A climate for change: agriculture and greenhouse gas mitigation in the 21st century

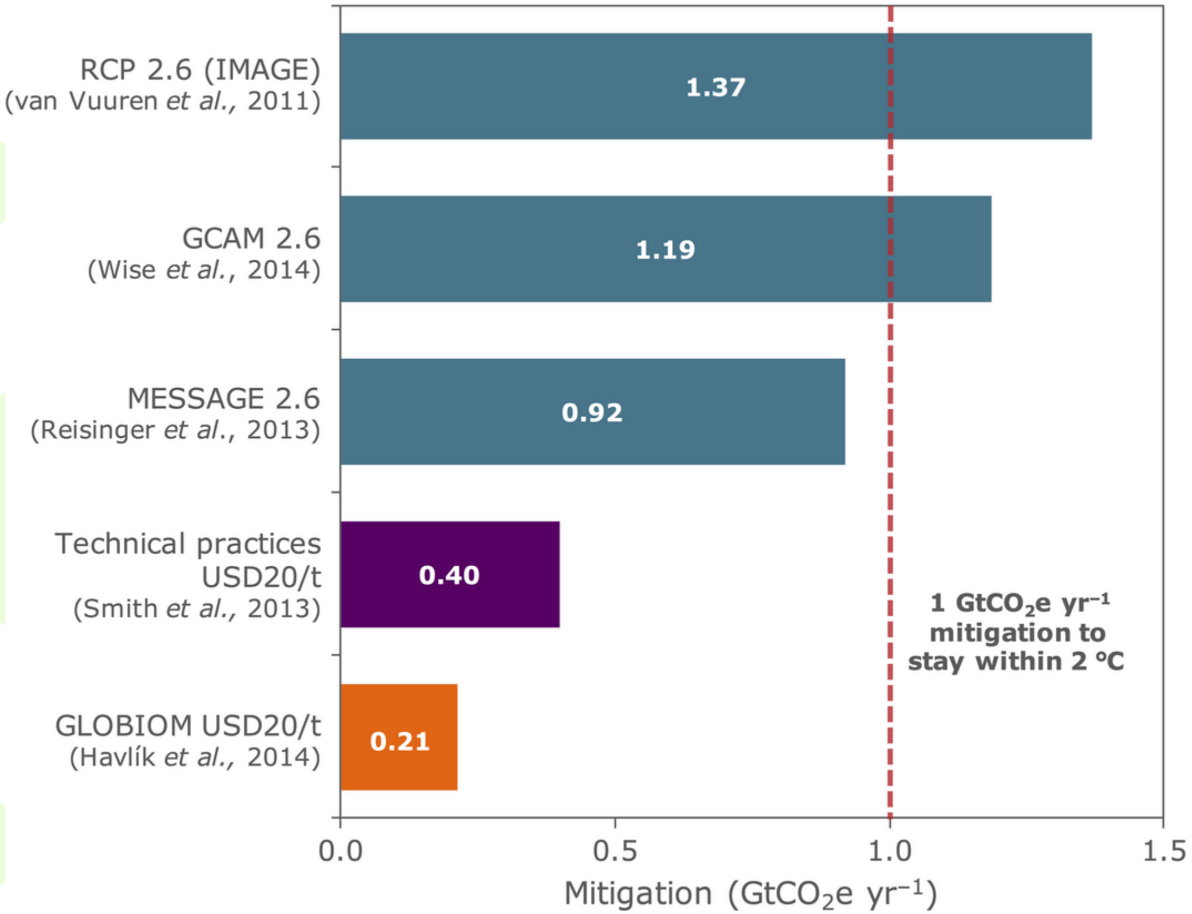
Professor Bob Rees, SRUC Edinburgh



Italian Society of Agricultural Chemistry, 24-26th September 2018

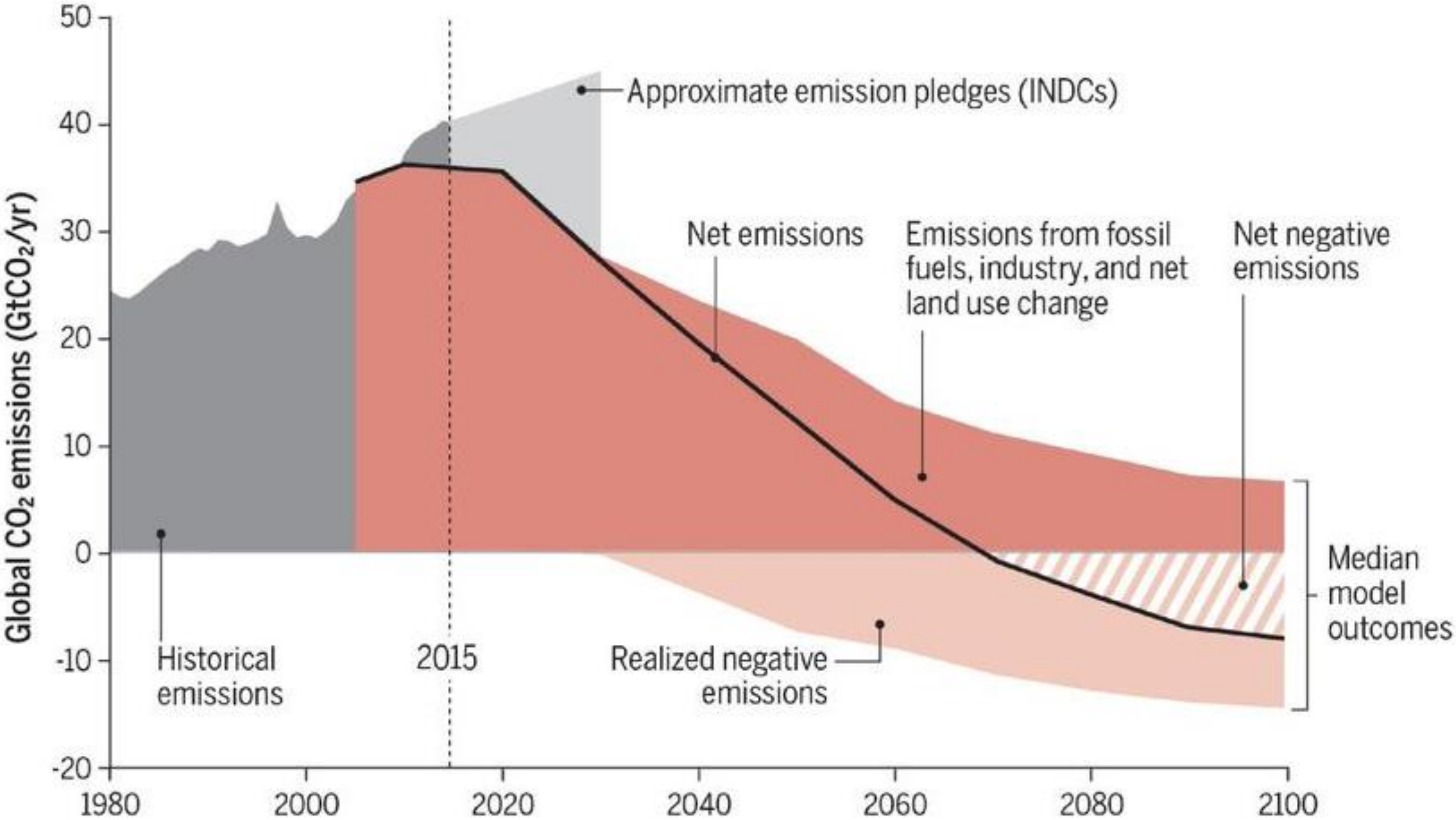
Two degrees matters!

Reducing emissions from agriculture to meet the 2 °C target



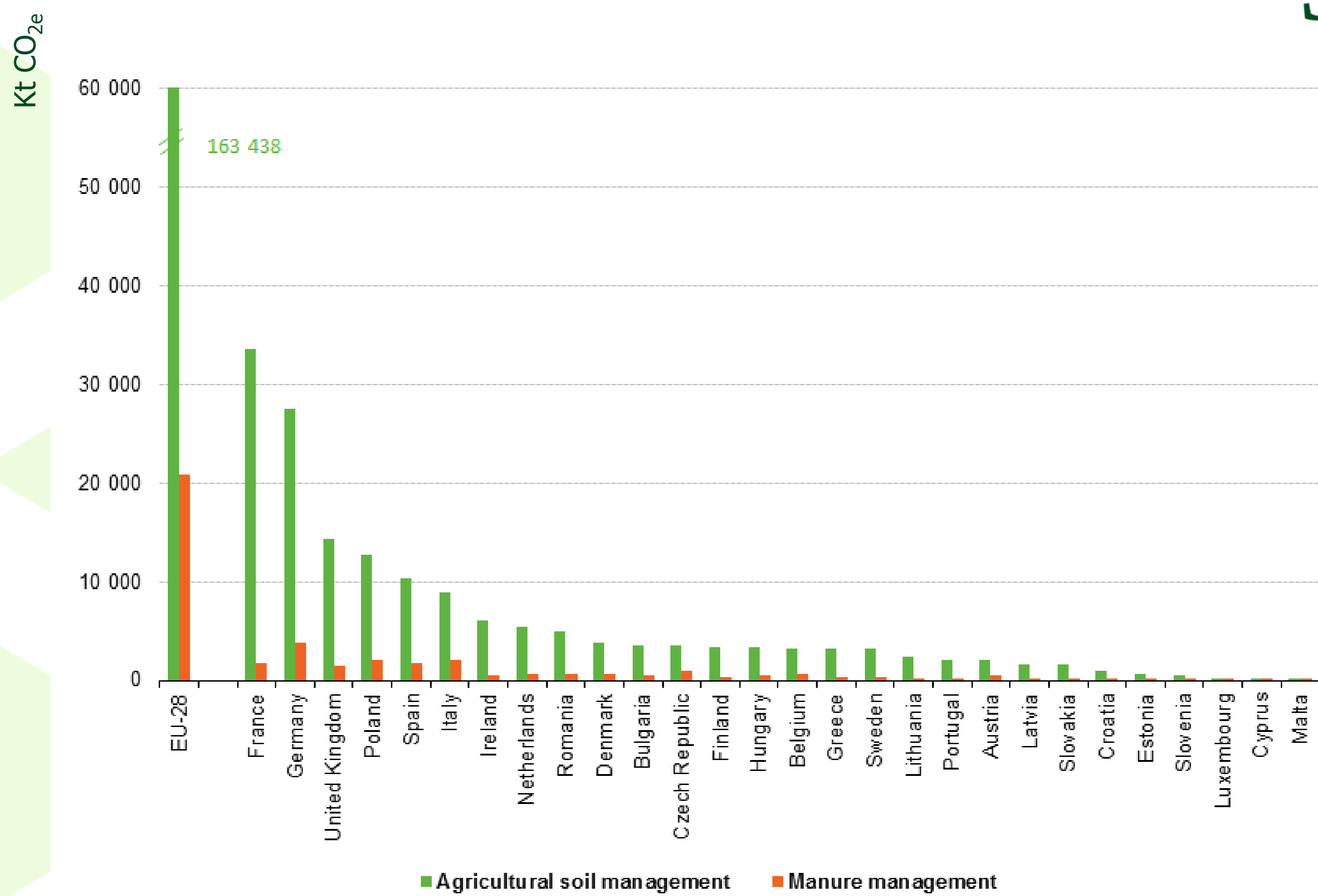
Wollenberg et al 2016, Global Change Biology, 22, 3859-3864

Negative emissions required for 2°C



Anderson and Peters 2016, Science 354, 182-183

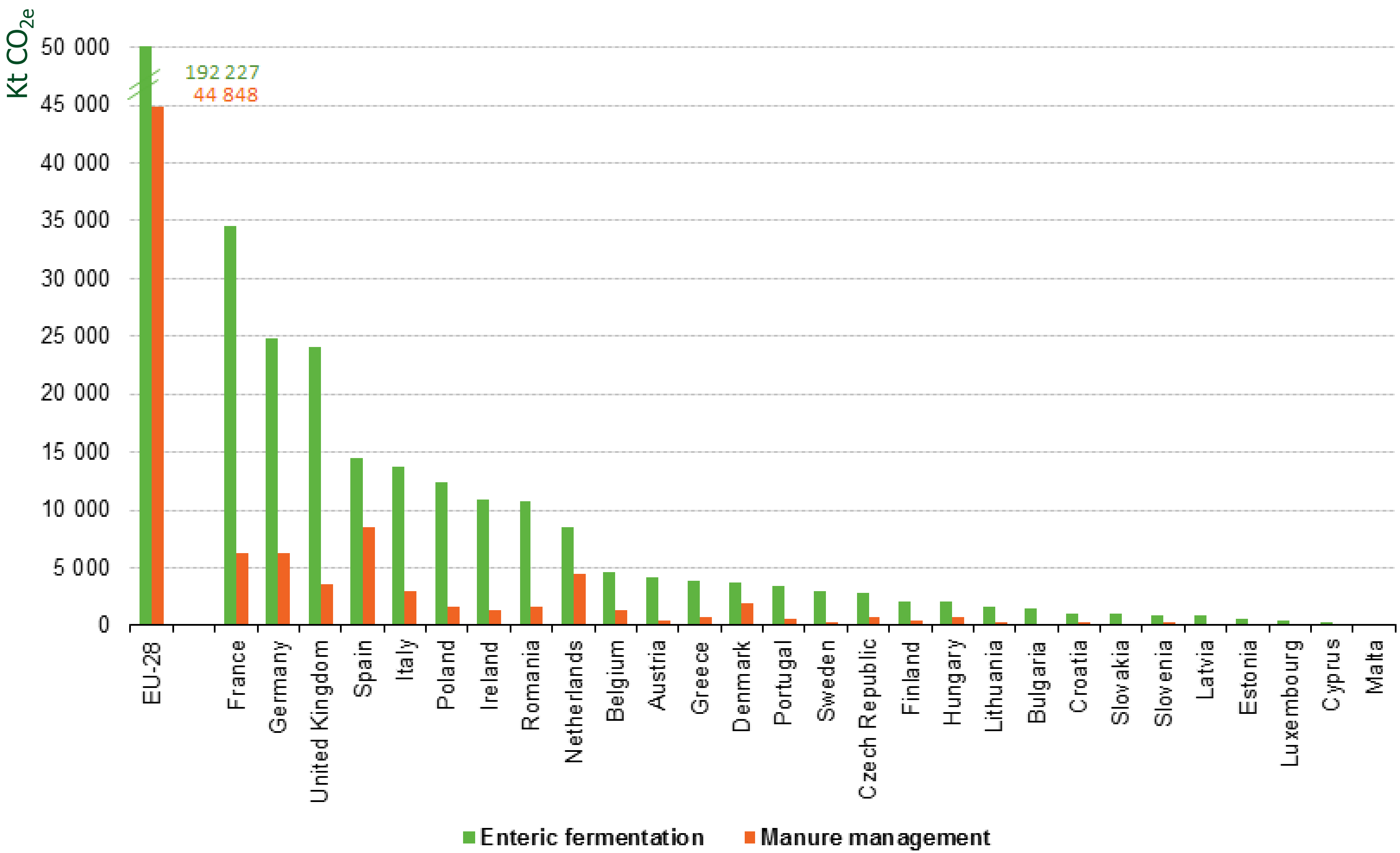
Nitrous oxide emissions from agricultural soils and manure management



Note: Field burning of agricultural residues also contribute to nitrous oxide emissions. However, this is a small source compared with the two main emission sources illustrated.

Eurostat, 2018

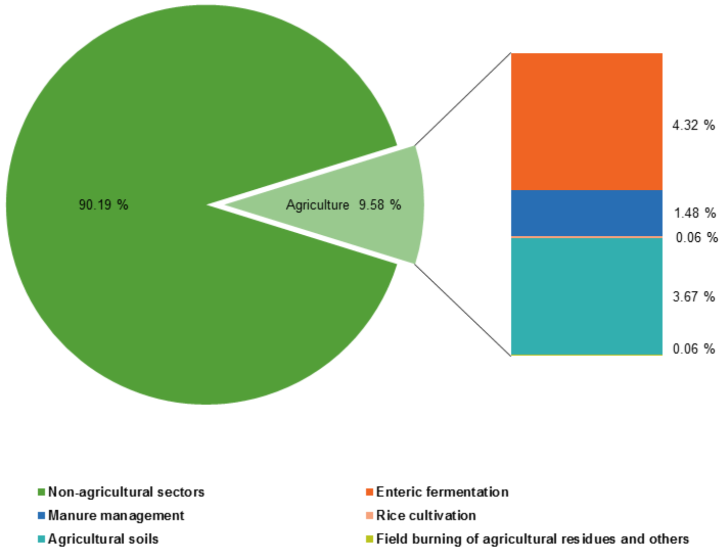
Methane emissions from enteric fermentation and manure management



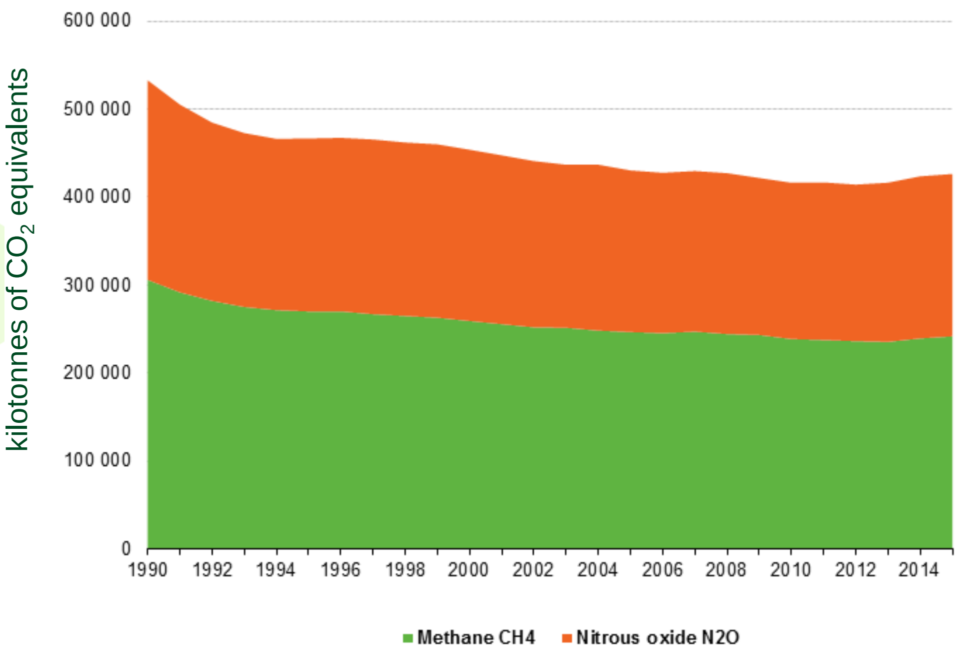
Eurostat, 2018

Contribution of agriculture to total GHG emissions (%), EU-28, 2015

Total emissions,2016 4401 Mt CO_{2e}

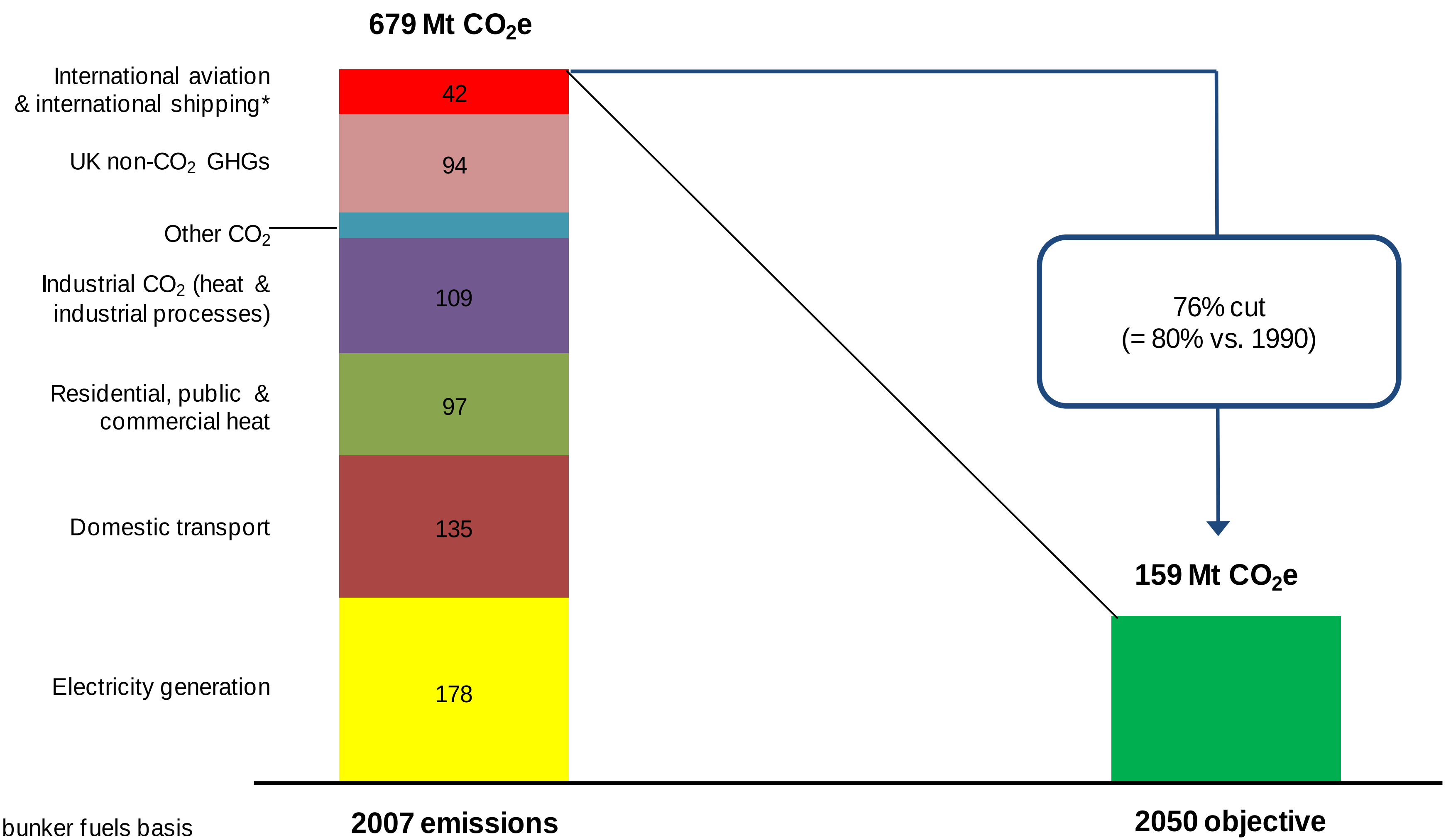


Note: Total GHG emissions do not include LULUCF CO_2 equivalents.



Eurostat 2018

UK targets for greenhouse gas mitigation



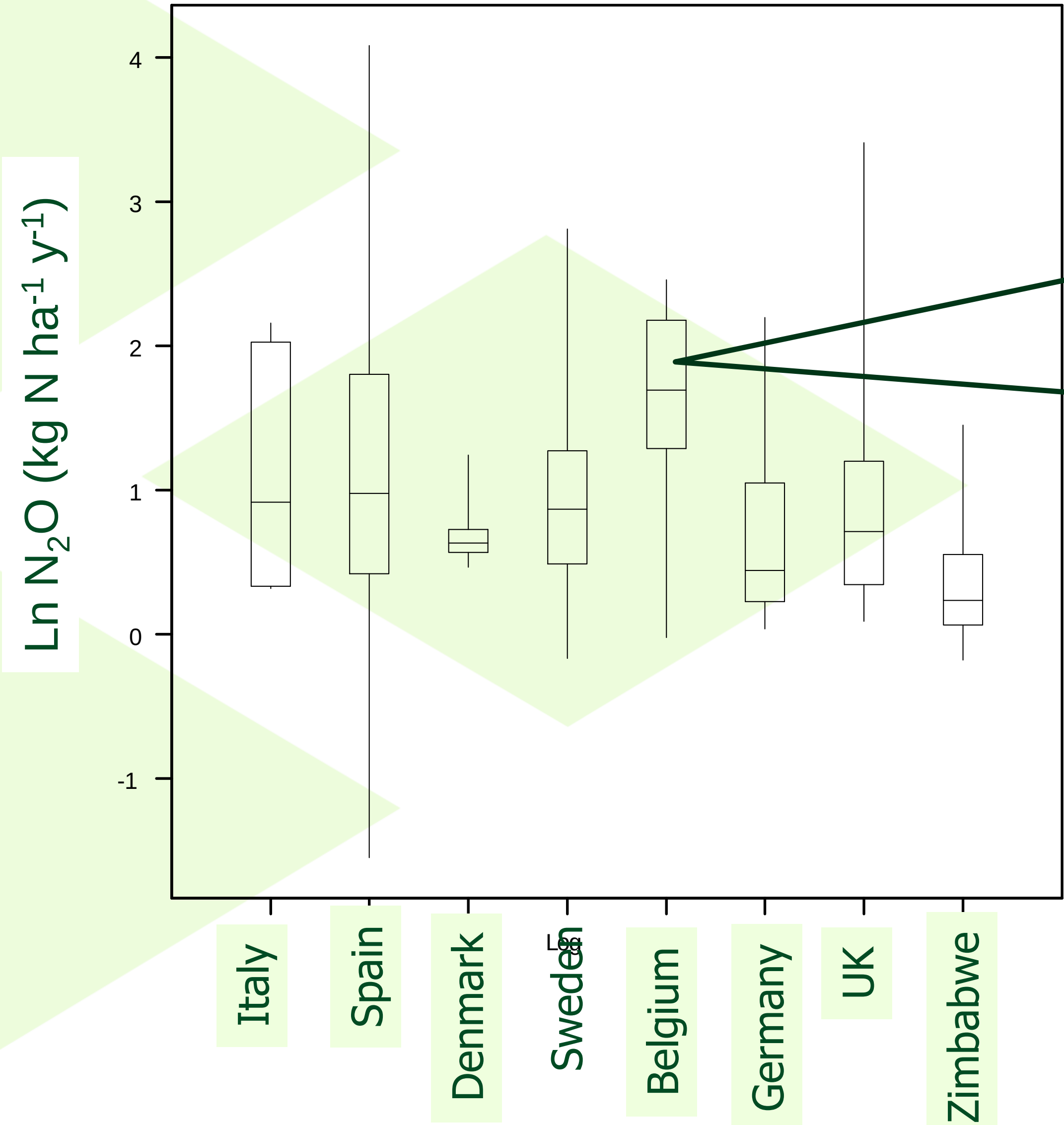
* bunker fuels basis

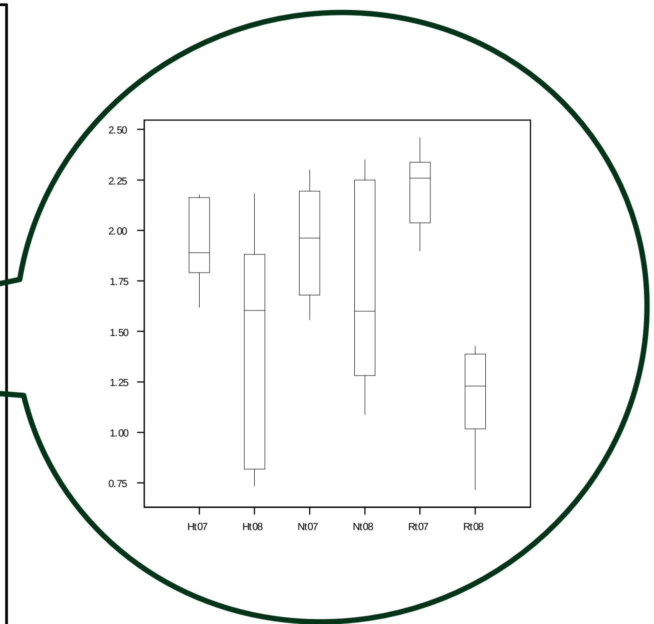
DEFRA 2009

Agriculture and land-use are different

- Biological emissions
- Non-CO_2 greenhouse gases
- Emissions and uptake
- Food production is a basic human need
- Wider socio-economic implications
- Net zero emissions within agriculture probably not possible

Variability in N_2O emissions between arable sites





Rees et al, 2013, Biogeosciences

Achieving greenhouse gas mitigation in agriculture

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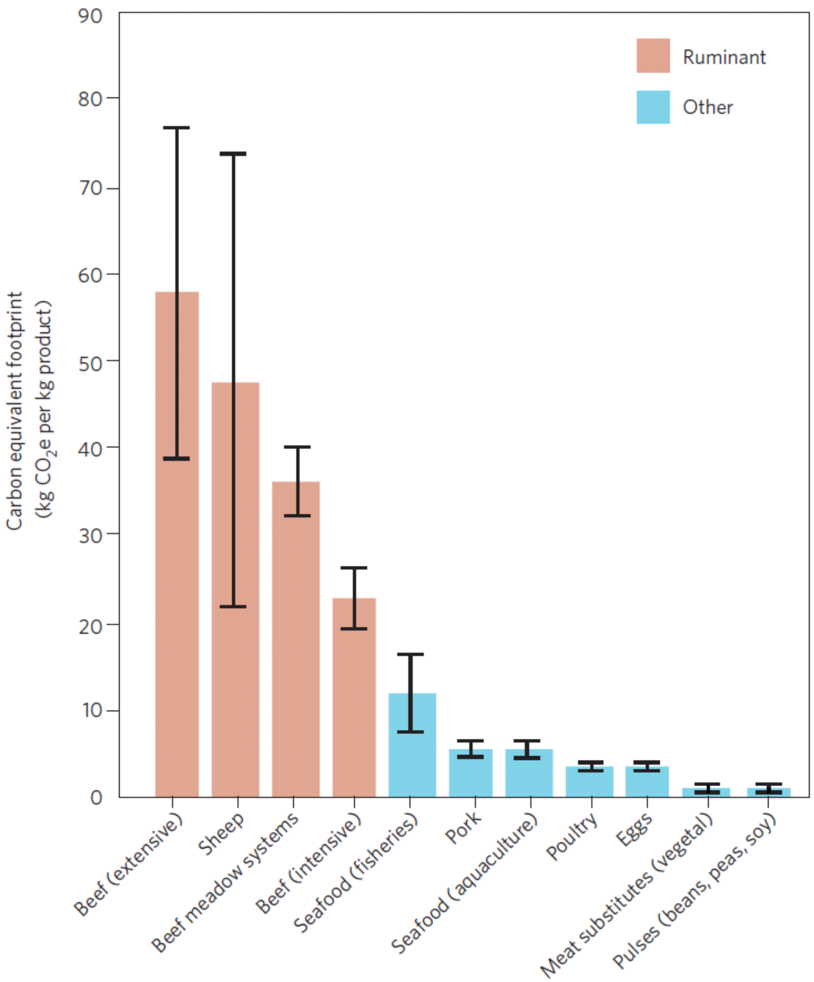
- Improved efficiency in fertiliser and manure use
- Increasing legume production
- Improved livestock management (feed and wastes)
- Improved livestock and crop health
- Soil management

Use of technology

- Precision farming
- Automation and robotics
- Earth observation and modelling
- New genetics
- Decision support tools

Shifting consumption away from carbon intensive production



Halving the consumption of meat and dairy in the EU would result in a 25-40% reduction in associated greenhouse gas emissions.

Smith et al 2014. Nature Climate Change

Westhoek at al 2014. Global Environmental Change

Management options

What are the current baseline conditions?
How do you upscale mitigation potential?
What are the affects on food production?
How do they affect profitability?

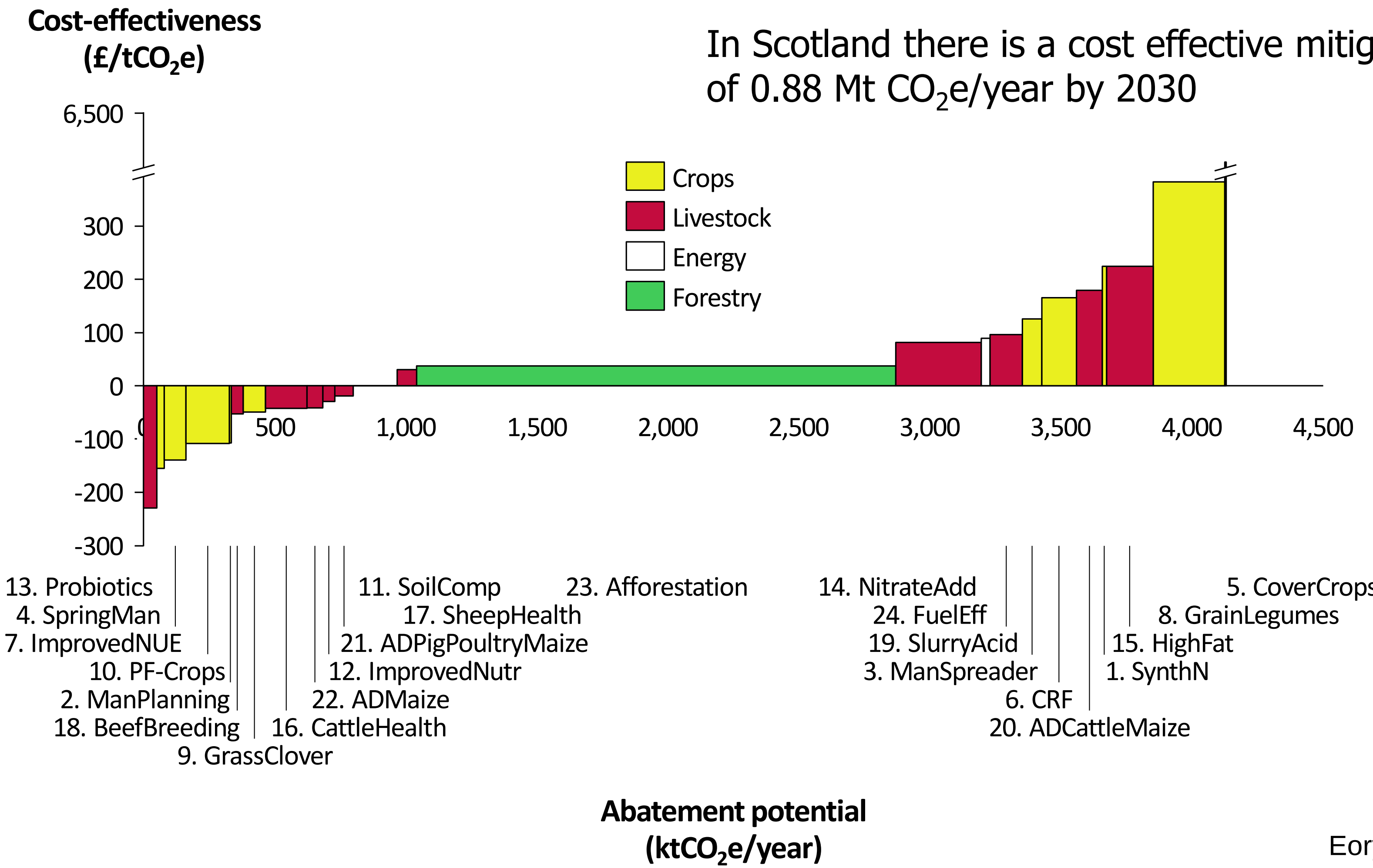
- Adop... reliant on inputs
- Imp...
- Usi...
- Av...
- F...
- R...
- Fertilisation re...
- Precision farming
- Land use change
- Regionally optimised plant and animal production
- Improved timing of mineral fertiliser N application
- Land drainage

- Loosen compacted soils / Prevent soil compaction
- Biochar
- ...rease feed protein quality
- ...f wetlands
- ...ng cultivars
- ...ed N fertiliser
- ...oultry manure
- ...nt
- Peat an... ...ration of soil forming conditions
- Re-locate high N input cropping to drier, cooler areas

Marginal Abatement Cost Curve for ALULUCF

UK 2030,CFP, 3.5%

In Scotland there is a cost effective mitigation potential of 0.88 Mt CO_2e/year by 2030



Eory et al. 2015

Improved reporting

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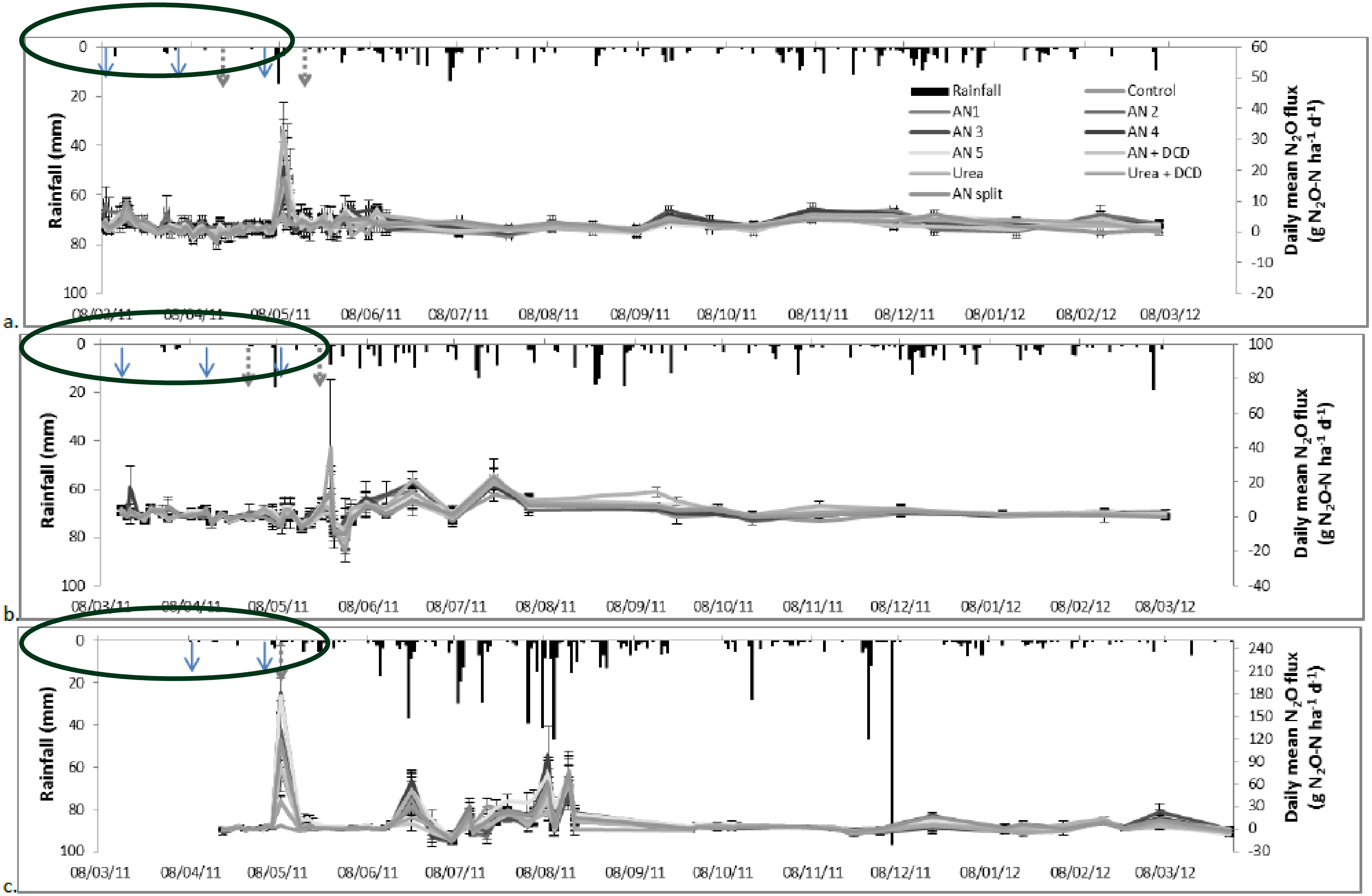
- Nationally replicated experiments and protocols
- Typically involving a comparison of 10 treatments with 15 reps
- High frequency sampling over 12 months
- Measurements of N inputs and losses
- Verification of methodologies

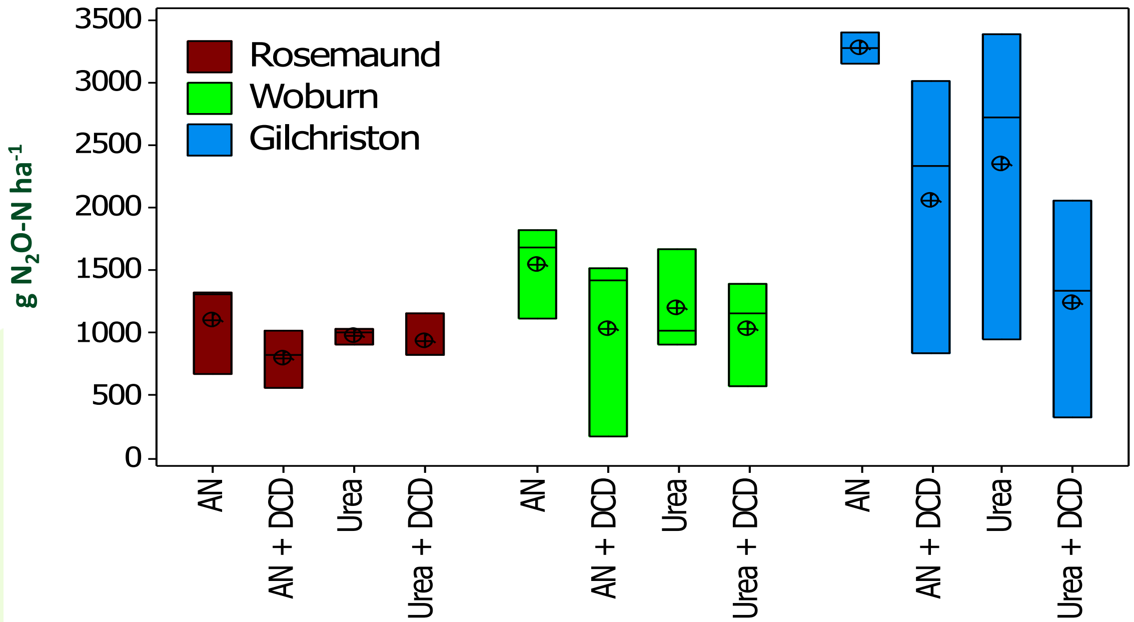
Environmental and soil variables: N_2O emissions



Rainfall and N_2O at: a. Rosemaund, b. Woburn, c. Gilchriston

Bell et all, Agriculture Ecosystems and Environment, 2015, 212, 134-347.

Mitigation options to reduce N_2O emissions?



Urea vs. AN?

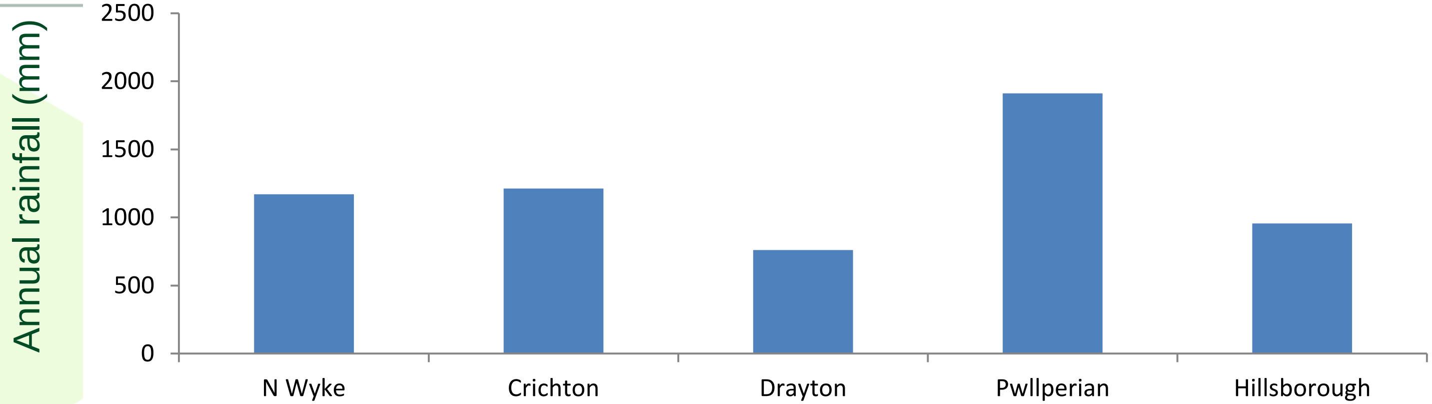
- No significant difference in annual emissions at any site

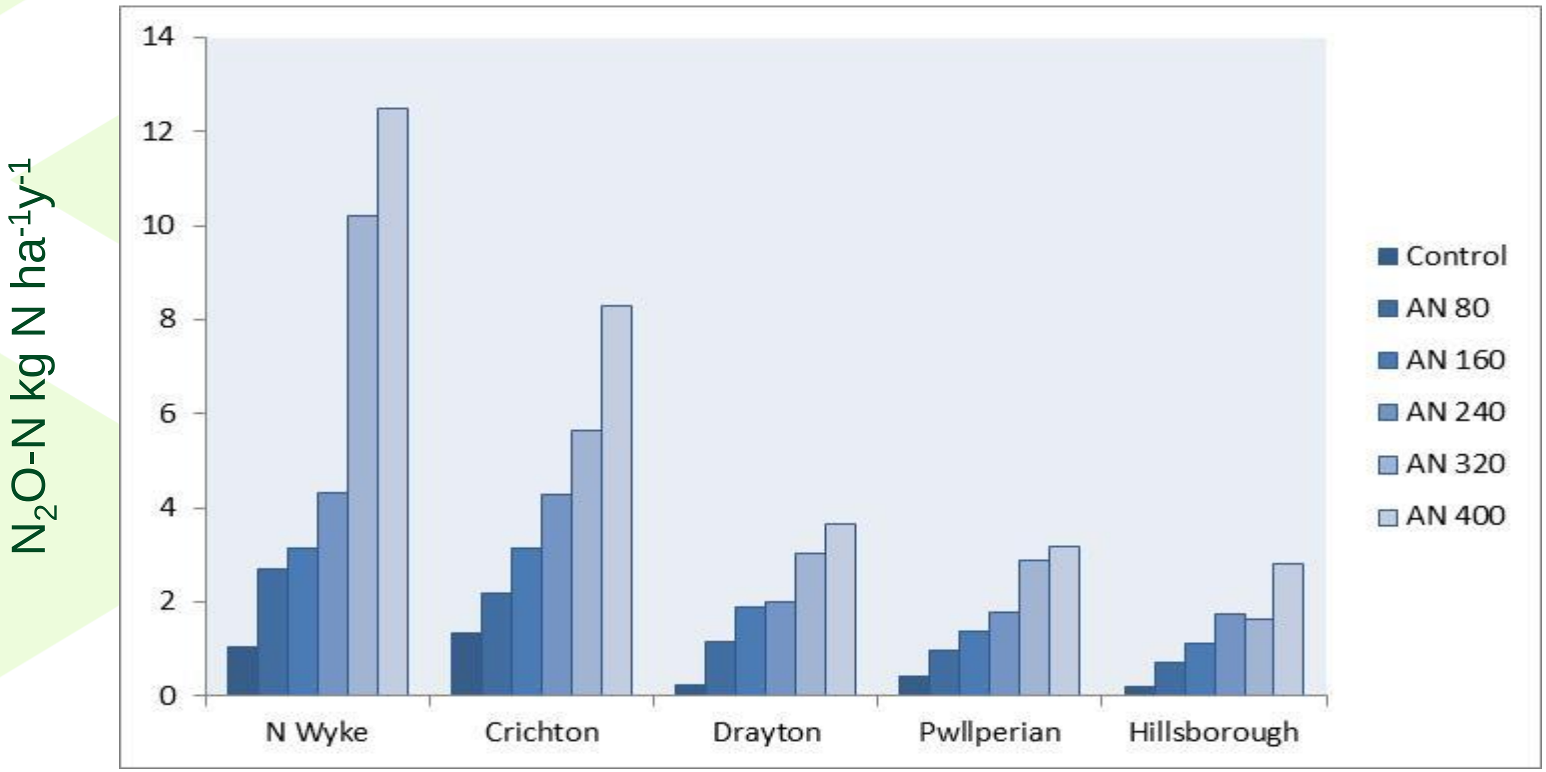
Application of DCD?

- Significant reduction in annual emissions when added to urea: all sites
- Significant reduction in annual emissions when added to AN: all sites

Bell et all, Agriculture Ecosystems and Environment, 2015, 212, 134-347.

Nitrous oxide cumulative annual emissions

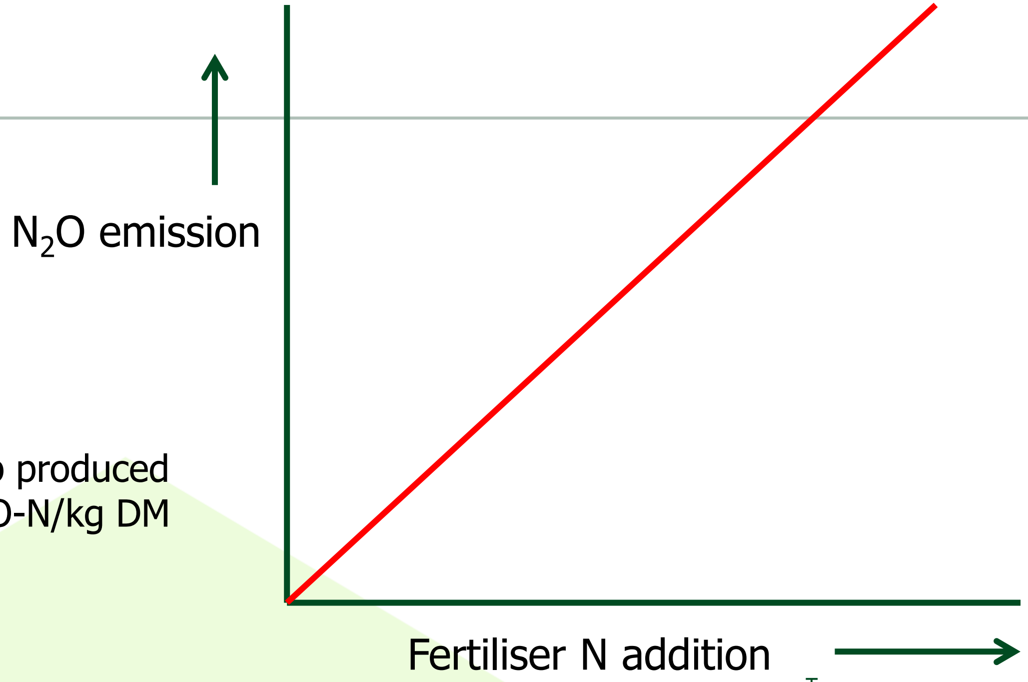


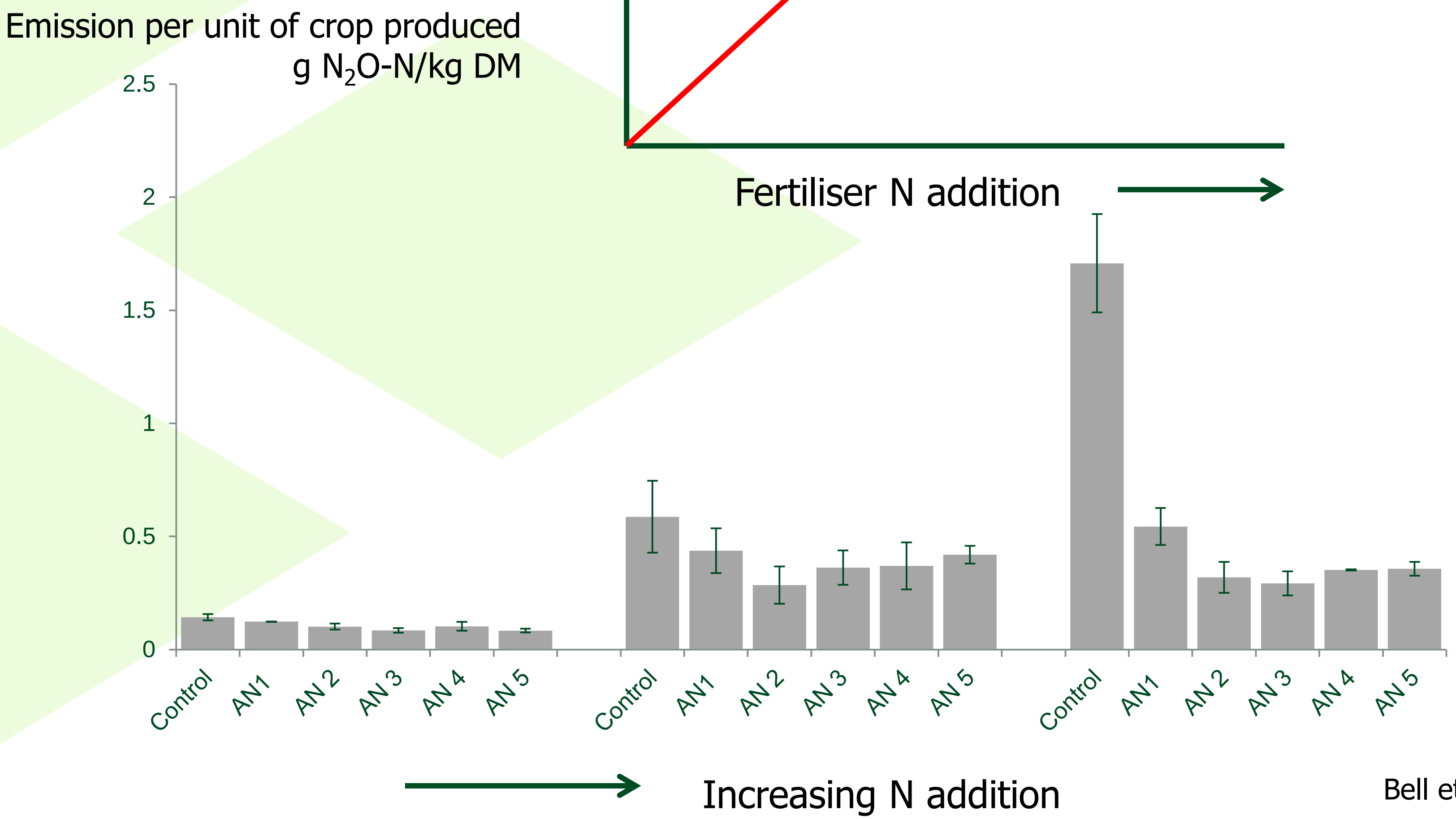


** ** **

Cardenas et al, in preparation

Metrics





Bell et al., 2015

Characterising emissions from contrasting N sources

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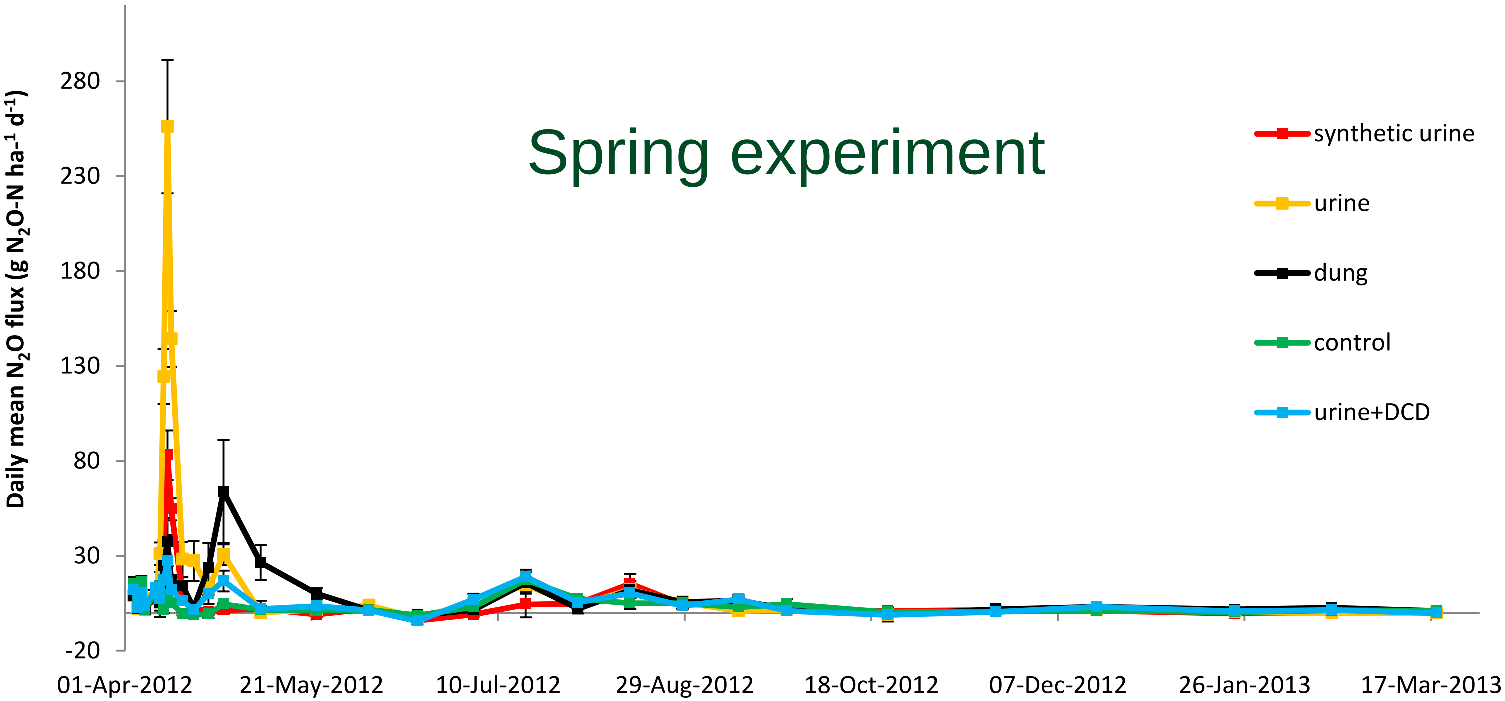
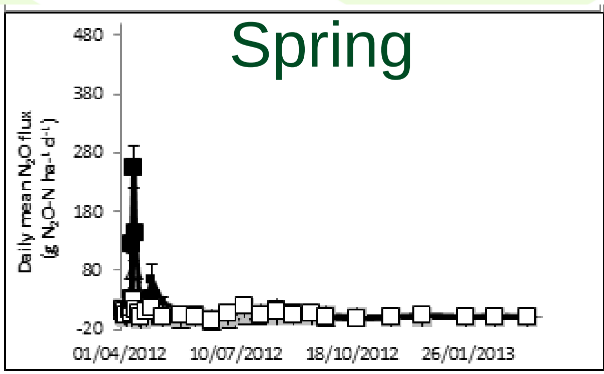
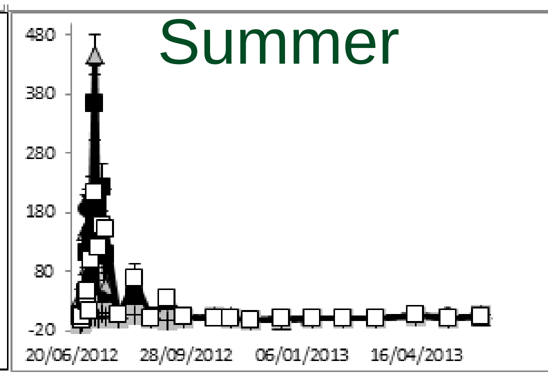
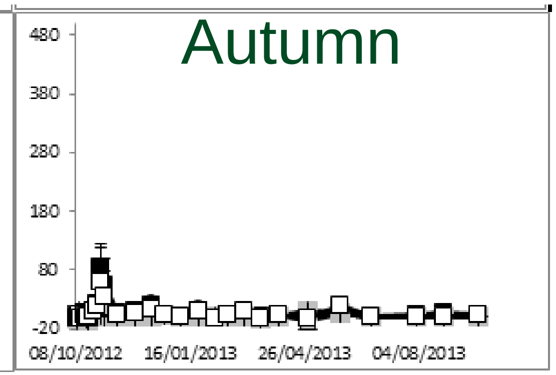








Bell et al, 2016. Geoderma, 264, 81-93

Decision support to manage grazing

T van der Weerden, S Laurenson, I Vogeler, P Beukes,
S Thomas, R Rees, C Topp, G Lanigan, C de Klein. AgResearch, New Zealand. Plant and Food Research, New Zealand. Scotland's Rural College, UK Teasgasc Ireland

Setting the rules

Assess background environment

Monitor soil wetness and compare against threshold values

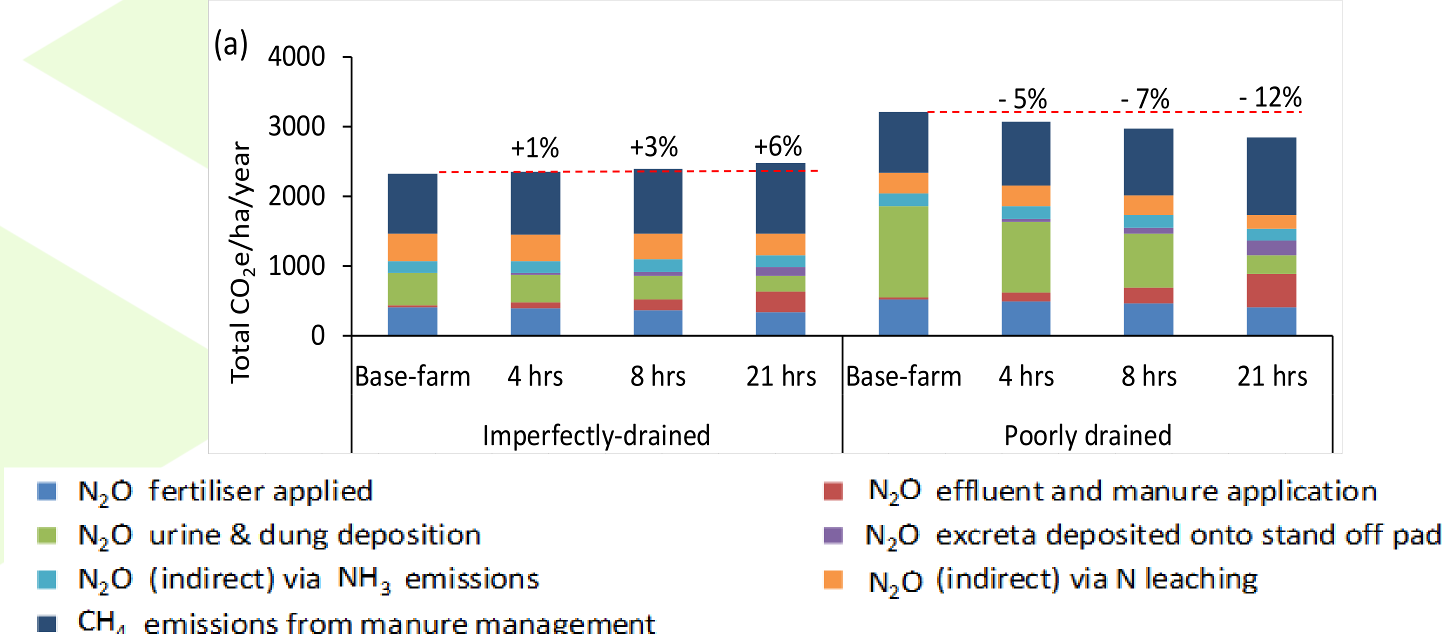
Move cattle when soil wetness exceeds threshold value

van der Weerden et al, 2017 Agricultural Systems, 156, 126-138

Decision support approach

Imperfectly drained		Poorly drained	
If VWC ≤ CWC	If VWC > CWC	If VWC ≤ CWC	If VWC > CWC
Safe to graze	Remove stock	Safe to graze	Remove stock

VWC = soil water content, on a volumetric basis; CWC = critical water content, for imperfectly drained soils CWC= 105% of field capacity (FC) and for poorly drained soils CWC = 85% of field capacity (FC).



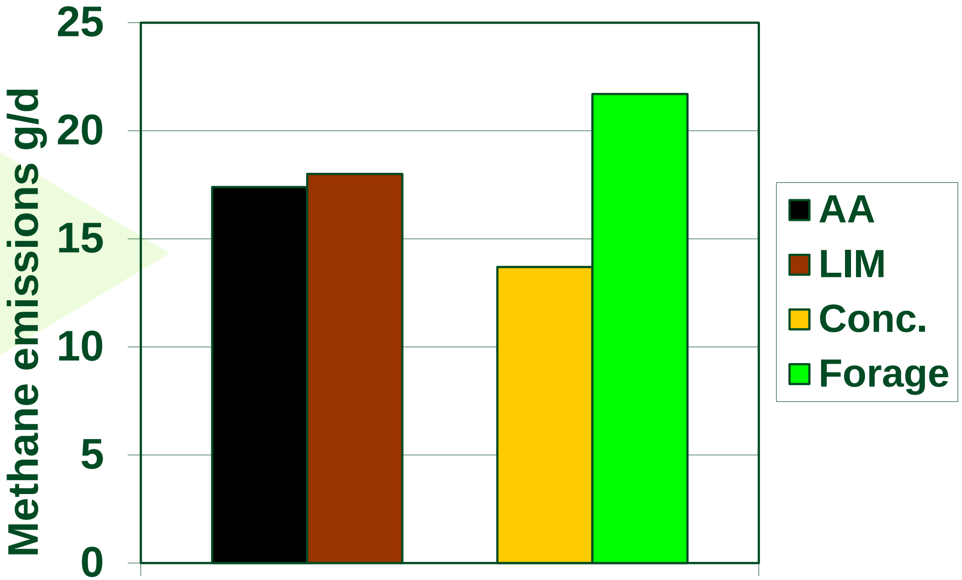
van der Weerden et al, 2017 Agricultural Systems, 156, 126-138.

Enteric Fermentation

- Major global anthropogenic source (90 Tg/y)
- Ruminants are large CH_4 emitters

- **Mitigation**
  - Improve feed use efficiency
  - Optimise genotype to environment
  - Reduce animal numbers and intensify to maintain productive output

Methane mitigation in livestock



Waterhouse et al, 2015

Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt

4 PER 1000

CARBON SEQUESTRATION IN SOILS FOR FOOD SECURITY AND THE CLIMATE

The quantity of carbon contained in the **atmosphere** increases by **4.3** billion tons every year

+4.3 bn tons carbon / year

CO_2 emissions

Forests ⊖⊖

Oceans ⊖⊖

Human activities ⊕⊕⊕⊕

Deforestation ⊕

⊖ *absorption* ⊕ *emission*

The world's **soils** contain **1 500** billion tons of carbon in the form of organic material

absorption of CO_2 by plants

storage of organic carbon in soils

1 500 bn tons carbon

If we increase by 4‰ (0.4%) a year the quantity of carbon contained in soils, **we can halt the annual increase in CO_2 in the atmosphere,** which is a major contributor to the greenhouse effect and climate change

increased absorption of CO_2 by plants :

farmlands, meadows, forests…

+4‰ carbon storage in the world's soils

= more fertile soils

= soils better able to cope with the effects of climate change

Emissions

HOW CAN SOILS STORE MORE CARBON?

The more soil is covered, the richer it will be in organic material and therefore in carbon.
Until now, the combat against global warming has largely focused on the protection and restoration of forests.
In addition to forests, we must encourage more plant cover in all its forms.

- *Never leave soil bare and work it less, for example by using no-till methods*
- *Introduce more intermediate crops, more row intercropping and more grass strips*
- *Add to the hedges at field boundaries and develop agroforestry*
- *Optimize pasture management – with longer grazing periods, for example*
- *Restore land in poor condition e.g. the world's arid and semi-arid regions*

*"This international initiative can reconcile the aims of **food security** and the **combat against climate change,** and therefore engage every concerned country in COP21."*

Stéphane Le Foll, French Minister of Agriculture, Agrifood and Forestry

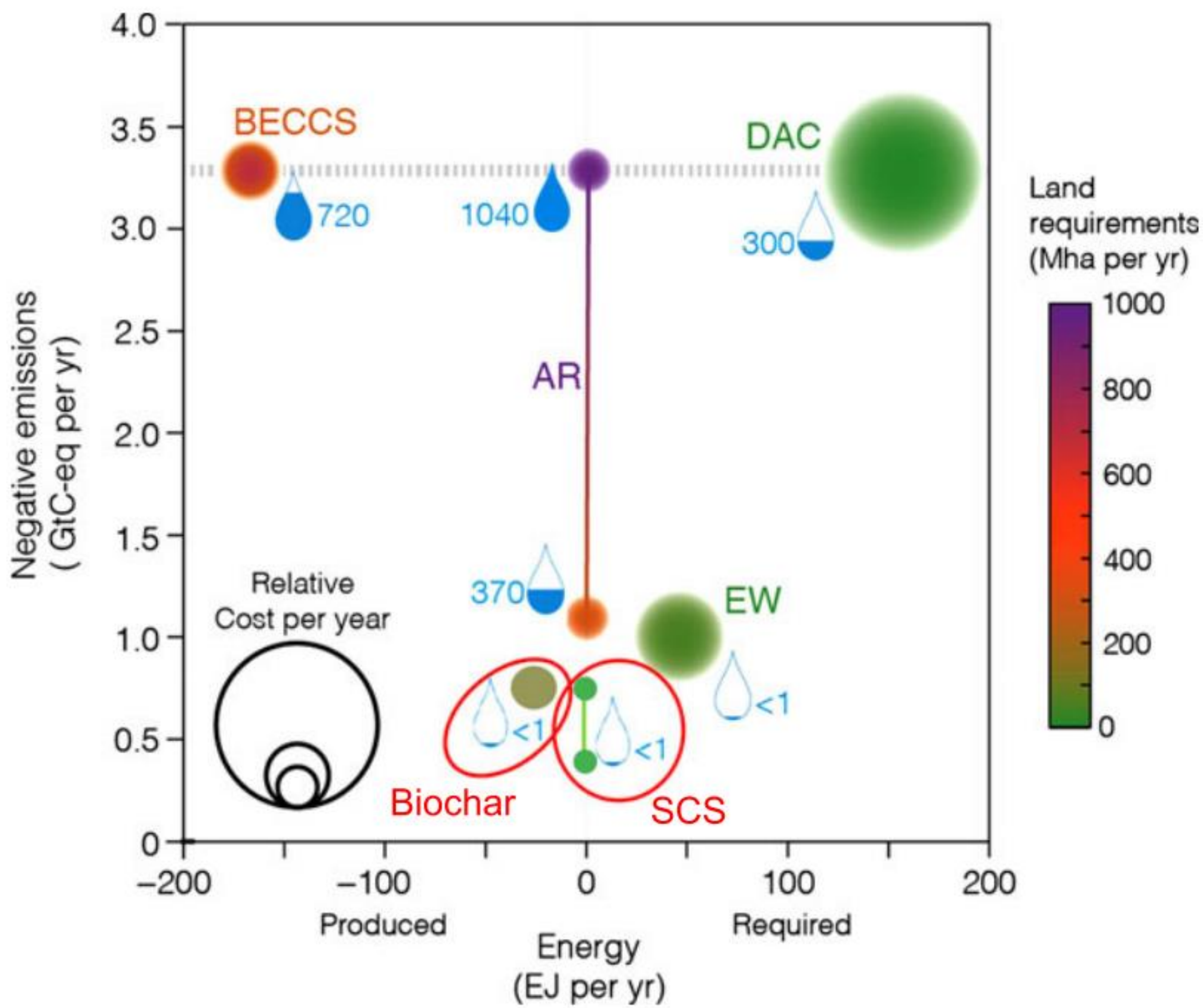
Is 4 per mil achievable?

- Where will it happen?
- How will we know it is happening?
- What measures are we need to undertake to achieve it?
- What are the costs and co-benefits?

Why soil carbon sequestration?

Contending GGRTs

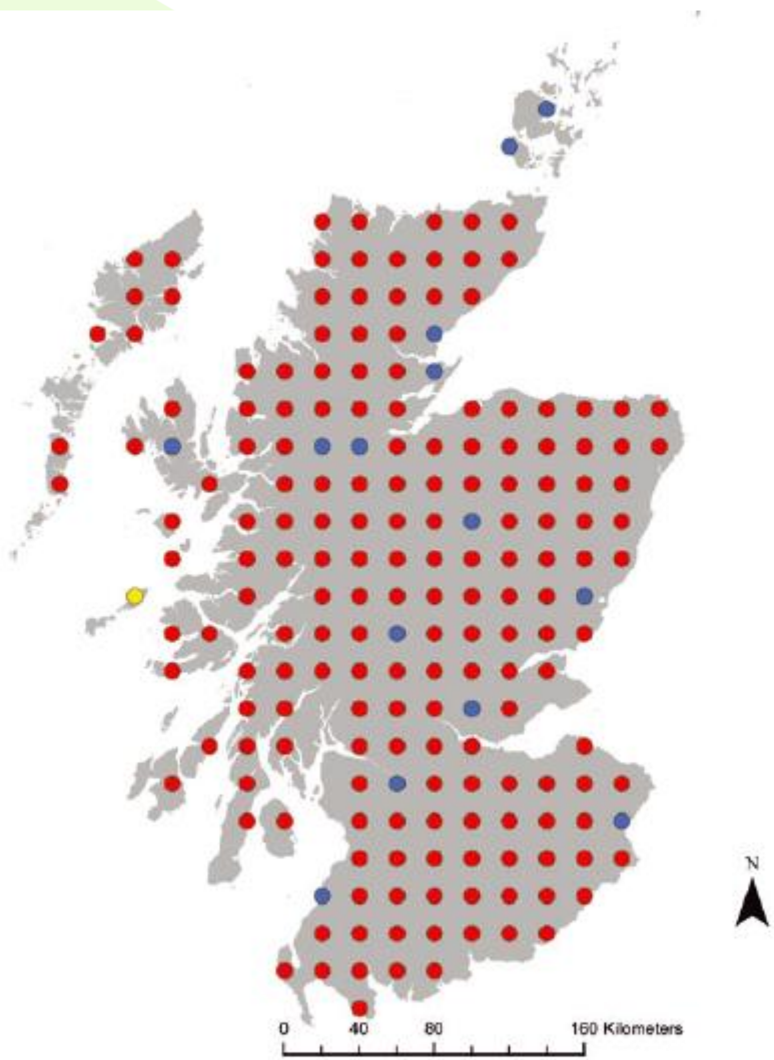
- Bioenergy with Carbon Capture and Storage (BECCS)
- Direct Air Capture (DAC)
- Enhanced Weathering (EW)
- Afforestation/ reforestation (AR)

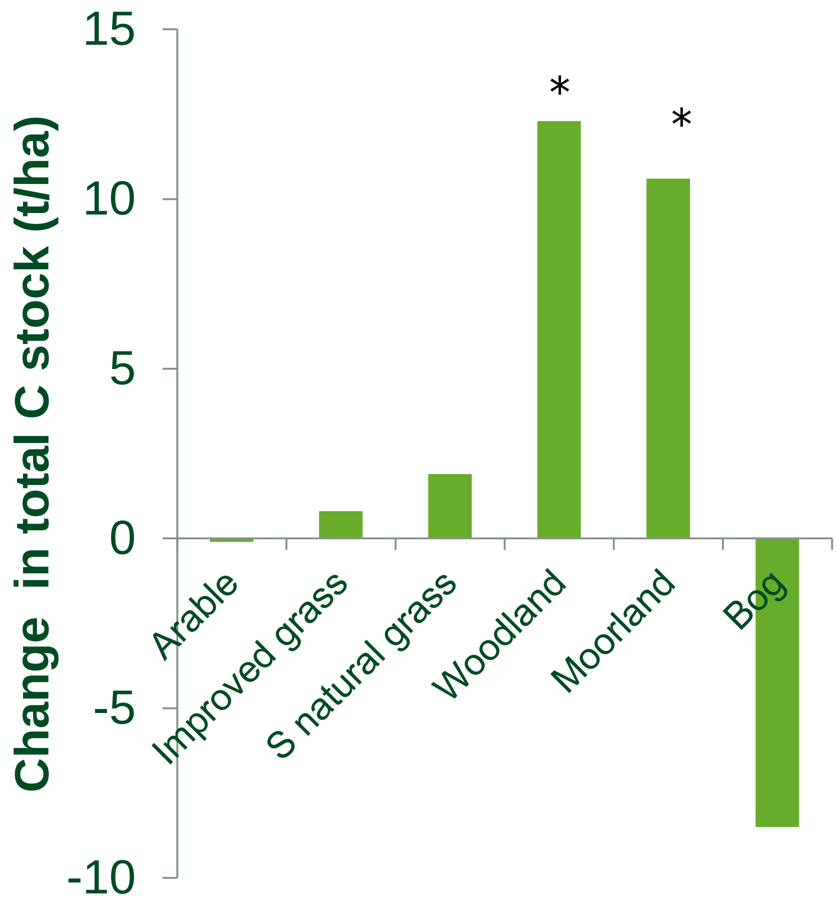


Source: Smith, P. (2016) Soil carbon sequestration and biochar as negative emission technologies. *Global Change Biology* 22, 1315-1424

How will we know it is happening?

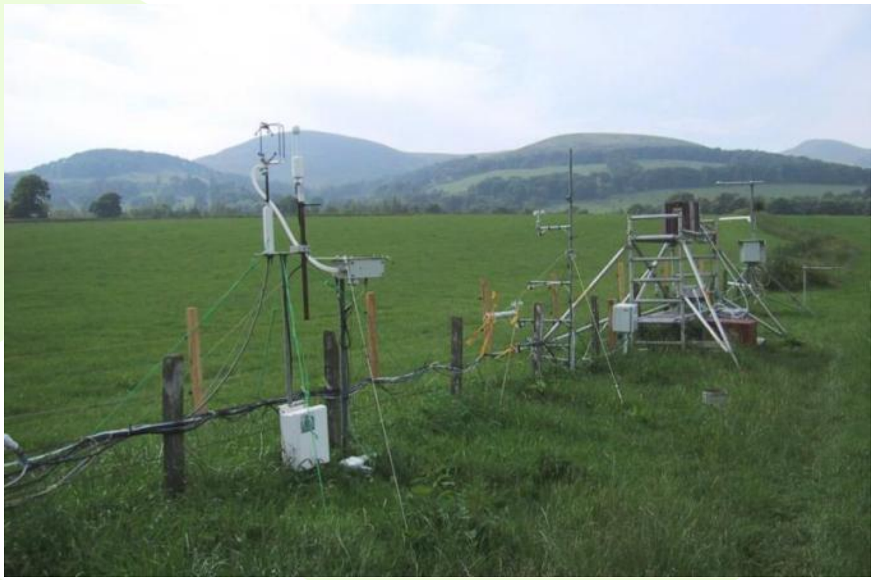
Changes in soil carbon in Scotland 1978-2009





Lilly *et al*. 2013. European Journal of Soil Science, 64, 455-465

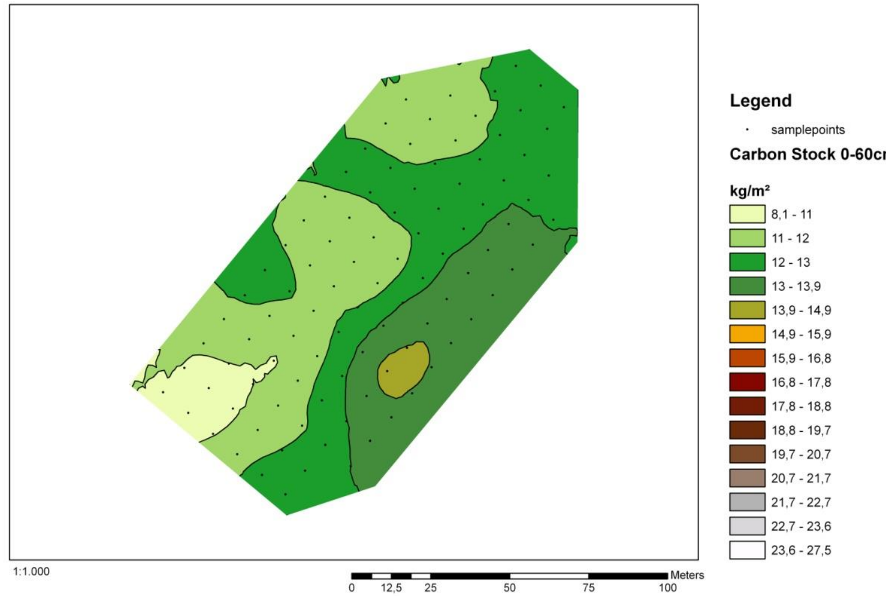
How will we know it is happening? Detailed nutrient cycling studies



Flux measurements

(- export of cut grass, meat, wool, C leaching, CH_4)

-180 (+/- 180) g C m^{-2} y^{-1}

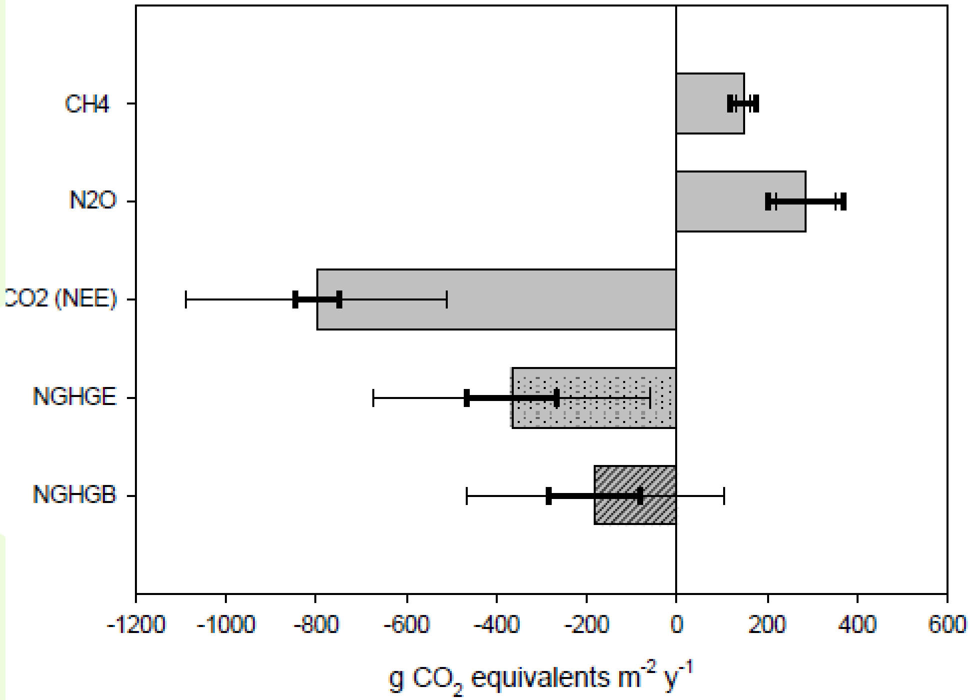


Carbon stock change (repeated soil cores)

29 (+/38) g C m^{-2} y^{-1}

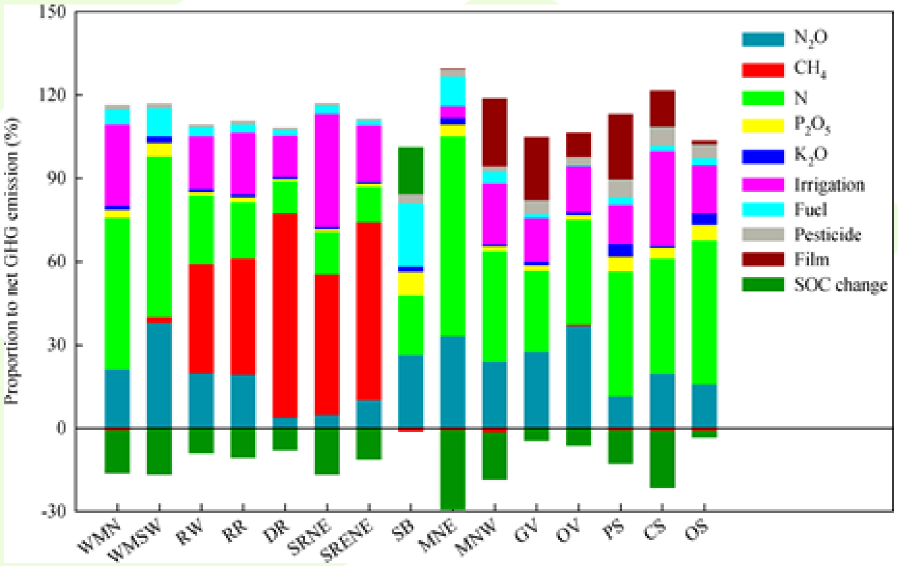
Jones *et al*. Biogeosciences 2017, 14, 2069-2088

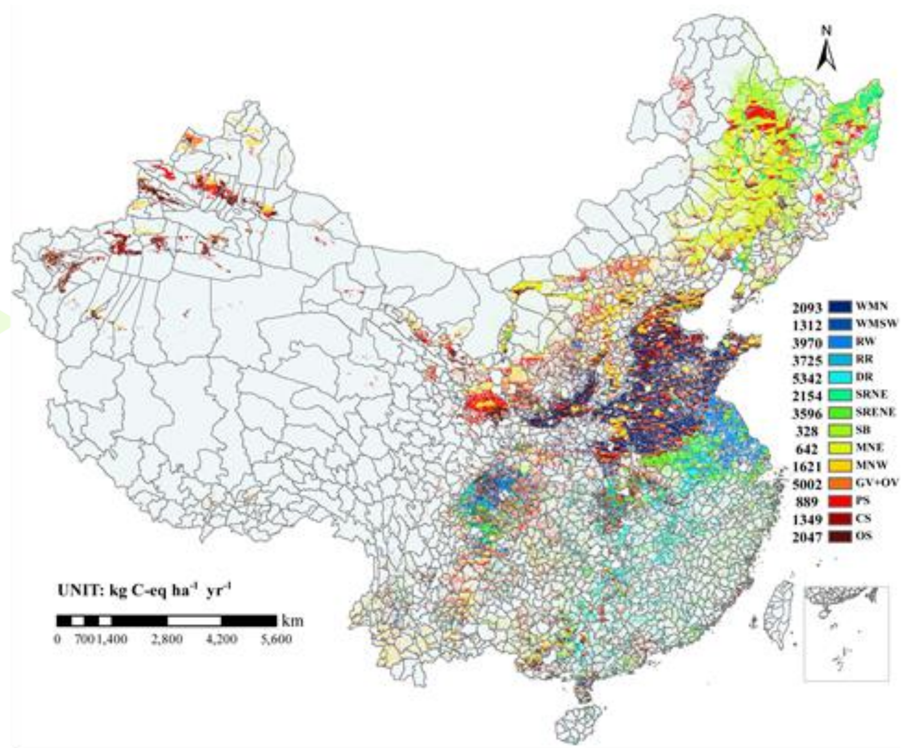
Net greenhouse gas balance for a grazed grassland



Easter Bush, 2002-2008. Jones *et al*, Biogeosciences 2017 14, 2069-2088

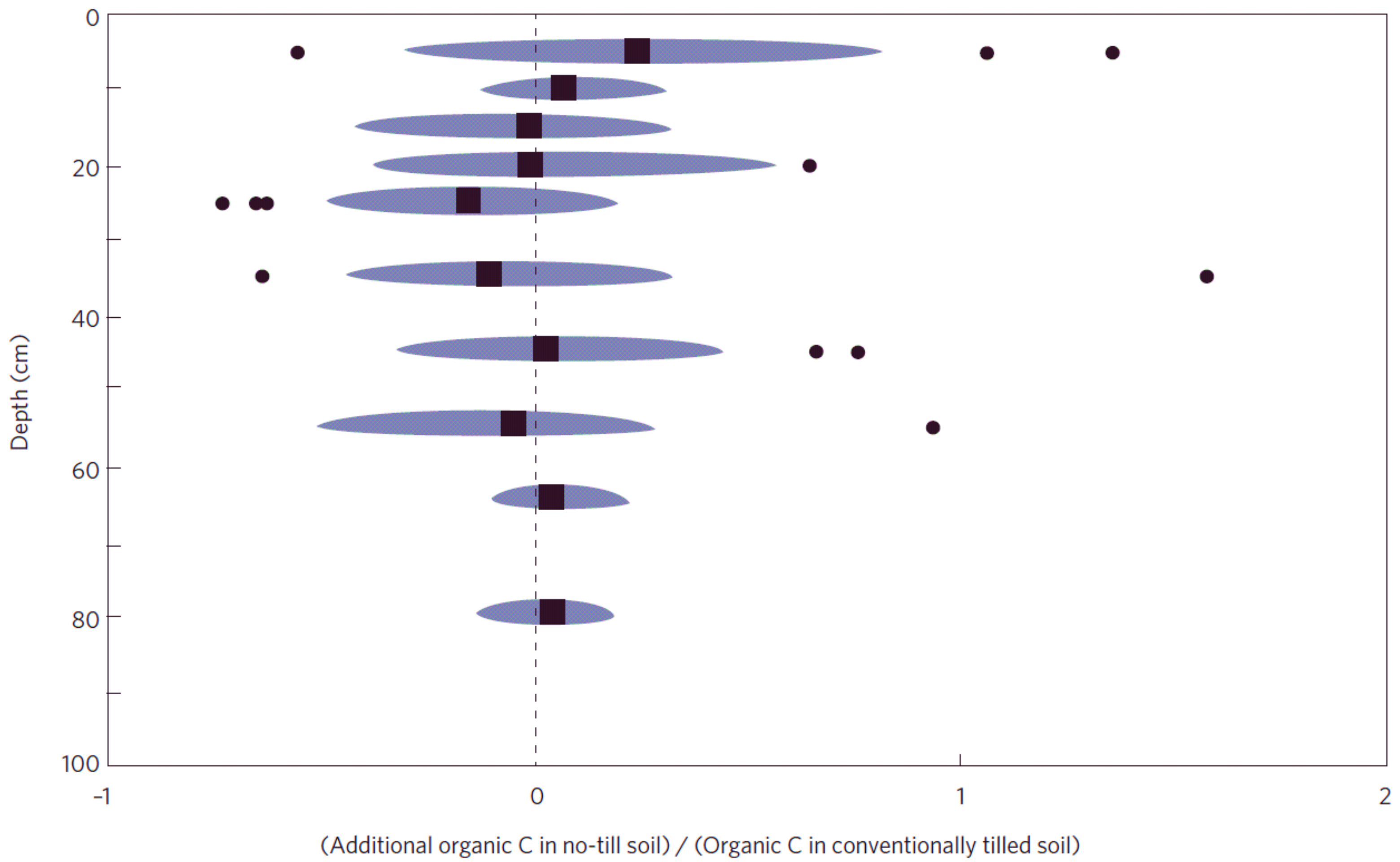
Carbon sequestration can be small relative to total net GHG emissions





Gao et al, 2018, Global Change Biology

What measures are needed?
reduced tillage



Powlson *et al*, 2014. Nature Climate Change, 4, 678-683

4 per mil provides opportunities and challenges

- Opportunities
  - Low cost GHG mitigation
  - Co-benefits in terms of soil fertility, resilience and crop productions
  - Widespread opportunity
- Challenges
  - Reversibility of carbon storage and carbon saturation
  - Implied nitrogen costs
  - Non-CO_2 emissions
  - Verification

Conclusions

- There is an urgent need to reduce greenhouse gas emissions from agricultural systems
- Increasing efficiency can reduce emissions and emission intensities
- Nitrogen management will play a particularly important role in reducing N_2O emissions
- In order to achieve Paris targets there will need to be significant removal of CO_2 from the atmosphere by 2050
- We are likely to depend upon both supply and demand side measures to achieve policy objectives

Acknowledgements

- Thank you for your attention
- Funding from the Scottish Government, UK Research Councils and the EU is gratefully acknowledged