Integrating an economic model for European agriculture with a mechanistic model to estimate nitrogen and carbon losses from arable soils in Europe – net climate impact of rapeseed cultivation for biofuels

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TFIAM/COST729/NinE
Workshop on integrated modelling of nitrogen
28-30 November, 2007 – Laxenburg, Austria

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Chemistry World, 21. September 2007

Biofuels could boost global warming, finds study

21 September 2007

Growing and burning mar
greenhouse gas emission

Crutzen has shown.[1] Th
which warned nations not
they cause food shortage

Crutzen and colleagues h
used biofuel crops releas
gas nitrous oxide (N_2O)

not using fossil fuels and
work appears in *Atmosp*
open review.

'The significance of it is t
disputable than had been
from the University of Edi
that [growing many biofu
making the climate issue worse.

Crutzen, famous for his work on nitrogen oxides and the ozone layer, declined to comment before the paper is officially published. But the paper suggests that microbes convert much more of the nitrogen in fertiliser to N_2O than

"What we are saying is that growing biofuels is probably of no benefit and in fact is actually making the climate issue worse"
- Keith Smith

« Commentary: Fuel subsidies for bottom-trawling fishing vessels are a money losing investment, for less than 1% of global marine catch value that does incomparable damage to the ocean floors.

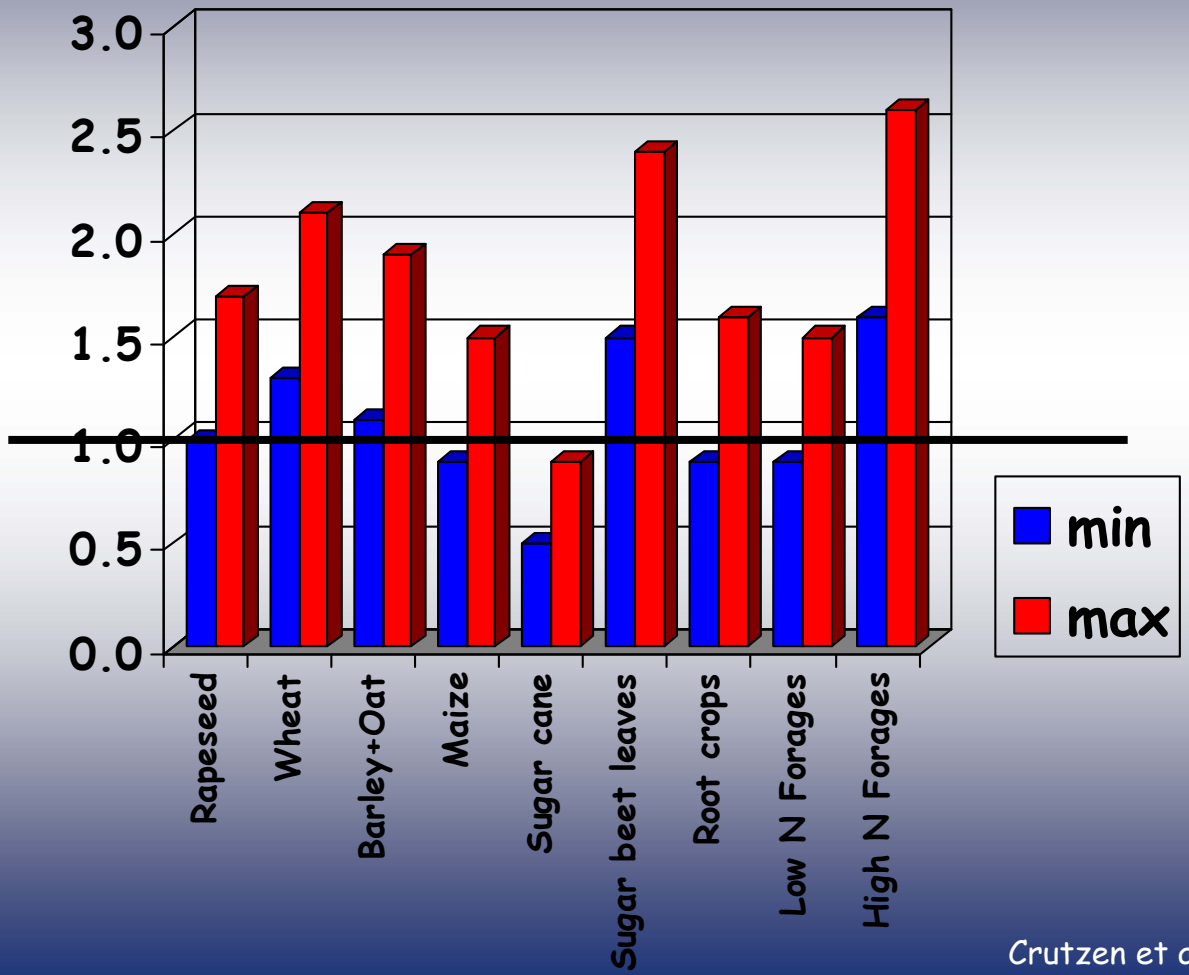
63% of Canadian homeowners & 70% of American homeowners understood benefits of green building products, but thought green building products was usually just marketing, though 60% of Canadians surveyed were willing to pay more upfront for green products compared to 56% for Americans. »

80% of Europe's biodiesel comes from rapeseed, which's nitrous oxide emissions does global warming damage 1 to 1.7 times the CO2 saved from using fossil fuels; corn bioethanol's factor is 0.9 to 1.5; but sugar cane bioethanol is sustainable at 0.5 to 0.9.

Posted by **envirostats** on September 22nd, 2007

Relative warming derived from N_2O production

$$\frac{N_2O - emissions\ [CO_{2-eq}]}{Saved\ CO_2\ emissions\ [CO_{2-eq}]}$$



Crutzen et al. 2007, Atmos. Chem. Phys. Discuss.

Application of CAPRI/DNDC-EUROPE on rapeseed cultivation in Europe

→**Policy framework**

→**CAPRI / DNDC-EUROPE**

→**Set-up of bio-crop simulations**

→**Does N_2O negate CO_2 savings?**

Renewable energy directive

Biofuel directive 2003

→ **Target for min. proportion for biofuels: 5.75% (energy content) of all petrol and diesel for transport purposes by dec. 2010**

Commission Communication: Limiting Global Climate Change to 2ºC (2007) and EU Spring Summit 2007

→ **Binding targets for the overall share of renewable energy (20%) and for the share of biofuels in petrol and diesel (10%) in 2020**

Directive on renewable energy (DG TREN finalized by end 2007)

→ **Targets confirmed**

→ **Sustainability criteria**

- Achieving a minimum level of GHG savings
- Avoiding major reduction in carbon stocks through land use change
- Avoiding major biodiversity loss from land use change

Fuel quality directive

→DG-ENV is proposing to amend the fuel quality directive to include GHG efficiency of the EU road-fuel mix

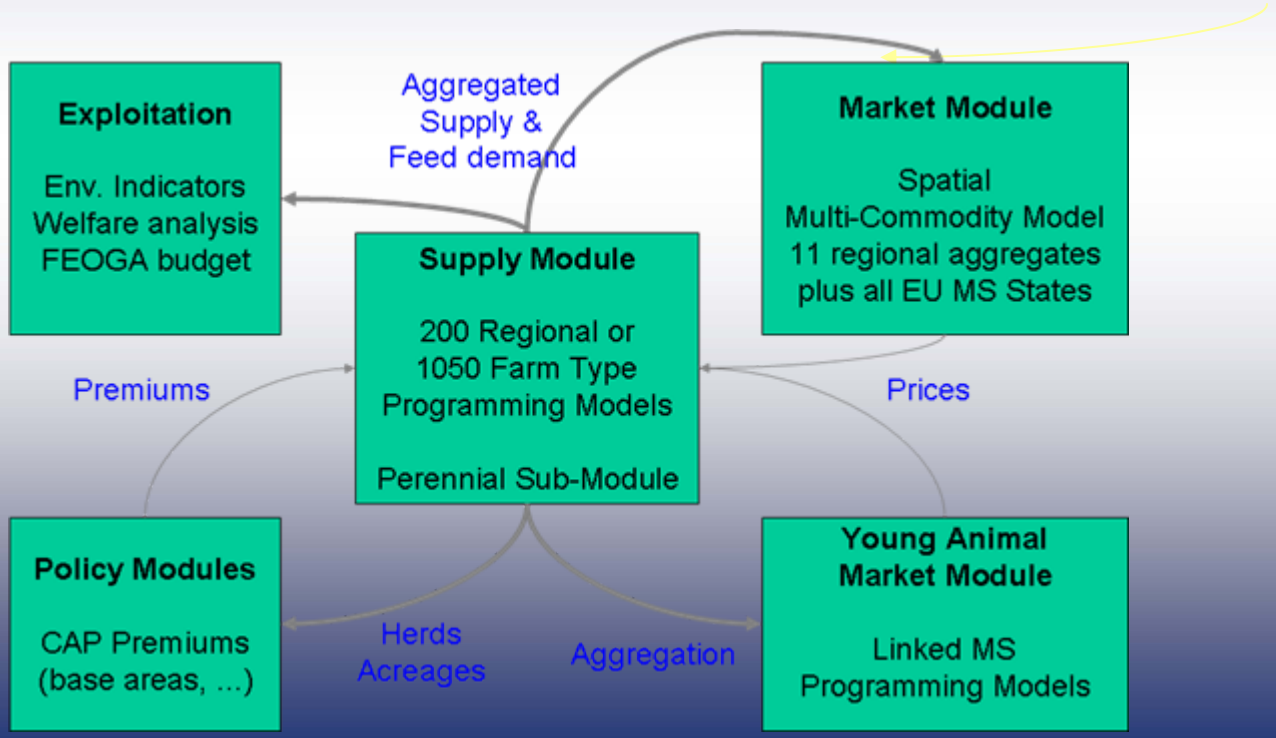
- decrease of 10% in the average GHG-intensity of road fuel
- most of it must come from the use of bio-fuels
- stronger target than renewable energy directive

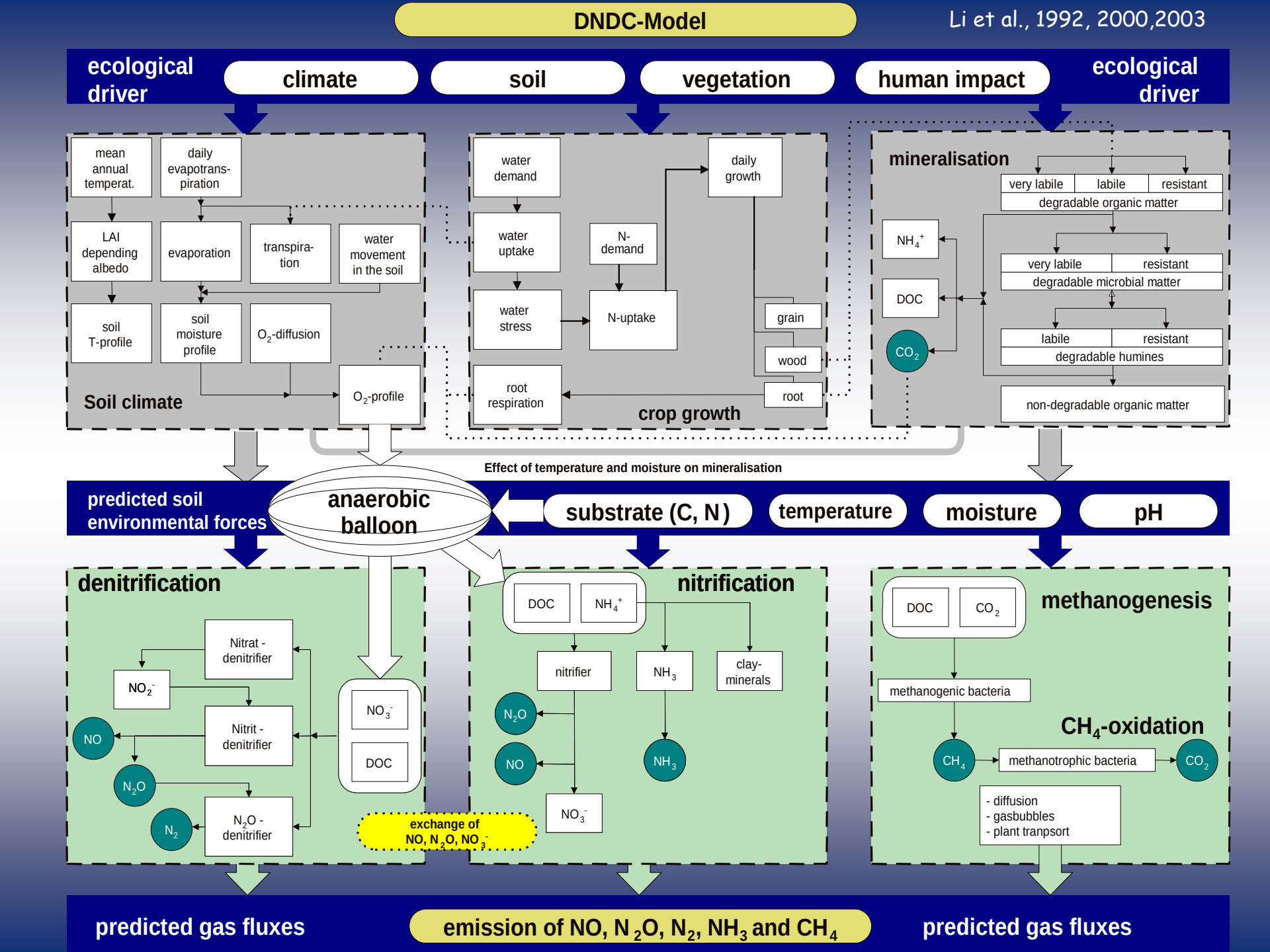
→ requires comprehensive and careful lifecycle analysis including N_2O emissions!

CAPRI/DNDC-EUROPE framework

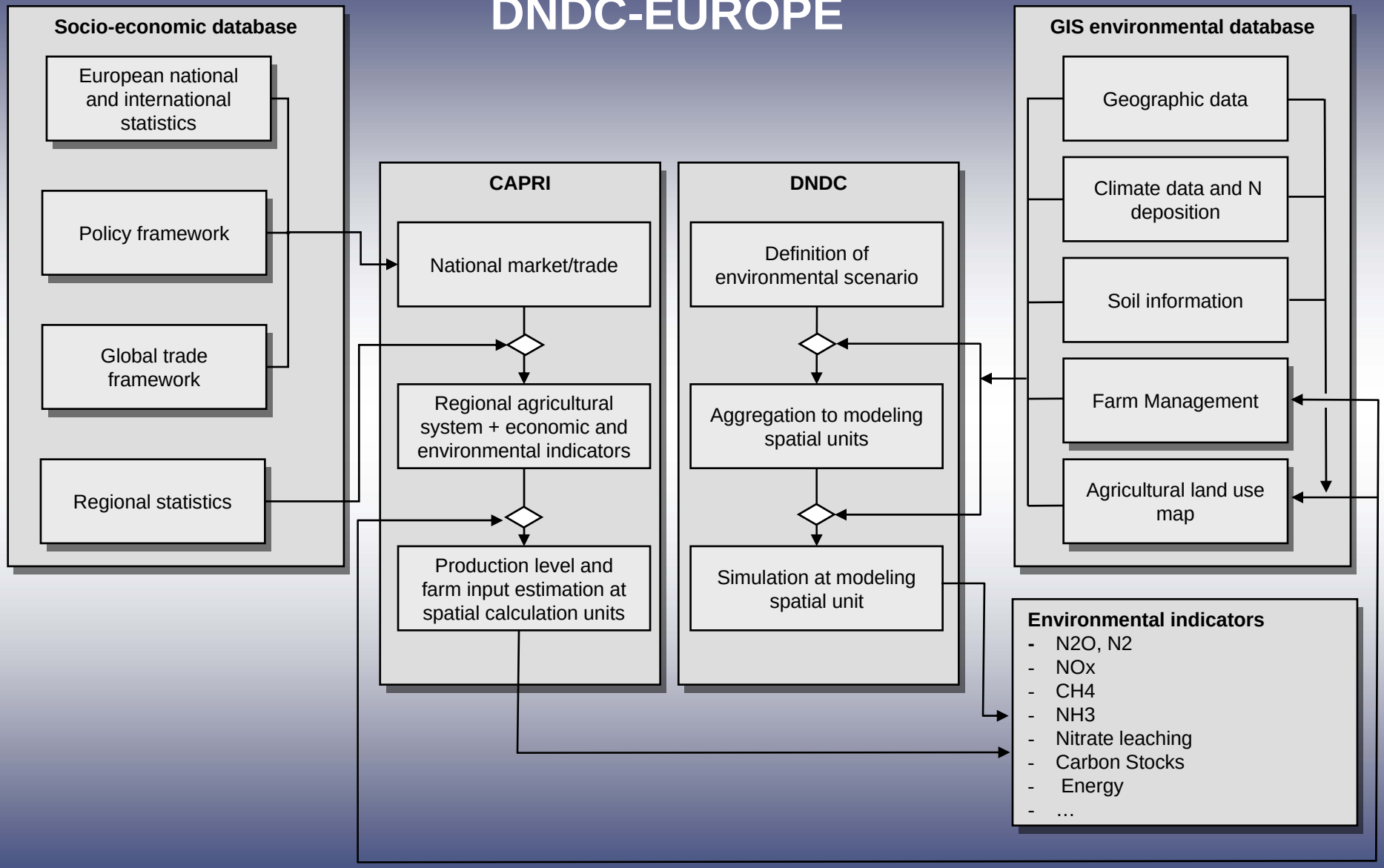
A "multi-purpose" modeling system for EU's agriculture, allows to analyze

- → **Market policies (administrative prices/tariffs/preferential agreements)**
- → **Premium systems/quotas/set-aside at regional level (CAP)**
- → **Environmental policies (standards/market solutions)**



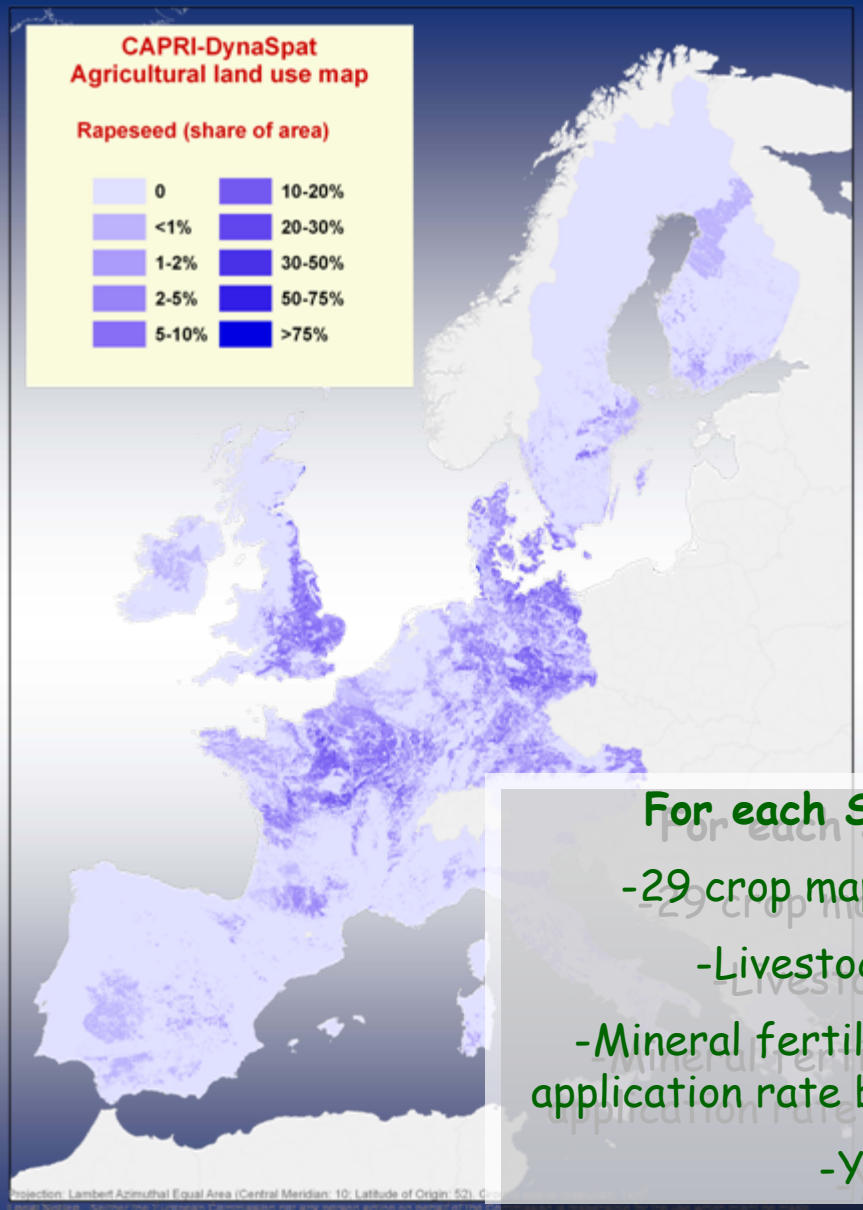

DNDC-Model
Li et al., 1992, 2000,2003
ecological driver
climate
soil
vegetation
human impact
ecological driver
mean annual temperat.
daily evapotrans-piration
LAI depending albedo
evaporation
transpira-tion
water movement in the soil
soil T-profile
soil moisture profile
O2-diffusion
O2-profile
Soil climate
water demand
daily growth
water uptake
N-demand
water stress
N-uptake
grain
wood
root respiration
root
crop growth
mineralisation
very labile
labile
resistant
degradable organic matter
NH4+
very labile
resistant
degradable microbial matter
DOC
CO2
labile
resistant
degradable humines
non-degradable organic matter
Effect of temperature and moisture on mineralisation
predicted soil environmental forces
anaerobic balloon
substrate (C, N)
temperature
moisture
pH
denitrification
Nitrat - denitrifier
NO2-
Nitrit - denitrifier
NO
N2O
N2
N2O - denitrifier
NO3-
DOC
exchange of NO, N2O, NO3-
nitrification
DOC
NH4+
nitrifier
NH3
clay-minerals
N2O
NO
NO3-
NH3
methanogenesis
DOC
CO2
methanogenic bacteria
CH4-oxidation
CH4
methanotrophic bacteria
CO2
- diffusion
- gasbubbles
- plant tranpsort
predicted gas fluxes
emission of NO, N2O, N2, NH3 and CH4
predicted gas fluxes

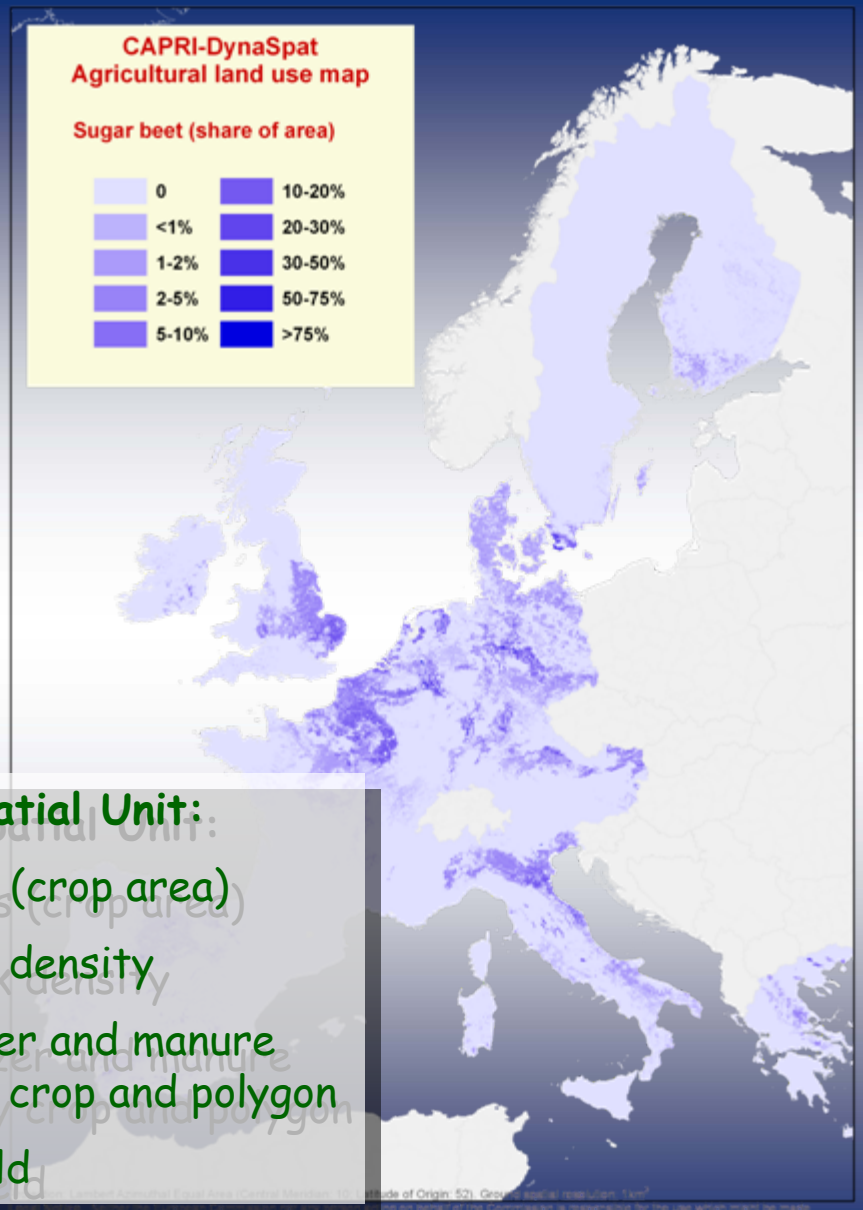
CAPRI - DNDC-EUROPE



Developed in CAPRI-DynaSpat

Leip et al, 2007, Biogeosciences Discussions





For each Spatial Unit:

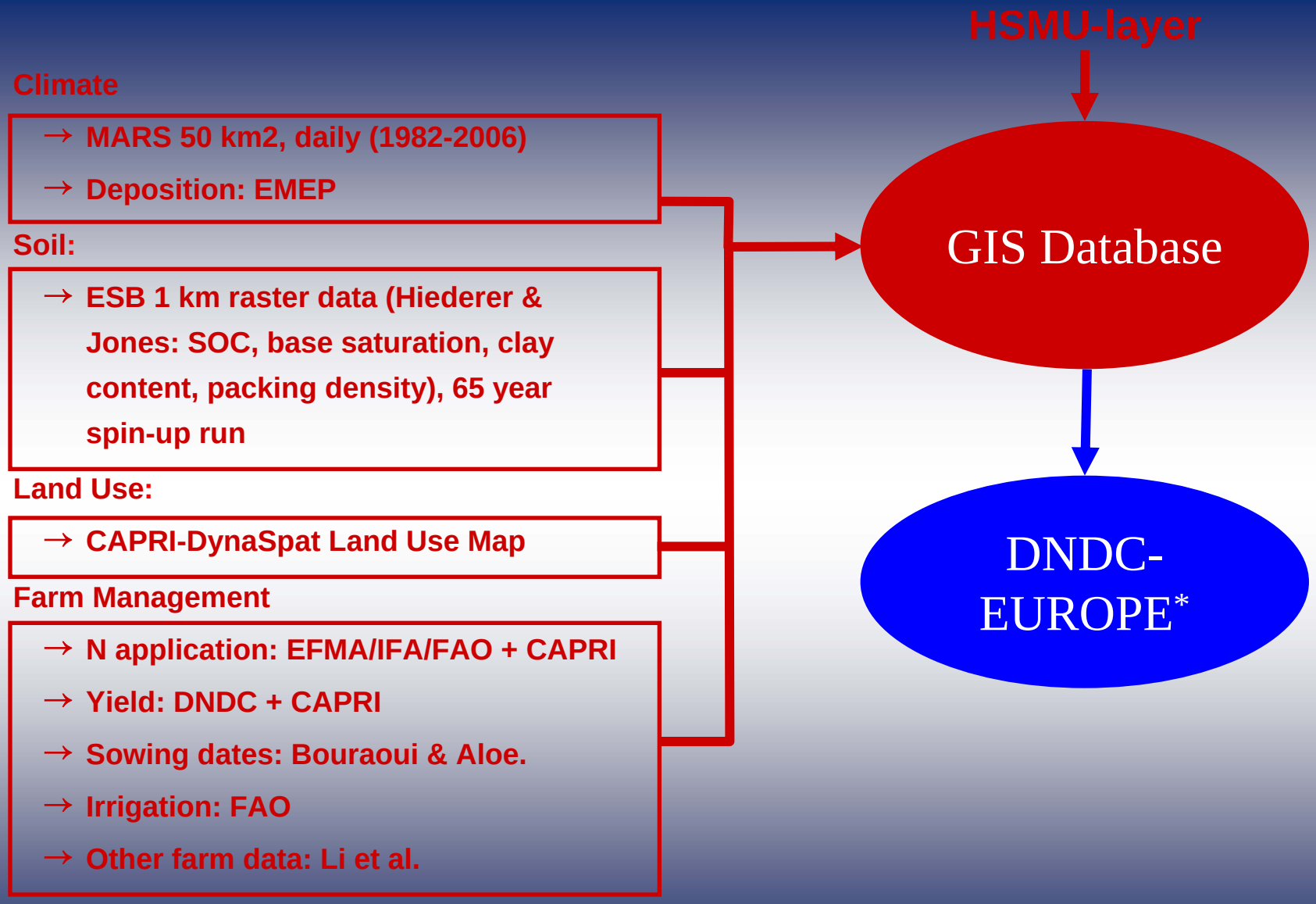
-29 crop maps (crop area)

-Livestock density

-Mineral fertilizer and manure application rate by crop and polygon

-Yield

Set-up of DNDC



* modified DNDC V.89 to accommodate simulations of HSMU for in- and output handling

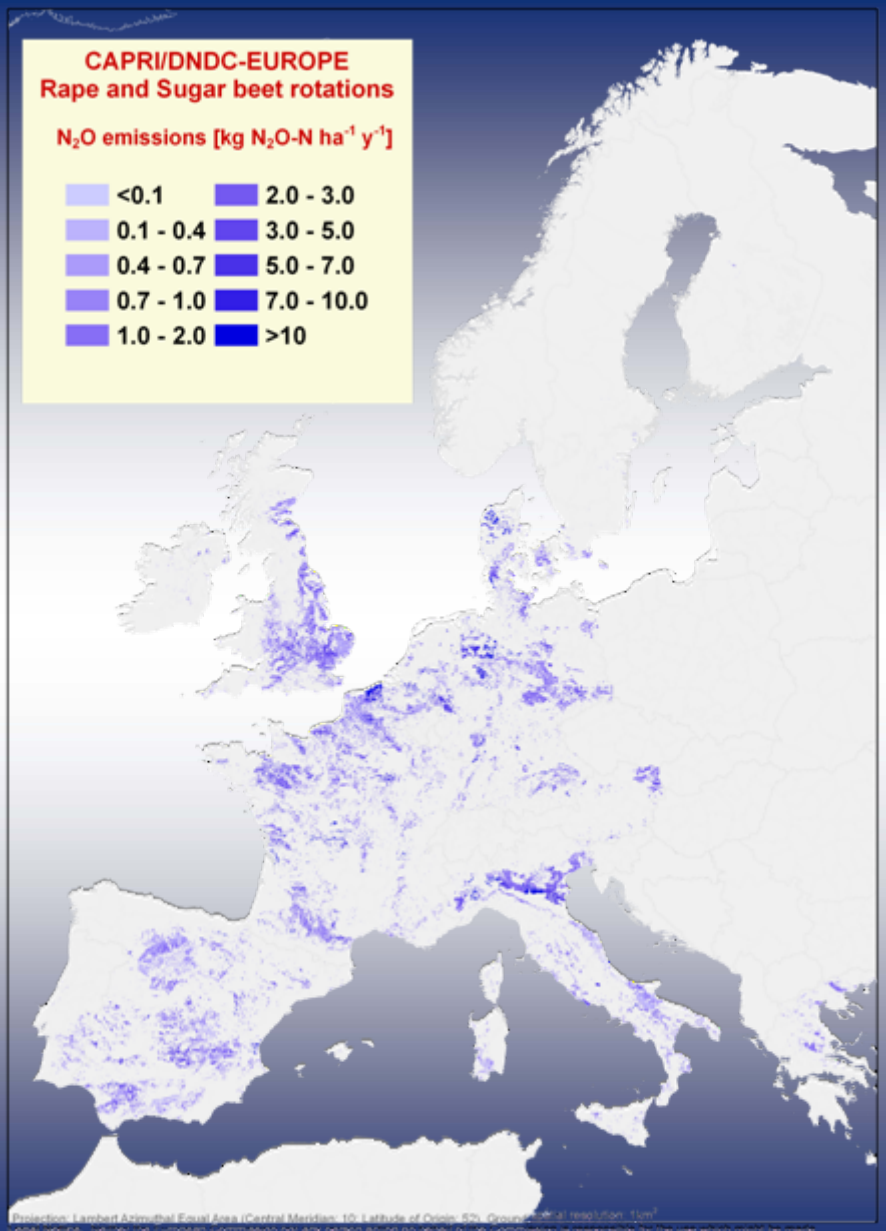
Generation of crop rotation

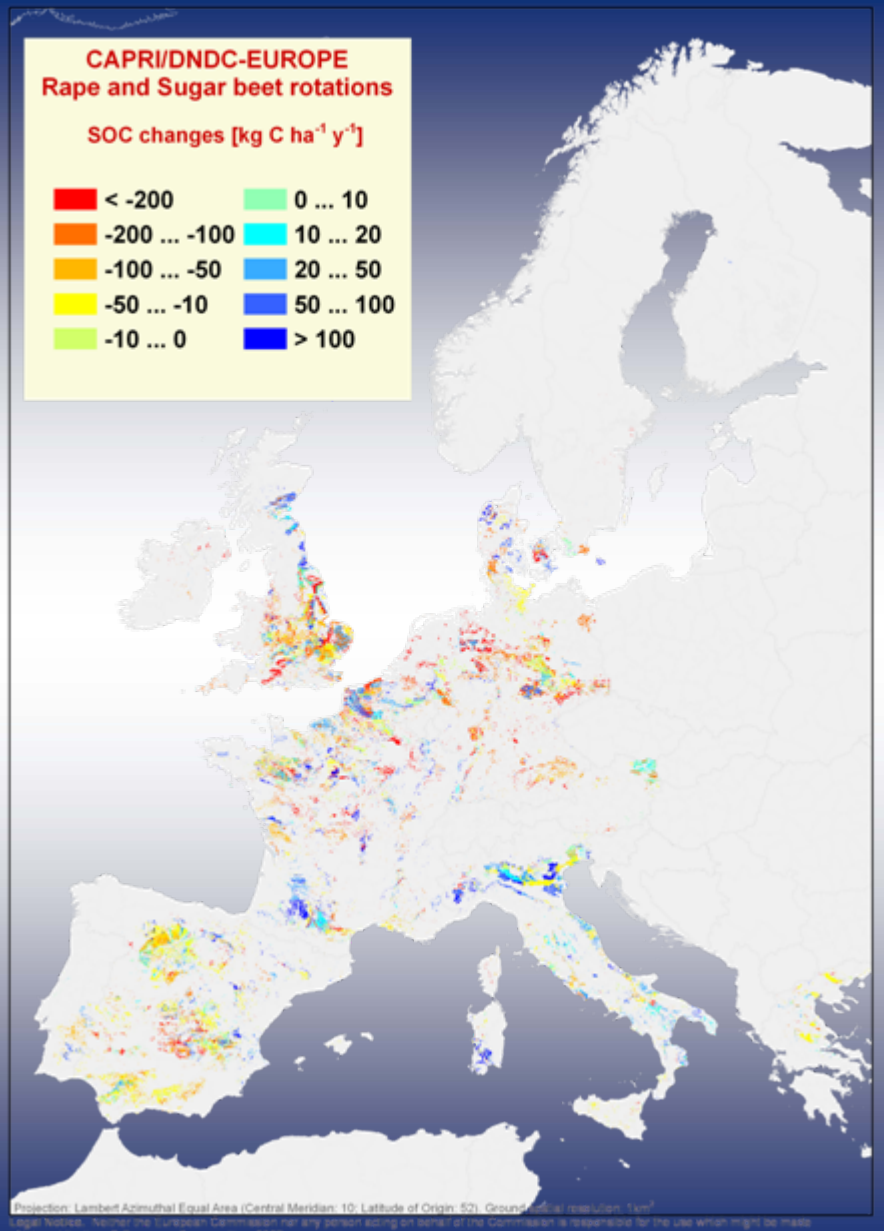
→**Linked to land uses within simulation unit**

→**A priori assumption on possible rotations**

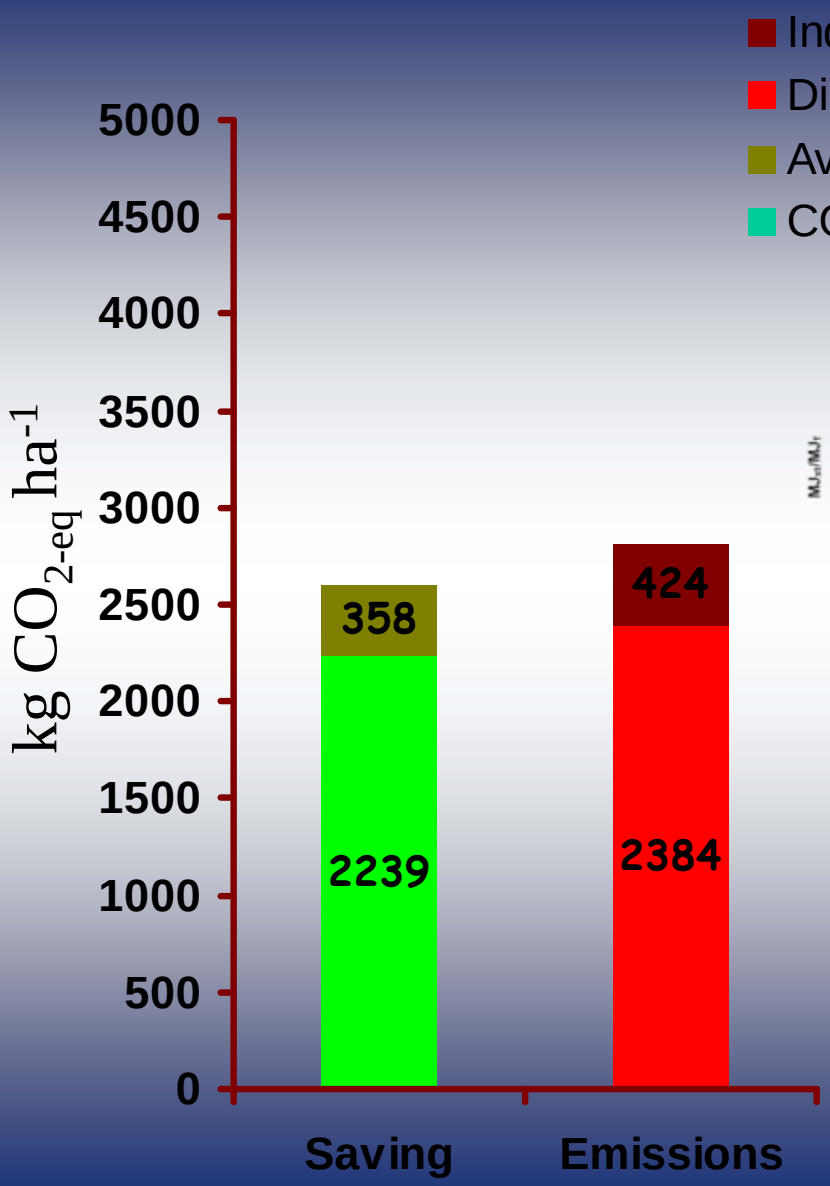
Rotations are generated consistent with national statistics, environmental conditions, and farm practice recommendations

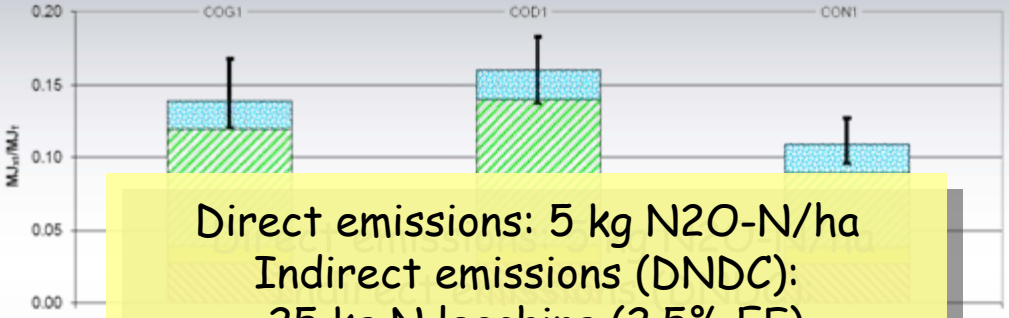
RESULTS (10-years average)





CO_2 savings vs. N_2O emissions





Direct emissions: 5 kg N2O-N/ha
Indirect emissions (DNDC):
-25 kg N leaching (2.5% EF)
-50 kg N volatilised (1%EF)

Yield: 1300 kg C/ha
(DNDC)

Energy input fossil fuel: 0.16 MJ/MJ
(JEC, 2007. Well-to-Wheel study)

On-farm energy input

Detailed assessment of energy requirements (CAPRI)

→Direct energy input

- Fuel for farm machinery
- Lubricants
- Electricity

→Indirect energy input

- Plant protections/Irrigation/Seeds
- Depreciation/Repair of farm machinery and buildings
- Drying of cereals

Kraenzlein et al., 2007

GHG emissions from fertilizer manufacture

→ Main use of fertilizer

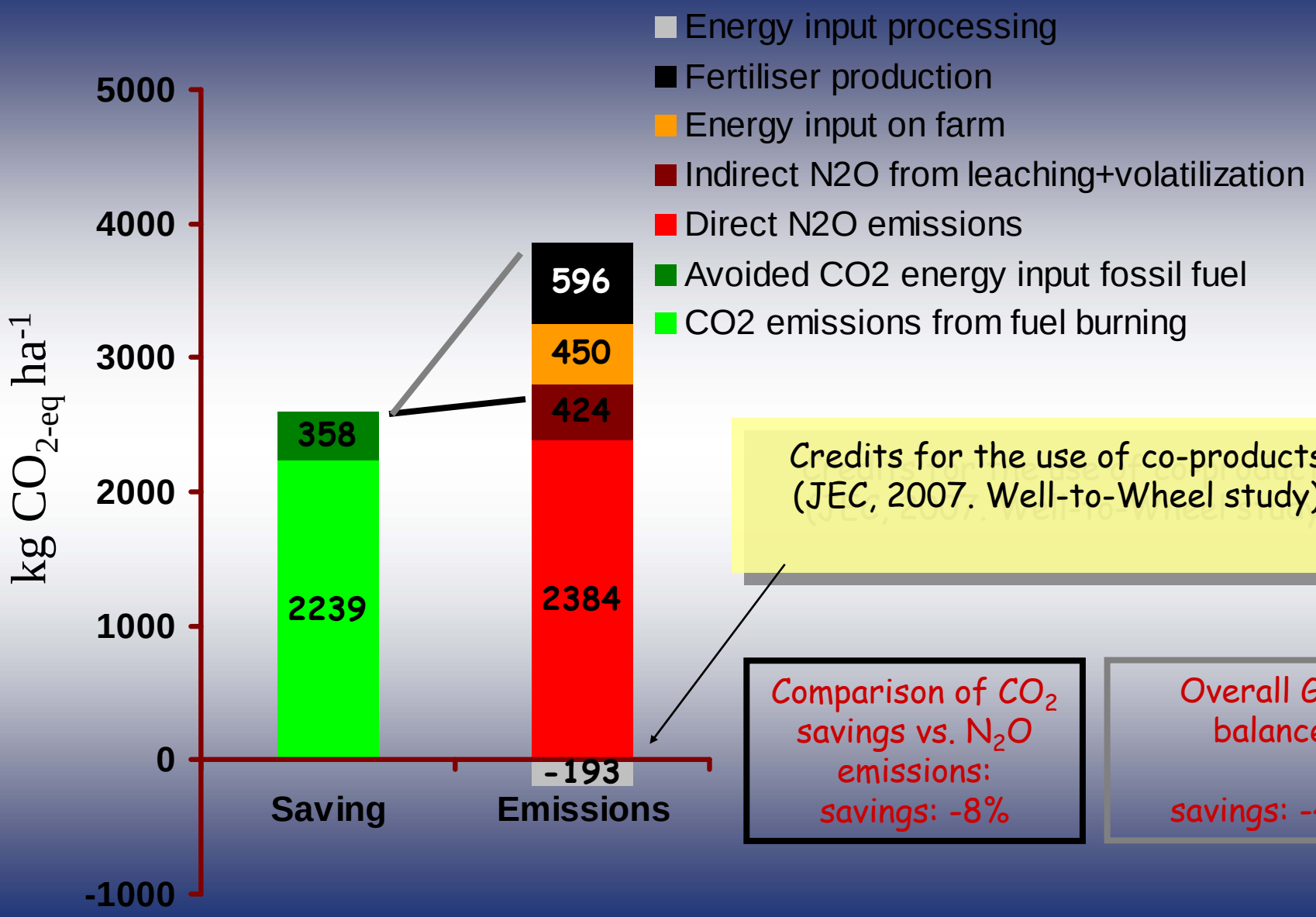
Calcium ammonium nitrate	27%
NPK/NP/NK fertilizers	22%
Ammonium nitrate	21%
Urea	11%
Nitrogen solutions (mainly UAN)	10%

→ Emission factors

Calcium ammonium nitrate	7.2	kg $CO_{2\text{-eq}}$/kg N
NPK/NP/NK fertilizers	5.4	kg $CO_{2\text{-eq}}$/kg N
Ammonium nitrate	6.9	kg $CO_{2\text{-eq}}$/kg N
Urea	4.0	kg $CO_{2\text{-eq}}$/kg N
Nitrogen solutions (mainly UAN)	5.8	kg $CO_{2\text{-eq}}$/kg N
Ammonium sulphate	5.6	kg $CO_{2\text{-eq}}$/kg N
Other straight N fertilizers **	5.6	kg $CO_{2\text{-eq}}$/kg N

EFMA, 1997 & Wood and Cowie, 2004

GHG balance of rapeseed cultivation (I)

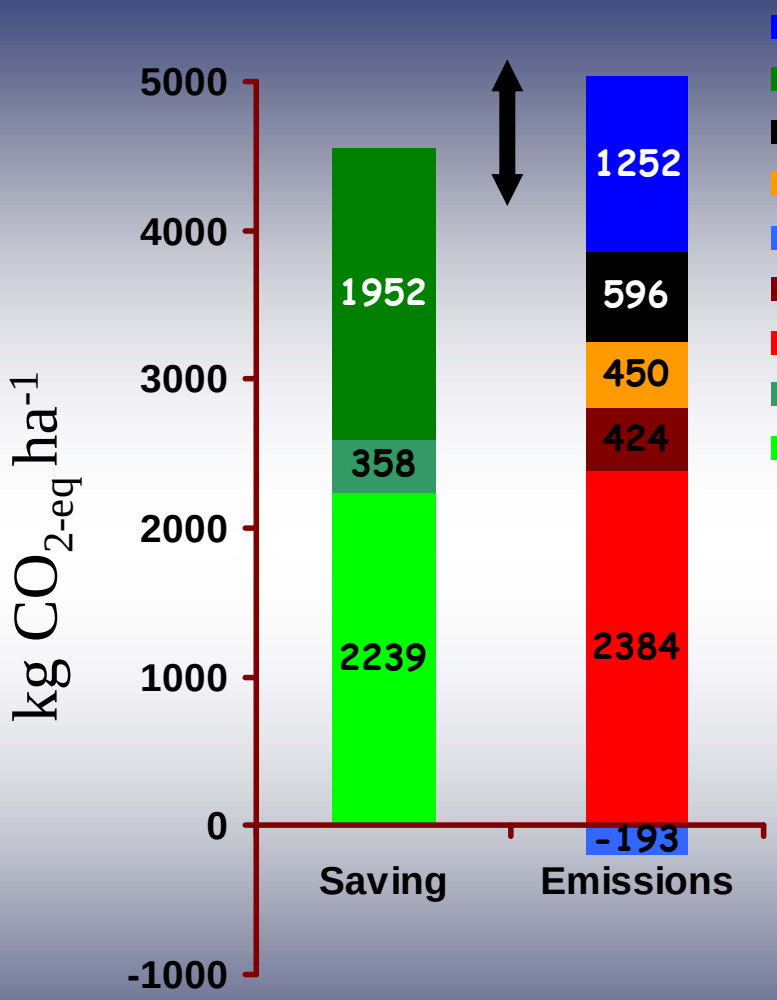


Credits for the use of co-products (JEC, 2007. Well-to-Wheel study)

Comparison of CO_2 savings vs. N_2O emissions: savings: -8%

Overall GHG balance: savings: -40%

GHG balance of rapeseed cultivation (II)



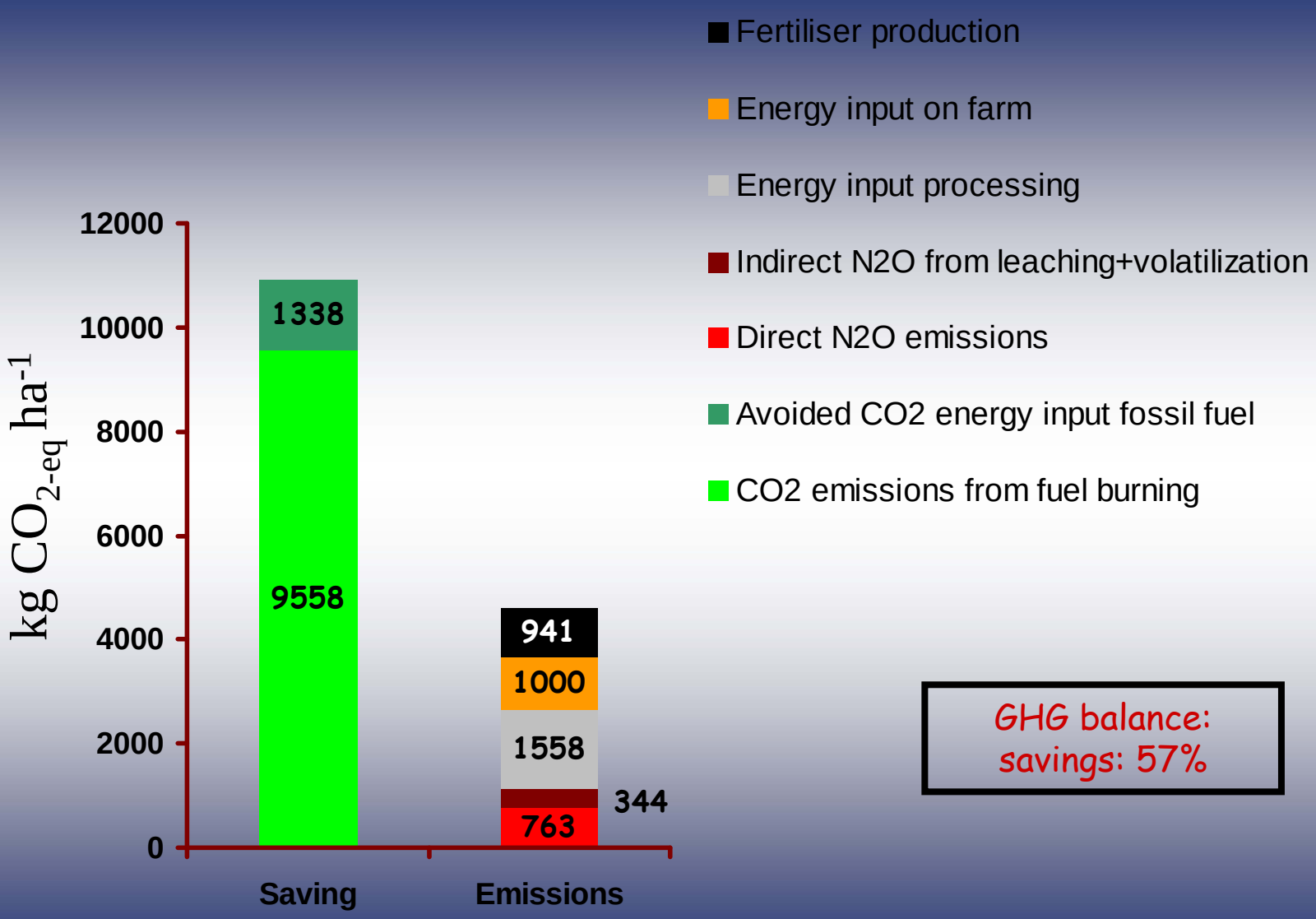
- Carbon losses from arable fields
- Enhanced Carbon sink
- Fertiliser production
- Energy input on farm
- Energy input processing
- Indirect N2O from leaching+volatilization
- Direct N2O emissions
- Avoided CO2 energy input fossil fuel
- CO2 emissions from fuel burning

Carbon-sink sensitivity to N deposition

25 g C / g N

Contribution to carbon sequestration:
10% of volatilizes NH_3+NO_x+$N_{biofuel}$

GHG balance of sugarbeet cultivation



GHG balance:
savings: 57%

Conclusions

→ **Regionalization of the assessment is a pre-requisite for policy advice**

- Matching of agricultural activities with soil and farm management can change the picture

→ **The current simulation results suggest significant N2O emissions**

- For rapeseed similar magnitude then CO2 savings, for sugar beet less

→ **Effect of carbon can be huge**

- Improvement of estimates urgent

→ **The methodology allows a detailed analysis of N2O emissions from biofuel production**

- Scale-consistency “from plot to continent”
- Consistency with cultivation pattern and farming practices
- Comprehensive *ex ante* policy analysis possible (incl. structural changes)

→ **Challenge to factor-out marginal emissions caused by bio-fuels**

- How would the land be used otherwise?
- Where is the ‘former’ land use happening now?