bc3
BASQUE CENTRE
FOR CLIMATE CHANGE
Klima Aldaketa Ikergai

summer school 2013

Potential options for mitigation of climate change from agriculture

Agustin del Prado
agustin.delprado@bc3research.org

LAND GHG
LAND_GHG
modeling GHG within and between multifunctional landscapes

EUSKO JAURLARITZA GOBIERNO VASCO
HEZKUNTZA, UNIBERTSITATE ETA IKERKETA SAILA
INGURUMEN, LURRALDE PLANGINTZA, NEKAZARITZA ETA ARRANTZA SAILA
DEPARTAMENTO DE EDUCACIÓN, UNIVERSIDADES E INVESTIGACIÓN
DEPARTAMENTO DE MEDIO AMBIENTE, PLANIFICACIÓN TERRITORIAL, AGRICULTURA Y PESCA

Universidad del País Vasco Euskal Herriko Unibertsitatea

ikerbasque Basque Foundation for Science

ihobe

How does agriculture contribute to GHG emissions

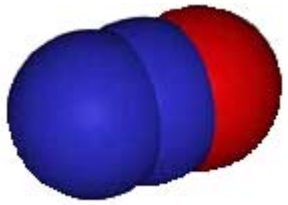
Carbon dioxide (CO_2)

- Decomposition of soil organic matter
- Plant biomass burning
- Burning of fossil fuels

Methane (CH_4)

- Bacterial processes in anaerobic conditions (rice cultivation, enteric, manures, crop residues)

21 times warmer than $CO_{2\ (100yrs)}$

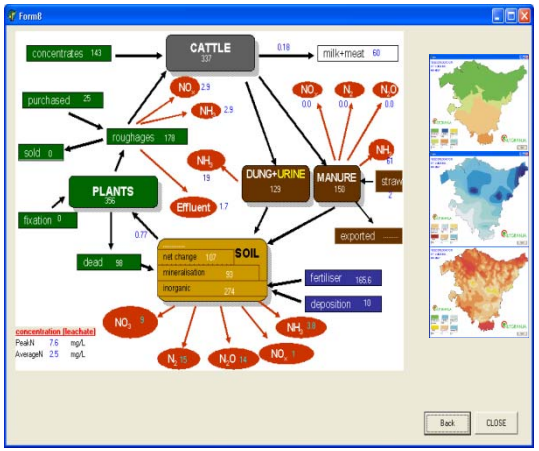


Nitrous oxide (N_2O)

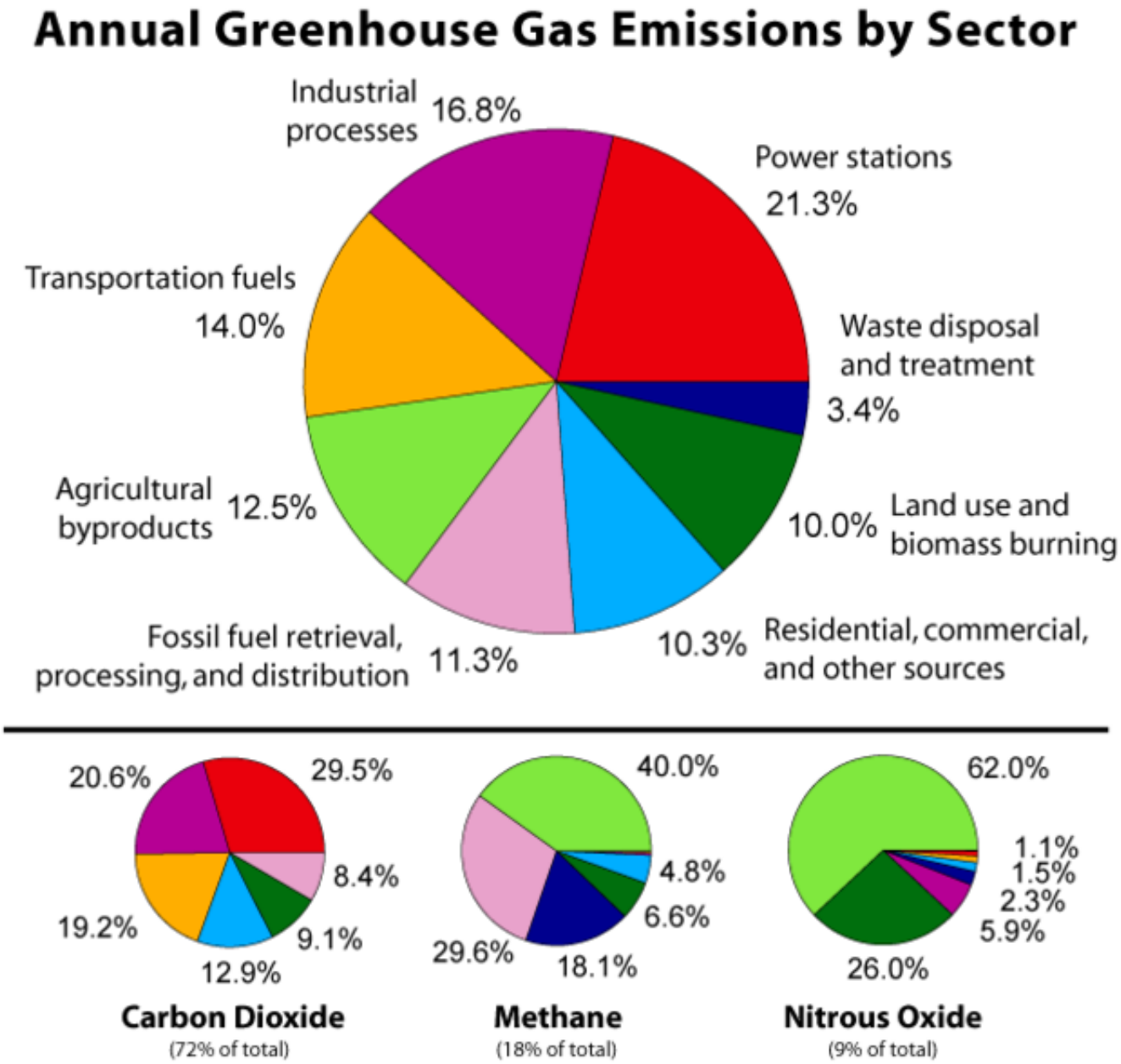
- Bacterial processes in semi-anaerobic conditions (nitrification and denitrification): e.g. after fertilisation, grazing, manure…
- Indirect emissions from Nitrate leaching and NH_3 volatilisation

310 times warmer than $CO_{2\ (100yrs)}$

Quantification of GHG in agriculture is not easy

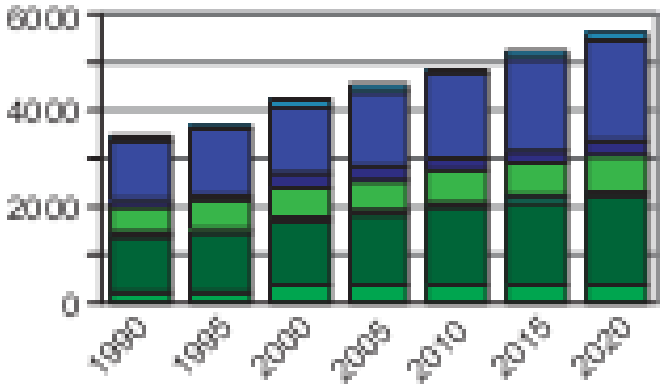


How much agriculture does contribute to GHG emissions?

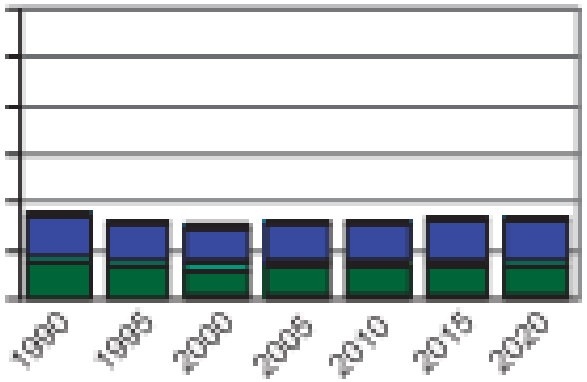


Trends of GHG from agriculture since 1990

Developing regions (Non-Annex I)



Developed regions (Annex I)



- N_2O manure
- N_2O soils
- N_2O burning
- CH_4 rice
- CH_4 manure
- CH_4 enteric
- CH_4 Burning

+32%

1990-2005

-15%

1990-2005

How can agriculture mitigate GHG emissions?

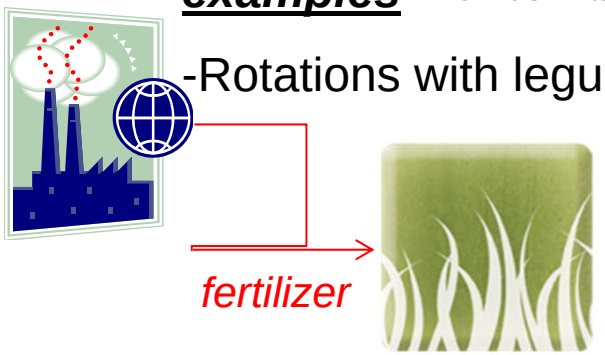
- Reducing emissions
- Enhancing removals
- Avoiding (or displacing emissions)

How can agriculture mitigate GHG emissions?

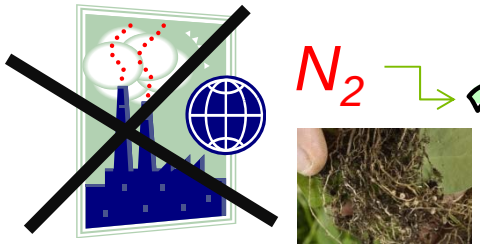
Cropland management

examples *From del Prado et al. (2011)*

-Rotations with legume crops (legume systems fix N from atmosphere)

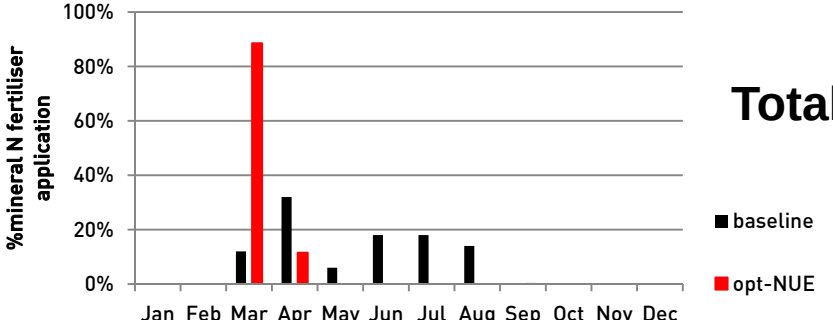


grass

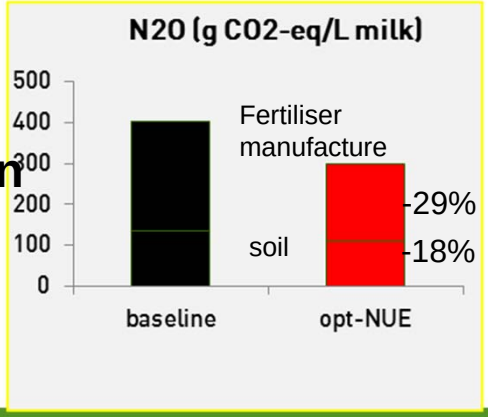


Clover (legume)+grass

-Improving nitrogen use efficiency (fertilizing better)



Total GHG reduction -25%



How can agriculture mitigate GHG emissions?

Cropland management

-Improving soil carbon sequestration

Table 9 Overview of carbon sequestration rates in European grassland

Observed effect on carbon sequestration in grasslands soil	Net carbon sequestration (−) or emissions (+) in kg CO_2e m^{-2} yr^{-1}	Reference
Increased soil carbon storage under grass with liming	−2.0 to +0.33	Fornara *et al.* (2011)
Variable soil carbon storage in a review of a range of studies	−1.3 to +0.6	Soussana *et al.* (2010)
Treatments with and without *T. pratense*, seed addition and fertilizer use	−1.2 to +0.03	De Deyn *et al.* (2011)
Carbon input by roots depending on plant diversity	−1.5 to −0.21	Steinbeiss *et al.* (2008)
Predicted range of European grassland carbon balance	−0.6 to +0.2*	Janssens *et al.* (2005)
Conversion from cropland to pasture	−0.37	Conant *et al.* (2001)
Net soil carbon sequestration increases with plant diversity	−0.3 to +0.05†	Tilman *et al.* (2006)
Net root carbon sequestration increases with plant diversity	−0.2 to −0.06	Tilman *et al.* (2006)
Carbon sequestration after conversion of arable cropland to grassland	−0.18	Soussana *et al.* (2004)
Improved grazing	−0.13	Conant *et al.* (2001)
Fertilization	−0.11‡	Conant *et al.* (2001)
Reduction of nitrogen input	−0.11§	Soussana *et al.* (2004)
Conversion to grass legume mixtures	−0.11 to −0.18	Soussana *et al.* (2004)
Short duration leys to permanent grassland	−0.11 to −0.15	Soussana *et al.* (2004)
Increasing duration of leys	−0.07 to −0.18	Soussana *et al.* (2004)

*Only in Portugal grassland was a net source, potentially due to climate.
†Monoculture.
‡But net GHG emissions when considering emissions from fertilizer production and application.
§in highly intensive grass leys.

Bellarby *et al.* (2013)

How can agriculture mitigate GHG emissions?

Livestock and manure management

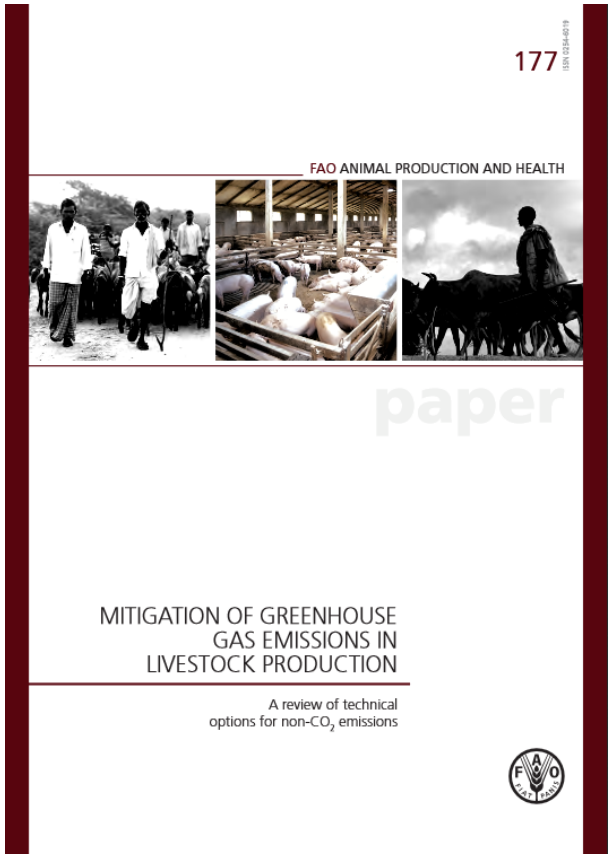


TABLE A2
Manure handling strategies offering non-CO_2 greenhouse gas mitigation opportunities

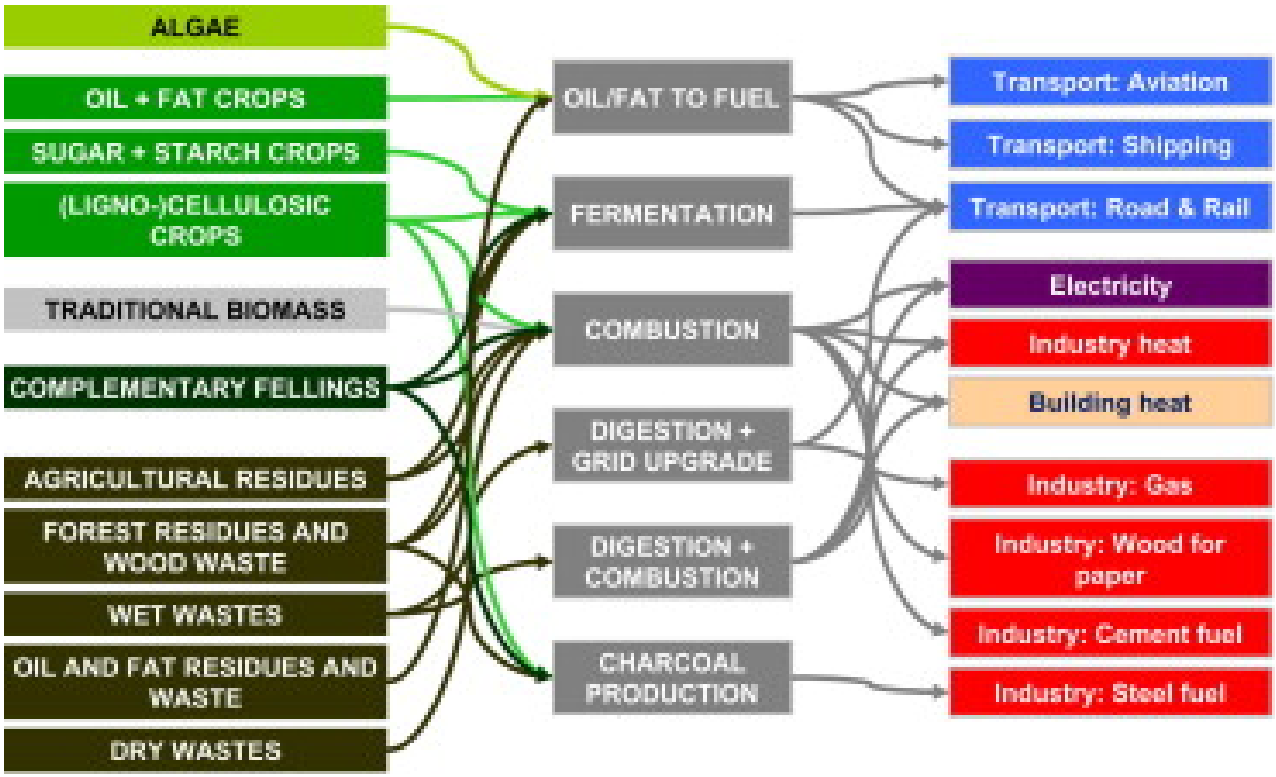
Category	Species[1]	Potential CH_4 mitigating effect[2]	Potential N_2O mitigating effect[3]	Potential NH_3 mitigating effect[3]	Effective[4]	Recommended[5]	Applicability to region[6]
Dietary manipulation and nutrient balance							
Reduced dietary protein	AS	?[6]	Medium	High	Yes (N_2O, NH_3)	Yes (N_2O, NH_3)	All
High fibre diets	SW	Low	High	?	Yes (N_2O)	Yes (N_2O)	All
Grazing management							
Grazing intensity[7]	AR	?	High?[7]	?[7]	Yes (N_2O)	Yes (N_2O)	All
Housing							
Biofiltration	AS	Low?	?	High	Yes (NH_3, CH_4?)	Yes (NH_3, CH_4?)	All
Manure system[8]	DC, BC, SW	High	?	High	Yes (CH_4, NH_3)	Yes (CH_4, NH_3)	All
Manure treatment							
Anaerobic digestion	DC, BC, SW	High	High[9]	Increase?[10]	Yes (CH_4, N_2O)	Yes (CH_4, N_2O)	All
Solids separation	DC, BC	High	Low?[9]	?[11]	Yes (CH_4)	Yes (CH_4)	NA,SA,EU, OC
Aeration	DC, BC	High	Increase?[12]	?[12]	Yes (CH_4)	Yes (CH_4)	NA,SA,EU
Manure acidification	DC, BC, SW	High	?[13]	High[13]	Yes (CH_4, NH_3)	Yes (CH_4, NH_3)	NA,EU,OC
Manure storage							
Decreased storage time	DC, BC, SW	High[14]	High[14]	High[14]	Yes (all)	Yes (all)	All
Storage cover with straw	DC, BC, SW	High	Increase?[15]	High	Yes (CH_4, NH_3)	Yes (CH_4)	NA,EU
Natural or induced crust	DC, BC	High	Increase?[15]	High	Yes (CH_4, NH_3)	Yes (CH_4)	NA,EU
Aeration during liquid manure storage	DC, BC, SW	Medium to High	Increase?[12]	?[12]	Yes (CH_4)	Yes (CH_4)	NA,EU
Composting	DC, BC, SW	High	?[12]	Increase[12]	Yes (CH_4)	Yes (CH_4)	All
Litter stacking	PO	Medium	N/A	?	Yes (CH_4)	Yes (CH_4)	All
Storage temperature	DC, BC	High	?	High	Yes (CH_4, NH_3)	Yes (CH_4, NH_3)	N/A[16]
Manure application							
Manure injection vs surface application	DC, BC, SW	No effect to increase?	No effect to increase[18]	High	Yes (NH_3)	Yes (NH_3)	NA,EU,OC
Timing of application	AS	Low	High[19]	High	Yes (N_2O, NH_3)	Yes (N_2O, NH_3)	All
Soil cover, cover cropping	AS	?	No effect to High[20]	Increase?[21]	Yes (N_2O?)	Yes (N_2O?)	All
Soil nutrient balance	AS	N/A	High	High	Yes (N_2O, NH_3)	Yes (N_2O, NH_3)	All
Nitrification inhibitor[22]							
Applied to manure or after urine deposition in pastures	DC, BC, SH	N/A	High	N/A	Yes (N_2O)	Yes (N_2O)?	All[23]

(Cont.)

http://www.fao.org/docrep/018/i3288e/i3288e.pdf

How can agriculture mitigate GHG emissions?

Bioenergy



Bioenergy

Biomass as energy feedstock produced in agricultural land may cause indirect emissions reductions of up to 1,260 MtCO_2-e/yr by 2030 (at $ 20/t CO_2e)

Associated impacts: competition with other land and water uses, environmental impacts (C-debt), implications for food security

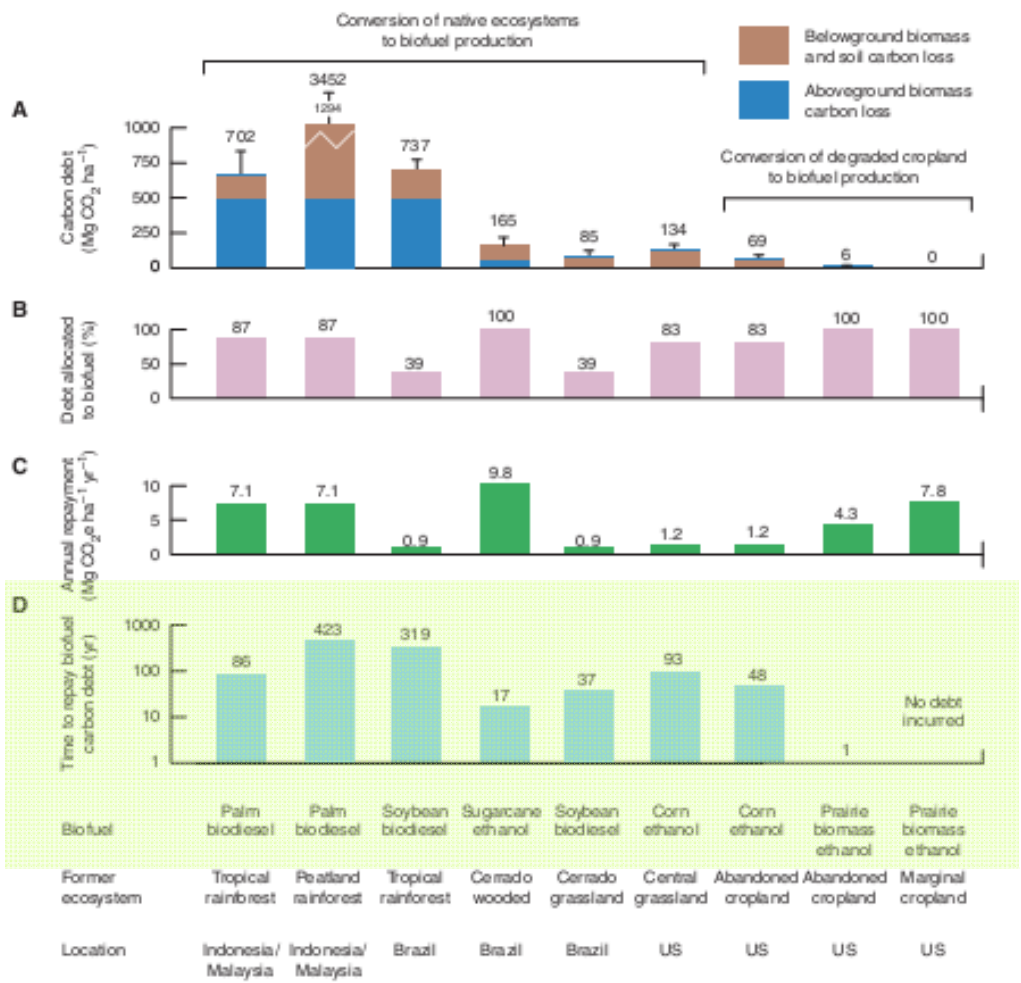
The carbon debt

GHG savings by using the biofuel instead of a traditional fossil fuel (***$GHG_{savings}$***).
GHG released during the production of the crop (***GHG_{crop}***).

Carbon debt (years)= ***GHG_{crop} / $GHG_{savings}$***

For example, if biofuel from a crop of soybeans would reduce carbon emissions by 1 ton each year, but the production of the biofuel would release 10 tons of carbon emissions, the biofuel's carbon debt would be 10 years.

Example: energy and GHG from bioenergy crops



Converting land to produce food crop-based biofuels creates a large "biofuel C debt" by releasing 17-420 times more CO_2 than the GHG reduction they provide displacing fossil fuels

Fargione *et al.* (2008) Science

How can agriculture mitigate GHG emissions?

The main findings of the IPCC AR4 assessment

Carbon price ($/t$CO_2$-e)		Mitigation potential (average) (Gt CO_2-e/yr)
20		*1.6*
50		*2.7*
100		*4.4*
Emissions in 2030		8.2

Main potential:
C sequestration
in cropland/grassland

11-17% of total mitigation potential

How can agriculture mitigate GHG emissions?

The Kyoto Protocol does not consider this potential

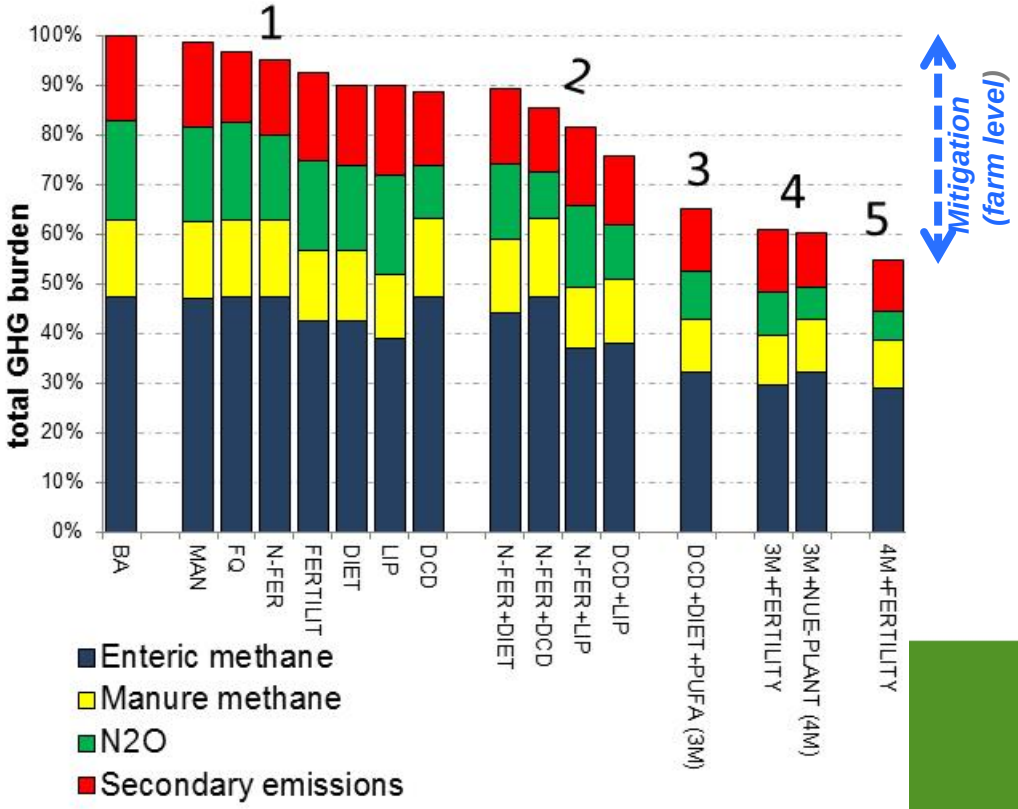
- 70% of mitigation potential is in developing countries (non-Annex-1)
- Cropland/grassland management is not selected under Art 3.4
- C leakage?

How can agriculture mitigate GHG emissions?

Some limitations of the IPCC AR4 assessment

- Mitigation potential for livestock may have been underestimated (unit of reference)
- Uncertainties remain very high
- Synergies/trade-offs between mitigation options may have not been captured

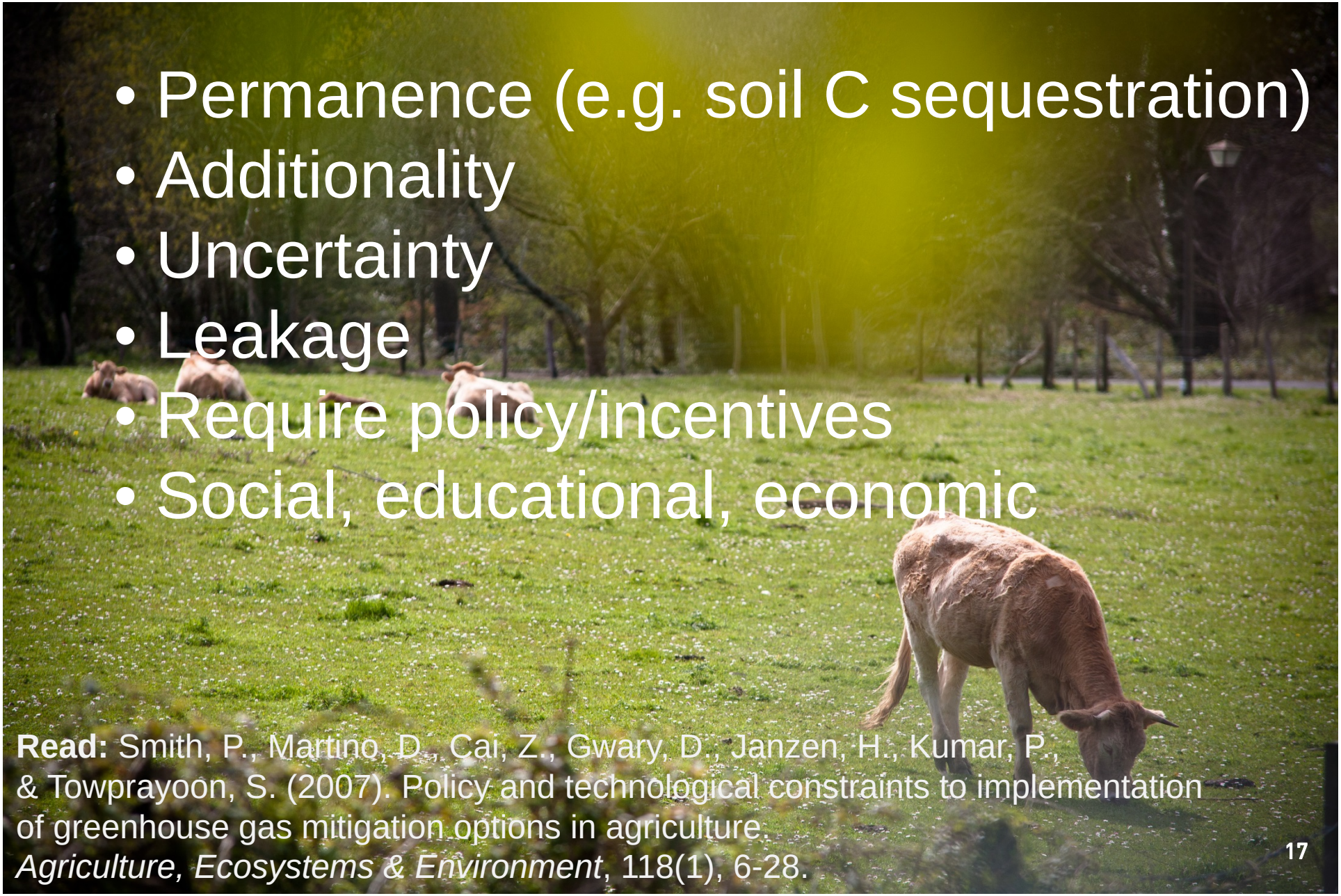
Mitigation measures introduced singly (1) or in combination (2, 3, 4 and 5)



-Measures applied in combination may have interactions amongst each other.

from del Prado K-N presentation at GGAA2013

Barriers of implementation of GHg mitigation measures

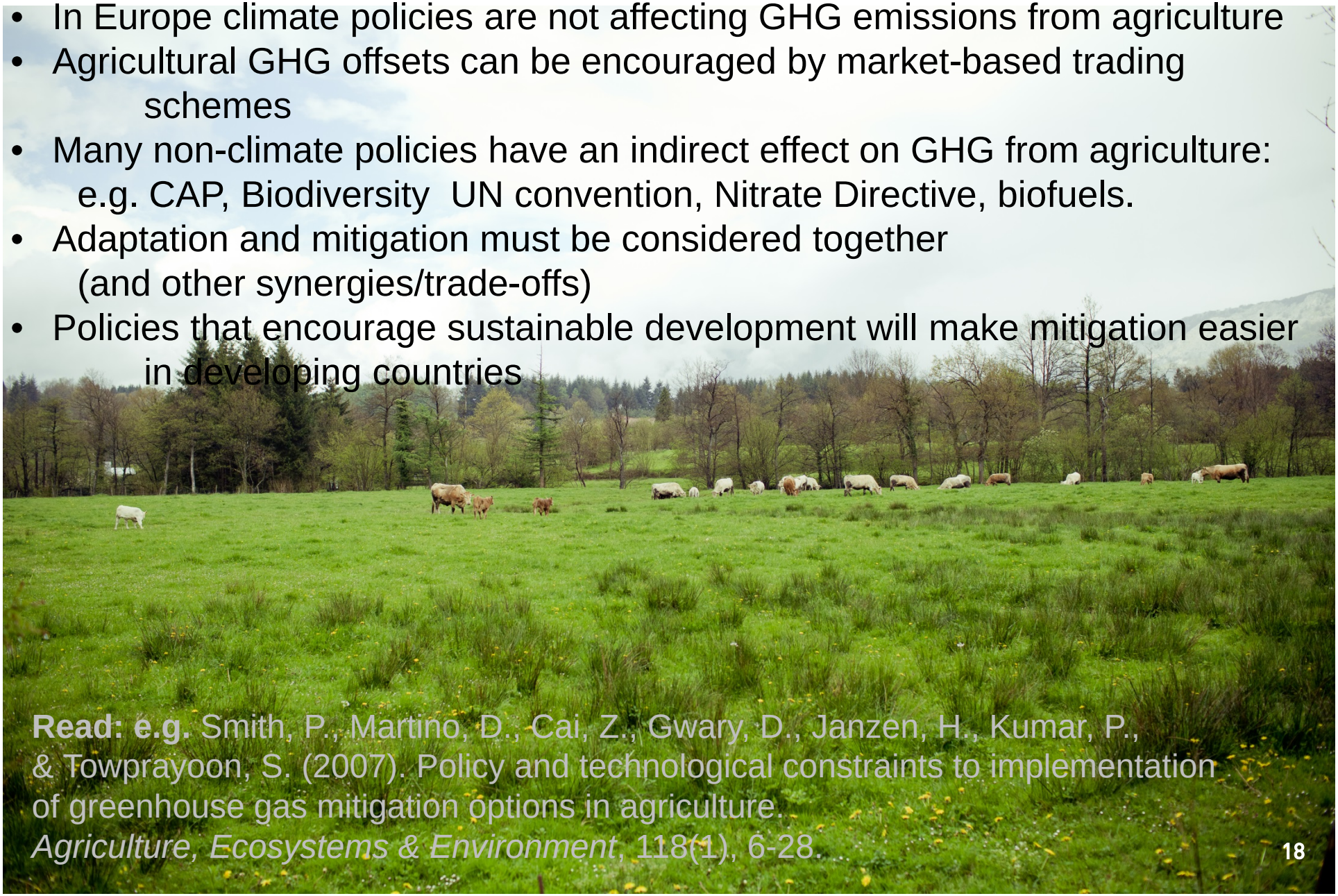


- Permanence (e.g. soil C sequestration)
- Additionality
- Uncertainty
- Leakage
- Require policy/incentives
- Social, educational, economic

Read: Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., & Towprayoon, S. (2007). Policy and technological constraints to implementation of greenhouse gas mitigation options in agriculture. *Agriculture, Ecosystems & Environment*, 118(1), 6-28.

Policies

- In Europe climate policies are not affecting GHG emissions from agriculture
- Agricultural GHG offsets can be encouraged by market-based trading schemes
- Many non-climate policies have an indirect effect on GHG from agriculture: e.g. CAP, Biodiversity UN convention, Nitrate Directive, biofuels.
- Adaptation and mitigation must be considered together (and other synergies/trade-offs)
- Policies that encourage sustainable development will make mitigation easier in developing countries



Read: e.g. Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., & Towprayoon, S. (2007). Policy and technological constraints to implementation of greenhouse gas mitigation options in agriculture. *Agriculture, Ecosystems & Environment*, 118(1), 6-28.

Climate-smart Agriculture

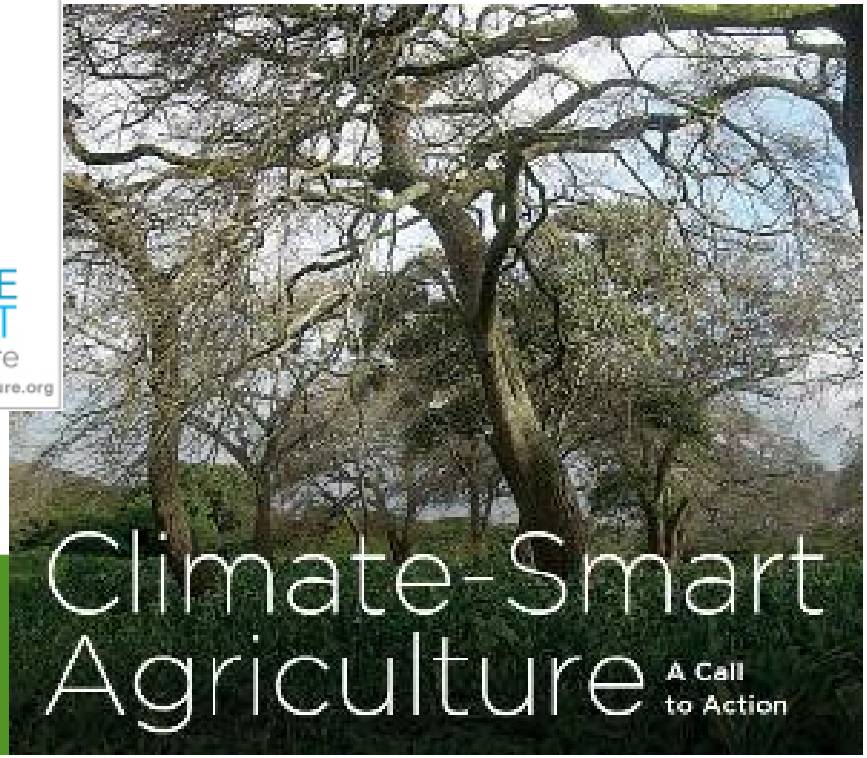
Agriculture that sustainably:

- increases productivity
- increases resilience (adaptation)
- reduces/removes GHGs

AND

- enhances achievement of national food security and development goals

CLIMATE SMART Agriculture
climatesmartagriculture.org



How does FOOD PRODUCTION contribute to GHG emissions?

One-third of our greenhouse gas emissions come from agriculture : Nature News & Comment - Mozilla Firefox

www.nature.com/news/one-third-of-our-greenhouse-gas-emissions-come-from-agriculture-1.11708

Home | News & Comment | Research | Careers & Jobs | Current Issue | Archive | Audio & Video | For Authors

News & Comment > News > 2013 > July > Article

Nature's news team scoop two prizes at journalism awards — Find out more

NATURE | NEWS

One-third of our greenhouse gas emissions come from agriculture

Farmers advised to abandon vulnerable crops in face of climate change.

Natasha Gilbert

31 October 2012

The global food system, from fertilizer manufacture to food storage and packaging, is responsible for up to one-third of all human-caused greenhouse-gas emissions, according to the latest figures from the Consultative Group on International Agricultural Research (CGIAR), a partnership of 15 research centres around the world.

Agricultural production is the main emitter of carbon dioxide in the global food system.
A. SACKS/GETTY

In two reports published today[1, 2], the CGIAR says that reducing agriculture's carbon footprint is central to limiting climate change. And to help to ensure food security, farmers across the globe will probably have to switch to cultivating more climate-hardy crops and farming practices.

"The food-related emissions and the impacts of climate change on agriculture and the food system will profoundly alter the way we grow and produce food," says Sonja Vermeulen, a plant scientist at the University of Copenhagen in Denmark and a co-author of one of the studies, which estimates the

print
email
rights & permissions
share/bookmark

Journal home | Subscribe
Current issue | E-alert sign up
For authors | RSS feed

E-alert | RSS | Facebook | Twitter

MACMILLAN SCIENCE COMMUNICATION
Nature-standard editing and advice on your scientific manuscripts

Recent | Read | Commented | Emailed

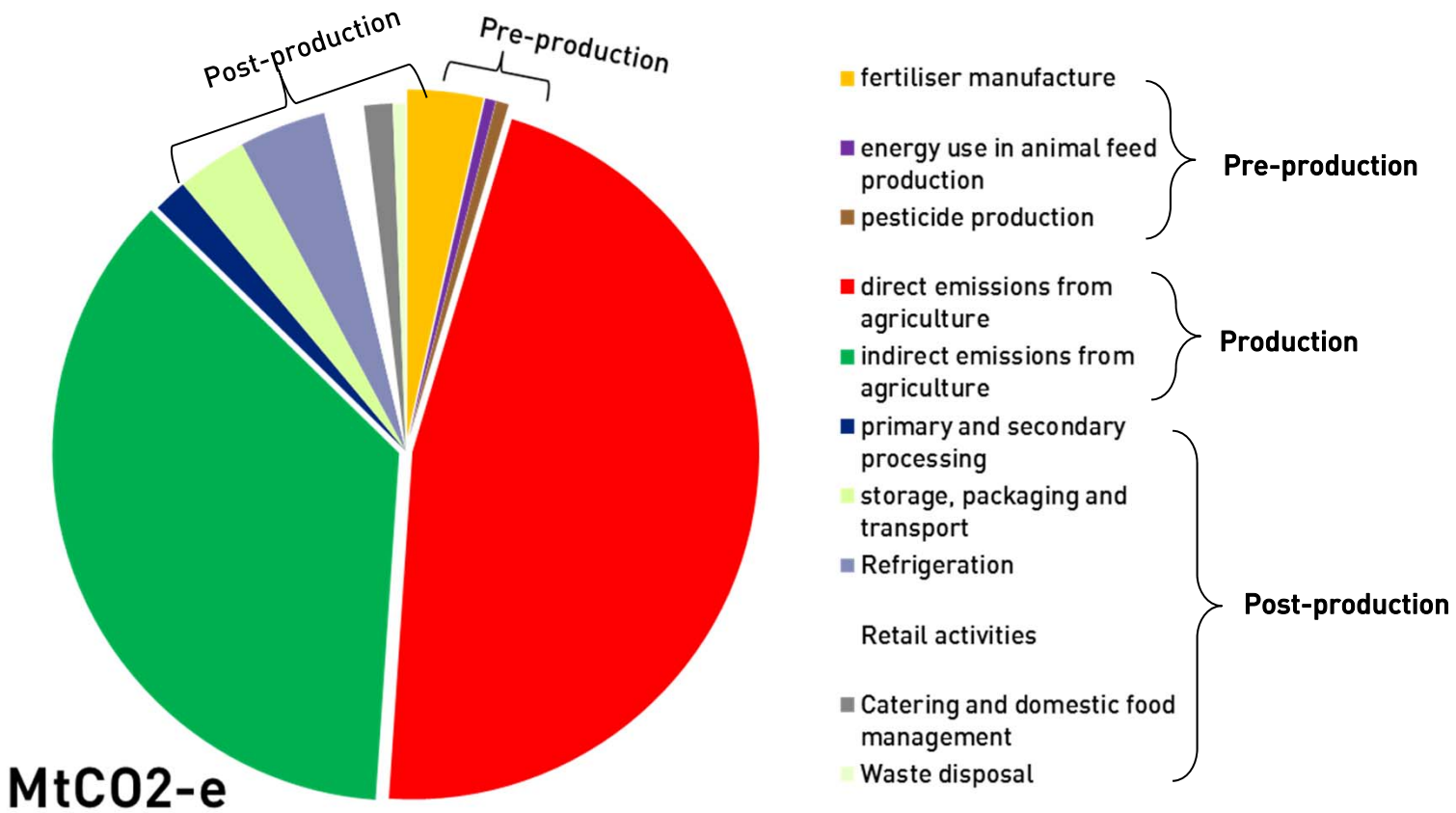
1. US Senate backs immigration plan — *Nature* | 03 July 2013
2. Biology must develop its own big-data systems — *Nature* | 03 July 2013
3. Hawkmoths zap bats with sonic blasts from their genitals — *Nature* | 03 July 2013
4. Evolution makes the grade — *Nature* | 03 July 2013
5. Bioengineers look beyond patents — *Nature* | 03 July 2013

nature 38.597* You pay the new Impact Factor

- Agricultural production
- Manufacturing fertiliser
- Refrigeration
- Indirect emissions from land use changes and deforestation

Vermeulen *et al.* (2012)

How does FOOD PRODUCTION contribute to GHG emissions?



$MtCO_2$-e=12,095 ± 2898

Vermeulen *et al.* (2012)

Nitrogen loss in food waste at consumption

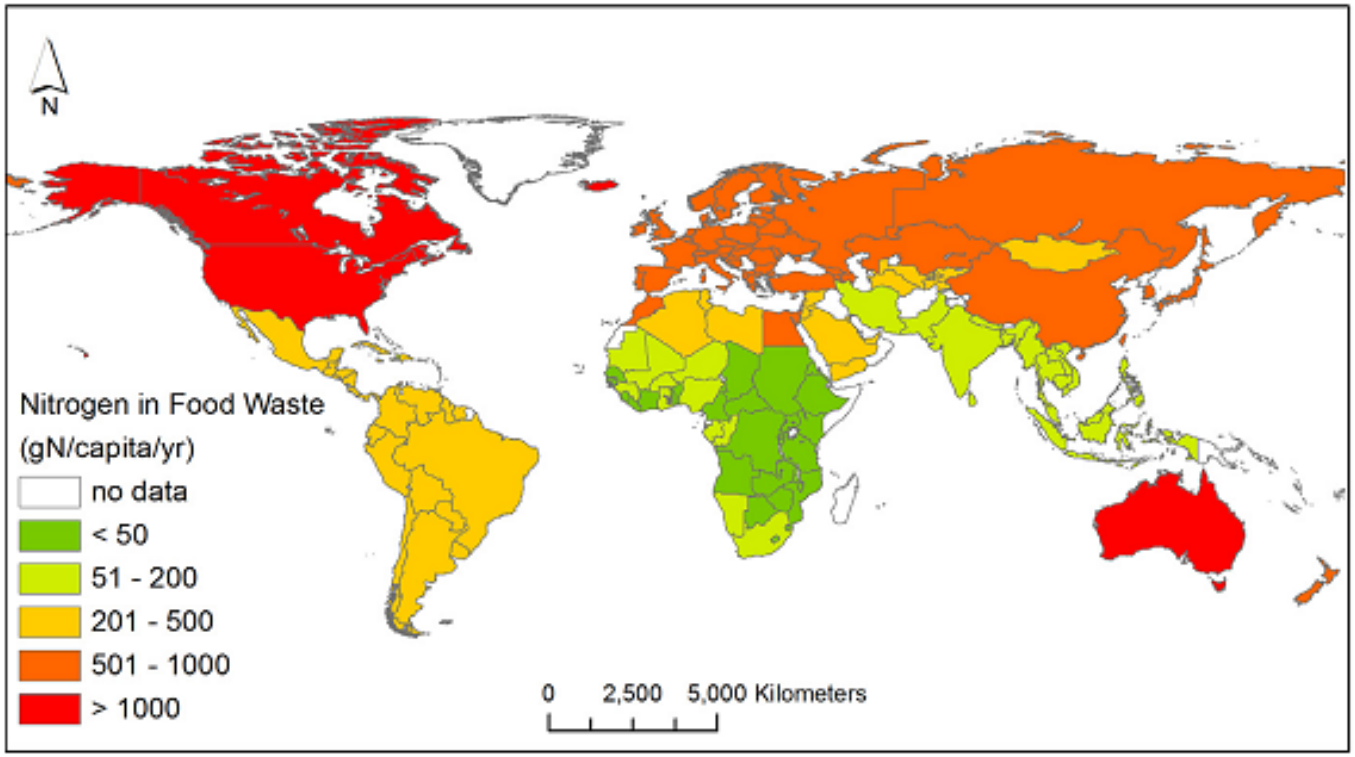


Fig. 1 – Nitrogen loss in food waste at consumption (gN per capita per country, 2007).

Grizzetti *et al.* (2013)

How can we reduce GHG emissions from food production?

Some important facts:

- 1/3 of the food produced in the world for human consumption gets lost or wasted.
- Consumers in rich countries waste almost as much food (222 million t) as the net food production of sub-Saharan Africa (230 million t).
- The amount of food lost or wasted every year is equivalent to more than half of the world's annual cereals crop (2.3 billion t in 2009/2010).
- In developing countries food waste and losses occur mainly at early stages of the food value chain
- In the USA 30% of all food, worth US$48.3 billion (€32.5 billion), is thrown away each year.
- It is estimated that about half of the water used to produce this food also goes to waste
- It is estimated that 20% of food products (8-12.5% of livestock products) go to waste in developed countries. GHGs mitigation potential: 39-79 Mt CO2eq (Bellarby *et al.,* 2013).
- Protein intake in the EU is 70% higher than the levels recommended by the WHO (Bellarby *et al.,* 2013).

Sources:
Global Food Losses and Food Waste - FAO, 2011
The environmental crisis: The environment's role in averting future food crisis – UNEP, 2009
Bellarby J., Tirado R., Leip A., Weiss F., Lesschen J.P. and Smith P. (2013) Livestock greenhouse gas emissions and mitigation potential in Europe. Global Change Biology 19 (1), 3-18.

How can we reduce GHG emissions from food production?

Table 11 Summary of mitigation options (for EU-27)

Description	Emission savings in Mt CO_2e per year	Emission reduction in%*	Reduction in consumption in%
Production related mitigation options			
Choice of production system to grass-fed beef	12–26	2–4	X%
Grassland management	4–10	1–2	0
Consumer-impacted mitigation options			
Eat no beef from South America	22–31†	3–5	4
Eat no meat from European beef suckler herd	67–94	10–14	32–45
One less serving of milk or 20 g less cheese (per week)	15–19	2–3	4
Waste reduction (waste rate of 2.4–3.9%)			
Waste minimization	56–115	8–17	0
Anaerobic digestion of unavoidable waste	14–22	2–3	0
Technical approaches			
Anaerobic digestion of all food waste	46–71	7–11	0
Combined techno-fixes	51–60	8–9	0
Totals‡			
No reduction in consumption§	101–207	15–31	0
Additional reduction in consumption¶	216–377	33–57	32–45

Bellarby *et al.*, 2013

How can we reduce GHG emissions from food production?

- Human diet changes (consumption)
- Reducing losses in the food chain (production, retailers, consumption)

Key messages

summer school 2013

- Agriculture and food production are large contributors to the overall GHG
- Large uncertainties associated to both estimates and mitigation potential
- Cropland management has large mitigation potential for agriculture
- Avoiding food waste and diet change are the best measures to reduce GHG from the entire food chain.
- There are still many barriers to fully implement successful GHG mitigation (e.g policies).

Acknowledgements & questions

GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD
SECRETARÍA DE ESTADO DE INVESTIGACIÓN, DESARROLLO E INNOVACIÓN

grant no. AGL2012-37815-C05-04 (NEREA-5)

EUSKO JAURLARITZA GOBIERNO VASCO
Departamento de Educación, Política Lingüística y Cultura

grant no. PC2010-33A