Department of Environmental Science
AARHUS UNIVERSITY

Restprodukter från bioenergiproduktion - effekter på marken

Waste materials from biogas production - effects on soil fertility and climate

Anders Johansen, Senior Scientist
Department of Environmental Science
Aarhus University
ajo[a]dmu.dk

Mette Sustmann Carter
Henrik Hauggaard Nielsen
Risø-DTU

Anne-Kristin Løes
Bioforsk/N

Soil and Climate

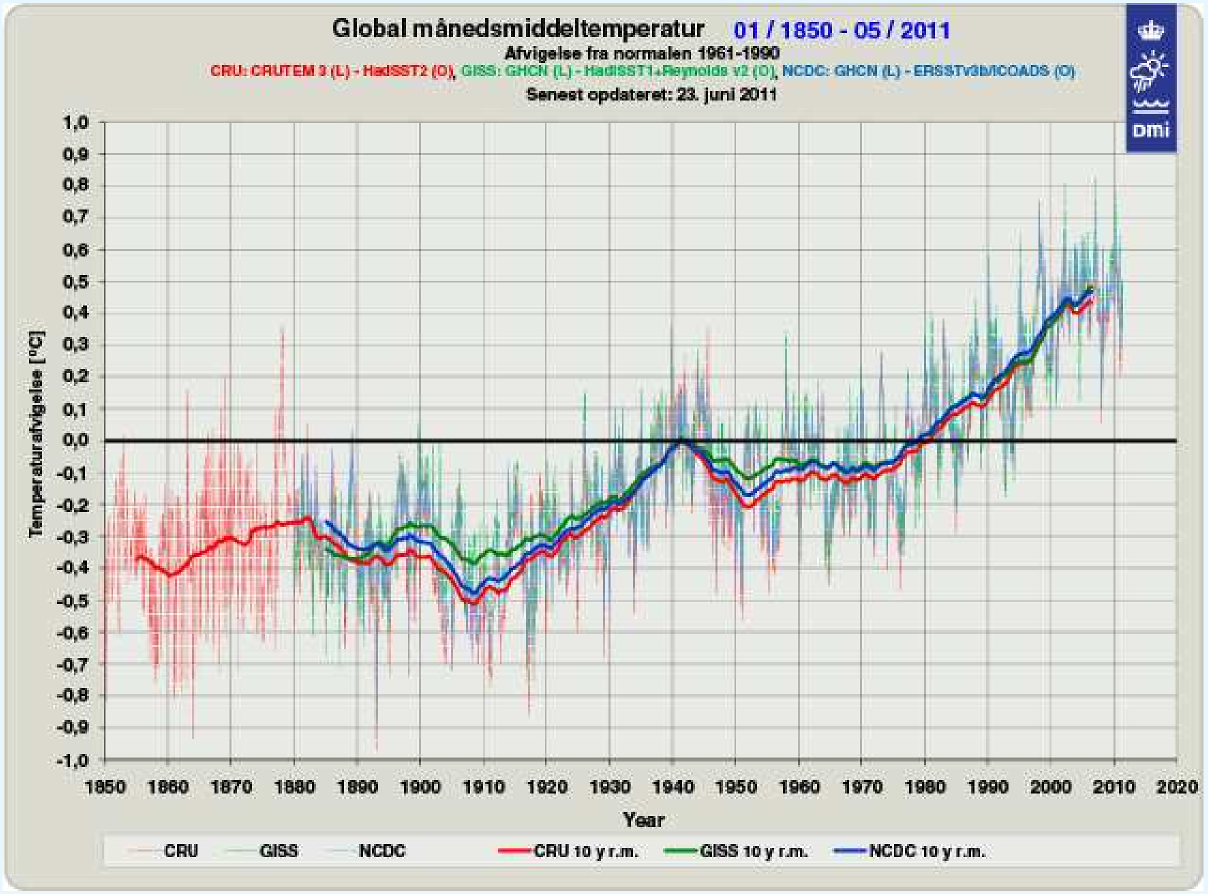
Overview

- **Climate change – background – greenhouse gases (GHGs) and agricultural influence.**
- **Bioenergy, cycling of nutrients and emission of GHGs.**
- **Focus on farmers influence on soil and climate.**
- **Global challenges and the future – what can we do?**

Department of Environmental Science
AARHUS UNIVERSITY

What is the problem? – it's the temperature!

Within the last 100 years, global average temperature has increased 0.74°C



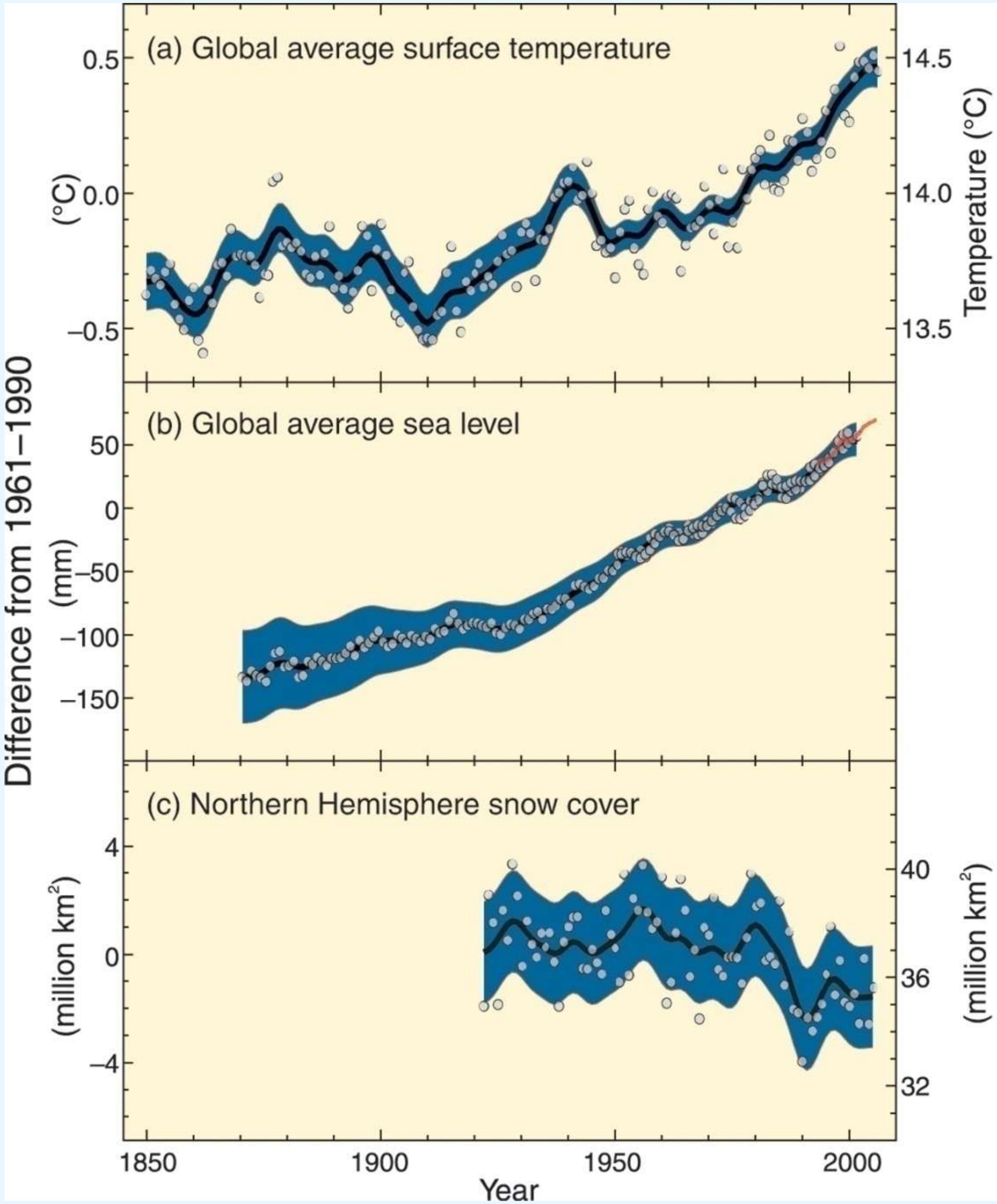
Development in global temperature. Data recorded by national metrologic Institutes (like DMI) and compiled by CRU.

Important changes!

Changes in global <u>temperatures.</u>

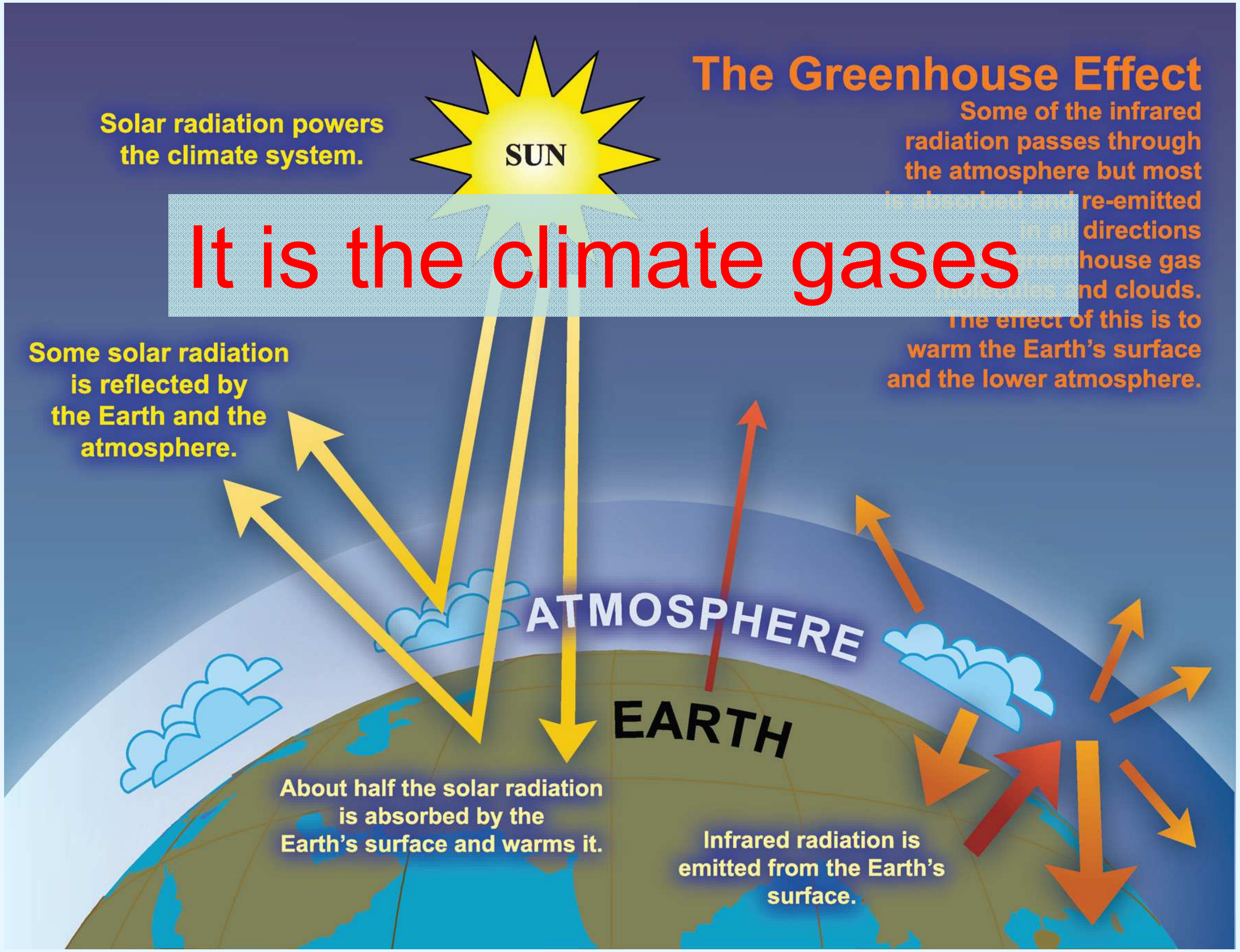
Changes in <u>sea level.</u>

Changes in <u>snow cover</u> on Northern hemisphere.



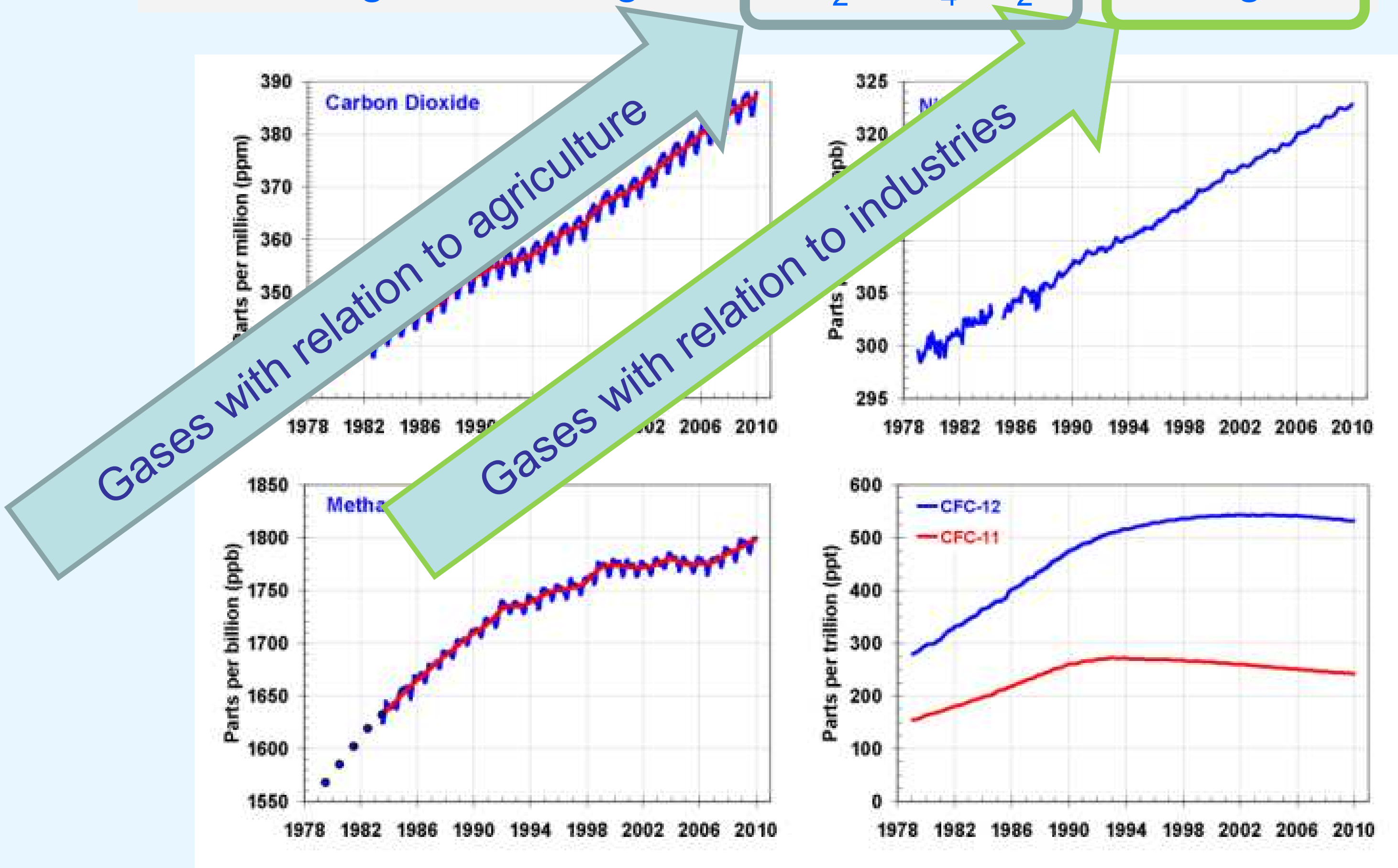
Department of Environmental Science
AARHUS UNIVERSITY

What is causing the increase in temperatures?



It is the climate gases

Trends in greenhouse gases CO_2, CH_4, N_2O freon gases



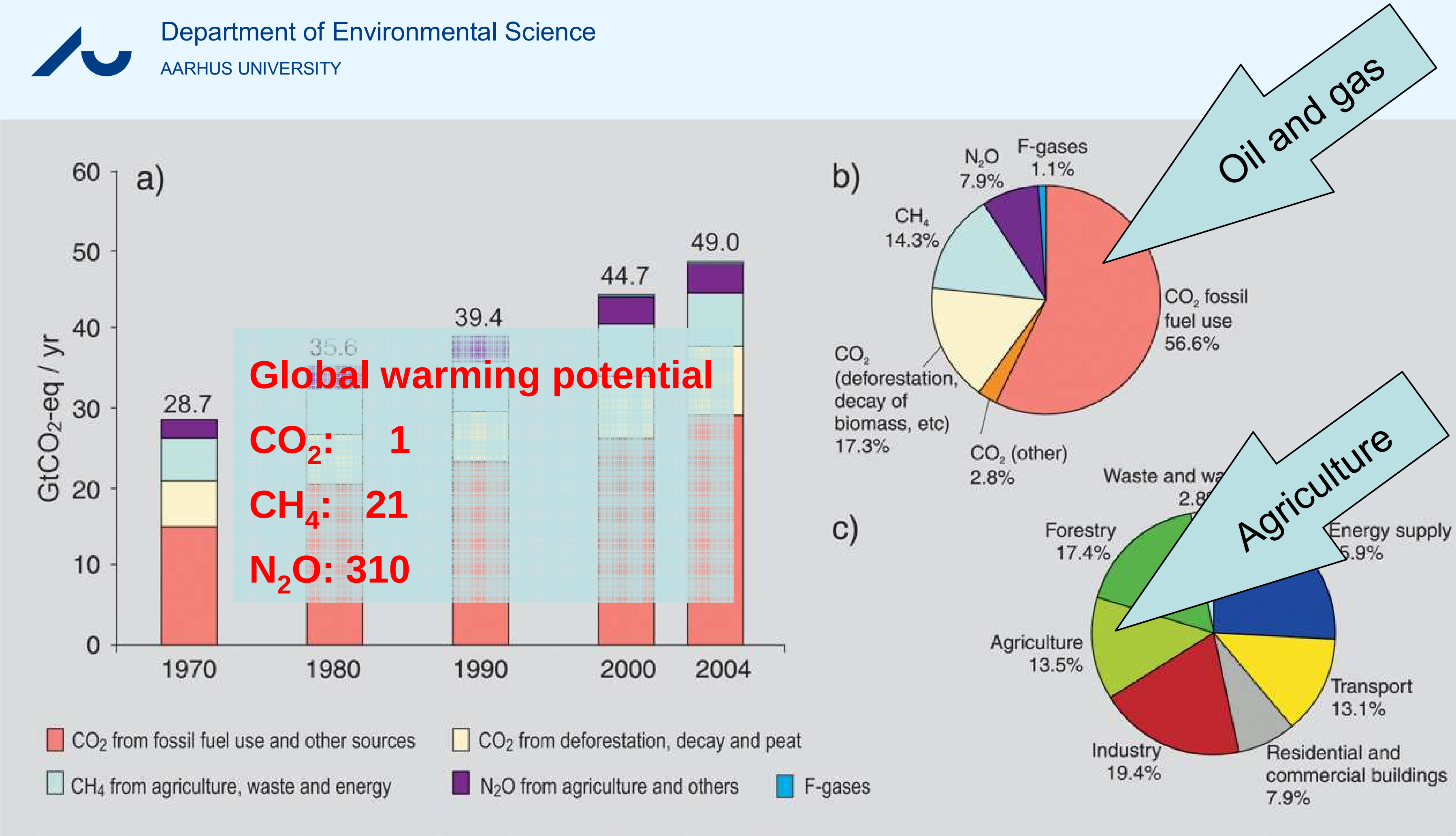


Figure 2.1. (a) Global annual emissions of anthropogenic GHGs from 1970 to 2004.5 (b) Share of different anthropogenic GHGs in total emissions in 2004 in terms of CO_2-eq. (c) Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO_2-eq. (Forestry includes deforestation.)

Q: Does Lomborg deny man-made global warming exists?
A: No. In *Cool It* he writes: "global warming is real and man-made. It will have a serious impact on humans and the environment toward the end of this century" (p8).
Q: But he used to deny it, didn't he?
A: No. In both his first Danish book in 1998 and the English version of *The Skeptical Environmentalist* in 2001, Bjorn Lomborg stressed that man-made global warming exists. The introduction to the section on climate change in *The Skeptical Environmentalist* clearly states, "This chapter accepts the reality of man-made global warming" (p259).

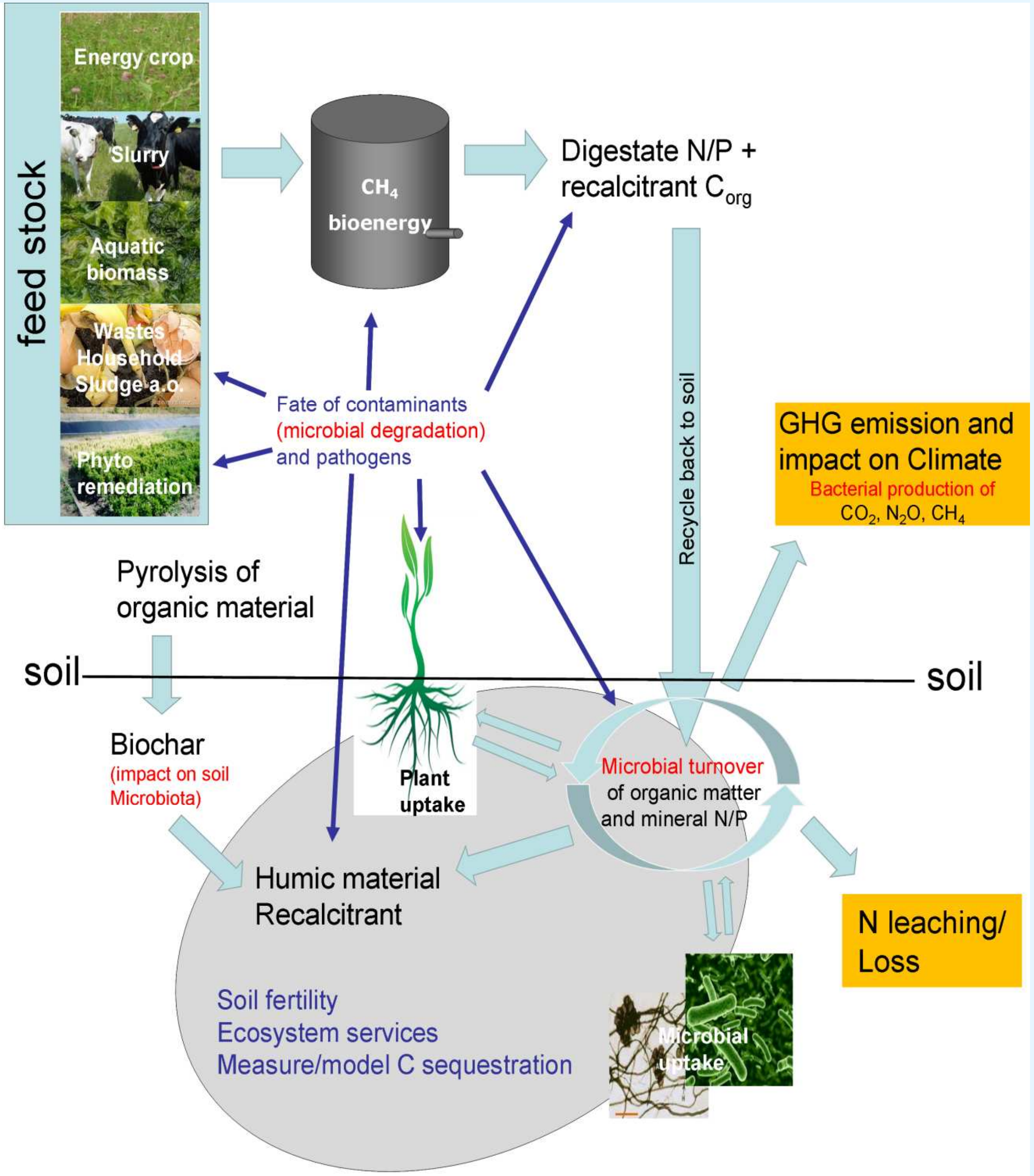
http://www.lomborg.com/

Overview

- Climate change – background – greenhouse gases (GHGs) and agricultural influence.
- **Bioenergy, cycling of nutrients and emission of GHGs.**
- Focus on farmers influence on soil and climate.
- Global challenges and the future – what can we do?

Department of Environmen

AARHUS UNIVERSITY



Soil fertility

Plant nutrient availability
Organic matter content
Soil structure
Active and diverse microflora

Ecosystem services

Ability to degrade contaminants
Retain water
Feed plants
Supress pathogens

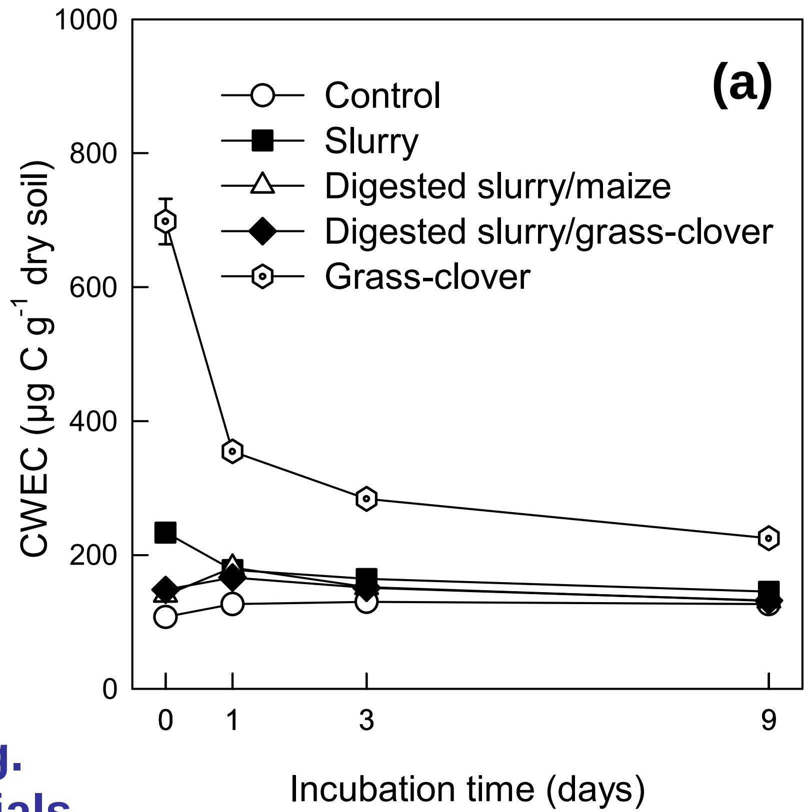
Carbon available to microorganisms after addition of digested materials to soil

Water (Control)

Raw cattle slurry

2 types digested material

Grass-clover



Measured in the soil
Grass-clover contains most available org. carbon

Raw slurry slightly more org. carbon than digested materials

Carbon respired by microorganisms after addition of digested materials to soil

Water (Control)

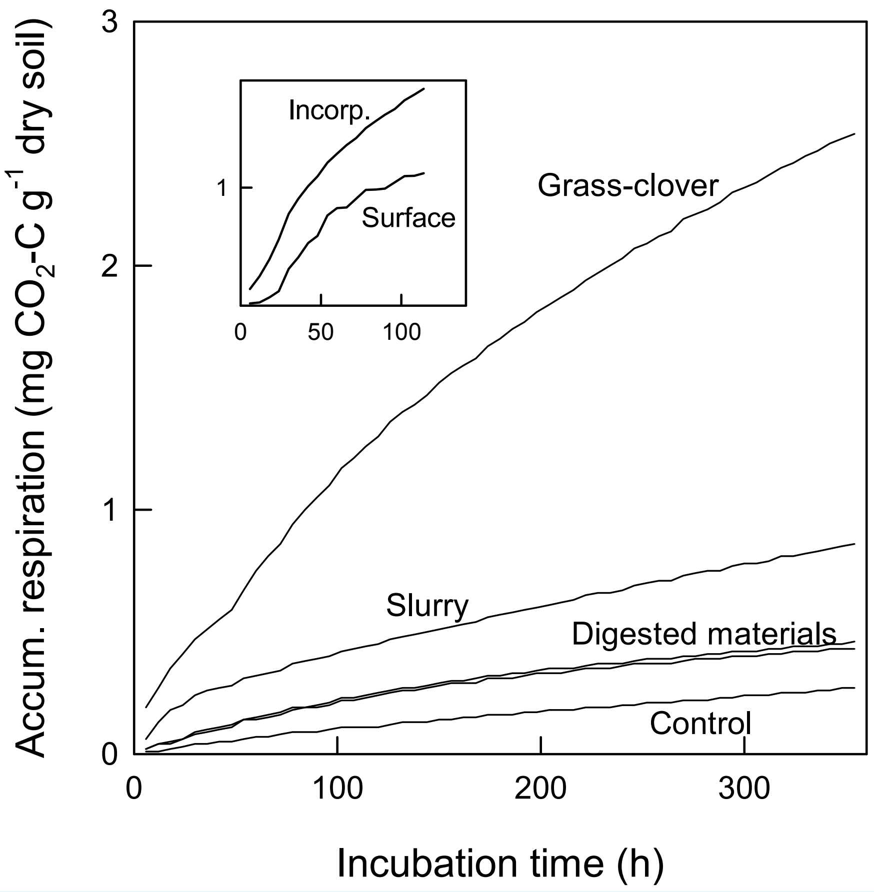
Raw slurry

2 types digested material

Grass-clover

The materials containing most available org. C are turned over most quickly

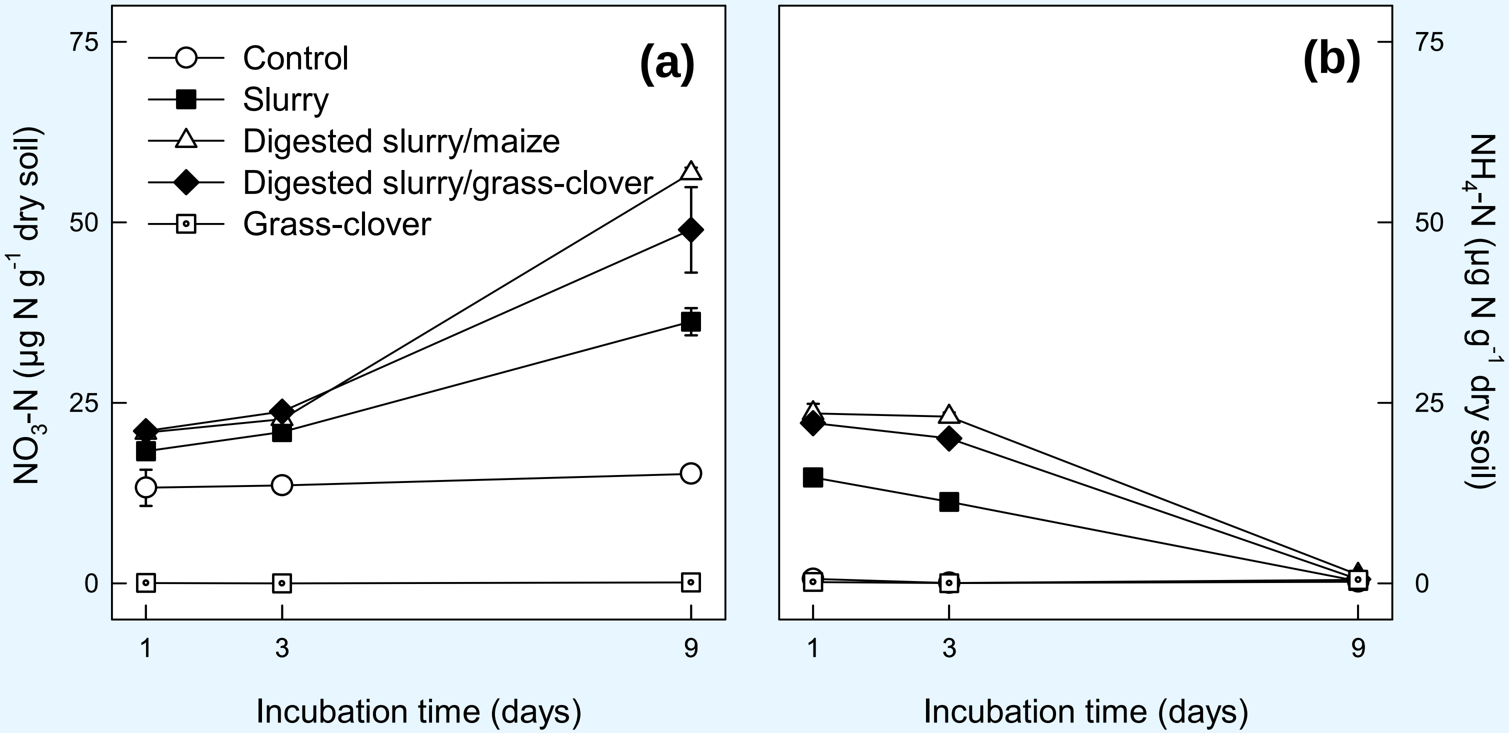
- and emit most CO_2



Department of Environmental Science

AARHUS UNIVERSITY

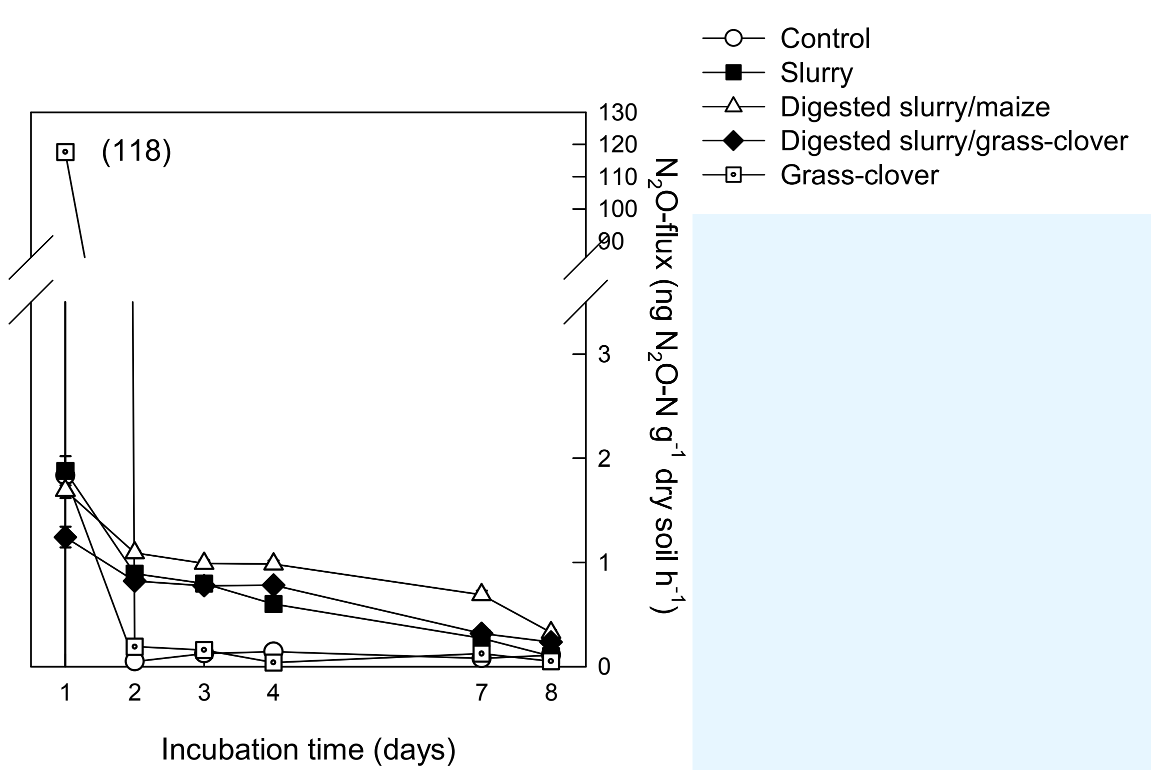
Nitrogen available to plants and microorganisms after addition of digested materials to soil



Most mineral N after addition of digested materials.
Mineral N immobilisered after addition of grass-clover (+denitrification)

Department of Environmental Science
AARHUS UNIVERSITY

Emission of N_2O from soil after addition of experimental materials

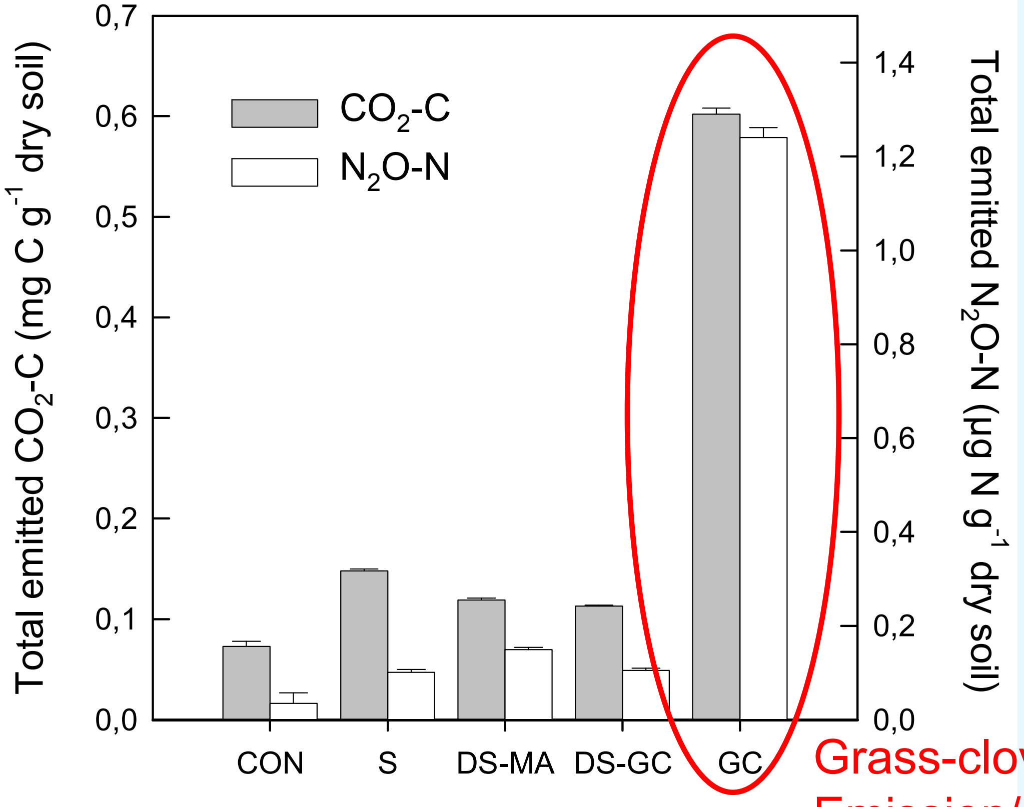


Much higer N_2O emission after addition of grass-clover than after addition of the other materials. Probably due to denitrifcation under anaerobic conditions.

Department of Environmental Science
AARHUS UNIVERSITY

Availability of C og N governs emissionen of climate gases CO_2 and N_2O

Con: water
S: slurry
DS-MA: digested slurry/maize
DS-GC: digested slurry/grass-clover
GC: grass-clover

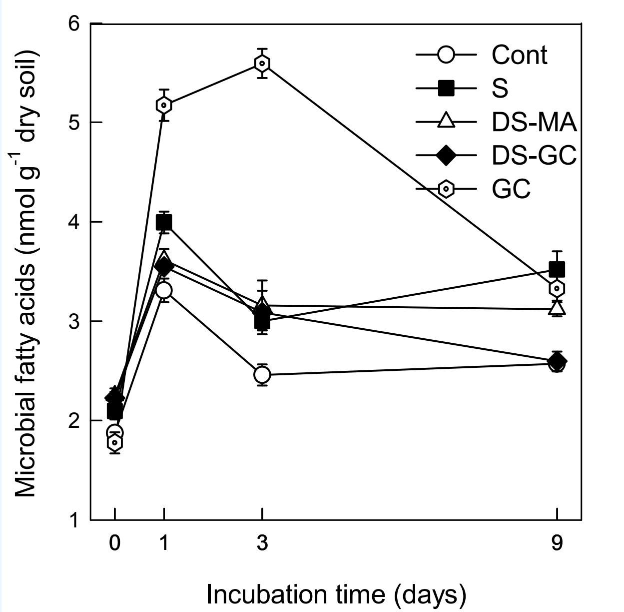


Grass-clover increases
Emission/loss of N og C

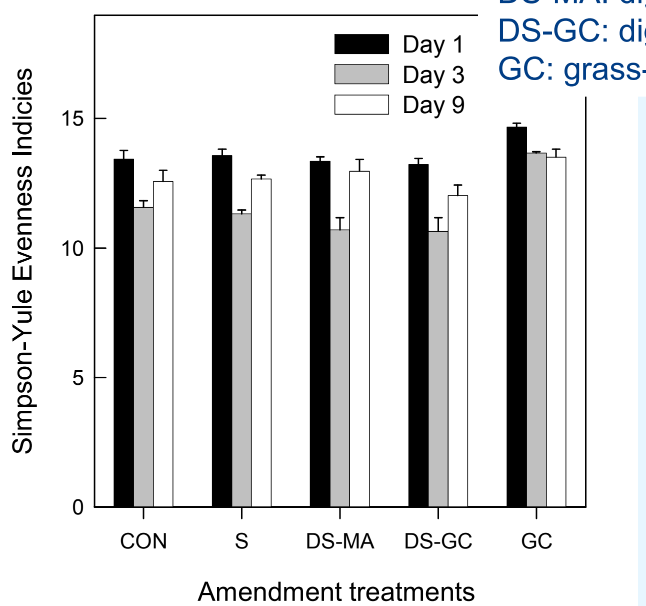
Department of Environmental Science
AARHUS UNIVERSITY

Soil microorganisms – response to addition of digestates

Membrane fatty acids
(total microbia biom.)



Functional diversity



Con: water
S: slurry
DS-MA: digested slurry/maize
DS-GC: digested slurry/grass-clover
GC: grass-clover

<u>Results showed that</u>:
Grass-clover induces a <u>short</u> growth respons in microbial population and that the functional diversity is high and not different between treatments.

Mikroorganisms ability to turn over nutrients seems <u>not</u> impared by the digestate material.

Overview

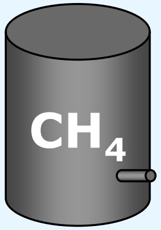
- Climate change – background – greenhouse gases (GHGs) and agricultural influence.
- Bioenergy, cycling of nutrients and emission of GHGs.
- **Focus on farmers influence on soil and climate.**
- Global challenges and the future – what can we do?

Department of Environmental Science
AARHUS UNIVERSITY

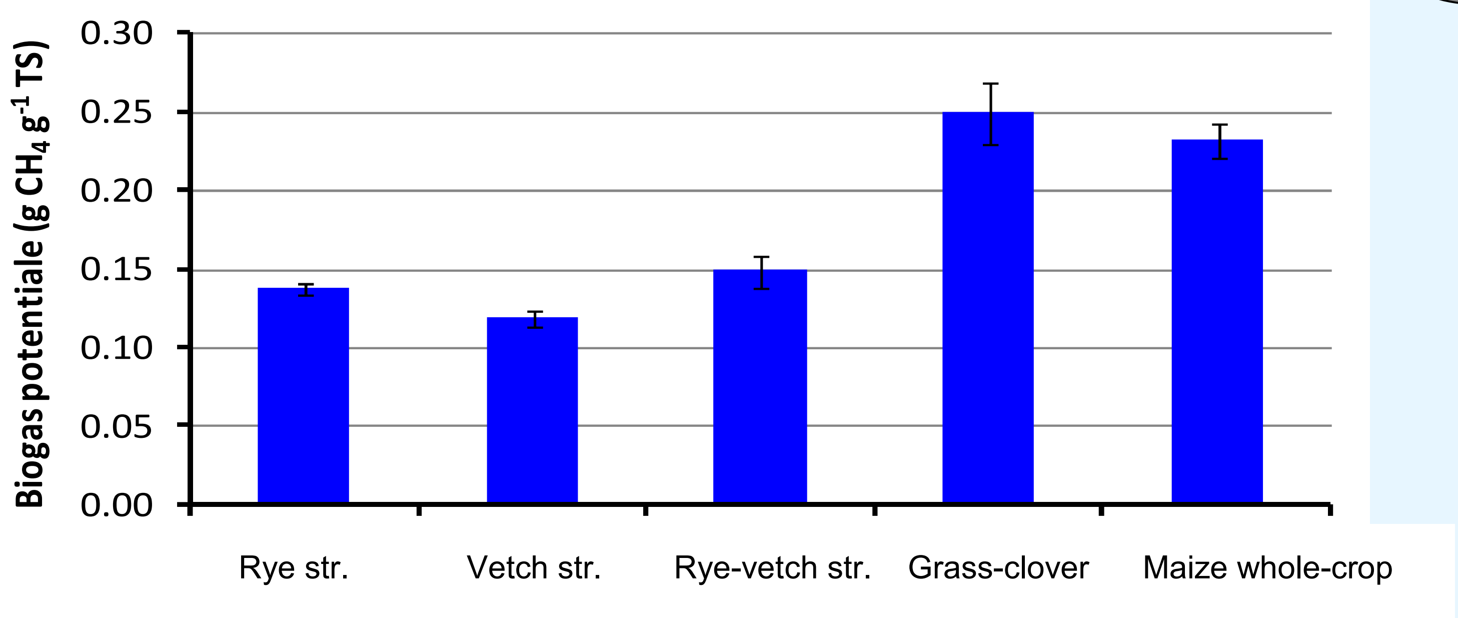
Field experiments with bioenergy cropping and derived effects on climate

CO_2-alleviation and N_2O effects

Department of Environmental Science
AARHUS UNIVERSITY



Potentiel biogas production



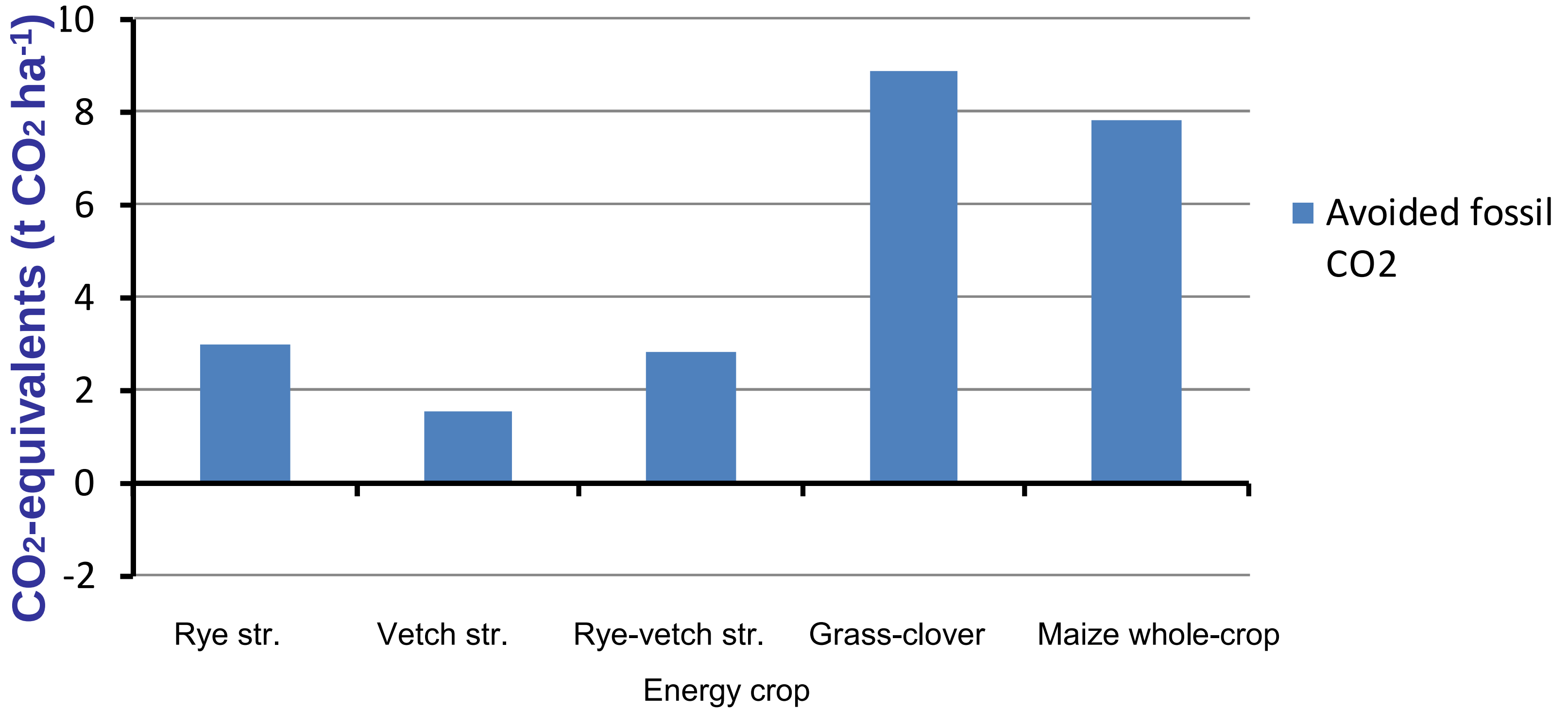
(non-fertilized)

Mette Sustman Carter et. al.

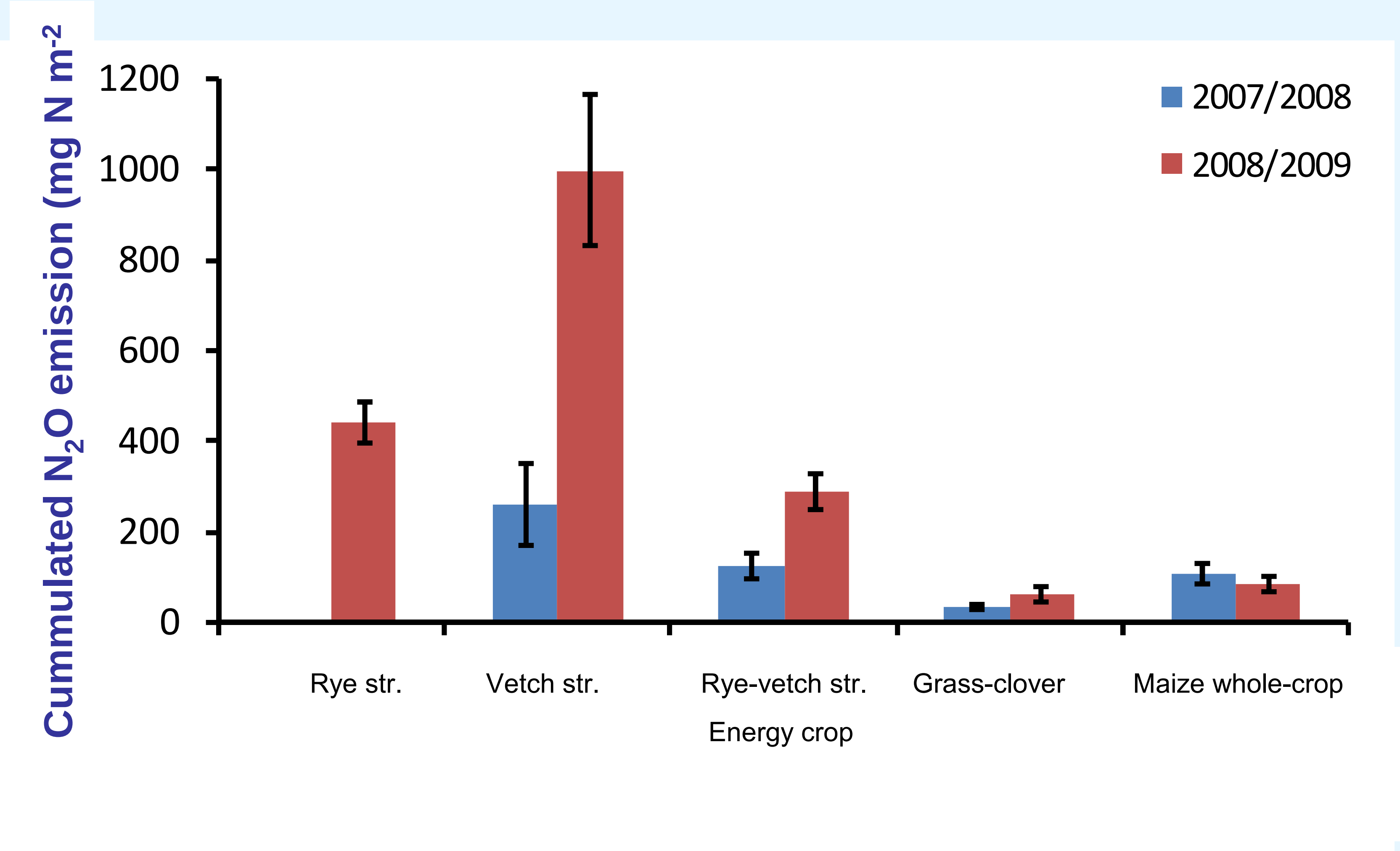
Department of Environmental Science
AARHUS UNIVERSITY

CO_2 avoided

(compared to fossil energy)

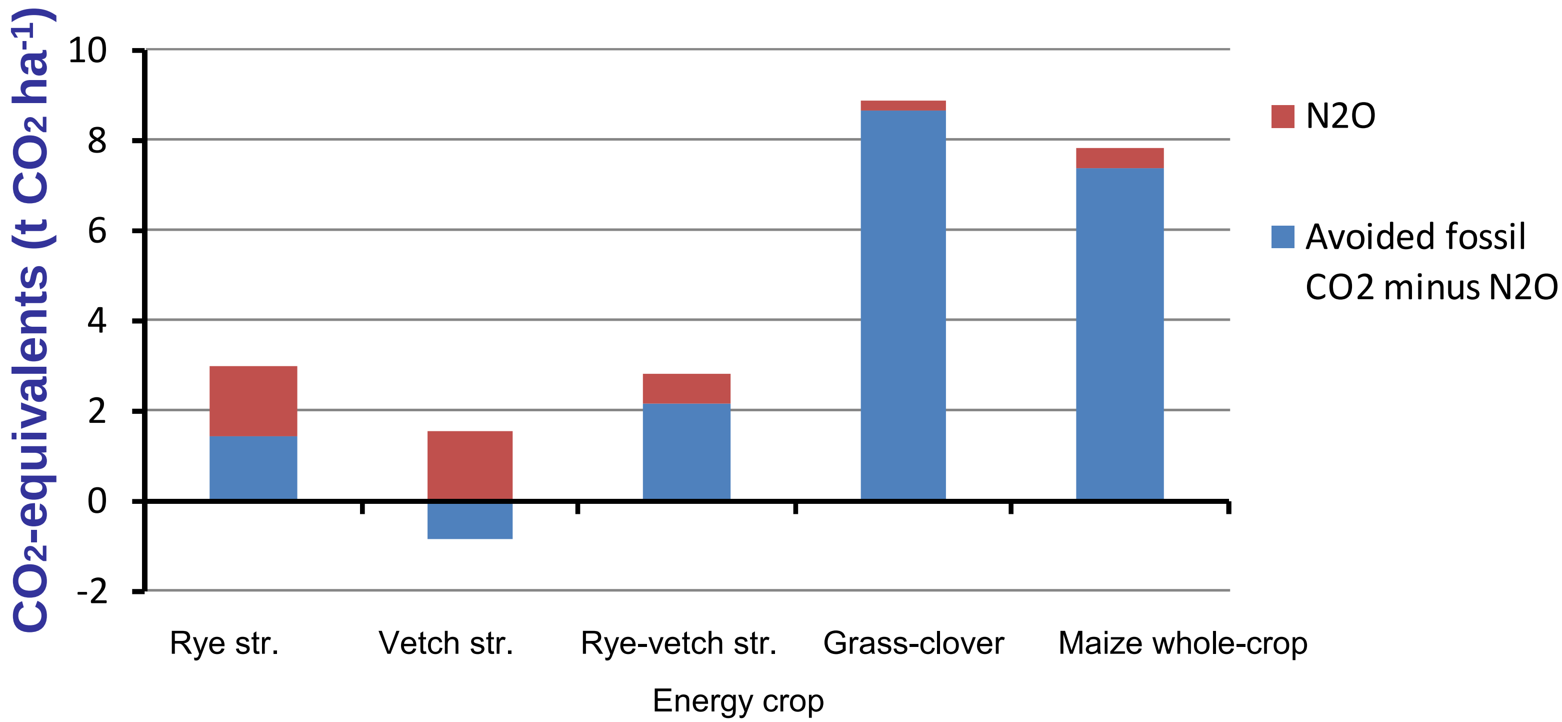


N_2O emission



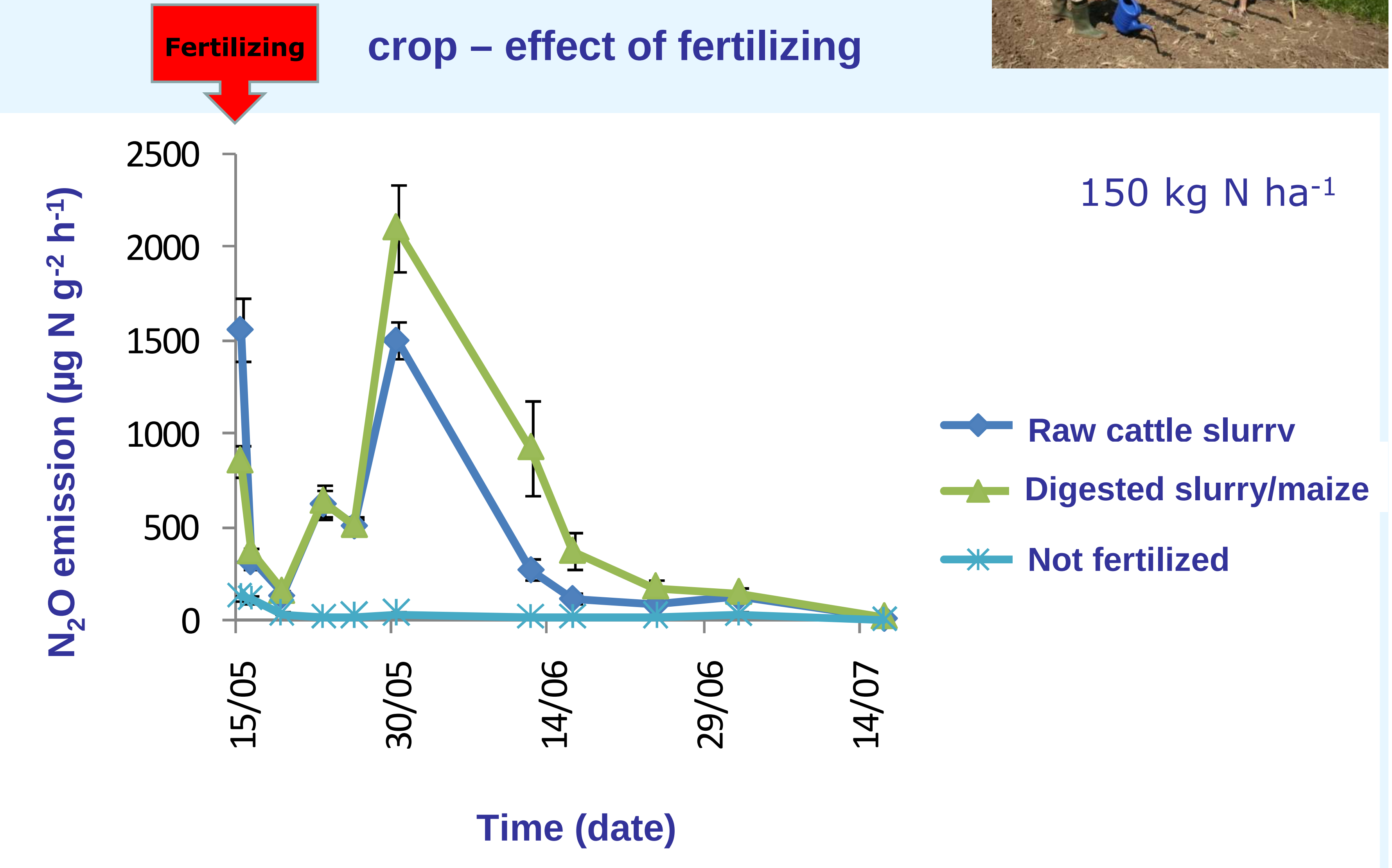
Department of Environmental Science
AARHUS UNIVERSITY

Effect of N_2O emission on avoidance of fossil CO_2



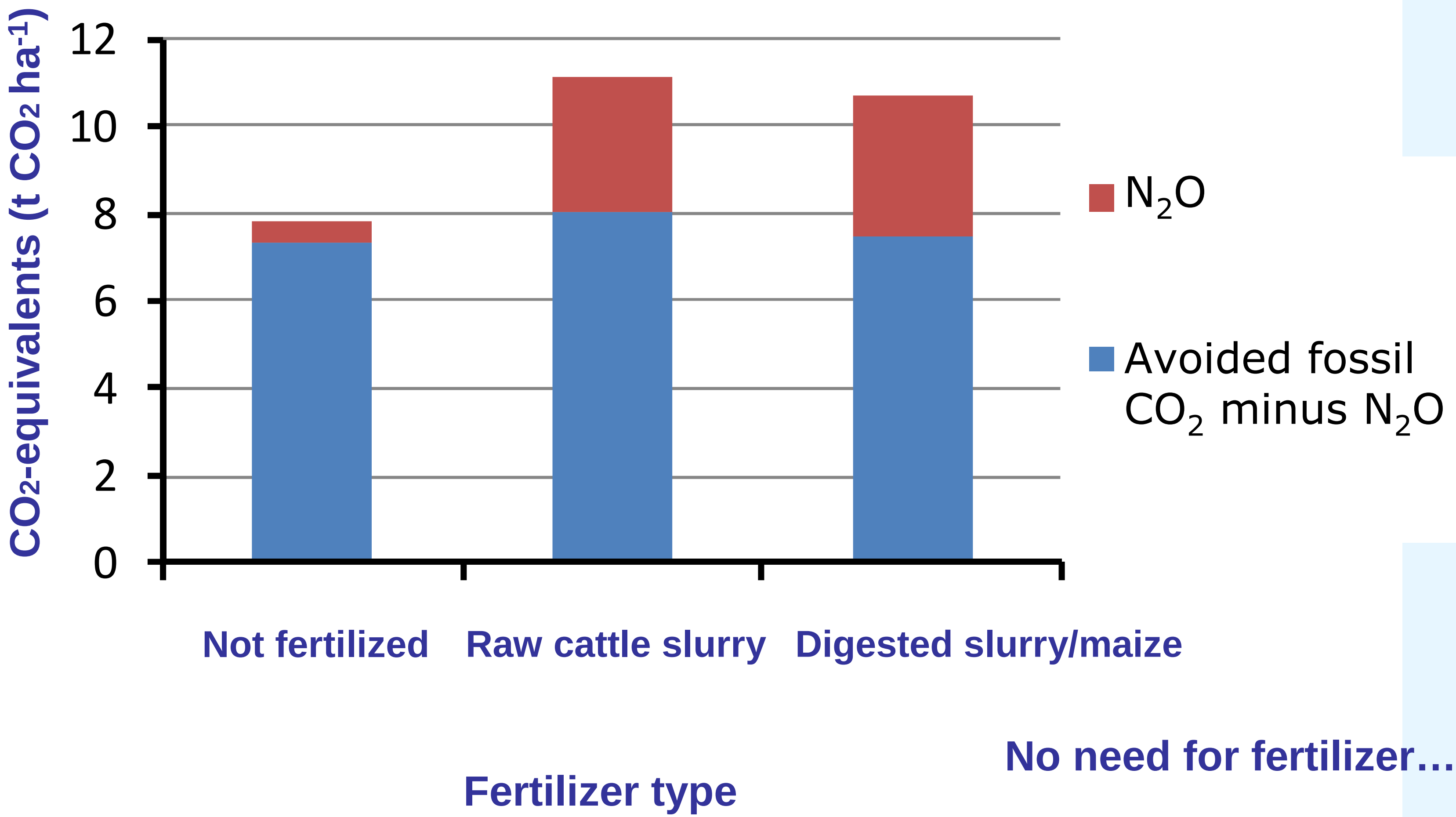
Department of Environmental Science
AARHUS UNIVERSITY

N_2O emission from maize crop – effect of fertilizing



Department of Environmental Science
AARHUS UNIVERSITY

Biogas produced on fertilized maize (2 Y data)

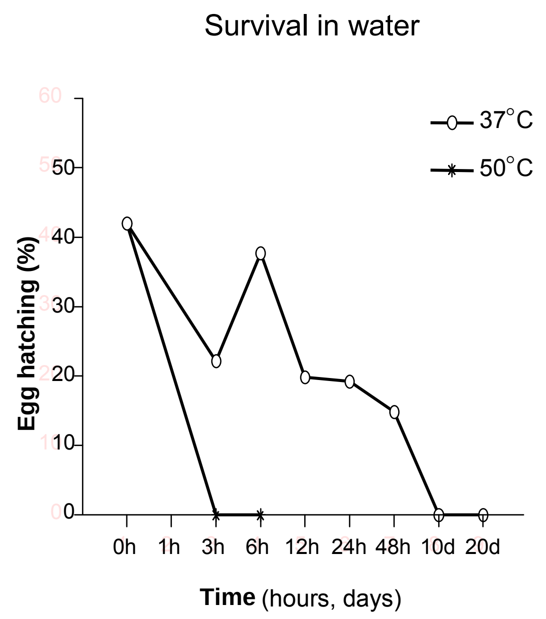


No need for fertilizer…

Other beneficial effects of biogas production

Avoid parasites and weed seeds

Survival of animal parasites in biogas plants



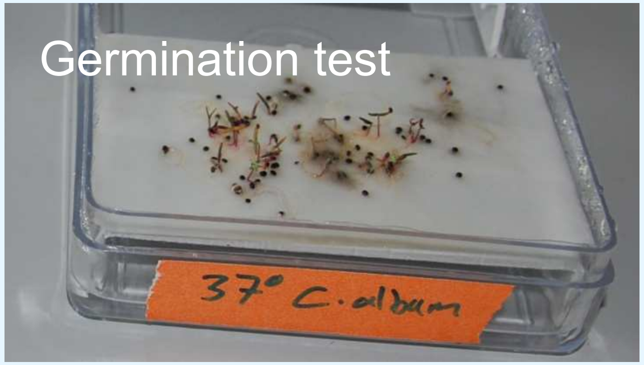
Results shows that the *Ascaris*-eggs were eliminated after few hours at 50 Cº, while at 37 Cº they could hatch after up to 10 Days in the biofermentor.

Eggs of the svine roundworm (*Ascaris suum*) was incubated in cattle slurry and Anaerobically digested at mesofile (37º) or termofile (50 Cº) conditions. Survival was measure during 20 days of incubation.


snerlepileurt
småblomstret gulurt
flyvehavre
canadisk gyldenris
hvidmelet
gåsefod
agersennep

Department of Environmental Science
AARHUS UNIVERSITY

Survival of weed seeds



Result: at 50 C° no seeds survived regardless of plant species or time of incubation. A few species could germinate after fermentation up to 7 days at 37 C°.

		Germination-% at 37 °C				
Plant species	**Characteristics**	**2 d***	**4 d**	**7 d**	**11 d**	**22 d**
Brassica napus	Seed survival >8Y	**1**	0	0	0	0
Avena fatua	Common, spread easy	0	0	0	0	0
Sinapsis arvensis	Competitive	0	0	0	0	0
Fallopia convolvolus	Good survival in dung	**7**	**2**	**2**	0	0
Amzinckia micranta	Invasive and aggressive	**1**	0	**1**	0	0
Chenopodium album	Common and tough	**78**	**56**	**28**	0	0
Solidago canadensis	New invasive species	0	0	0	0	0

At 50 °C no seeds were able to germinate at any time
***d: days of incubation in fermentor**

Overview

- Climate change – background – greenhouse gases (GHGs) and agricultural influence.
- Bioenergy, cycling of nutrients and emission of GHGs.
- Focus on farmers influence on climate.
- Global challenges and the future – what can we do?

Recirculation of biogas residues - benefits

- On-farm production of energy and minimizing GHG emission (especially organic farm systems).
- Possibility for utilizing waste stream materials (digestates) from bioenergy production as plant nutrients.
- Enables recycling of plant nutrients from of-farm waste streams (especially via biogas).
- More well-defined fertilizer (due to content of mineral N).
- Hygienization of waste products via anaerobic digestion.

Recirculation – what to worry about?

- Soil quality – especially degradation of soil organic pools (humus).
- Increased availability of nutrients in digestates (nutrient efficiency vs. loss).
- Long-term impact on biodiversity and activity (microorganisms, mesofauna, makrofauna).
- Spread af bacterial patogenes.

Future perspectives and challenges

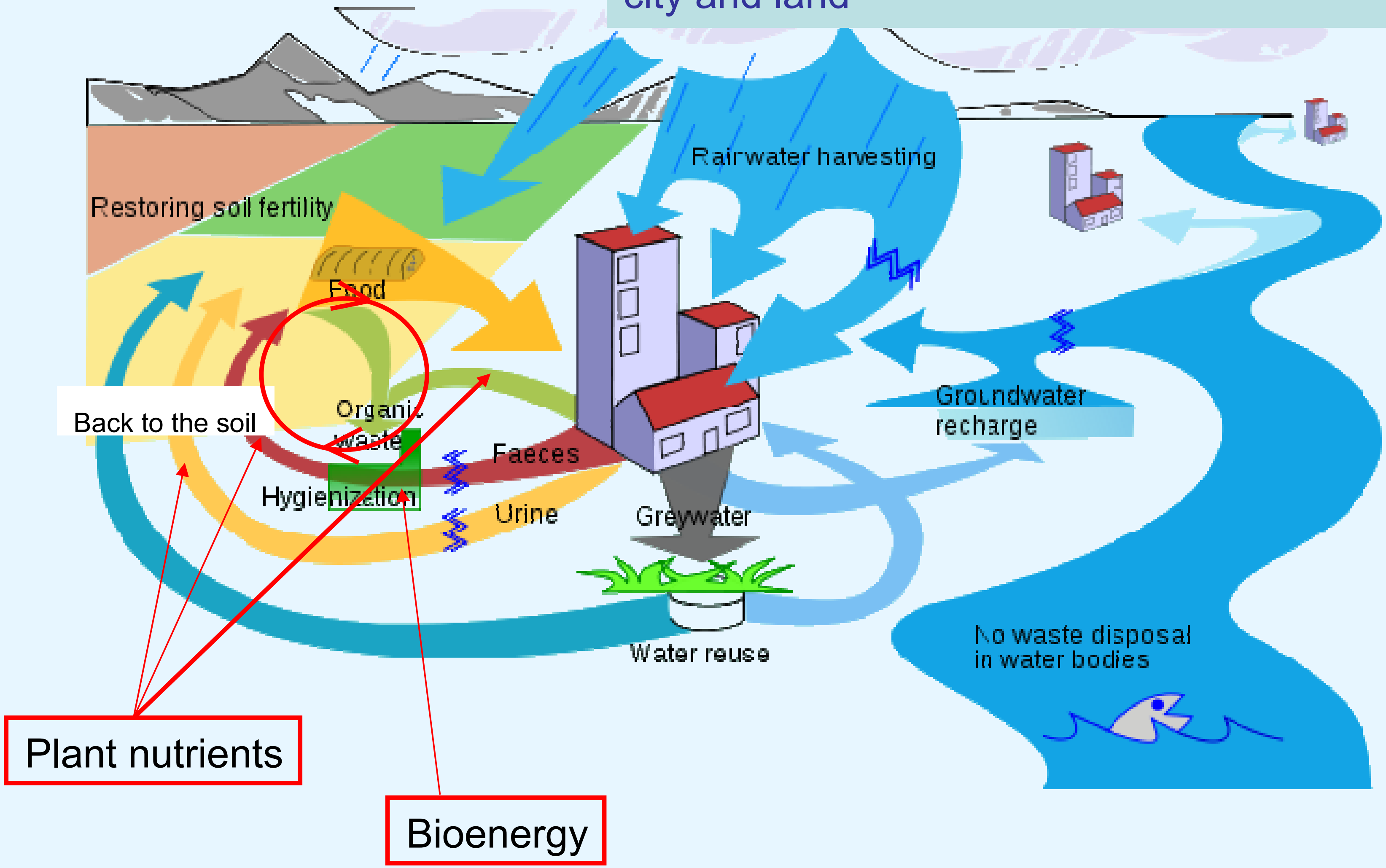
- **Close nutrient cycles further – minimizing loss of nutrients (phosphorus!).**
- **Precision-fertilization with biogas residues to deminish loss of N.**
- **Biogas conversion offers a good possibility to eliminate parasites, weed seeds (and some pathogenes + maybe org. contaminants).**
- **Utilizate waste streams from urban areas and industries better.**

- **Problem with long-term effects on soil pools of oranic C must be addressed – they should be increased – not degraded further.**

Department of Environmental Science
AARHUS UNIVERSITY

The closed recycling of nutrients – on the farm and between urban areas.

The waste streams are ”gold” and re-unites city and land-



Personer involveret

- Allan Roepstorff (KU-LIFE)
- Anne Grethe Holm (DMU/AU)
- Josefine Carlsgart (KU-LIFE)
- Christian Andreasen (KU-LIFE)
- Christian Mørk (KU-LIFE)
- Henrik Bangsø Nielsen (Risø-DTU)
- Mette S. Carter (RISØ-DTU)
- Per Ambus (Risø-DTU)
- Henrik H. Nielsen (Risø-DTU)
- Anne-Kristin Løes (BIOFORSK Norway)

Associated projects

BIOCONCENS: Biomass and bioenergy production in organic agriculture – consequences for soil fertility, environment, spread of animal parasites and socio-economy.

SOILEFFECTS: Effects of anaerobically digested manure on soil fertility - establishment of a long-term study under Norwegian conditions.

ANIMAL MANURE FOR BIOGAS PRODUCTION - WHAT HAPPENS TO THE SOIL?

Anne-Kristin Løes[1], Anders Johansen[2], Reidun Pommeresche[1], Hugh Riley[3]

Norwegian Institute for Agricultural and Environmental Research

Summary: Utilizing animal slurry to produce biogas may reduce fossil fuel usage and emissions of greenhouse gases. However, there is limited information on how the recycling of digested slurry as a fertilizer impacts soil fertility in the long run. This is of concern because organic matter in the slurry is converted to methane, which escapes the on-farm carbon cycle. In 2010, a study of this question was initiated on the organic research farm in Tingvoll, Norway. So far, a biogas plant has been built, producing anaerobically digested slurry to be compared with undigested slurry in perennial ley and arable crops. Effects on crop yields, soil fauna, microbial communities, soil structure, organic matter and nutrient concentrations are measured.

Background

On-farm biogas production converts various organic substrates to energy, and help to reduce dependency on fossil fuels and emission of greenhouse gases. However, especially organic farmers are concerned about the resulting reduced input of organic matter to the soil after digestion. What happens to soil life when we reduce the input of organic carbon?

Figure 1. Spreading manure, mixed 50% with water, on the research field.

Experimental details

On Tingvoll research farm, a biogas plant was recently built to digest the slurry from 25 dairy cows. The digested slurry (D) is compared with undigested slurry (U) in two cropping systems; arable crops and perennial ley, at low and high fertilization levels. Two plot experiments with four replicates are located next to each other in the field (Fig. 2), using ignition loss to find the plots with most even soil conditions. The soil is an imperfectly drained silty sand, from marine deposits, with 2.8-4.8 % organic matter in the arable plots and 3.9-9.6 % in the ley plots. Plot size = 3 m x 8 m.

Manure characteristics

In 2011, we had to purchase U and D from the Norwegian University of Life Sciences. The D had less dry matter, and more mineral N (Table 1).

Table 1. Chemical analyses of manure used 2011	Undigested slurry, U	Digested slurry, D
Dry matter, %	6,8	5,2
Total N (Kjeldahl), kg tonne^{-1}	2,7	2,8
Phosphorus, kg tonne^{-1}	0,50	0,46
Potassium, kg tonne^{-1}	3,3	3,0
Ammonium-N, kg tonne^{-1}	1,6	2,0
Calcium, kg tonne^{-1}	0,82	0,65
Magnesium, kg tonne^{-1}	0,46	0,39
pH	6,8	7,8

During storage, sawdust had precipitated in U. The analysis is from the liquid part. No sediment was found in the D tanks. The U was yellowish brown and had a strong smell. D was greenish grey, had a softer smell reminding of soil, and lower viscosity. The digestion impacted the N concentration and dry matter content (Table 1). In ley, 21/42 tonnes ha^{-1} of U, and 20/40 tonnes ha^{-1} of D were applied on May 4. Half of these amounts will be applied after the first cut. To cereals, 23/46 tonnes ha^{-1} of U or D were applied on May 11. Animal slurry is heterogeneous and difficult to handle, and to sample and spread evenly. We mixed it with water (1:1) to facilitate even spreading. The high levels were close to the limit of what could be infiltrated in the soil.

Figure 2. Seed planting on cereal plots, May 20, 2011. In the background, the ley plots are visible.

Initial measurements

To reveal time-dependent changes, earthworms and spring tails have been sampled (Fig. 3).

Figure 3, above. Blue-grey earthworm (*Octolasion cyaneum*) is found in the field, together with the common species *A. caliginosa*. Figure 3, below. Springtails and mites (red) comprise a significant, but so far little studied group of species in the agricultural soil fauna.

Soil mineral N, water extractable C, accumulated respiration, microbial biomass, and shifts in microbial community structure described by phospholipid fatty acid technique are measured before and after slurry application. Soil physics and nutrients are also characterized.

The project "Effects of anaerobically digested manure on soil fertility - establishment of a long-term study under Norwegian conditions" (Soileffects) runs 2010-2014. We acknowledge the Research Council of Norway, the Agricultural Agreement Fund, Sparebanken Møre and the Norwegian Centre for Ecological Agriculture (NORSØK) for funding.

soil effects

www.bioforsk.no
1) [illegible]; [illegible] Bioforsk Organic Food and Farming, Tingvoll, Norway
2) [illegible] National Environmental Research Institute, Aarhus University, Roskilde, Denmark
3) [illegible] Bioforsk Arable crops, Kapp, Norway
Bioforsk
Fr. A. Dahlsvei 20, NO-1432 Ås
Norway
NATIONAL ENVIRONMENTAL RESEARCH INSTITUTE
AARHUS UNIVERSITY