Organic agriculture and climate change – the scientific evidence

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Organic Agriculture and Climate Change

- The report of the Intergovernmental Panel on Climate Change (IPCC)
- Mitigation options for the agricultural sector
  - Methane (CH_4) emissions
  - Nitrous oxide (N_2O) emissions
  - Carbon sequestration potentials
- Lessons learned from the DOK long-term field experiment in Switzerland
- Conclusions

The report of the Intergovernmental Panel on Climate Change (IPCC)

- **Emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxides (N_2O) are mostly due to human activity**
- **The most important drivers are identified as:**
  - **Fossil fuel combustion**
  - **Land-use change (conversion of forest and natural to agricultural land)**
  - **Agriculture (N-fertilizers, paddy rice fields, drainage and use of peatland)**

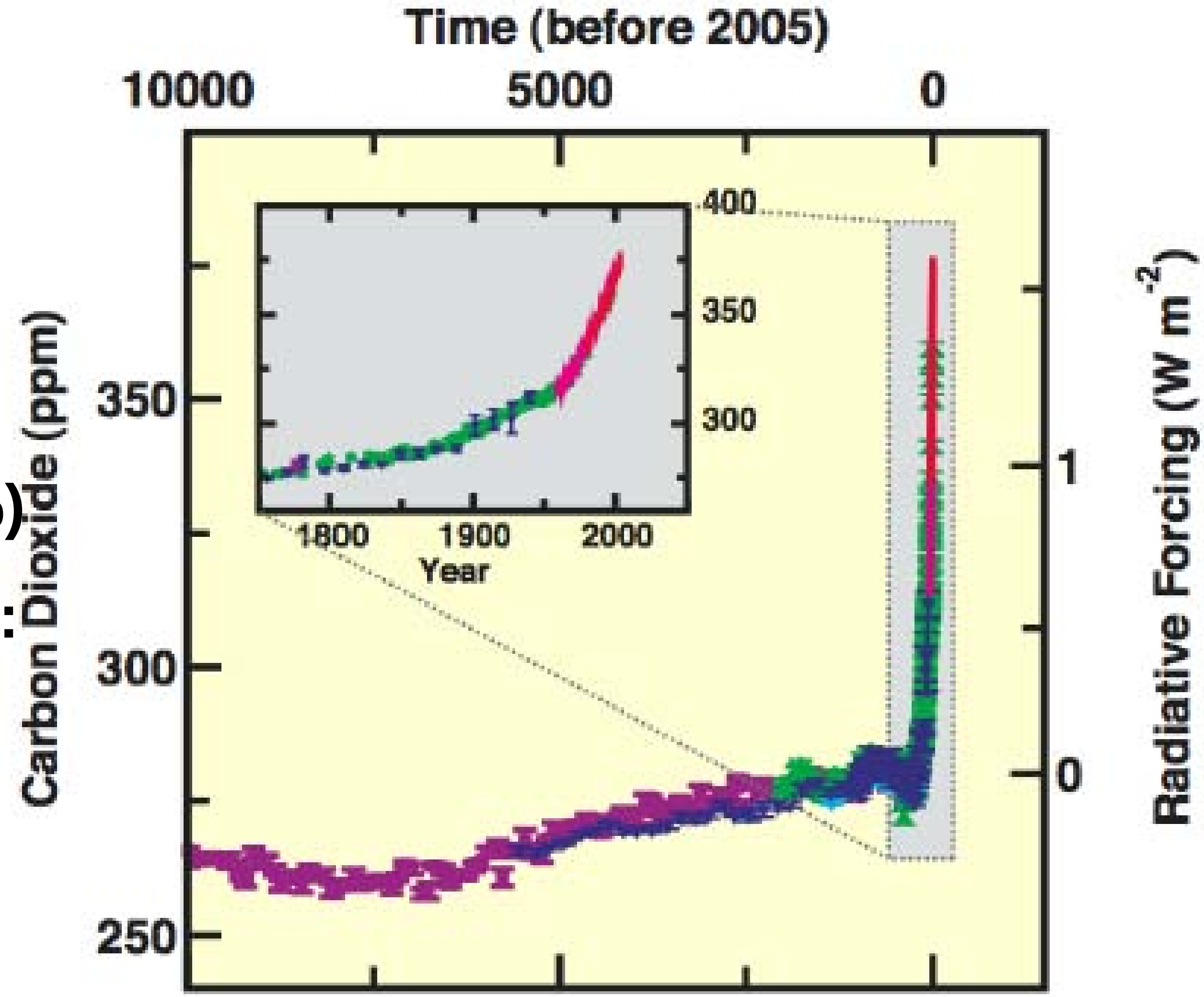
IPCC (2007) 4th assessment report

Atmospheric concentration of CO_2

Contribution to CO_2 emissions:

Fossil fuel combustion: 23.5 Pg CO_2 (80%)

Land use change: 5.9 Pg CO_2 (20%)

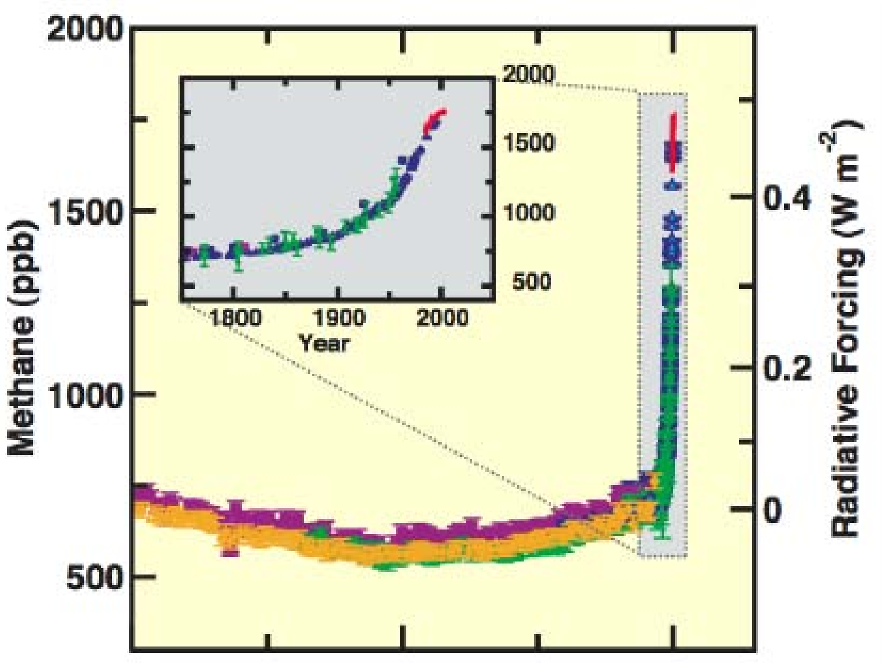


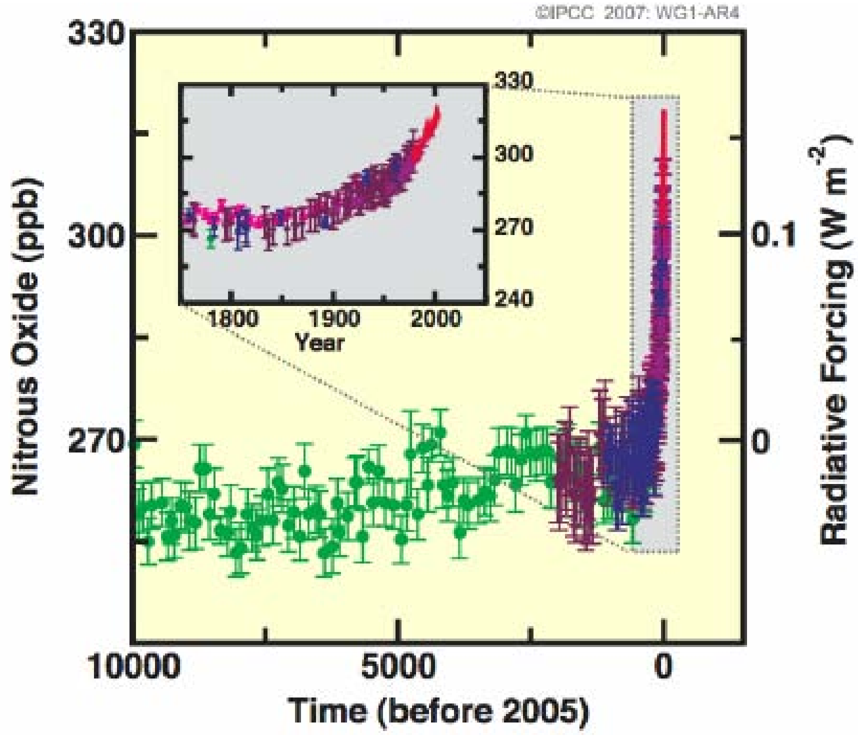
1 Pg = 1 Gt = 10^{15} g

IPCC (2007) 4th assessment report

Atmospheric concentration

Greenhouse warming potential:
Methane (CH_4): 21 * CO_2 Nitrous oxide (N_2O): 296 * CO_2





IPCC (2007) 4th assessment report

Experienced and expected trends for weather changes

> Warmer and fewer cold days and nights
> Warmer and more frequent hot days and nights
> More frequent heat waves
> More frequent heavy weather and precipitation events
> Increase in drought affected areas
> Increase in tropical cyclones
> Increased incidence of high sea level

IPCC (2007) 4th assessment report

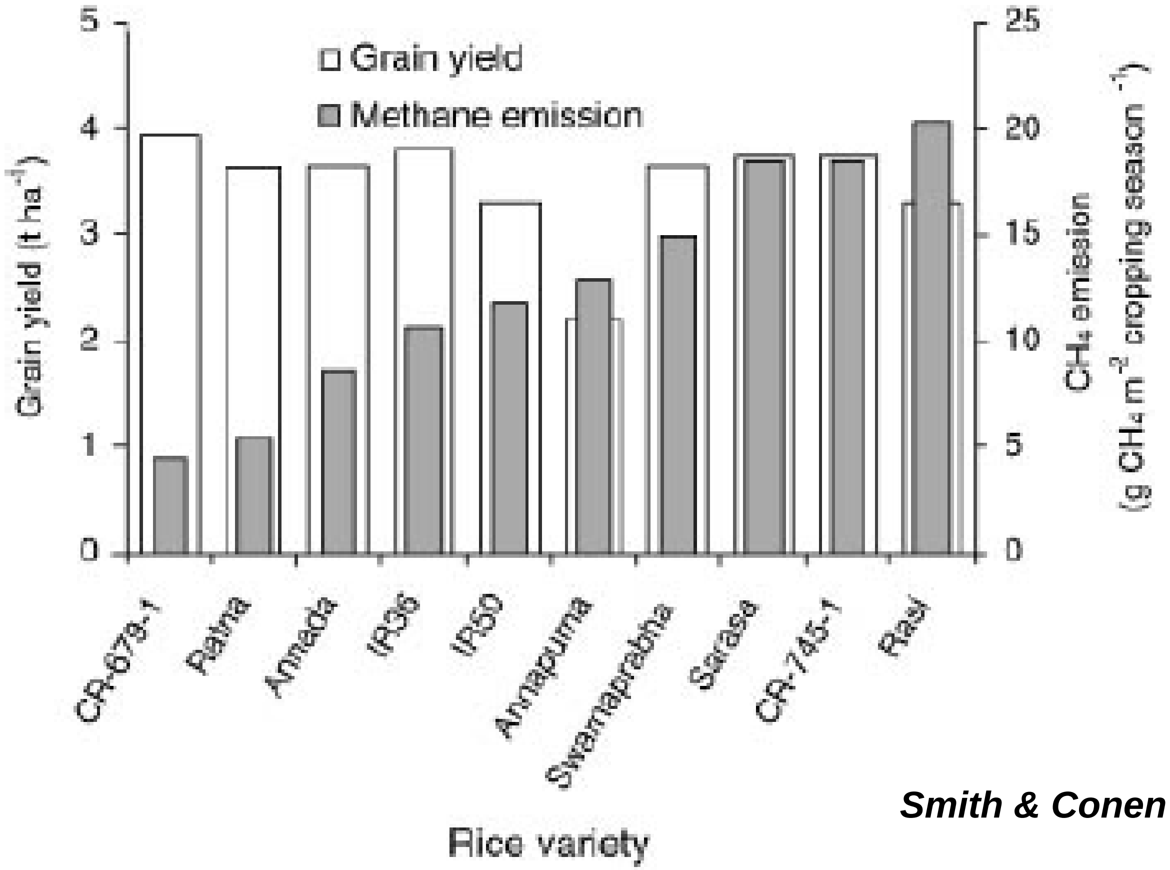
Mitigation options for the agricultural sector

	Role of organic farming
> Cutting emissions	
> Reduction of high energy inputs	👍
> Mineral fertilizer, pesticides	👍
> Transport	
> Feedstuff	
> Afforestation	
> Biofuel, esp. by perennial crops	
> Water regime improvement to avoid high methane emissions	
> Reduce mineral N levels to avoid nitrous oxide emissions	👍
> Soil carbon sequestration	👍

Methane (CH_4) emission

- Methane develops under strictly anaerobic conditions as a microbial product in
  - Water logged soils (paddy rice fields, peatland)
  - Sediments and landfills
  - Ruminants & soil dwelling termites
- Methane in soils may as well be oxidised to CO_2 under aerobic conditions (reversibility)
- Water regime and manure use in paddy rice field critical ⇒ dry rice production?
- Drainage may improve CH_4 but may enhance N_2O emissions
- Rice varieties differ considerably ☞

Methane emission of rice varieties

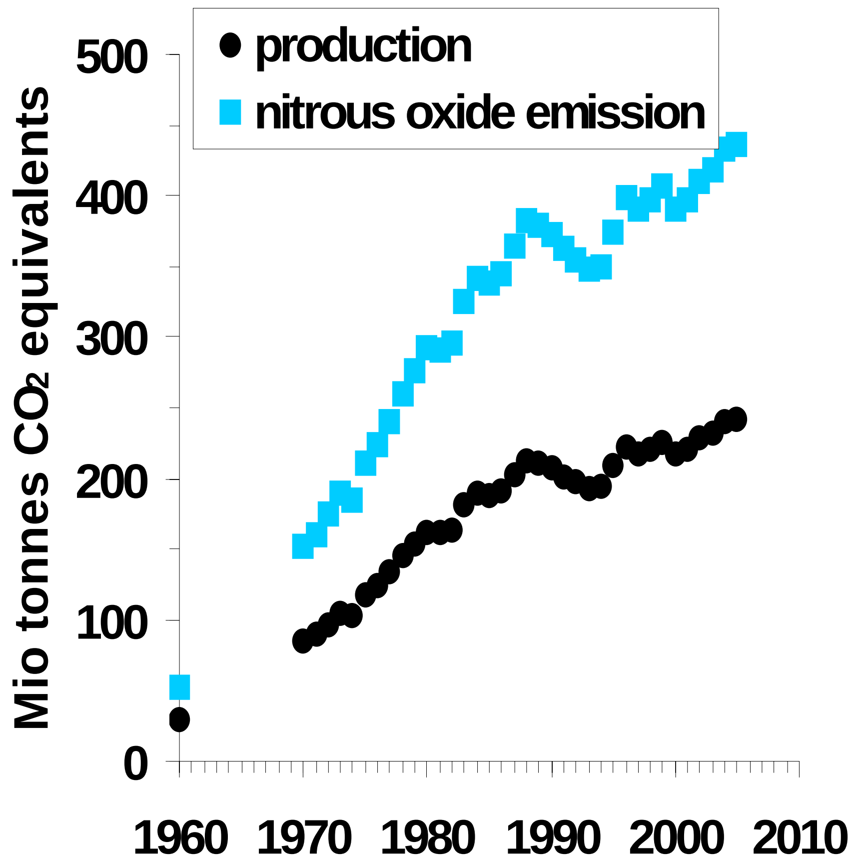


Smith & Conen (2004) SUM 20

Figure 2. Methane emission and grain yield for 10 different varieties planted under uniform field conditions in India. (Based on data from Satpathy *et al.* 1998.)

Climatic relevance of nitrogen

- Annual production of 90 Mio tonnes N is 1/3 of the naturally fixed nitrogen
- 1% of the world's fossil fuel consumption is used for nitrogen production – and nitrous oxide emission contibute with another 1.5%
- The data for N_2O emission is poor – Need for research!
- Where has the nitrogen gone?
  - Crop 50%?
  - Soils no
  - Increased flux rates?
  - Atmosphere N_2O, N_2
  - Water NO_3



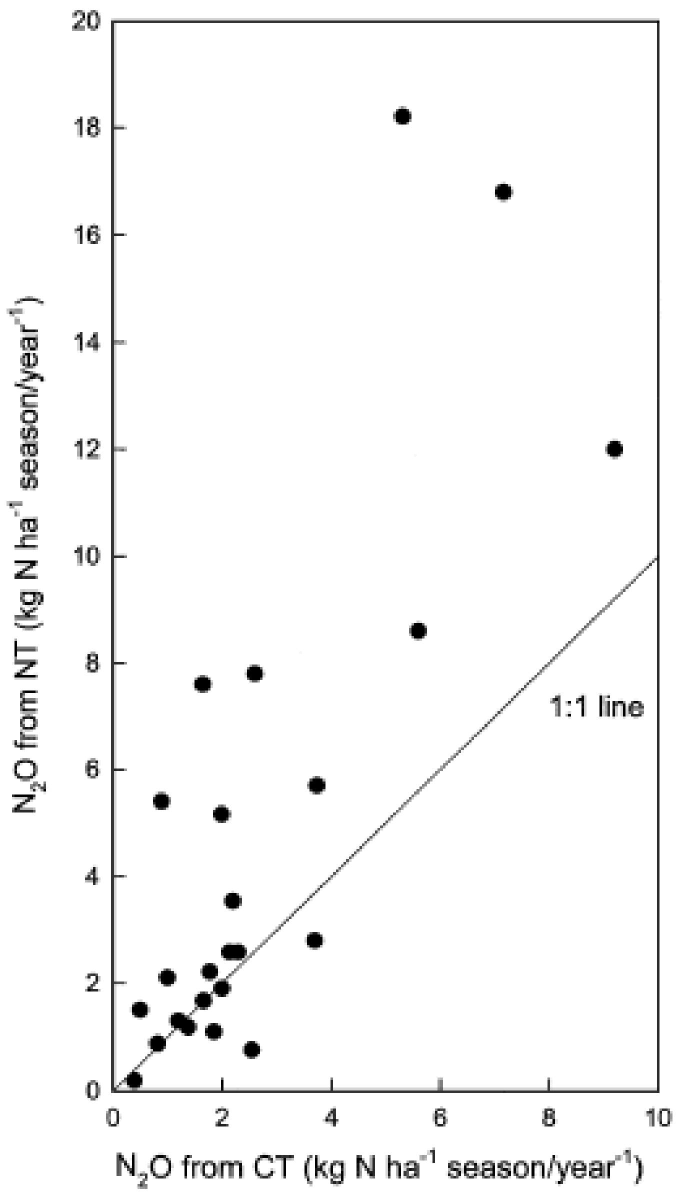
The nitrogen dilemma

- World food production at present is largely driven by synthetic fertilizers
- A growing population with a demand for a meat diet requires energy demanding livestock production
- Organic production is based on cycling nutrients by either livestock or N-fixation by leguminous plants
- Nitrous oxides are also emitted from organic fertilizers and mineralization processes, but:
  - Lower application rates – lower losses and emissions.
  - Internal element cycles on farm – no additional N

N_2O-emissions

- N_2O emissions mainly depend on
  - Nitrogen inputs
  - Crop type
  - Temperature (N-flux rate)

  (*Petersen et al. 2006*)
- Synchrony of N-mineralisation with plant uptake
- No-till shows higher emission than conventional tillage, when flux rates are high due to
  - compaction,
  - reduced porosity and
  - increased denitrification,

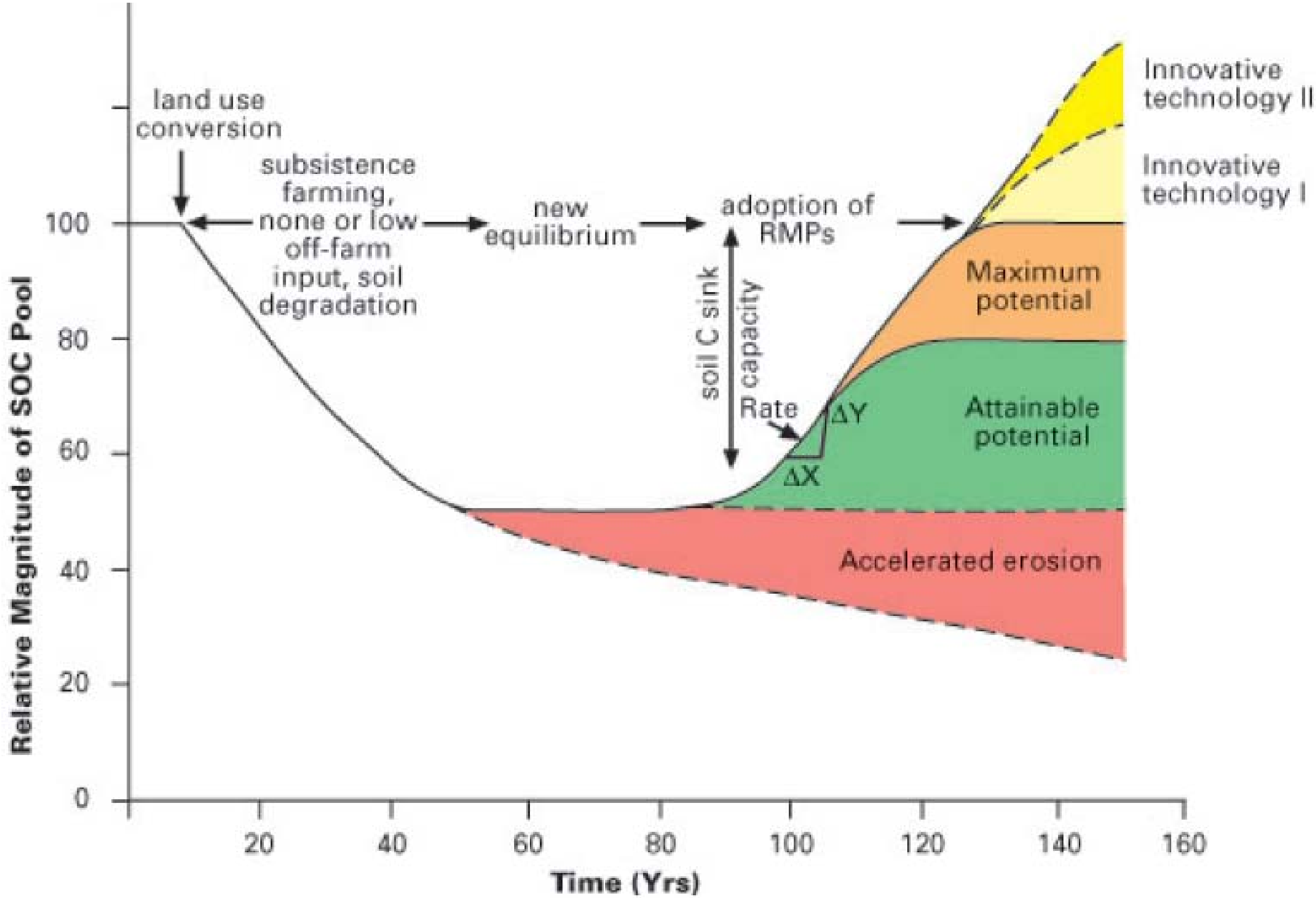


Smith & Conen (2004) SUM 20

Soil carbon sequestration

- Soils contain 1550 Pg (1Pg = 10^{15} g) of carbon,
  - three times the amount in vegetation and
  - twice the amount in the atmosphere
- Carbon sequestration can be achieved by
  - Increasing fluxes from the atmosphere to the soil
    - enhancing plant productivity
    - improving and diversifying crop rotations
    - perennial crops
  - Stabilization of organic matter in soils
    - manure or compost amendment
  - Slowing down decomposition
    - reduced or no tillage

Soil organic carbon (SOC) dynamics



Lal, Science (2004)

Potential for soil carbon sequestration

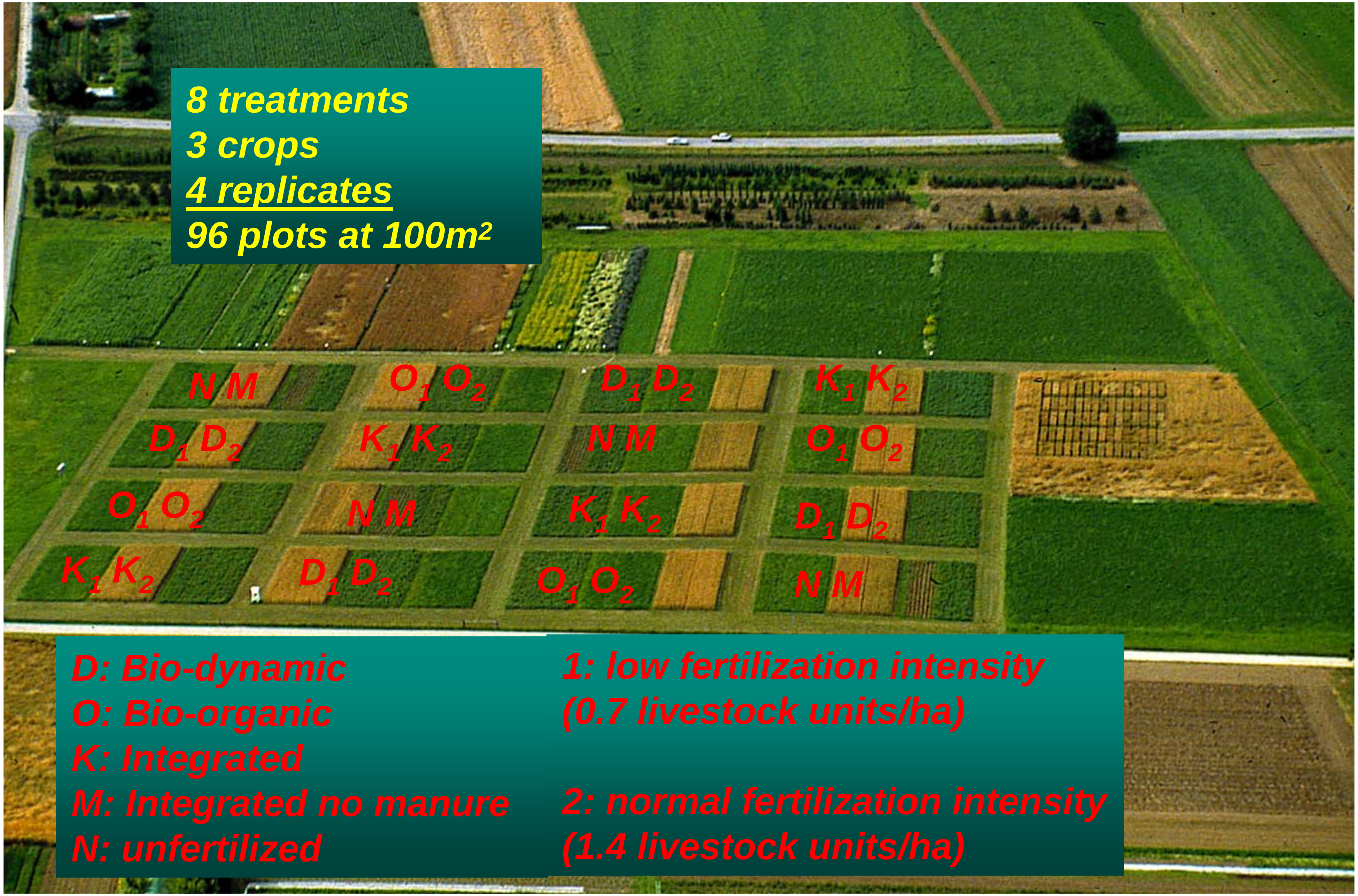
- Estimates are between 1/3 (1 Pg yr^{-1}) to 2/3 (2 Pg yr^{-1}) of the annual atmospheric CO_2 increase (*Lal, 2004, Smith 2004*)
- Organic farming is the only effective incentive for enhancing carbon stocks at present (*Smith, 2005*)
- The process is reversible, and limited in duration
- Despite the limitations soil carbon build-up represents a win-win situation
  - Capturing atmospheric CO_2
  - Increasing soil stability
  - Increasing soil fertility

Lessons learned from the DOK long-term field experiment in Switzerland

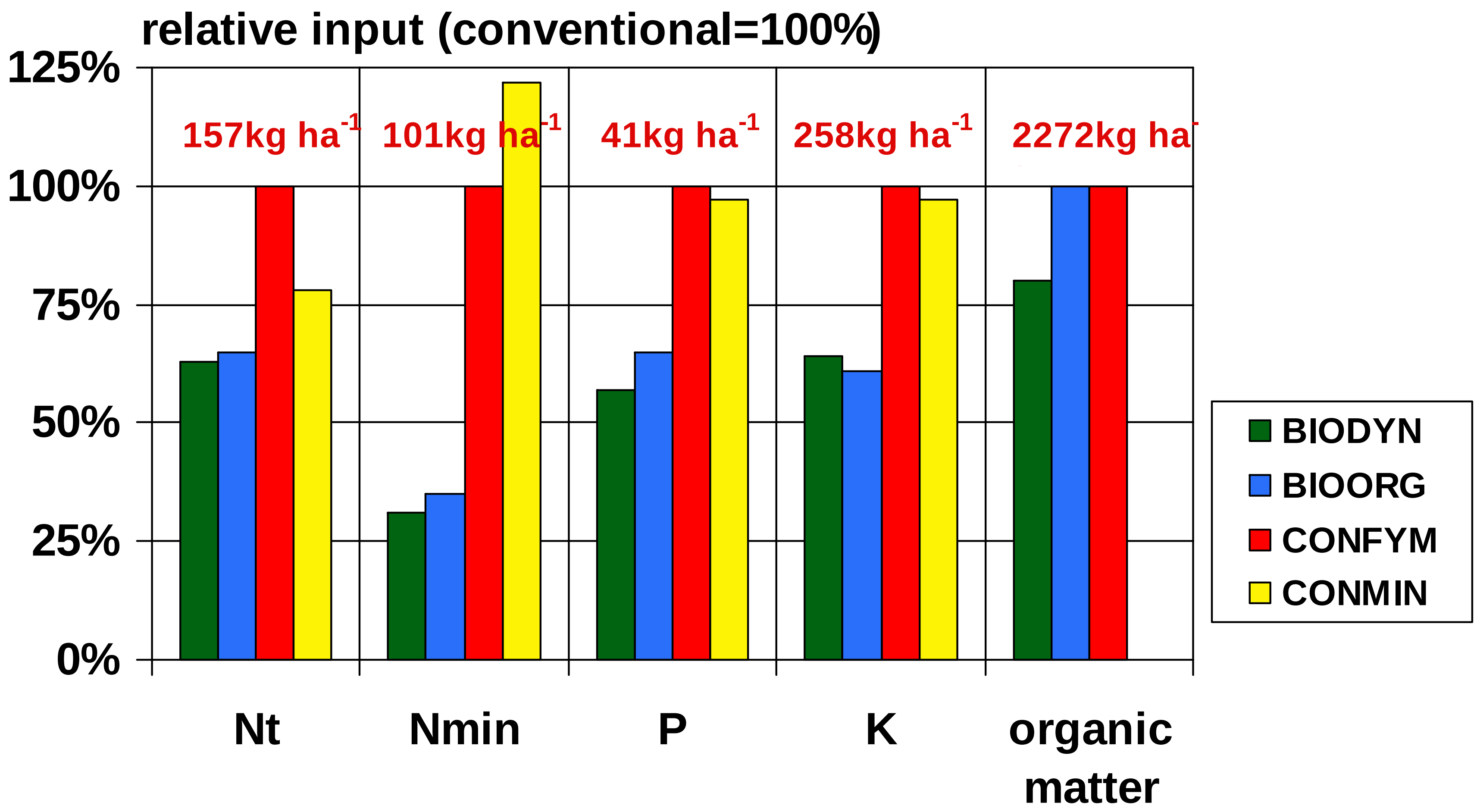
> Comparison of organic and conventional farming systems
  > The same livestock density, crop rotation, soil tillage
  > Started in 1978 (collaboration of Agroscope ART Reckenholz and FiBL)

> Farming systems of the DOK trial
  > BIODYN: biodynamic with composted manure
  > BIOORG: bioorganic with rotted manure
  > CONFYM: conventional with manure and mineral fertilizer
  > CONMIN: conventional with mineral fertilizer only

The field trial and the farming systems



DOK trial - Input of nutrients (Ø 1978-2005)

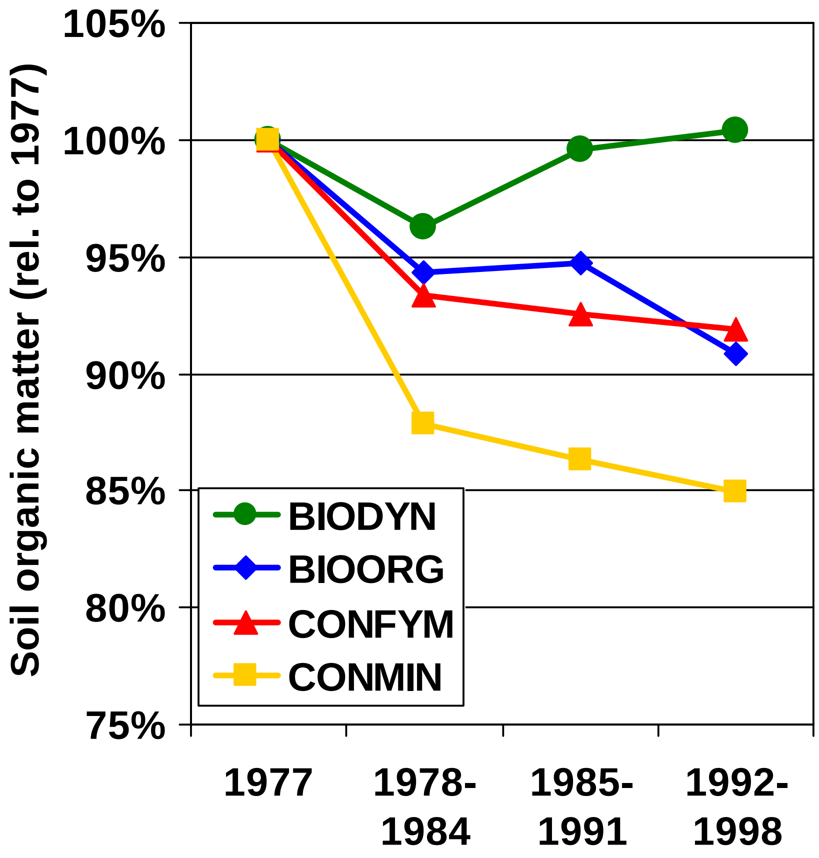


Mäder et al., 2006,

BioFach, 17.02.2007

Changes in soil organic matter

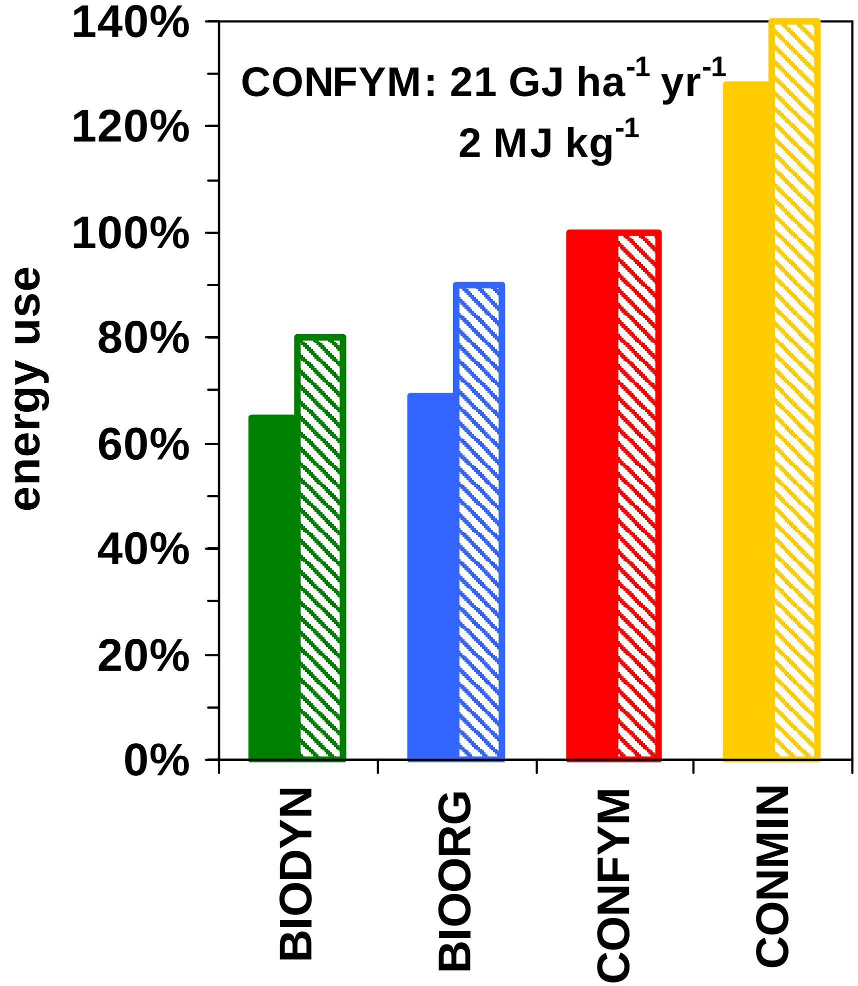
> Up to 15% higher soil organic carbon in soils of organic systems – this corresponds to 700 kg organic carbon sequestered annually
> Manure use is an effective option to increase soil organic carbon also in conventional systems
> Composted manure as in the biodynamic system has the greatest potential



Fließbach et al., 2007, AGEE

Results from life-cycle assessments: Energy use

- Energy use in organic systems is 33 % lower than in conventional and 48 % lower than in conv. mineral system
- The difference is mainly due to the indirect energy needed for N-fertilizer production



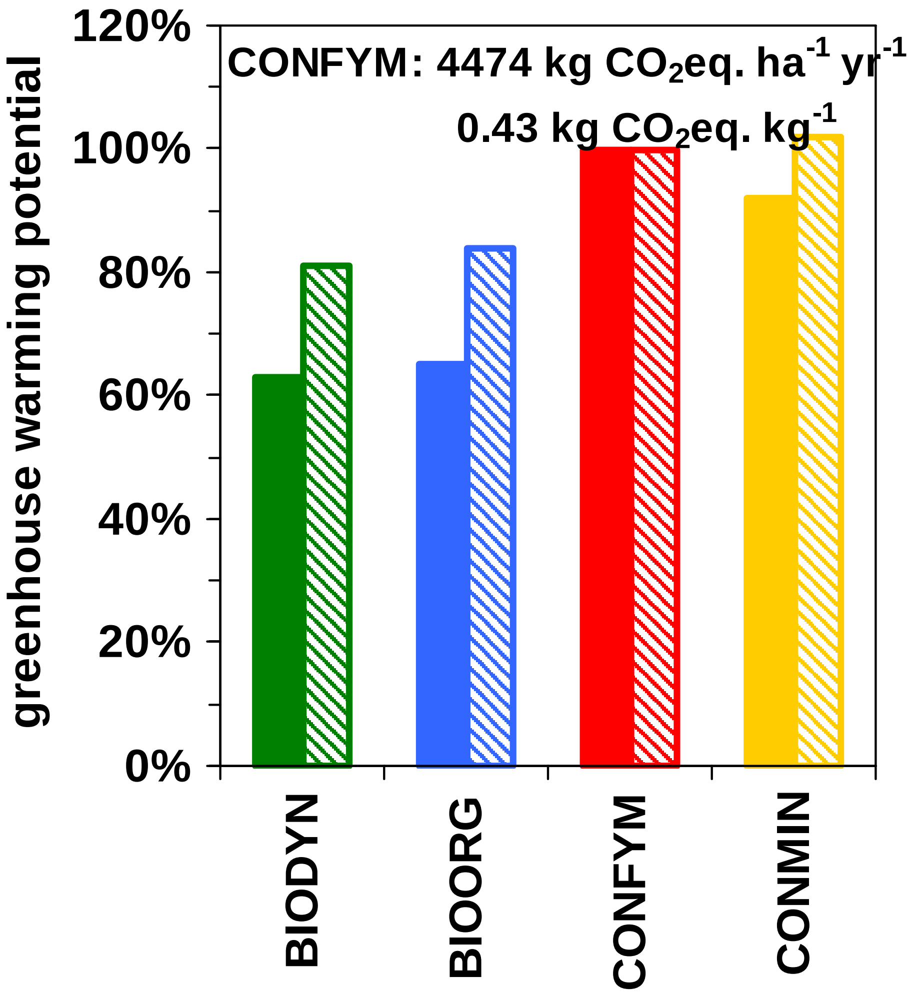
Nemecek et al., 2005,

Results from life-cycle assessments: Greenhouse warming potential (GWP)

> GWP in organic systems is 36 % lower than in conventional and 31 % lower than in conv. mineral system

> The difference is due to the energy needed for N-fertilizer production

> Due to the higher potential for eutrophication and acidification by manure the mineral system has a slightly lower GWP



Nemecek et al., 2005,

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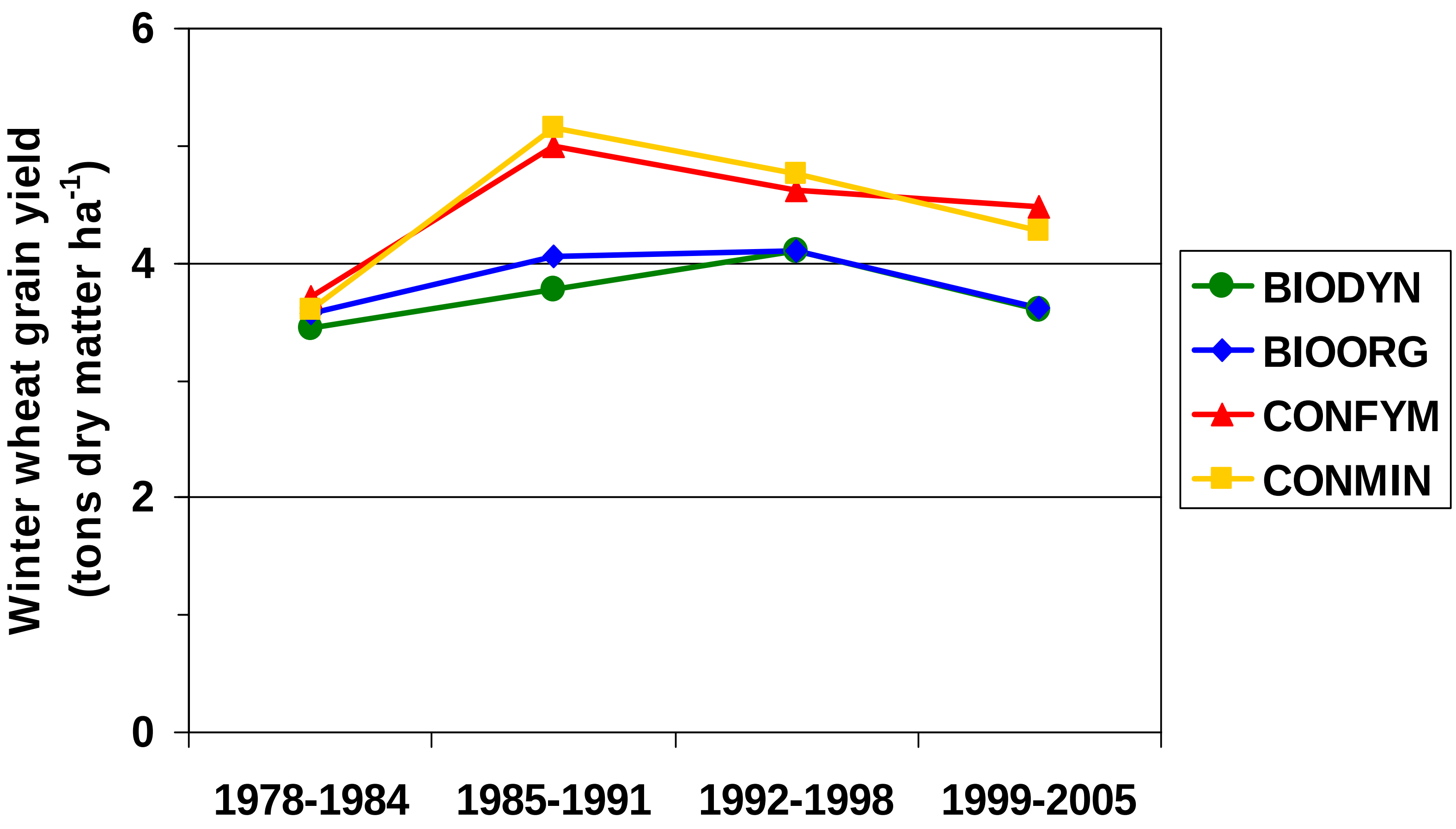
Development of winter wheat yield



Mäder et al., 2006, ISOFAR

Soil structural stability

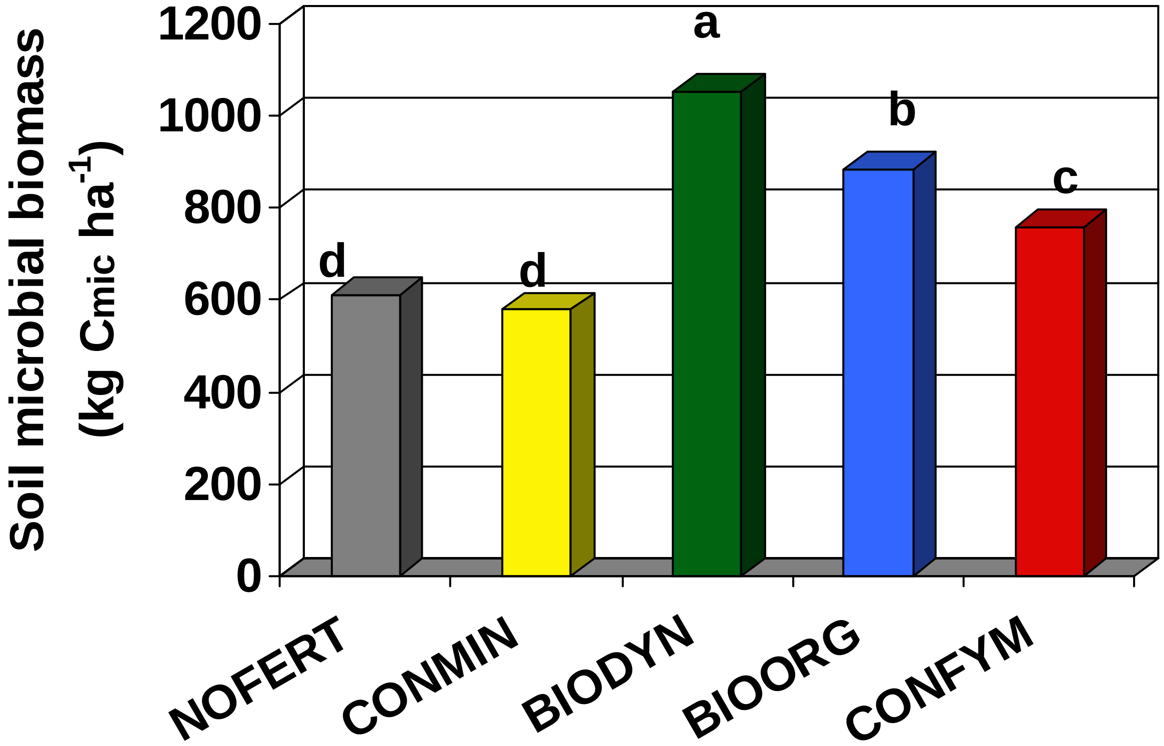
Fotos: Fliessbach Nov. 2002

Conventional
without manure

Bio-dynamic with
composted manure

DOK: Soil microbial biomass

Long-term average (1995-2002)



Calculated for 0-20cm at an average density of 1.4 g cm^{-3}

21 years of research in the DOK trial

	Organic	Conventional
> **Winter wheat** crop yield	**4.7 t/ha**	**5.6 t/ha**
> **Fertilization** NH_4NO_3 equivalent	**122 kg/ha**	**360 kg/ha**
> **Energy** gasoline equivalent	**340 l/ha**	**570 l/ha**
> **Plant protection** active ingredients	**0-200 g/ha**	**6.0 kg/ha**
> **Soil Fertility**	**40 t/ha**	**24 t/ha**
soil microbial biomass ≈	**700 sheep**	**400 sheep**

Mäder et al (2002)

Conclusions

> **Reducing emissions is a major task for organic and conventional management**
> **Organic farming has a great potential to mitigate climate change and its possible impacts by:**
  > **Reduced nitrogen fertilization**
  > **Manure amendments**
  > **Improved soil fertility and stability**
  > **Mixed livestock and plant production**
  > **Temporary or permanent grassland as fodder basis**
  > **Diversified crop rotations**
  > **… improvements of the management systems**