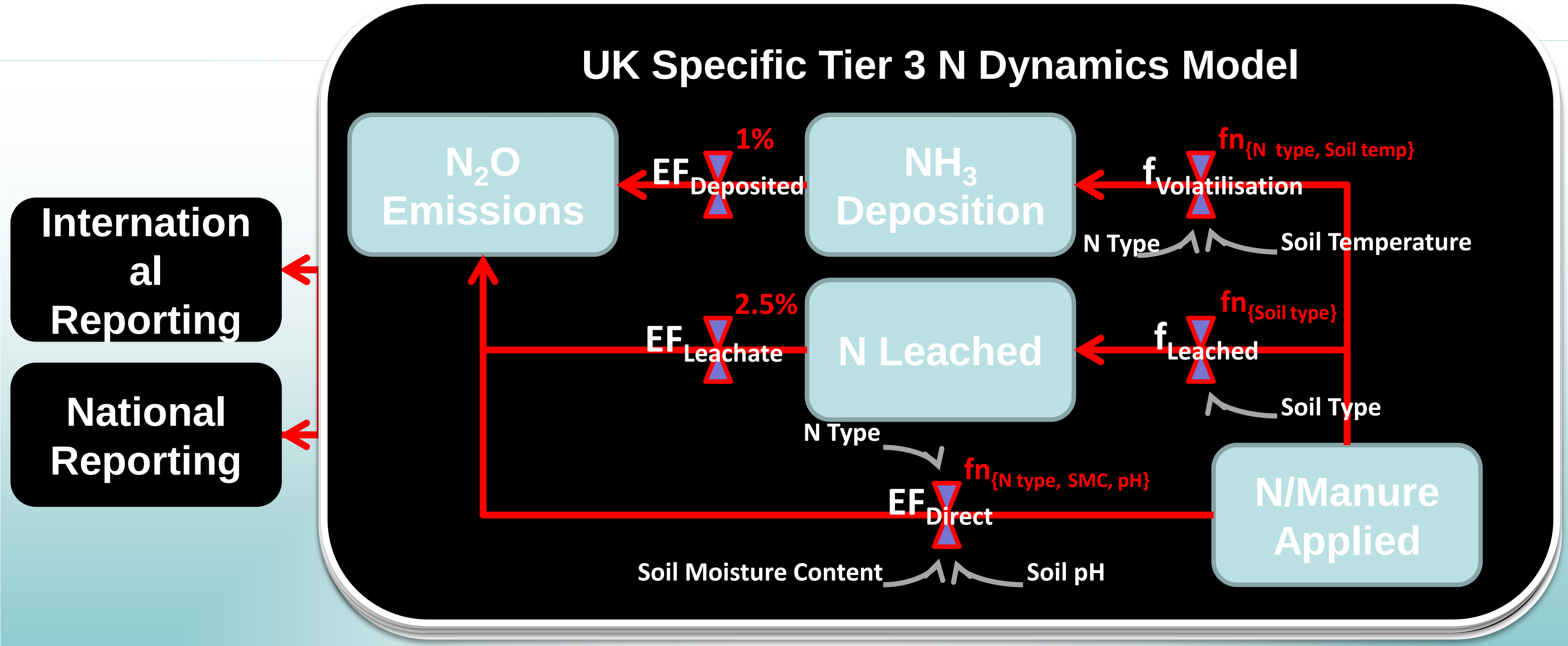
Developing the Black Box

The current inventory structure is 'bottom up'. Data from national surveys are multiplied by default IPCC emission factors based on international literature review. At present there is little in the way of external validation of the estimated emissions.



UK Specific Tier 3 N Dynamics Model

N_2O Emissions

$EF_{Deposited}$ 1%

NH_3 Deposition

$f_{Volatilisation}$ $fn_{\{N\ type,\ Soil\ temp\}}$

N Type

Soil Temperature

$EF_{Leachate}$ 2.5%

N Leached

$f_{Leached}$ $fn_{\{Soil\ type\}}$

Soil Type

N Type

EF_{Direct} $fn_{\{N\ type,\ SMC,\ pH\}}$

N/Manure Applied

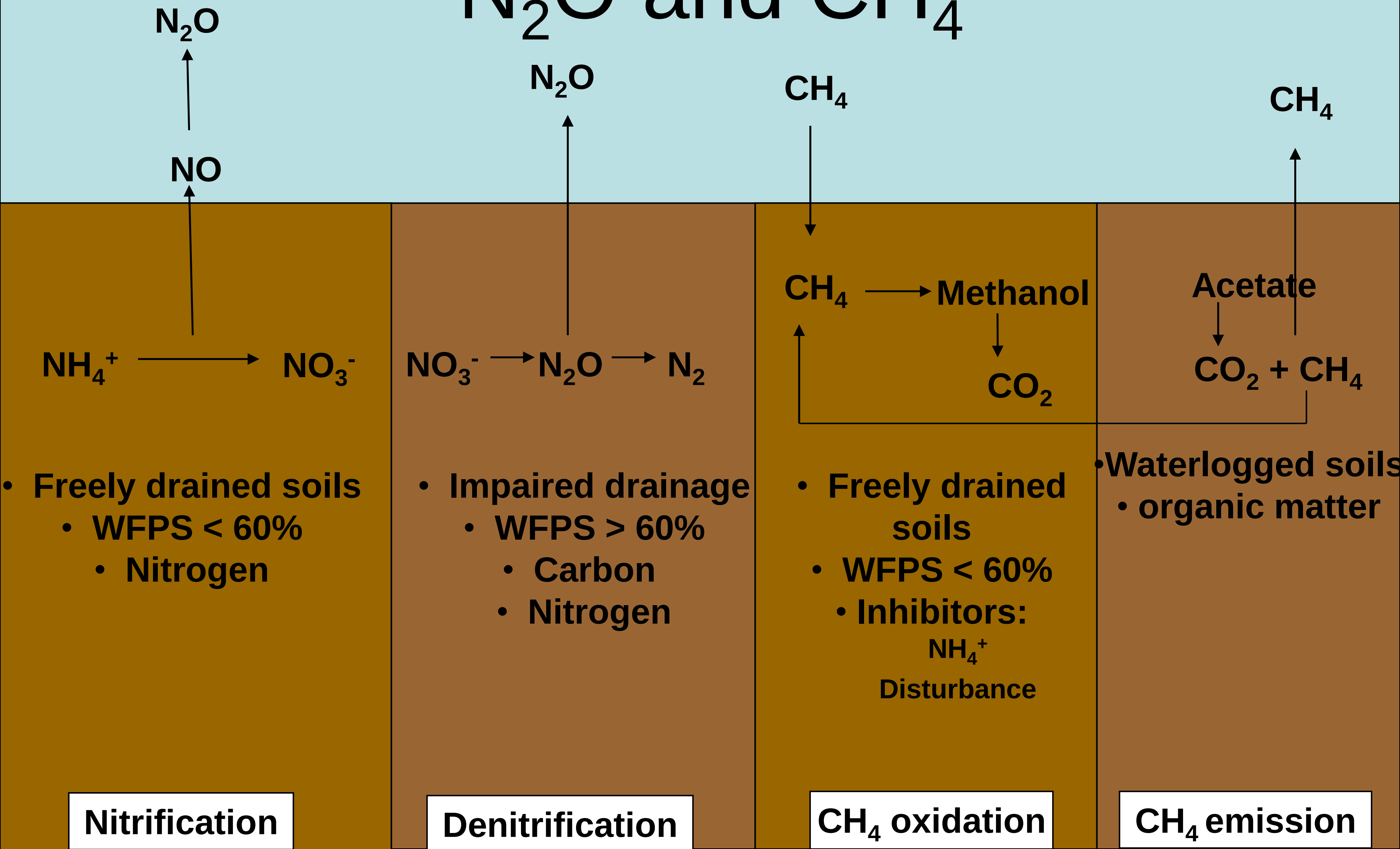
Soil Moisture Content

Soil pH

International Reporting

National Reporting

Microbes produce and consume N_2O and CH_4



N_2O

NO

NH_4^+ → NO_3^-

- Freely drained soils
  - WFPS < 60%
  - Nitrogen

Nitrification

N_2O

NO_3^- → N_2O → N_2

- Impaired drainage
  - WFPS > 60%
  - Carbon
  - Nitrogen

Denitrification

CH_4

CH_4 → Methanol

CO_2

- Freely drained soils
  - WFPS < 60%
  - Inhibitors:

NH_4^+

Disturbance

CH_4 oxidation

CH_4

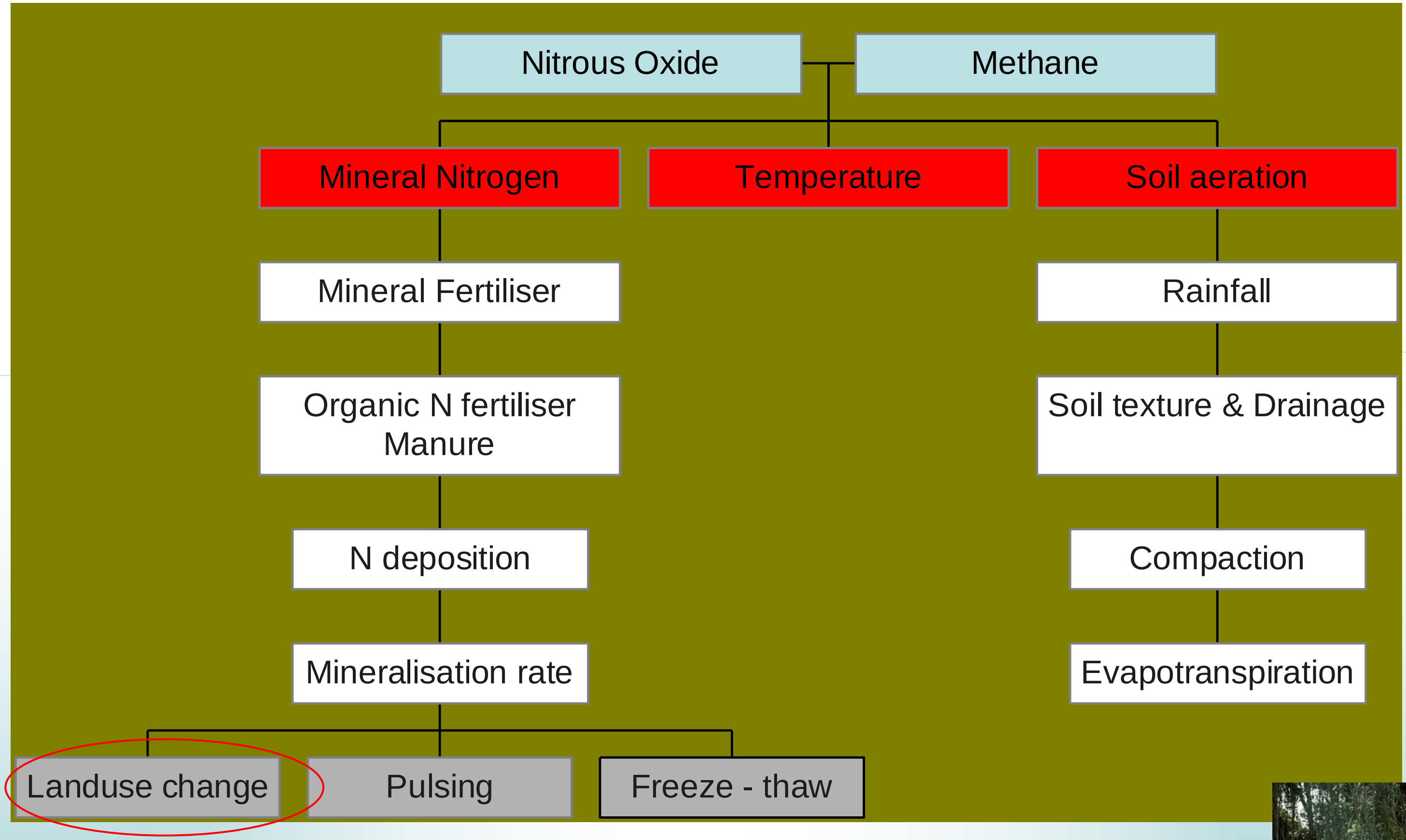
Acetate

$CO_2 + CH_4$

- Waterlogged soils
  - organic matter

CH_4 emission

The control of N_2O and CH_4



Nitrous Oxide
Methane

Mineral Nitrogen
Temperature
Soil aeration

Mineral Fertiliser
Organic N fertiliser Manure
N deposition
Mineralisation rate

Rainfall
Soil texture & Drainage
Compaction
Evapotranspiration

Landuse change
Pulsing
Freeze - thaw

Organic N input

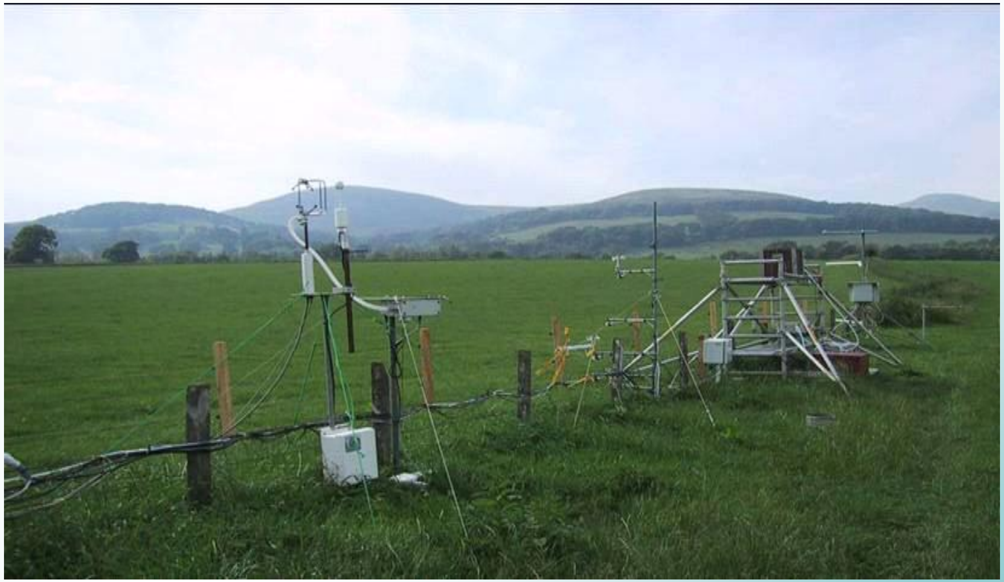
Soil is very heterogeneous

Tillage

Compaction

Most of our knowledge of N_2O and CH_4 has come from studies in temperate climates using static chambers

Trace gas flux measurements



Analytical techniques to measure N_2O and CH_4

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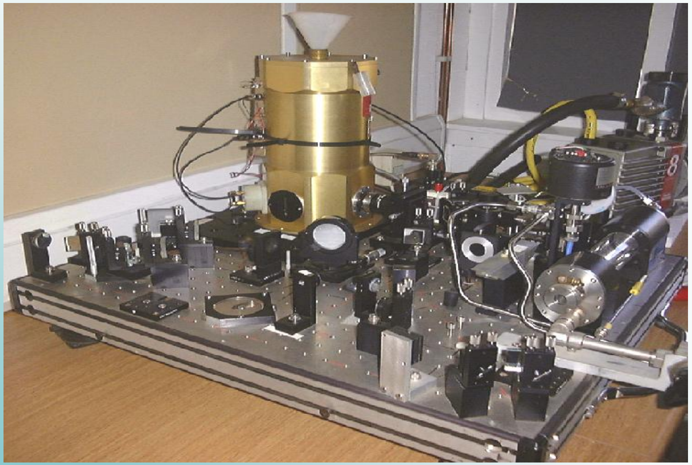
Gas chromatography

Photoacustic infrared detection

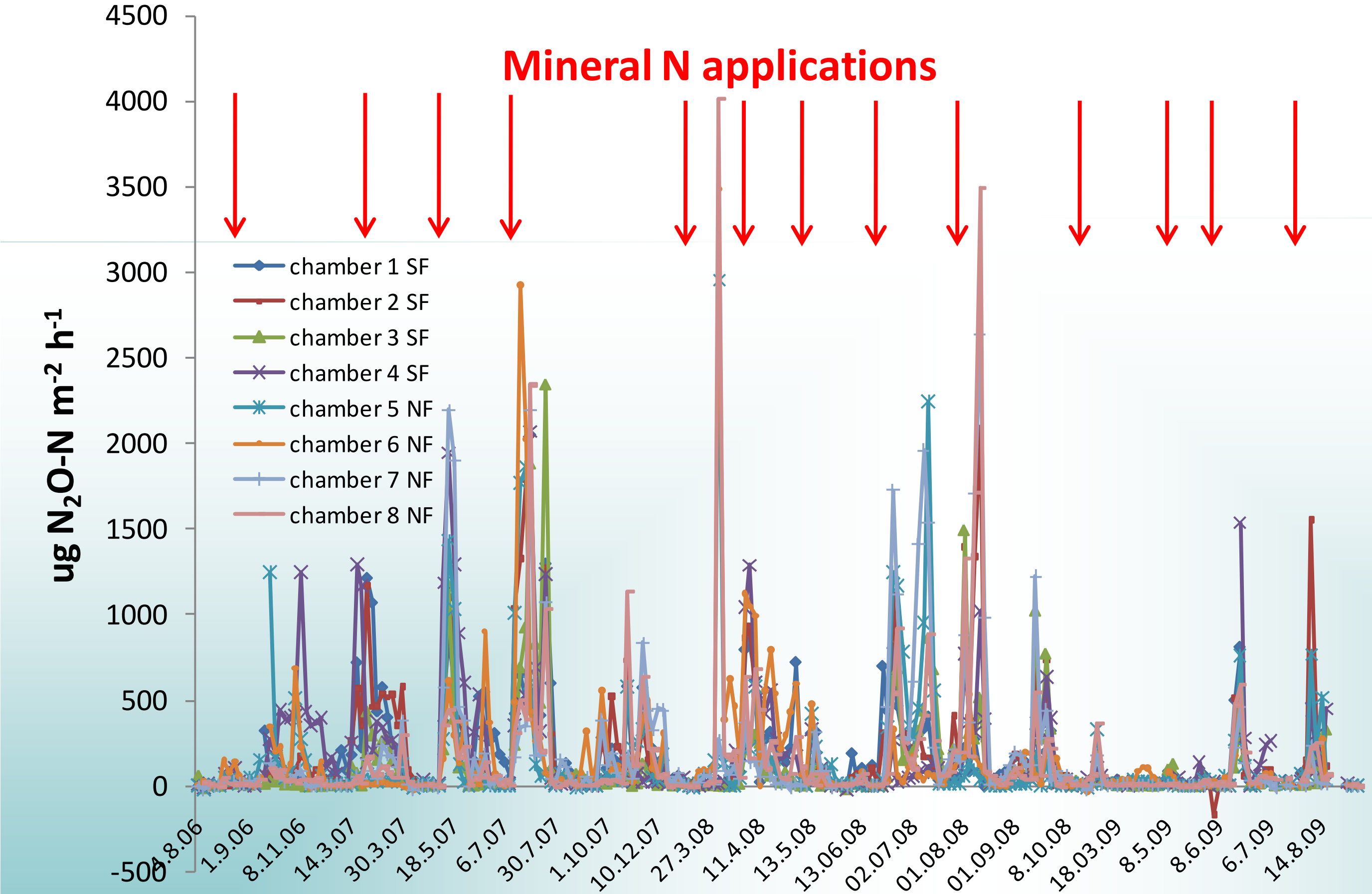


Infrared absorption (tunable diode laser)

Infrared absorption (quantum cascade laser)
Cavity ring down spectroscopy

Nitrogen stimulates N_2O emissions

Easter Bush, managed grassland



Skiba et al, Biogeochemistry Discussions 2012

Emission factor [% of N applied]	
2007	**6.5**
2008	**3.7**
2009	**1.6**

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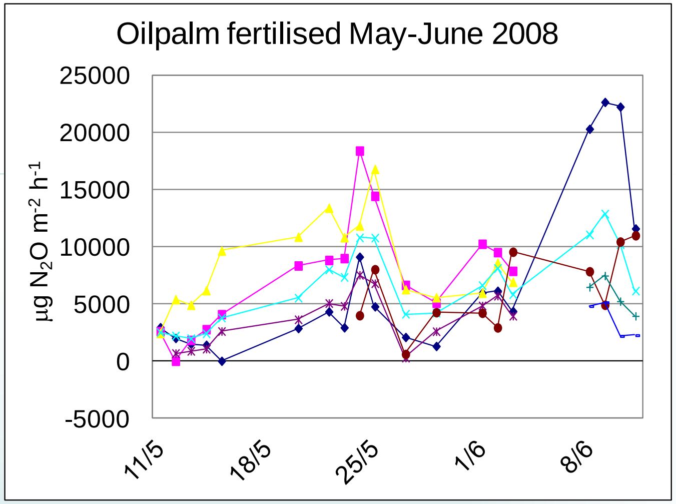
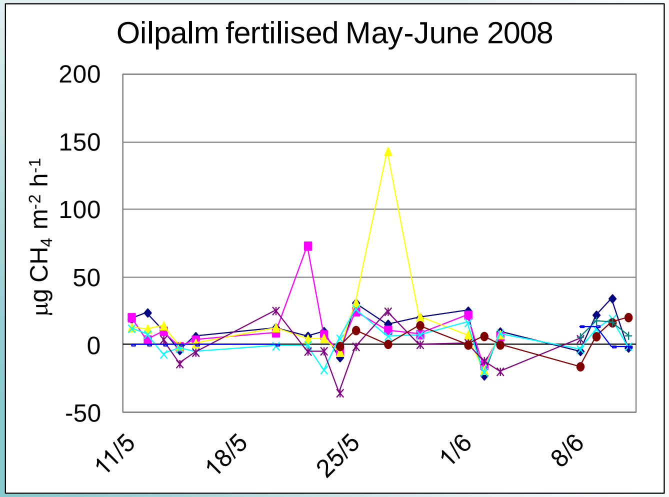
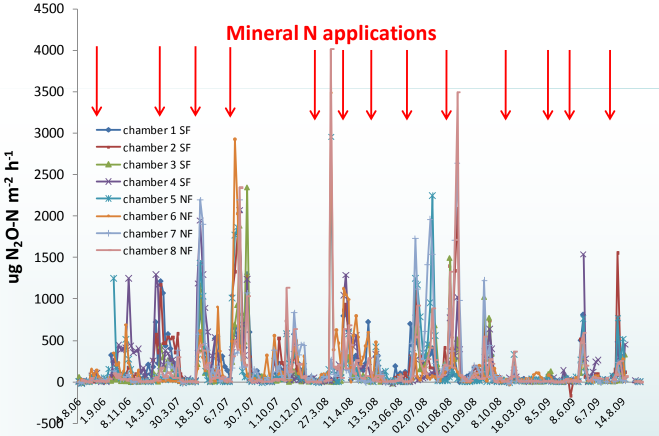
Spatial and temporal variability of N_2O and CH_4 fluxes is caused by changes in soil N and water filled pore space

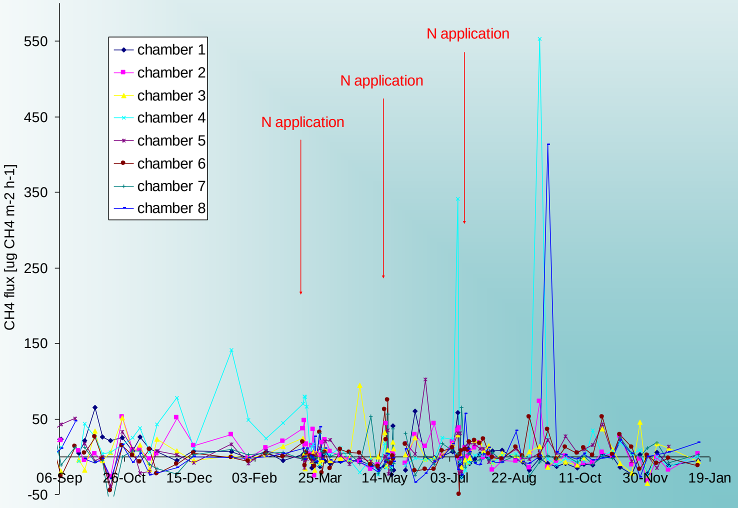
Siong, J., 2012



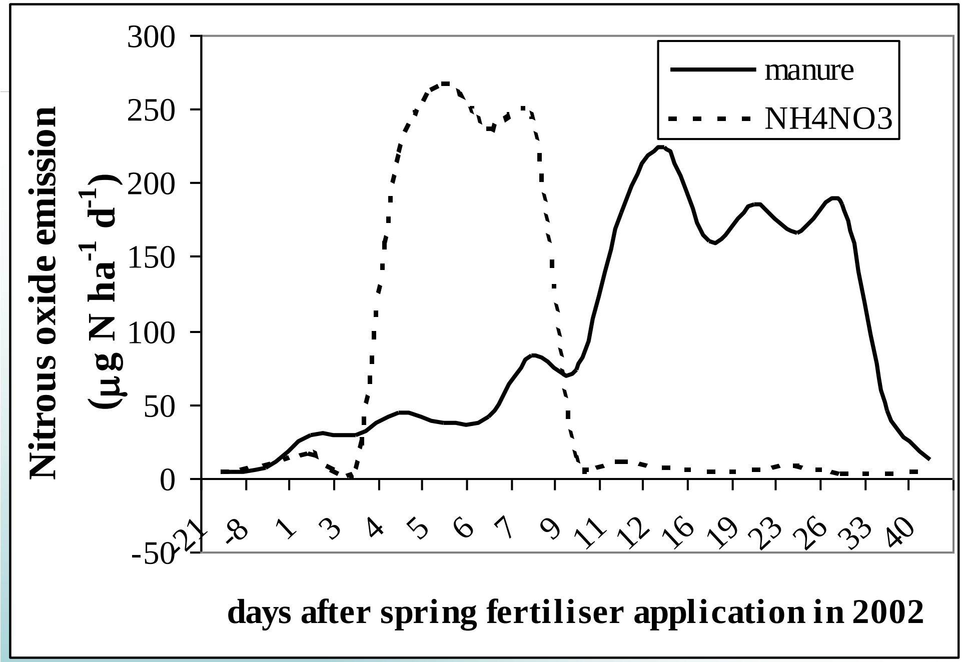


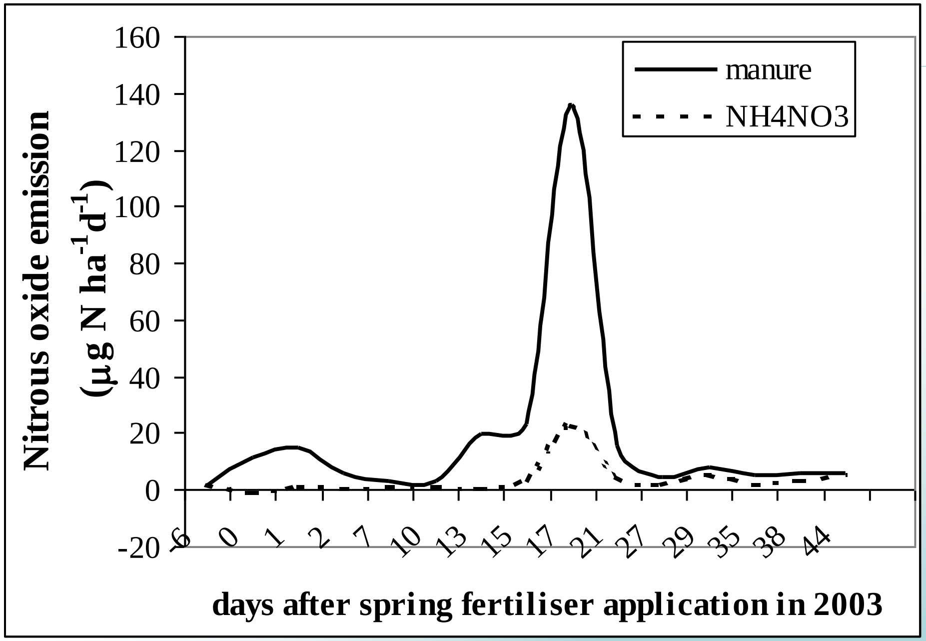
Easter Bush grazed grassland, Scotland





Nitrogen fertiliser type effects soil N_2O emissions



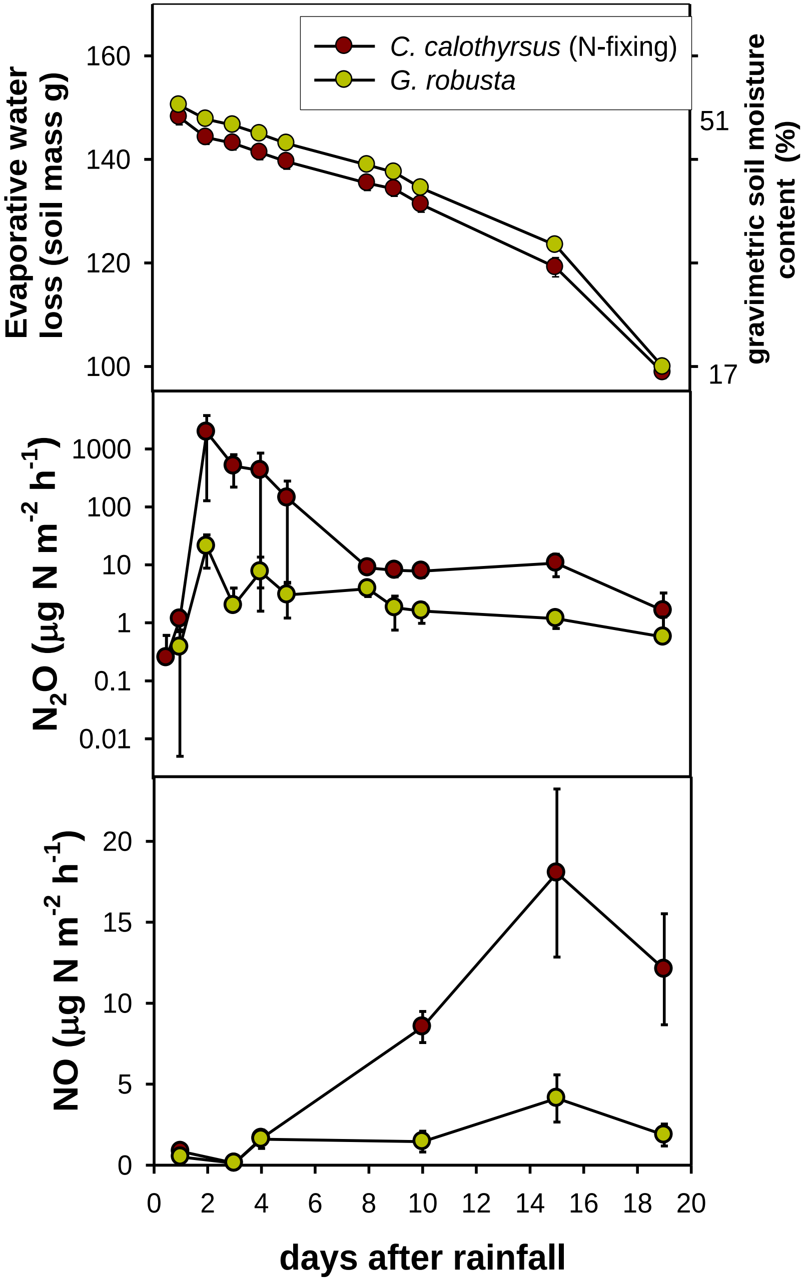


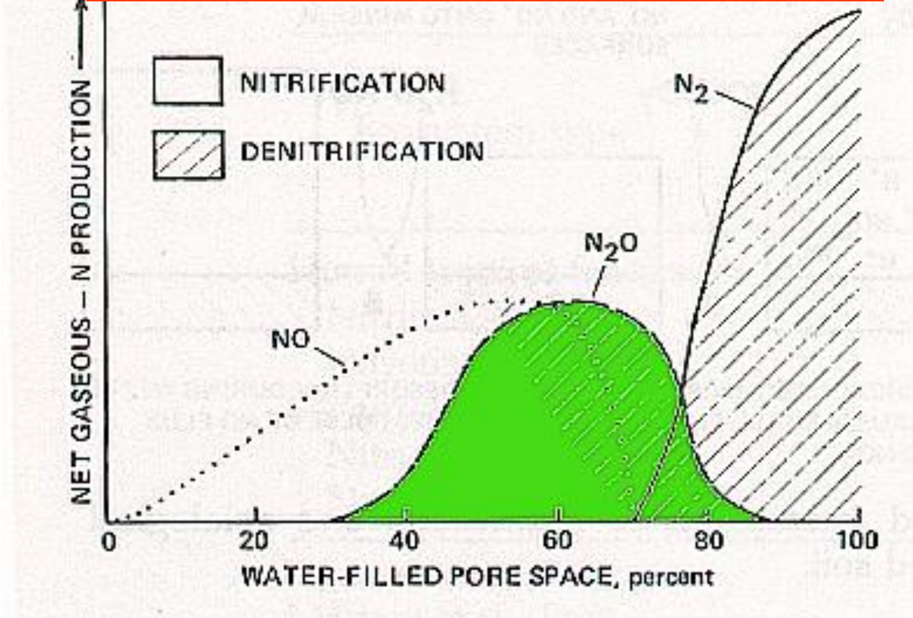
Fertiliser response depends on fertiliser type (organic or mineral) and rainfall

Jones et al., Agriculture, Ecosystems and Environment 121 (2007) 74–83

Rainfall effect on soil NO and N_2O emissions

The effect of one heavy rain event (25 mm) on NO and N_2O fluxes from a previously dry tropical soil



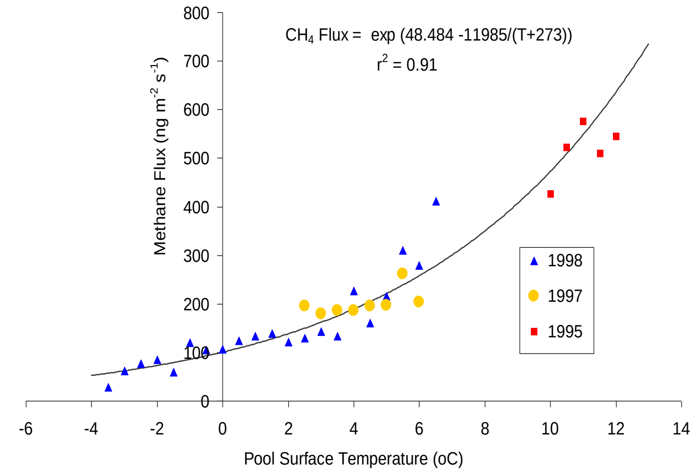


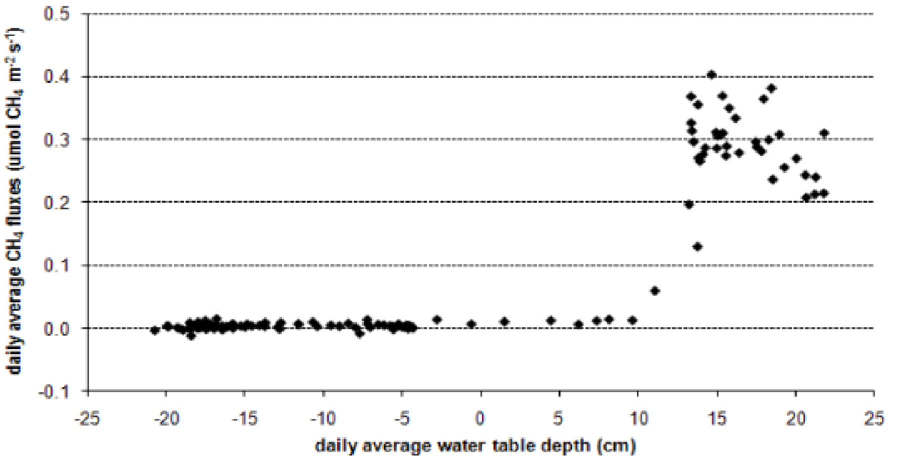
Model of the relationship between WFPS and N gases

Davidson, 1991 (In: Microbial Production and Consumption of Greenhouse Gases, ed J.E. Rogers & W.B. Whitman)

Dick, J., U. Skiba and J. Wilson 2001. Phyton-Annales Rei Botanicae. 41:73-80.

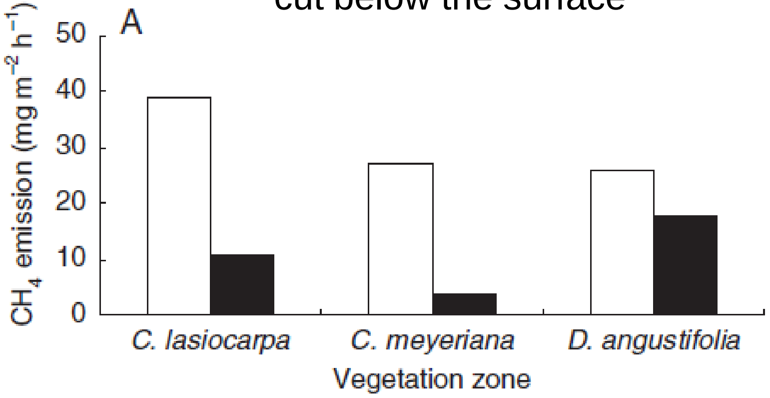
Methane emission is influenced by temperature, water table height and vegetation





Black bars: vegetation was cut below the surface

A Meijide et al., 2011. Biogeosciences Discuss., 8, 8999–9032, 2011




Plant transport of CH_4

Ding et al. 2005 Atmospheric Environment 39: 3199–3207.

CH_4 oxidation is reduced by disturbance and increased bulk density

Mbalmayo Forest Reserve, Cameroon

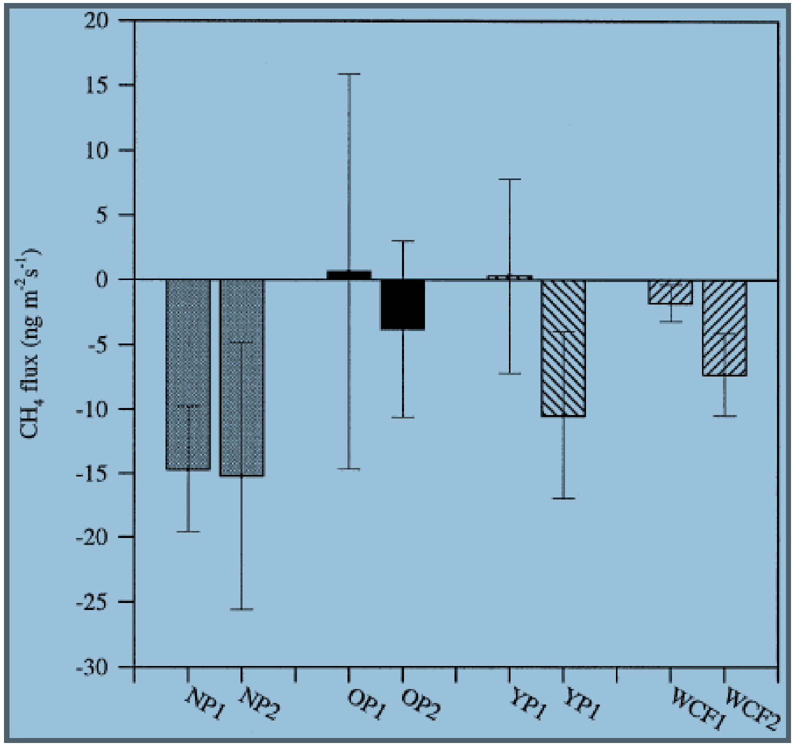


Fig. 2 Mean CH_4 flux (± standard deviation) from the forest disturbance gradient. NP, near primary (▦); OP, old plantation (■); YP, young plantation (▨); and WCF, weeded chromolaena fallow (▨) during sampling week 1 and 2.

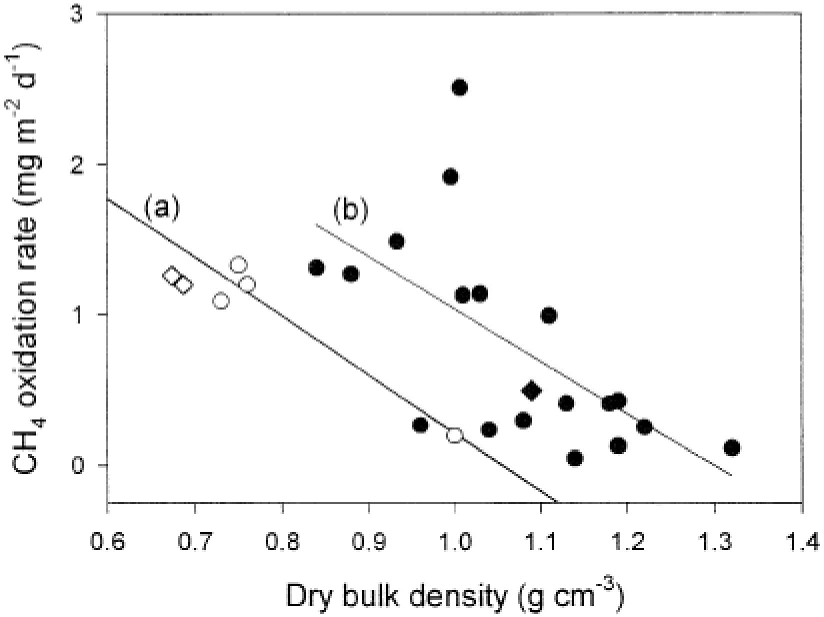


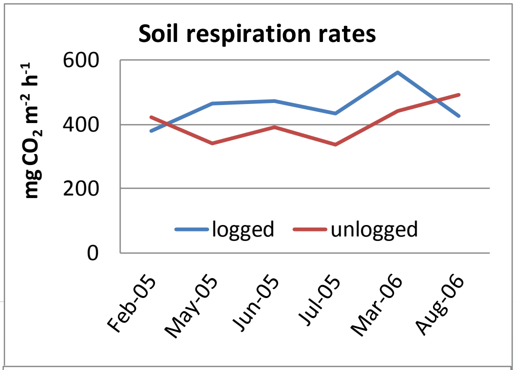
Fig. 7 CH_4 oxidation rate as a function of soil bulk density. Regression lines drawn through, respectively (a) tropical data points, for Cameroon (MacDonald 1998) (○), and Central American tropical forest/plantation (Keller & Reiners 1994; Reiners *et al.* 1994) (◇); (b) data points for temperate forest soils, for Europe (this study) (●), and Canada (Lessard *et al.* 1994) (◆).

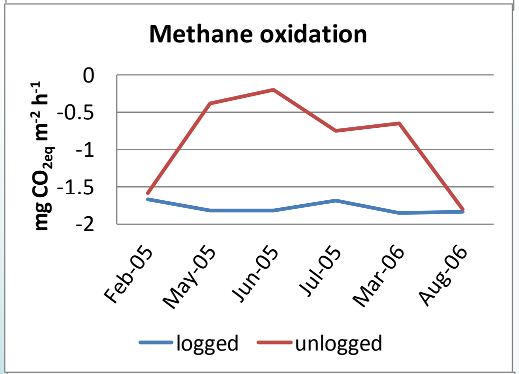
J.A. MacDonald et al.,1998. Global Change Biology, 4, 409-418.

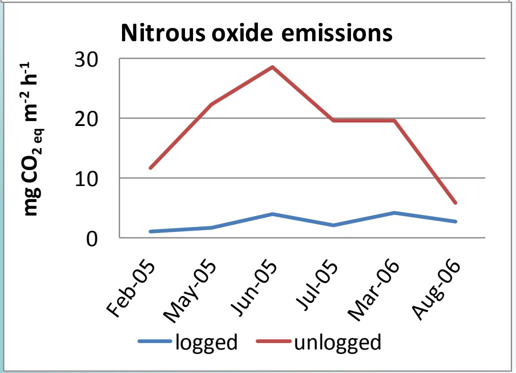
Smith K.A. et al., 2000. Global Change Biology, 6, 791-803.

Effect of logging on soil GHG fluxes

Yashiro et al., 2008. Agricultural & Forest Meteorology 148, 799 - 806


Soil respiration rates


Methane oxidation


Nitrous oxide emissions

- Pasoh Forest (70 km SE of Kuala Lumpur)
- Logging: removal of trees, stumps and brash remained

Logging increased

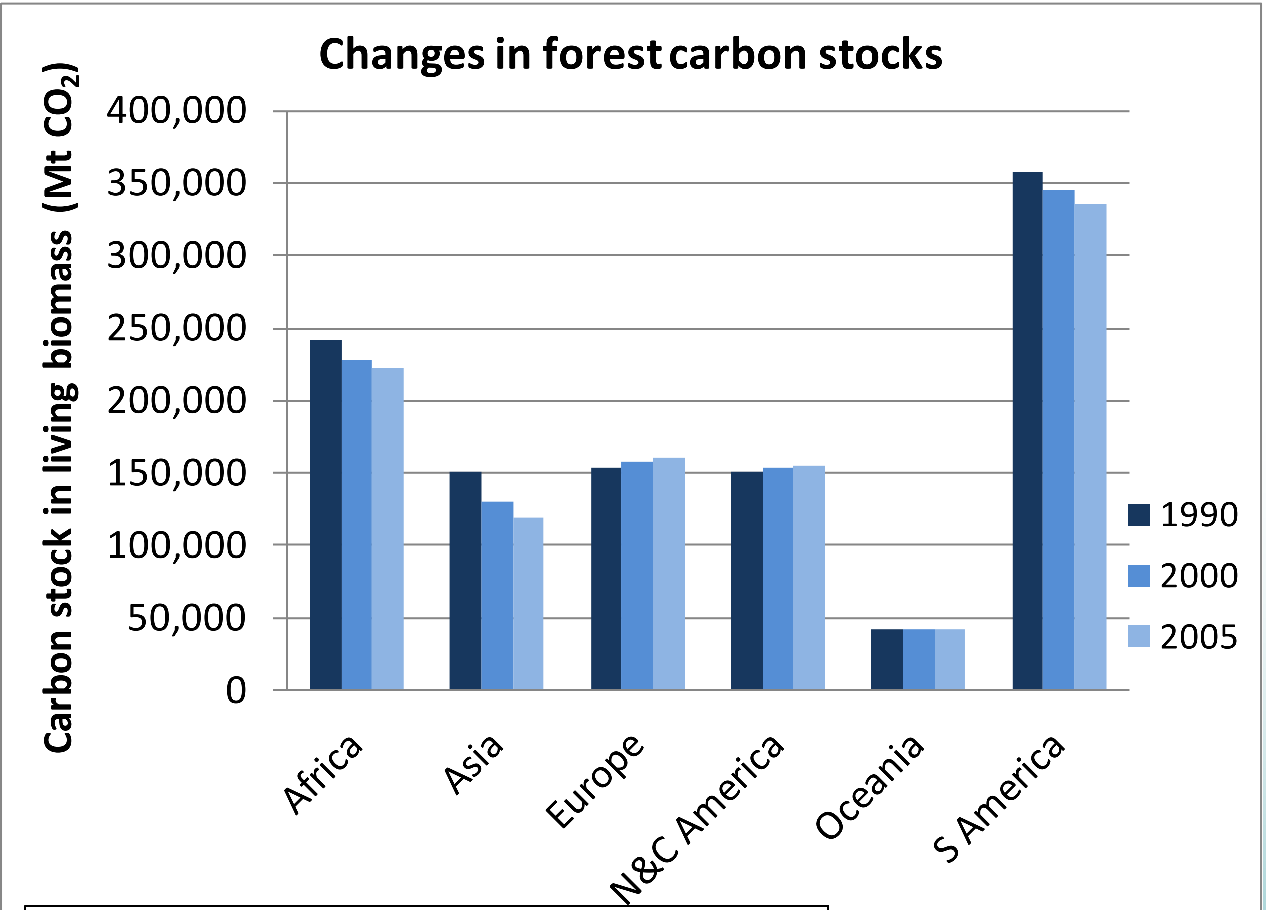
- Bulk density
- Soil temperature
- Mineral nitrogen

Consequences are

- Increased N_2O emissions
- Decreased CH_4 oxidation

for at least 1 year

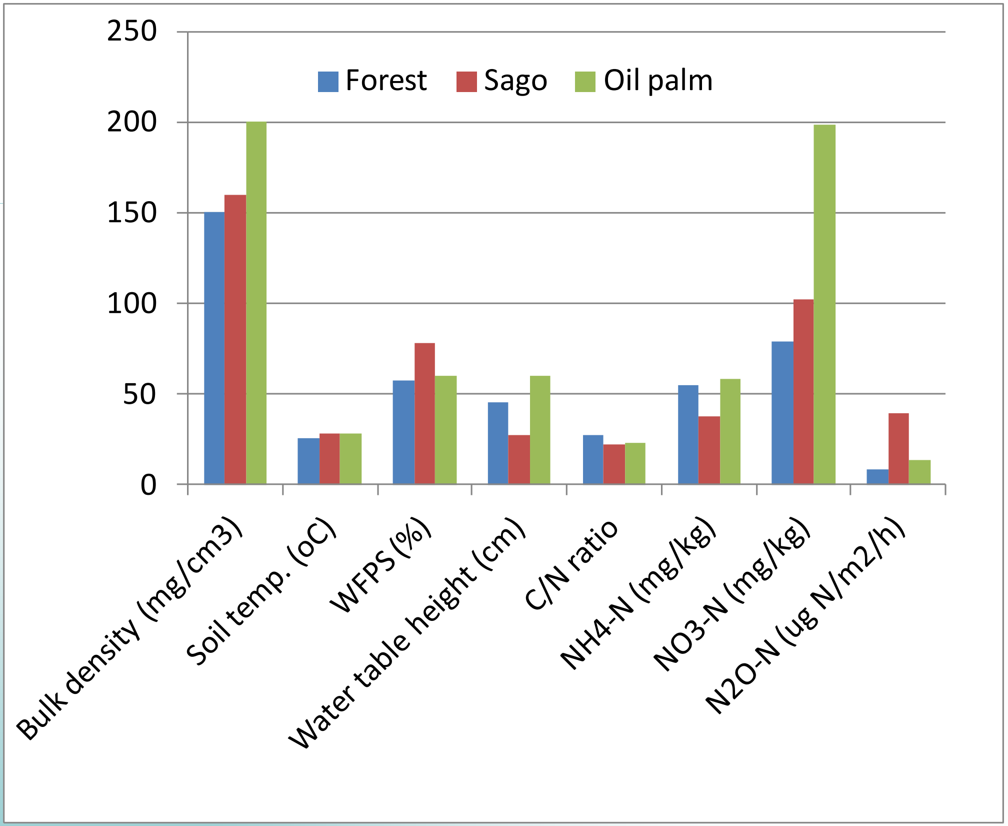
Deforestation



Global Forest Resources Assessment 2005. Progress towards sustainable forest management. FAO Forestry Paper 147, 320 pp.

Effects of deforestation on N_2O and CH_4 fluxes in temperate and tropical climates is not sufficiently studied to inform inventories

N_2O emissions from forest, sago, oil palm on peat, Mukah Div., Sarawak



Environmental factors determining N_2O fluxes

- Forest: Water table,+ NH_4
- Sago: Temp., NO_3
- Oil palm: WFPS, NH_4,Temp**.**

Melling et al.,2007, Soil Sci & Plant Nutr. 53, 792-805.

Cultivation of a peat swamp forest has increased N_2O emission by 371% (sago) and 71% (oil palm)

N_2O & CH_4 fluxes from forests & oil palm on mineral soil

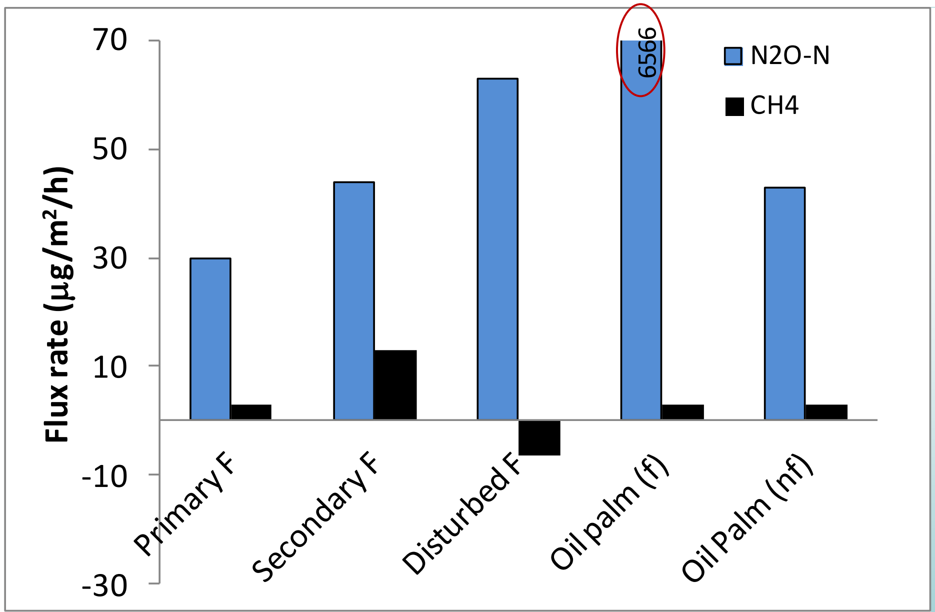
Sabah, Danum Valley & Lahad Datu

Primary forest

Secondary forest

Oil palm plantation

Heavily disturbed forest



Siong, J. 2012, Masters Thesis, University of Sabah, Malaysia.

In collaboration with NERC OP3

Annual N_2O and CH_4 emission estimates for oil palm at Lahad Datu

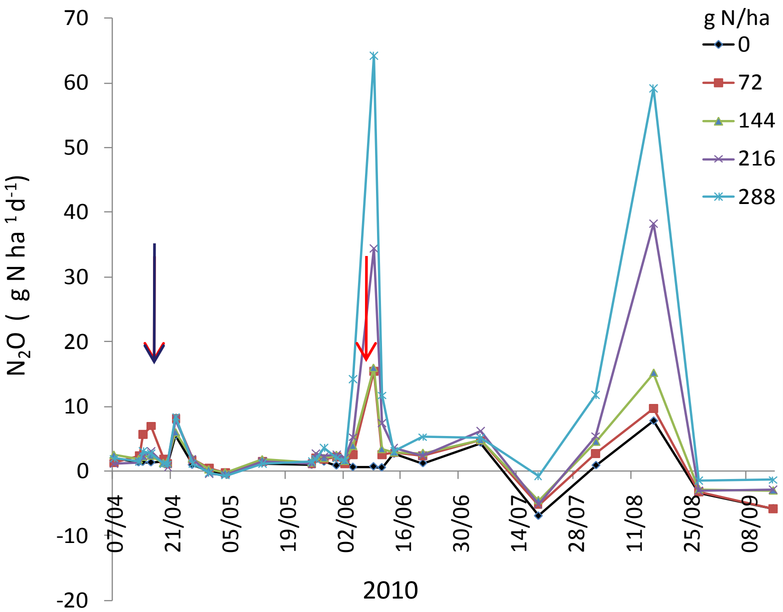
- Fertiliser application of 81 kg N/ha applied to 4 holes around stem
- Assumed increased N_2O for 2* 33 days over 2 m^2 / tree
- Annual flux 4.4 kg N_2O-N/ha/y & 3.5 kg CH_4/ha/y
- 4.4 kg N_2O-N/ha/y = 5.5 % of N input
- It is likely that fertiliser induced N_2O emissions from oil palm are larger than IPCC predicted emissions (Tier 1)

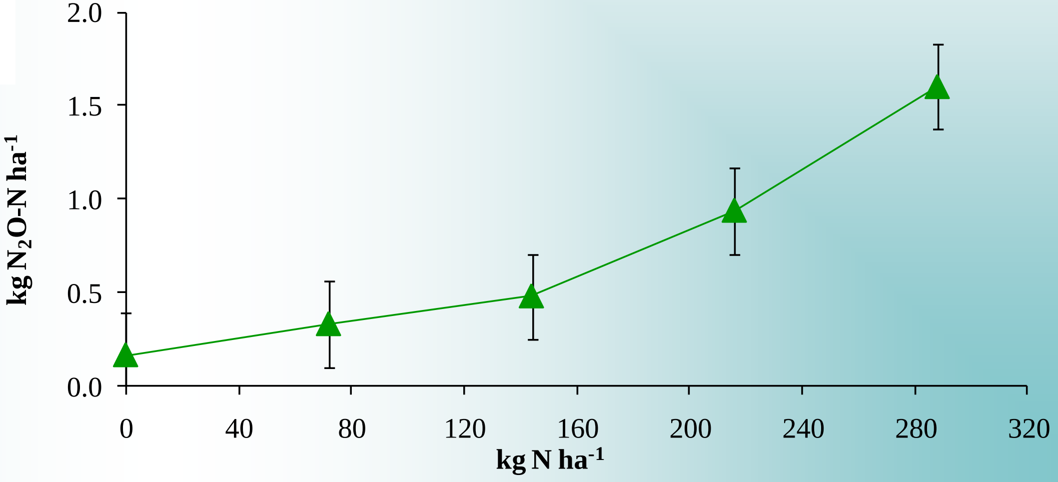
Mitigation of N_2O

- Aim for maximum yield
- Optimise fertiliser application rates
- Don’t fertilise before rainfall or when soil is very wet
- Use slow release fertiliser or nitrification inhibitors
- Maintain good soil structure
- Use legumes as biological N source
- Cultivate grasslands rather than forests

Mitigation of N_2O

Aim for maximum yield & optimise N fertiliser rate

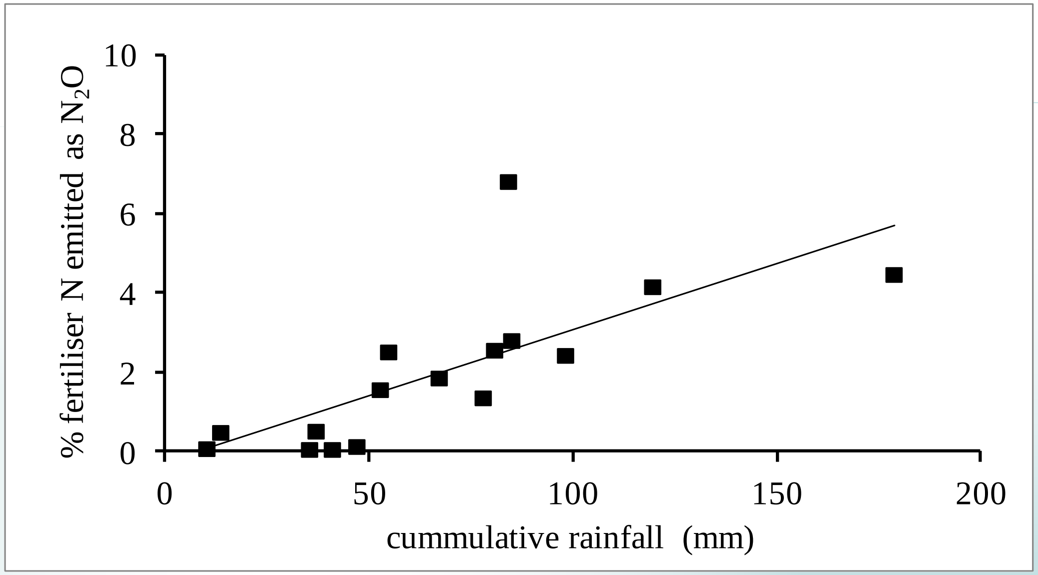




Pappa & Rees, SAC

Mitigation of N_2O

Don’t fertilise during or immediately before heavy rainfall

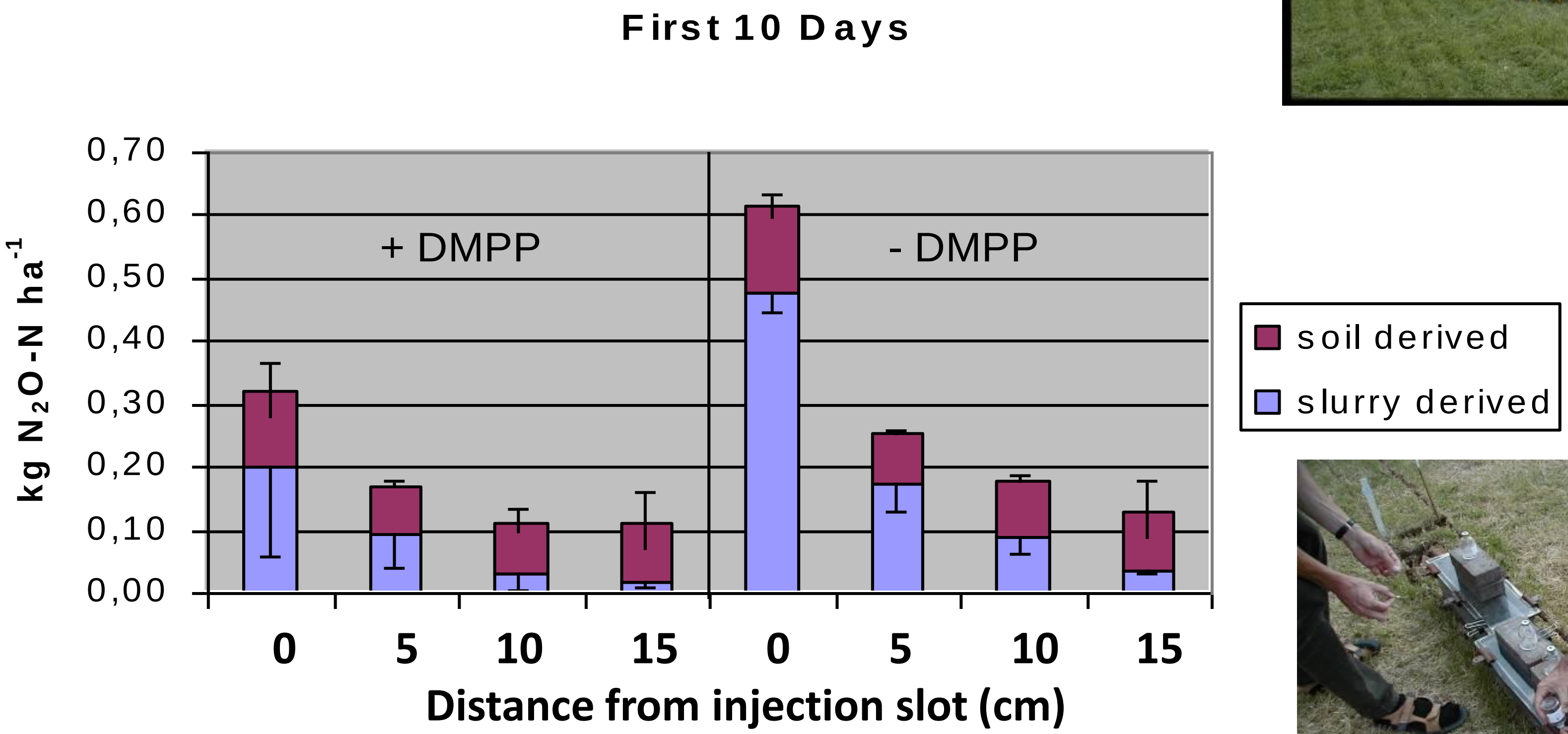


16 – 66% of annual N_2O emissions occurred in the 21 day period after fertiliser application

Mitigation of N_2O

Use slow release fertiliser or nitrification inhibitors

DMPP reduced N_2O emissions by >30%



Dittert et al., 2001

Mitigation of N_2O

- Use legumes as biological N source

  Synthesis of mineral N has a high carbon footprint

- Cultivate grasslands rather than forests

Conversion to oil palm	**Mg CO_2 ha^{-1} (over 25 years)**
Tropical grassland	-135
Tropical forest on mineral soil	+650
Tropical forest on peat	+1300

Germer & Sauerborn, 2007. Environ. Dev. Sustain. DOI 10.1007/s10668-006-9080-1

Mitigating CH_4

- Maintain high bulk density to maximise CH_4 oxidation

- Minimise soil disturbance during conversion from forest /grasslands to cropsystems

Summary

- Agricultural management and land use change often increases N_2O emissions and reduces CH_4 oxidation rates.
- Large uncertainties in fluxes need to be addressed by
  - improving spatial and temporal coverage of flux data and its key variables.
  - Detailed investigation of landuse change effects, especially in the tropics
- N_2O and CH_4 emissions need to be included in all carbon foot print analyses

Thank you for listening


Sheep grazed grassland, Midlothian


Outdoor pig farm, Lincolnshire


evon


Sheep grazed grassland,


Moorland, NW Scotland


Coniferous forest adjacent to improved


Secondary forest, Borneo


Secondary forest, Borneo


Miscanthus, Lincolnshire


Seminatural grassland, Dundee area


Dungmidden, Midlothia


Forest, Mid Wales

The CEH static chamber for N_2O and CH_4 flux measurements