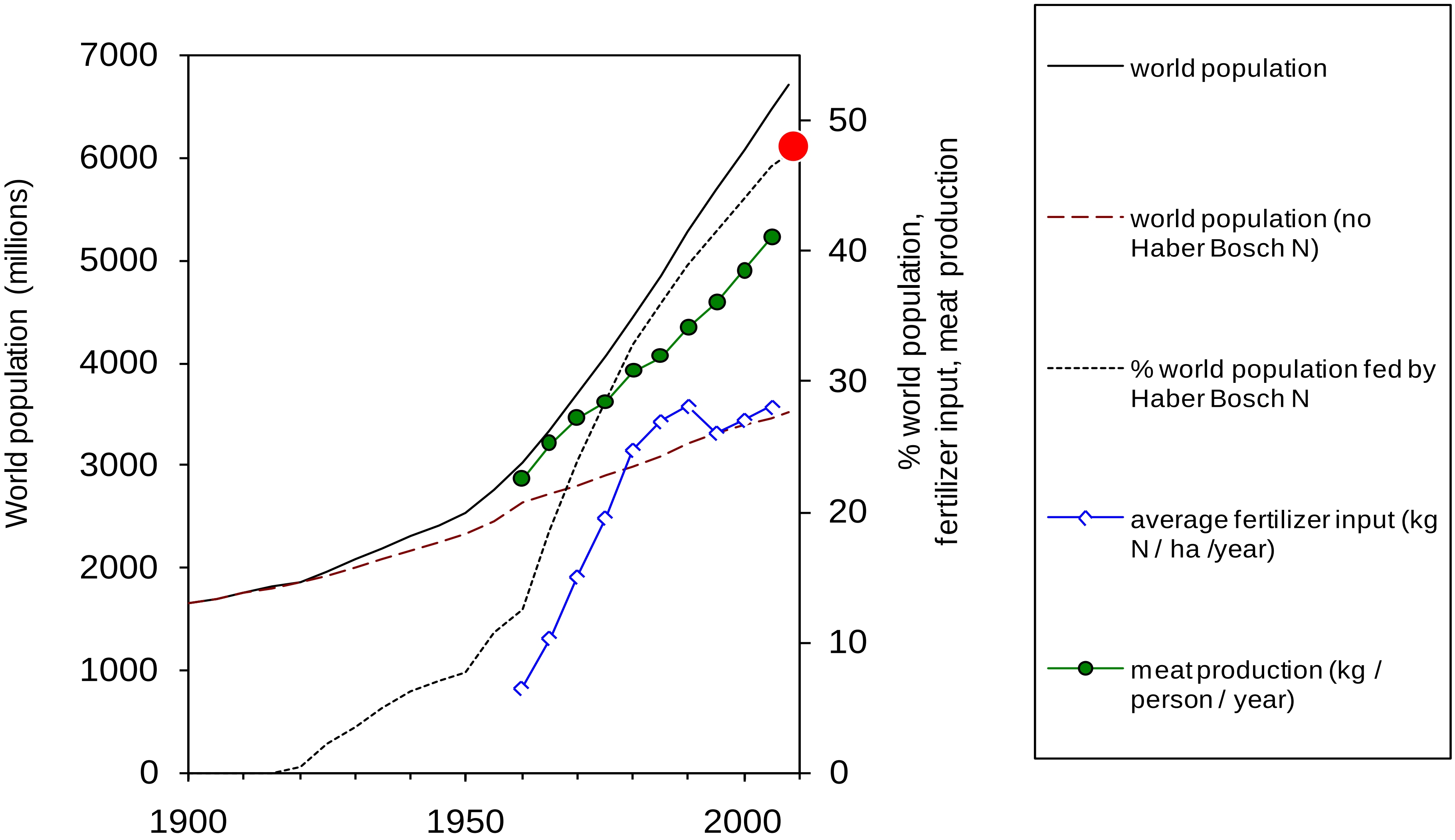
Nitrogen & the European greenhouse gas balance

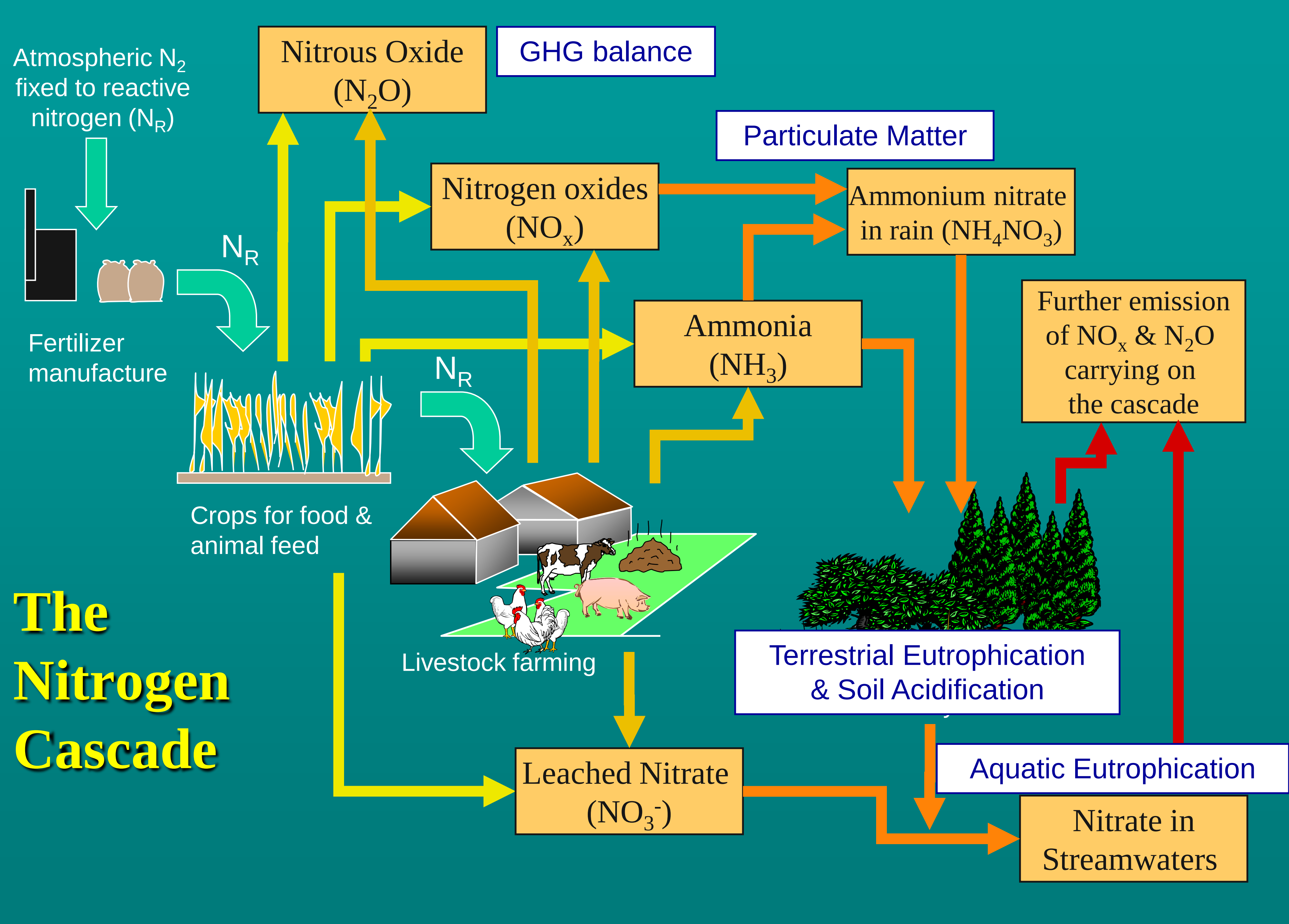
Mark Sutton

RSC, London 9 March 2010

Why care about reactive nitrogen (Nr)?



Erisman et al. 2008 Nature Geoscience



Sutton et al., European Nitrogen Assessment, CUP 2011

NitroEurope IP

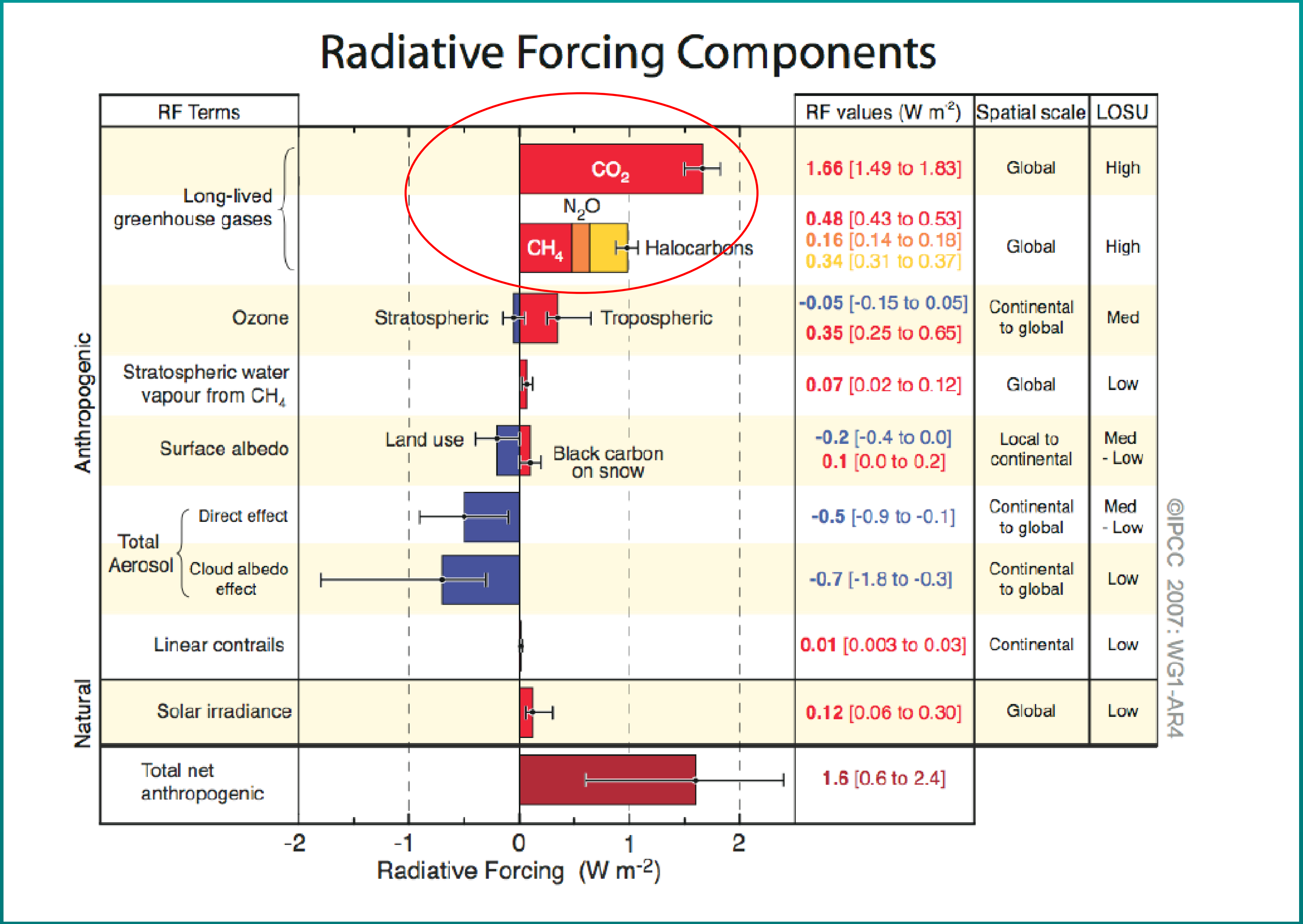
What is the effect of reactive nitrogen supply on the direction and magnitude of net greenhouse gas budgets for Europe?

Effect of N on the GHG balance:

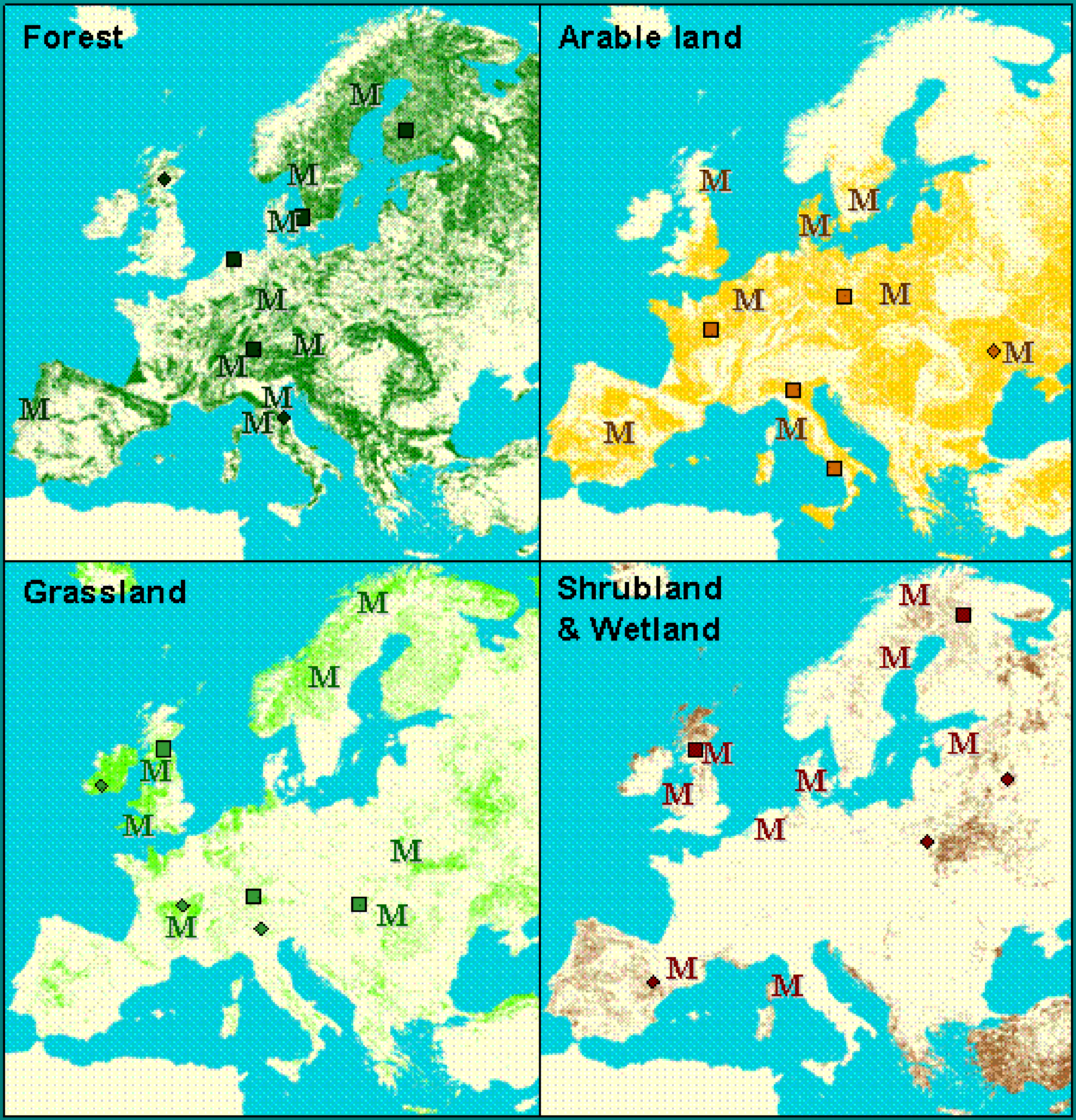
$\uparrow$ GHG	?	$\downarrow$ GHG
N_2O (+2' from NH_3, NO_3^-)	**Cattle CH_4**	**C uptake by plants**
CH_4 from wetlands	**SOM decomposition**	**Nitrogen aerosol**
$NO_x \rightarrow O_3 \rightarrow$ less primary production		

Sutton et al., *Environmental Pollution* (2007, **150**, 125-139)

IPCC 4th Assessment 2007



NitroEurope: Flux network (C1) & Manipulation network (C2)



13 Super Sites (Level 3)
9 Regional Sites (Level 2)
50 Inferential Sites (Level 1)

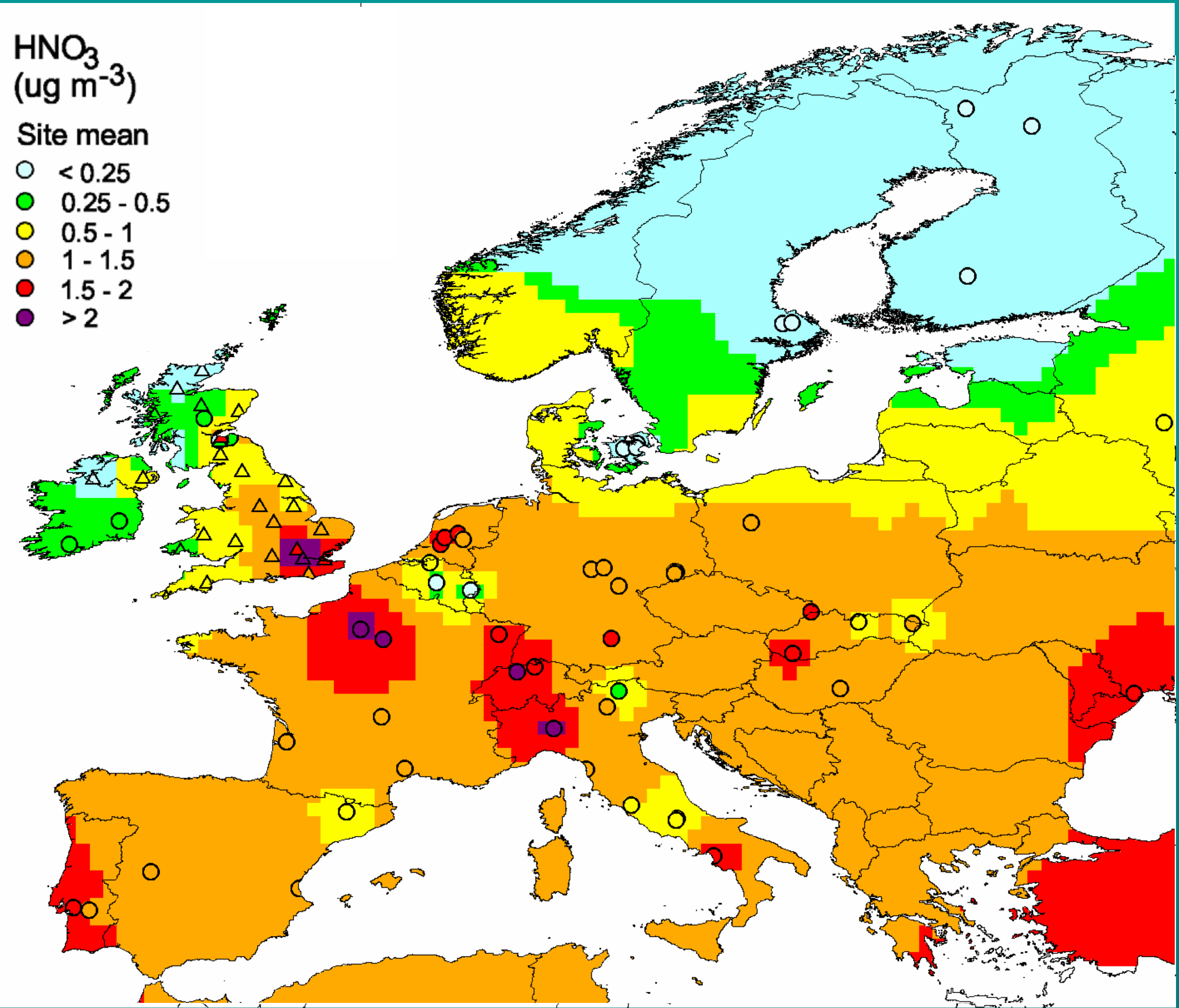
22 Core Manipulation Sites
14 Assoc. Manipulation Sites

NitroEurope IP

Sutton et al., *Environmental Pollution* (2007, **150**, 125-139)

Estimatting atmospheric N inputs (L1)

NitroEurope IP



Also for
NO_3^-, NH_3, NH_4^+, HNO_2, NO_2^-
for N deposition to Level 1 sites

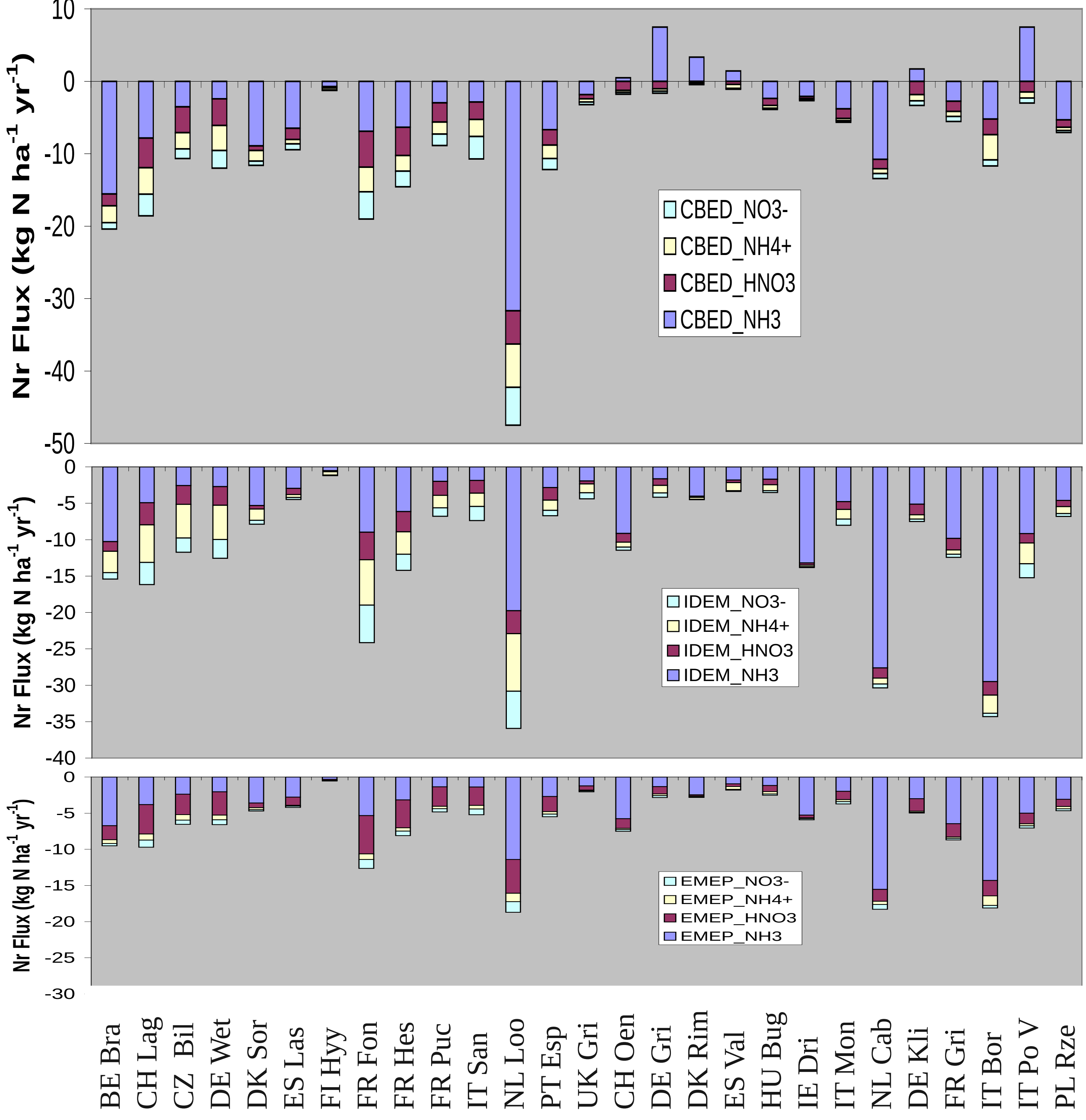
(Plus SO_2, SO_4^{2-}, HCl, Cl & Base Cations)

Tang et al.
Agriculture, Ecosystems & Environment. **133**, 183-195.

Calculating Dry N depos To the NEU Level 1 sites

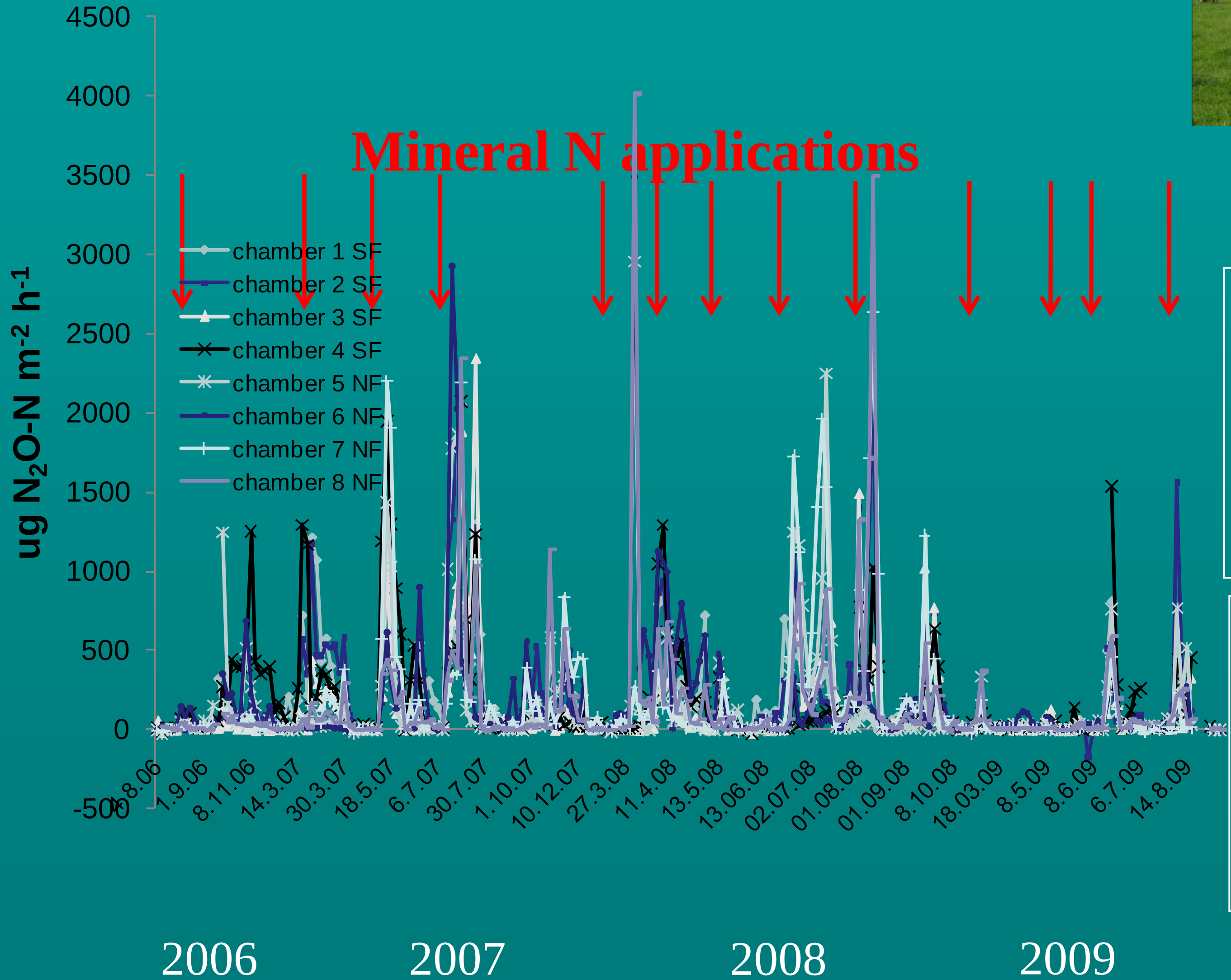
Ammonia is the biggest uncertainty

Flechard et al.
Atmos. Chem. and Physics, 2011



NitroEurope IP

N_2O fluxes from a grazed grassland in Scotland



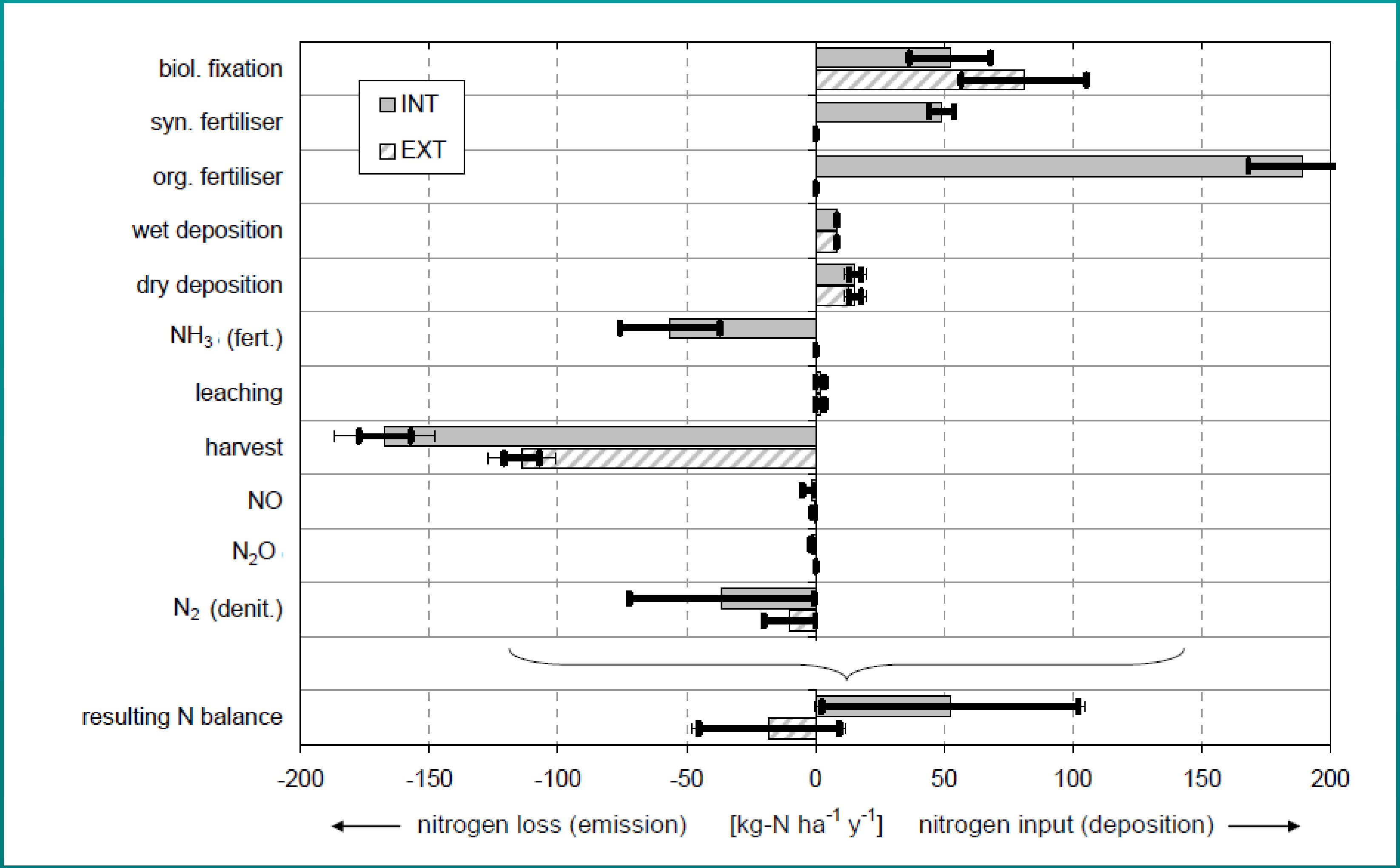
Cumulative flux	
[kg N ha^{-1} y^{-1}]	
2007	**11.2**
2008	**10.4**
2009	**4.0**

Emission factor	
[%]*	
2007	**6.5**
2008	**3.7**
2009	**1.6**

* N_2O as % of total fertiliser N added

Jones et al . Plant and Soil, 2011

Pulling the flux estimates together Oensingen NEU 'Super Site'



Ammann et al. 2009: Agric Ecosystems & Environment

Does N drive forest C sequestration?

NATURE|Vol 000|00 Month 2008 **BRIEF COMMUNICATIONS**

Ecologically implausible carbon response?

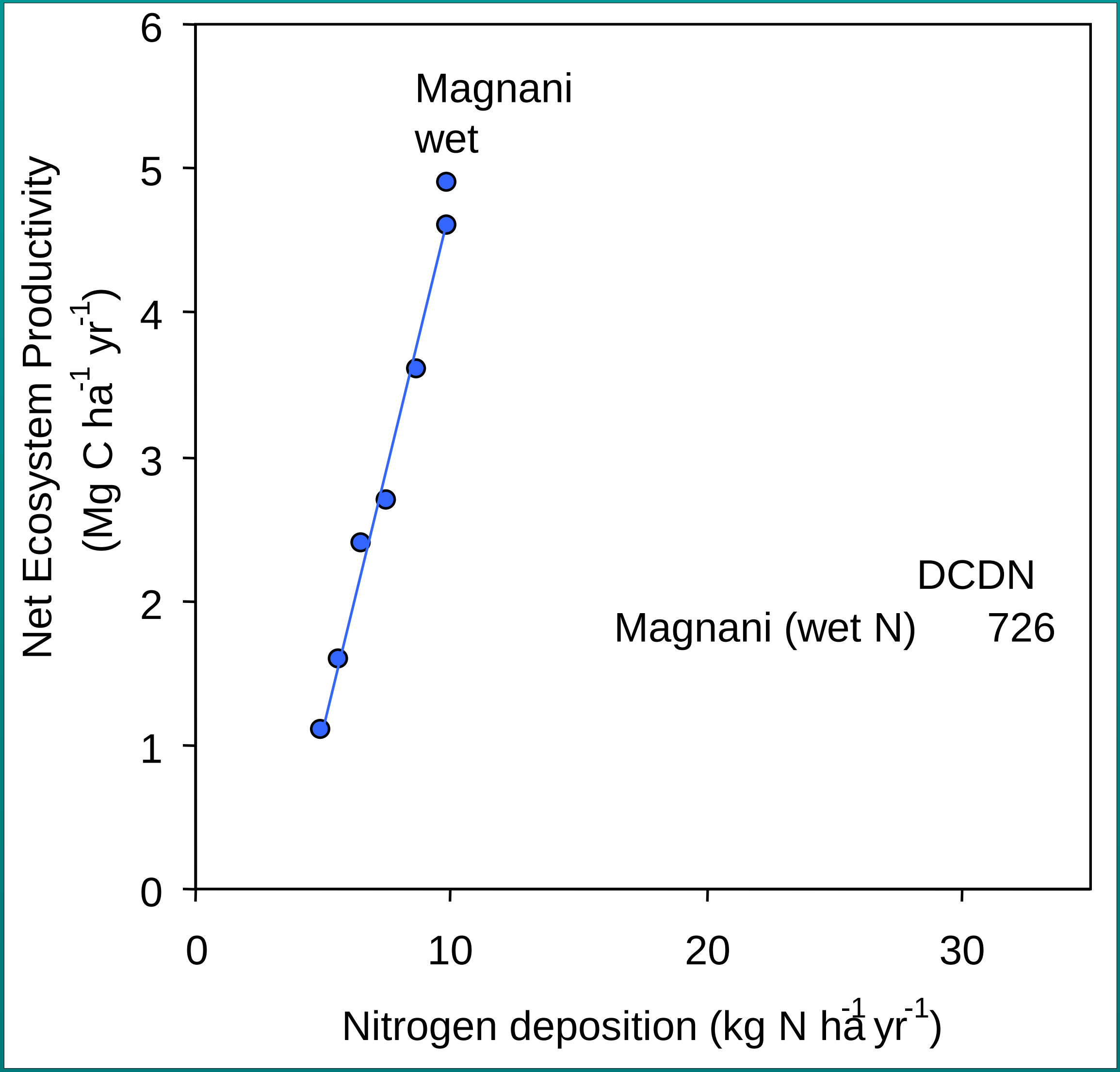
Arising from: F. Magnani *et al.* *Nature* 447, 848–850 (2007)

Magnani *et al.*[1] present a very strong correlation between mean lifetime net ecosystem production (NEP, defined as the net rate of carbon (C) accumulation in ecosystems[2]) and wet nitrogen (N) deposition. For their data in the range 4.9–9.8 kg N $ha^{-1} yr^{-1}$, on which the correlation largely depends, the response is approximately 725 kg C per kg N in wet deposition. According to the authors, the maximum N wet deposition level of 9.8 kg N $ha^{-1} yr^{-1}$ is equivalent to a total deposition of 15 kg N $ha^{-1} yr^{-1}$, implying a net sequestration near 470 kg C per kg N of total deposition. We question the ecological plausibility of the relationship and show, from a multi-factor analysis of European forest measurements, how interactions with site productivity and environment imply a much smaller NEP response to N deposition.

However, even this lower response is unlikely. ^{15}N-lab experiments in temperate forests indicate that N reten occurs in stem wood but mainly in the soil[7]. Consideri of N and the ranges in C:N ratios in forest ecosystem com this implies a carbon response near 50 kg C per kg N in fo tems[7,8]. Even though the above-ground C sequestrati underestimated by Nadelhoffer *et al.*[7], owing to neglectin of direct foliar uptake[9,10], this effect is likely to be small ground foliar N uptake is generally less than 5 kg N (ref. 11), whereas below-ground uptake is generally 50 kg N $ha^{-1} yr^{-1}$. Furthermore, similar results are foun term (15-30 yr) nitrogen-fertilizer trials at rates of nitrog below 50 kg N $ha^{-1} yr^{-1}$ (refs 12, 13) and in process-b

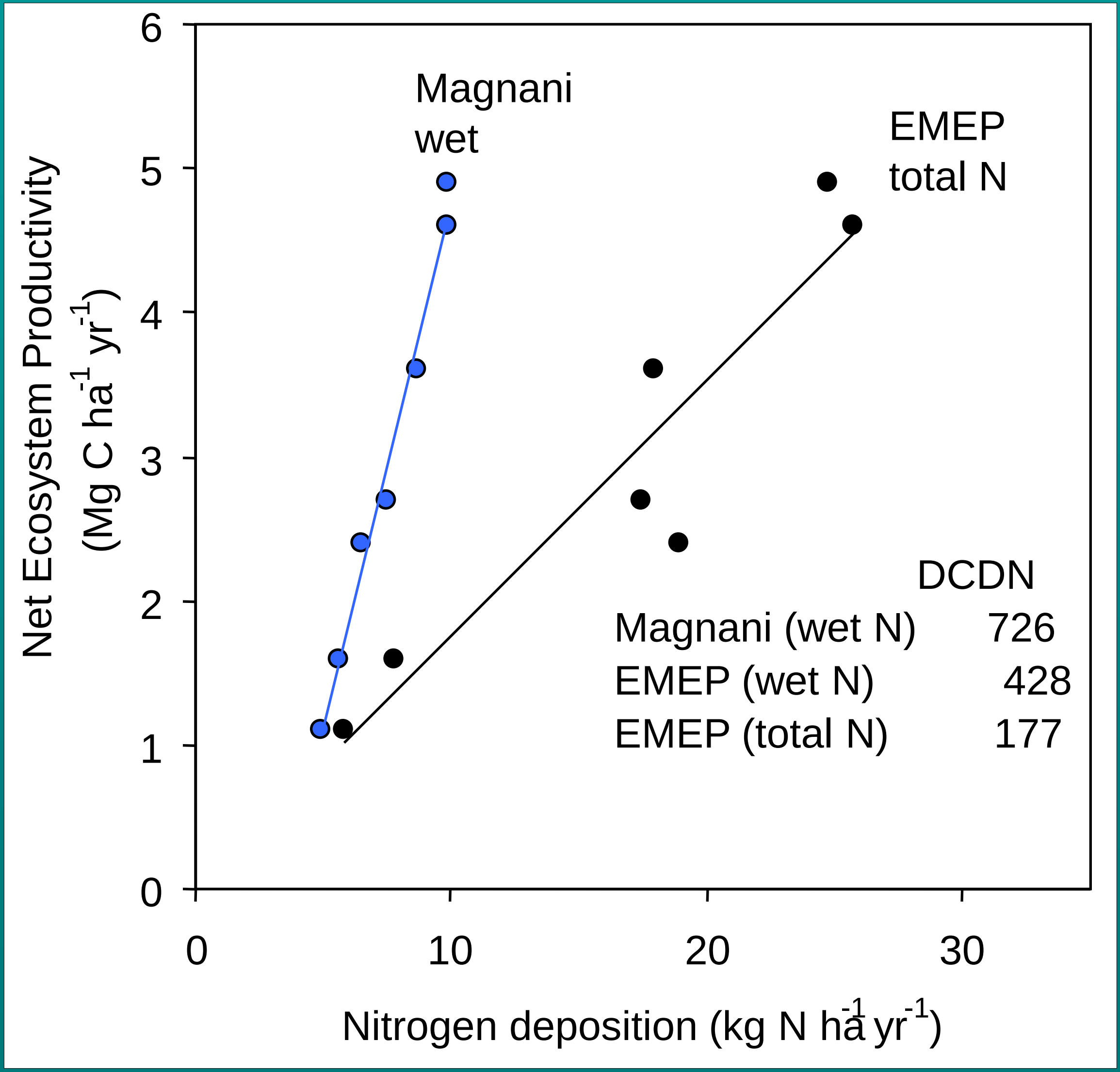
de Vries, Sutton et al.
Nature **451,** 15 Feb 2008

Re-interpreting the nitrogen interaction



Sutton et al. *Global Change Biology* 2008: **14**, 2057-2063

Re-interpreting the nitrogen interaction



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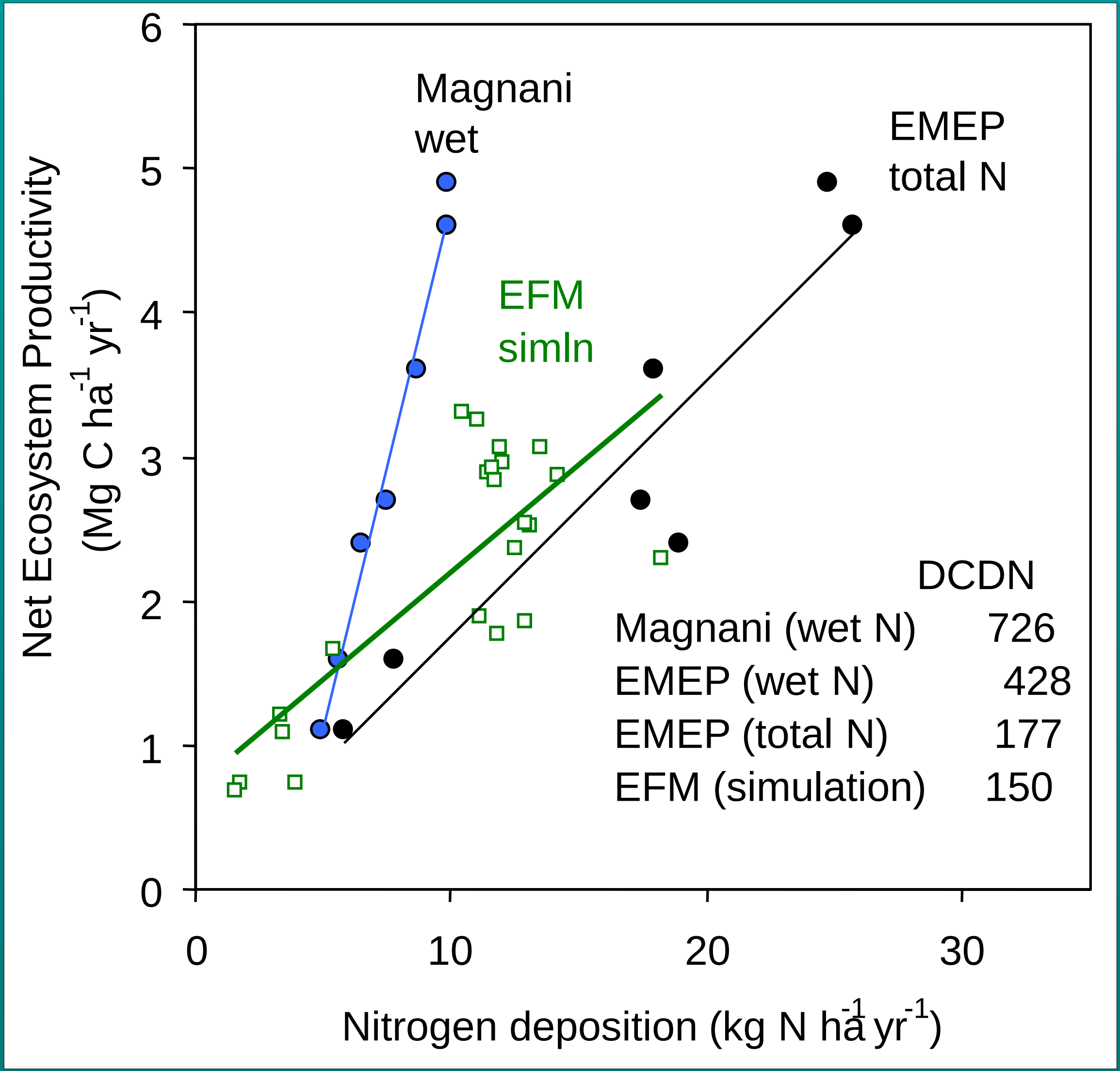
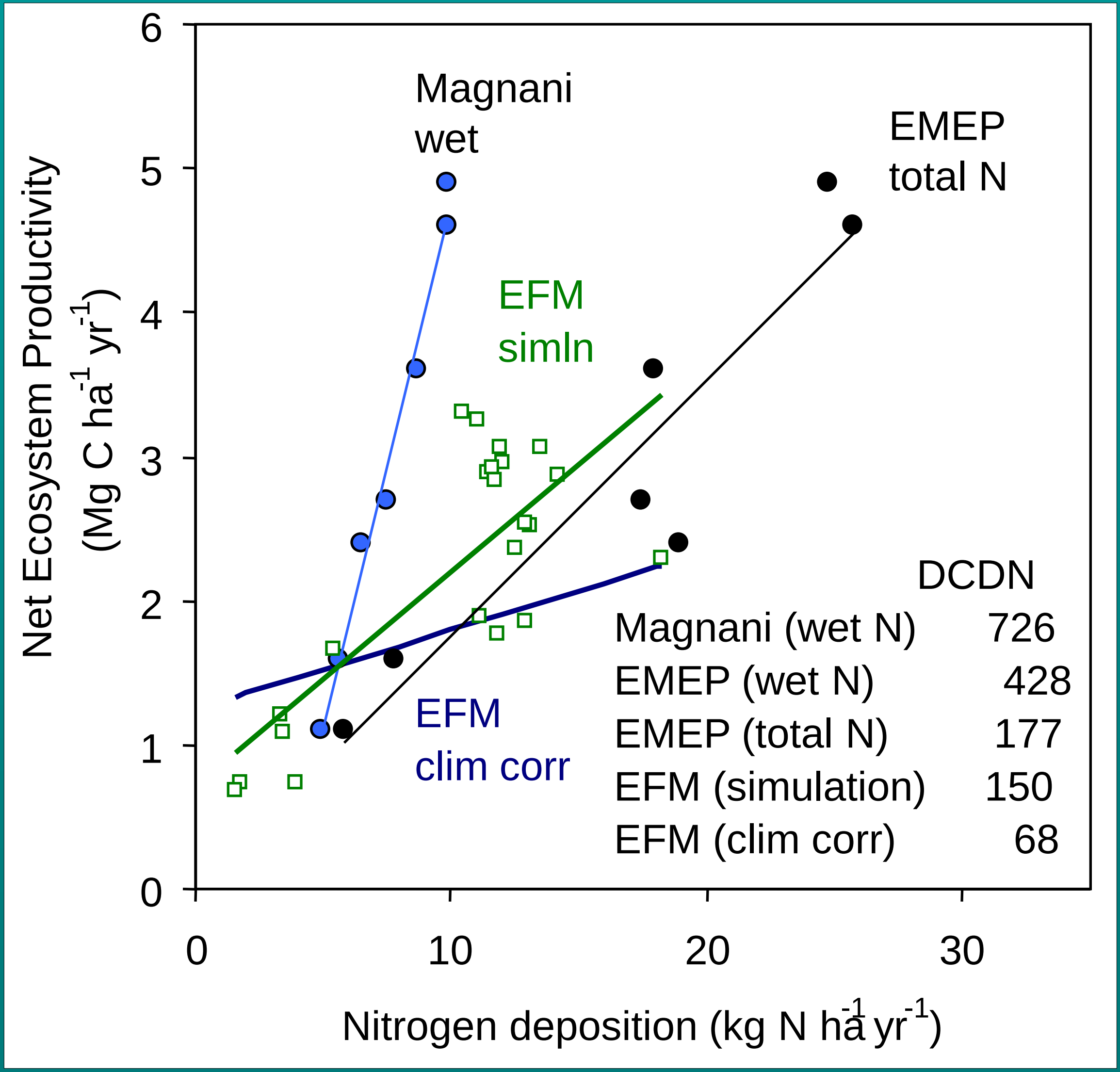
Re-interpreting the nitrogen interaction



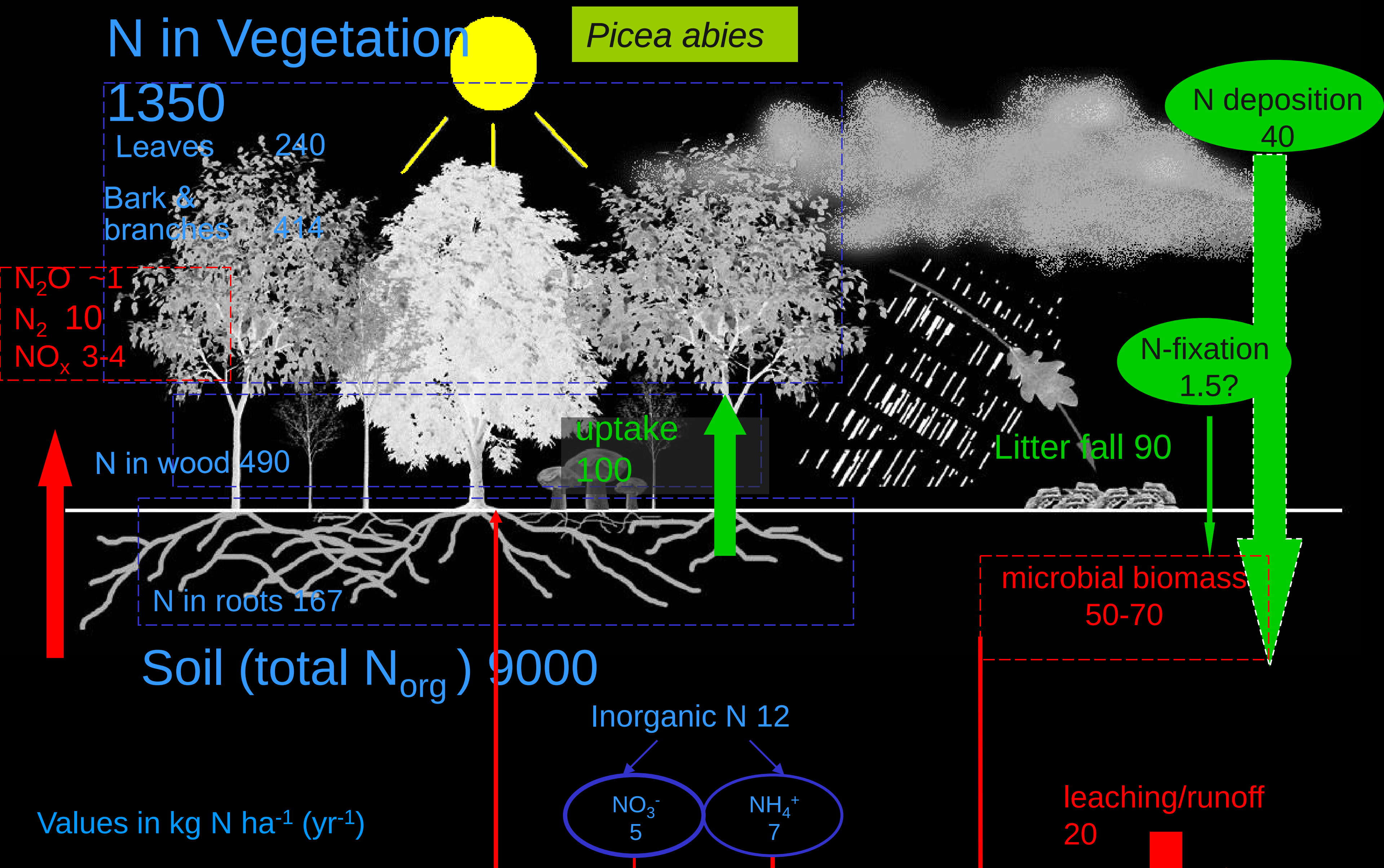
Sutton et al. *Global Change Biology* 2008: **14**, 2057-2063

Re-interpreting the nitrogen interaction



Sutton et al. *Global Change Biology* 2008: **14**, 2057-2063

Temperate Forest – Höglwald, Germany



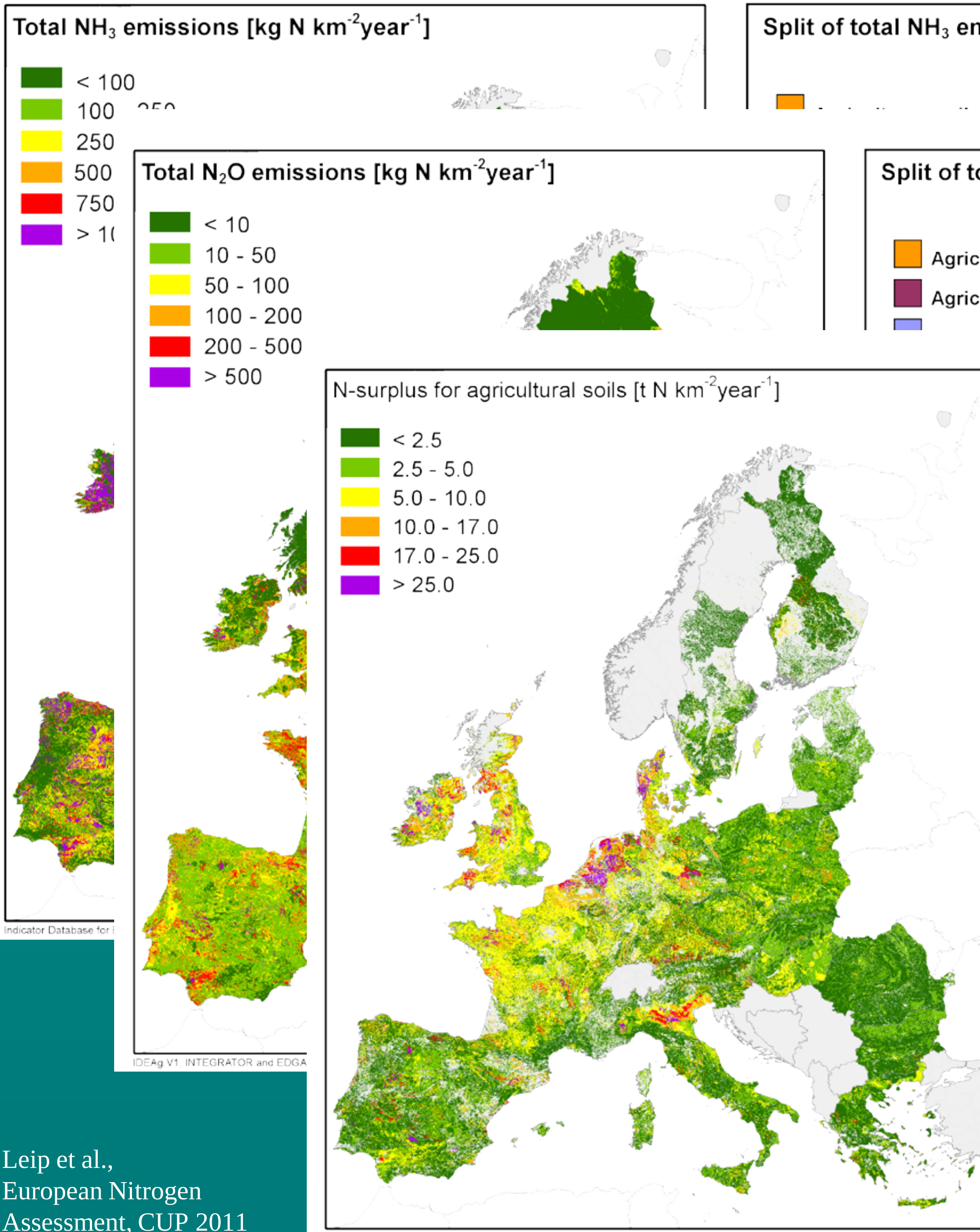
Butterbach Bahl et al.

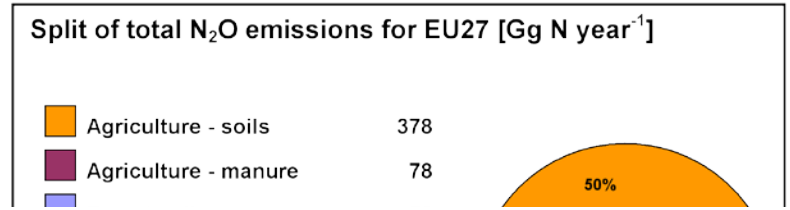
Nitrogen budgets for two contrasting NitroEurope Level 3 forests

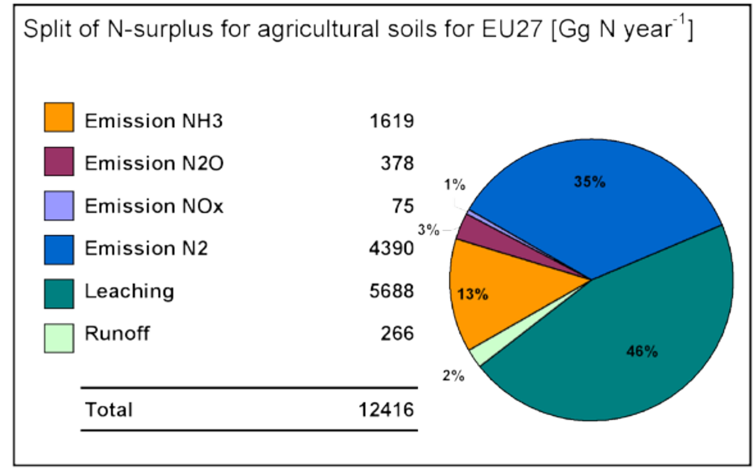
	Finland-Hyytiälä	**Germany-Höglwald**
N input (kg N / ha /yr)	4.1	41.5
N storage (kg N / ha)		
Vegetation	190	1350
Soil (organic N)	1570	9000
N loss (kg N / ha / yr)	1.8	34
Retained inputs	56%	18%

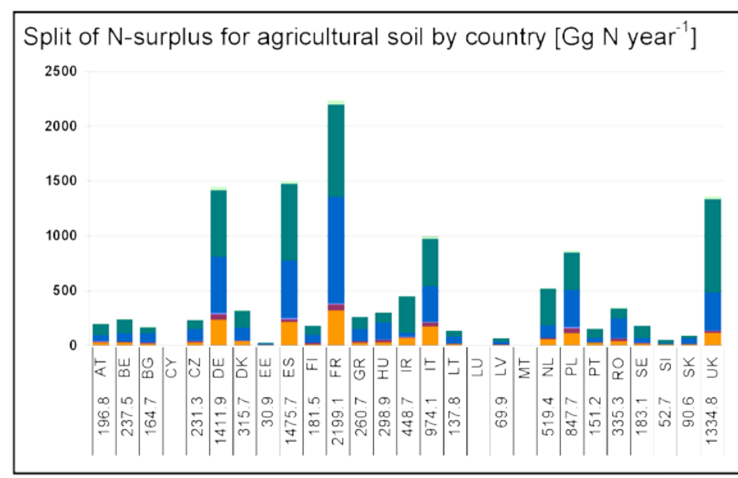
Vesala, Butterbach Bahl et al.

Upscaling to the EU27





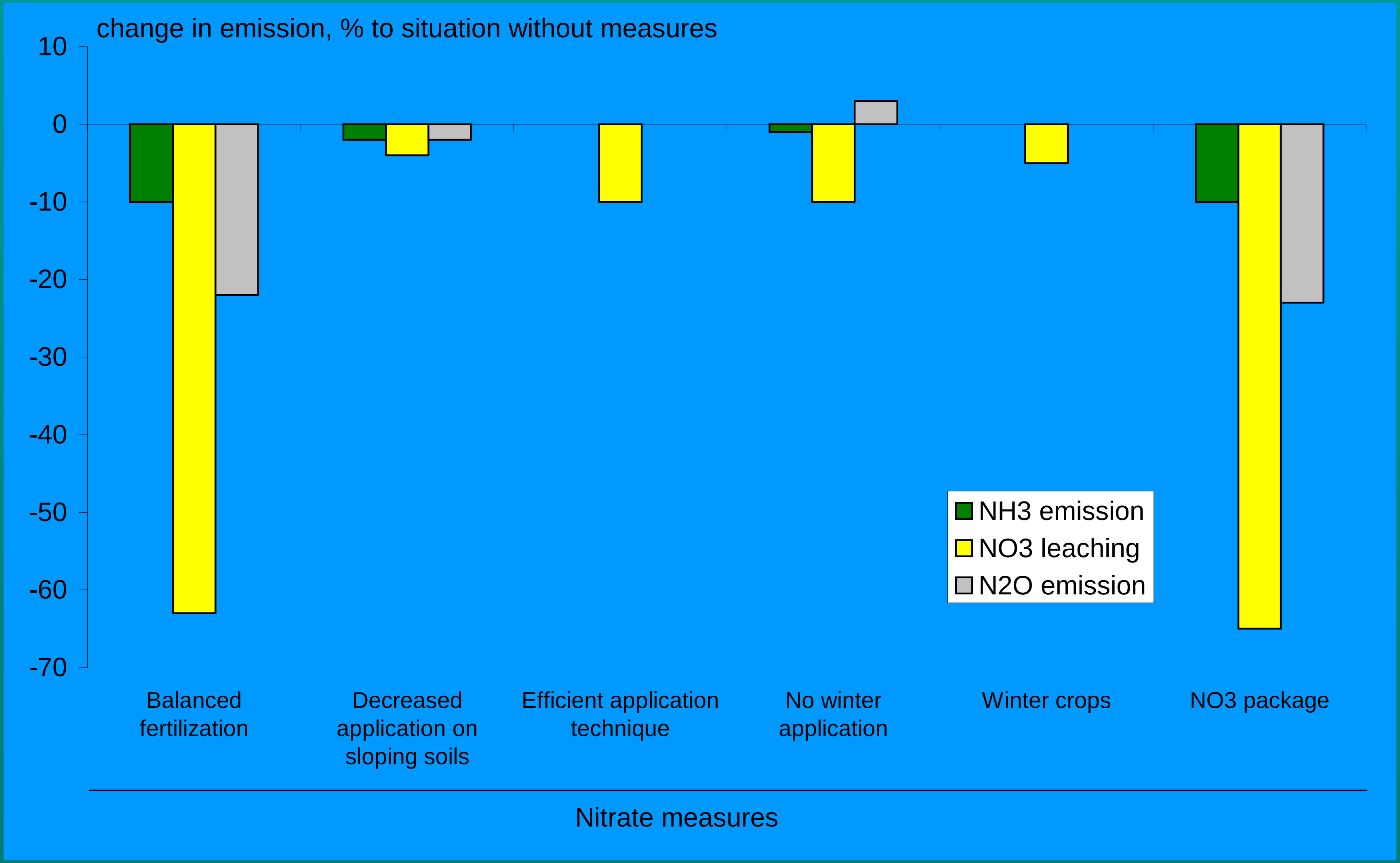




Leip et al.,
European Nitrogen
Assessment, CUP 2011

Mitigating nitrogen and the greenhouse balance

Effect of measures in EU Nitrates Policy



Nutrient management: soil

- Balanced fertilization
  - → Lower N input
- Maximum manure application rate
  - → Lower N input
  - May be compensated by fertilizer
- Manure incorporation
  - → Lower NH_3 emissions
  - → potentially higher N_2O emission
- Urea substitution by NH_4 fertilizers
  - → Lower N_2O emission (0.67×) (see Lesschen&Velthof)

A package of measures in agriculture to reduce N_2O emissions

- Relative changes in N_2O emission (%) for EU27

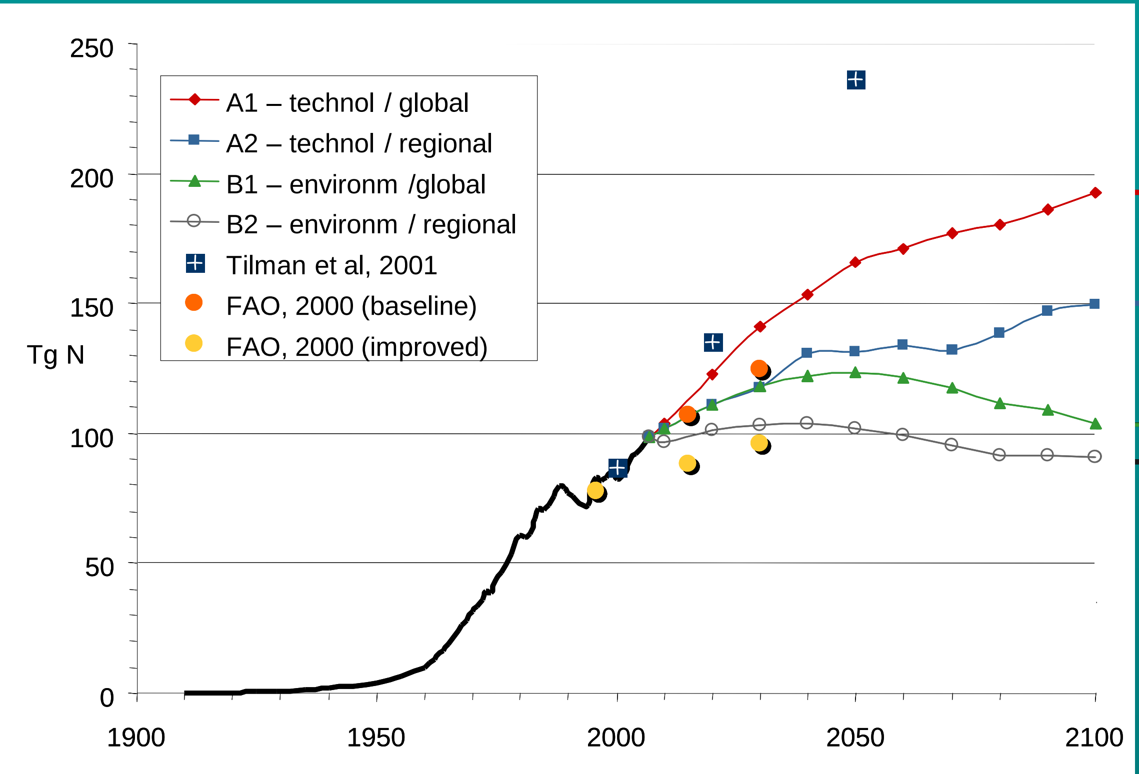
Measure	Housing and storage	Manure and fertilizer application	Other N inputs[1)]	Total
1. Reduced protein content	-1.4	-0.5	0.0	-1.9
2. Low $NH_{3\ em}$ housing, storage	0.0	0.0	0.0	0.0
3. Balanced fertilization	0.0	-8.8	-2.7	-11.5
4. Max manure application rate	0.0	-7.1	0.1	-7.0
5. Manure incorporation	0.0	0.2	0.0	0.2
6. Urea substitution	0.0	-0.3	0.0	-0.3
7. Restoration histosols	0.0	-0.8	-0.2	-1.0
All measures	-1.4	-17.4	-2.7	-21.5

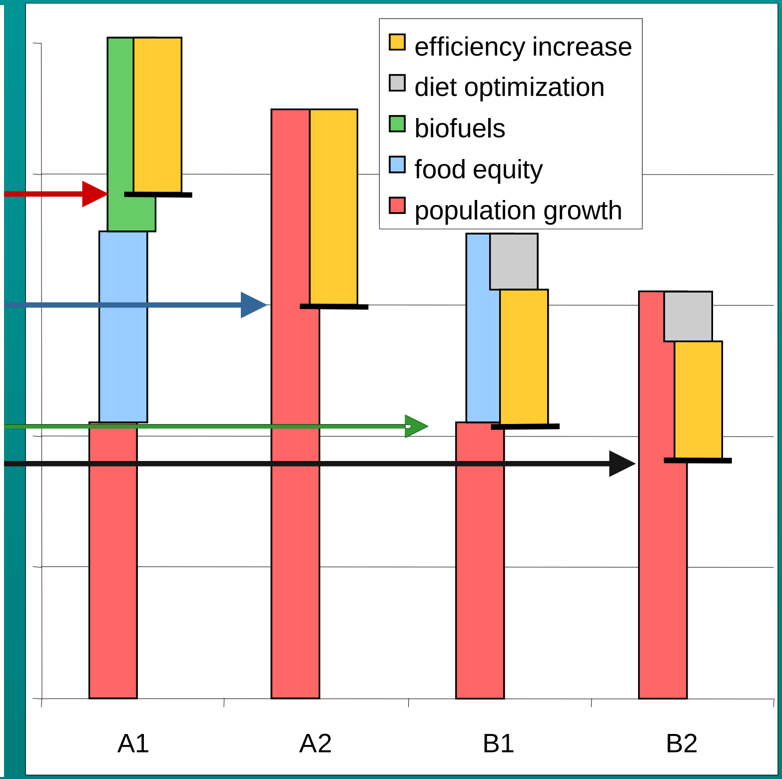
[1)] Includes emission through soil inputs by deposition, mineralization, fixation and crop residues

From N trade-offs to N co-benefits

- **Stage 1:** Ignore the interactions
- **Stage 2:** Highlight the trade-offs at field scale (pollution swapping: NH_3 vs N_2O)
- **Stage 3:** Discover that swapping is net neutral at the regional scale (NH_3 deposition effects)
- **Stage 4:** Start listing the co-benefits (low NH_3 emission, reducing fertilizer inputs and net N_2O savings)
- **Stage 5:** Quantify the climate benefits of reducing N losses and improving NUE.

A century of Haber Ammonia
Global N fertilizer consumption 1900-2100





NitroEurope IP

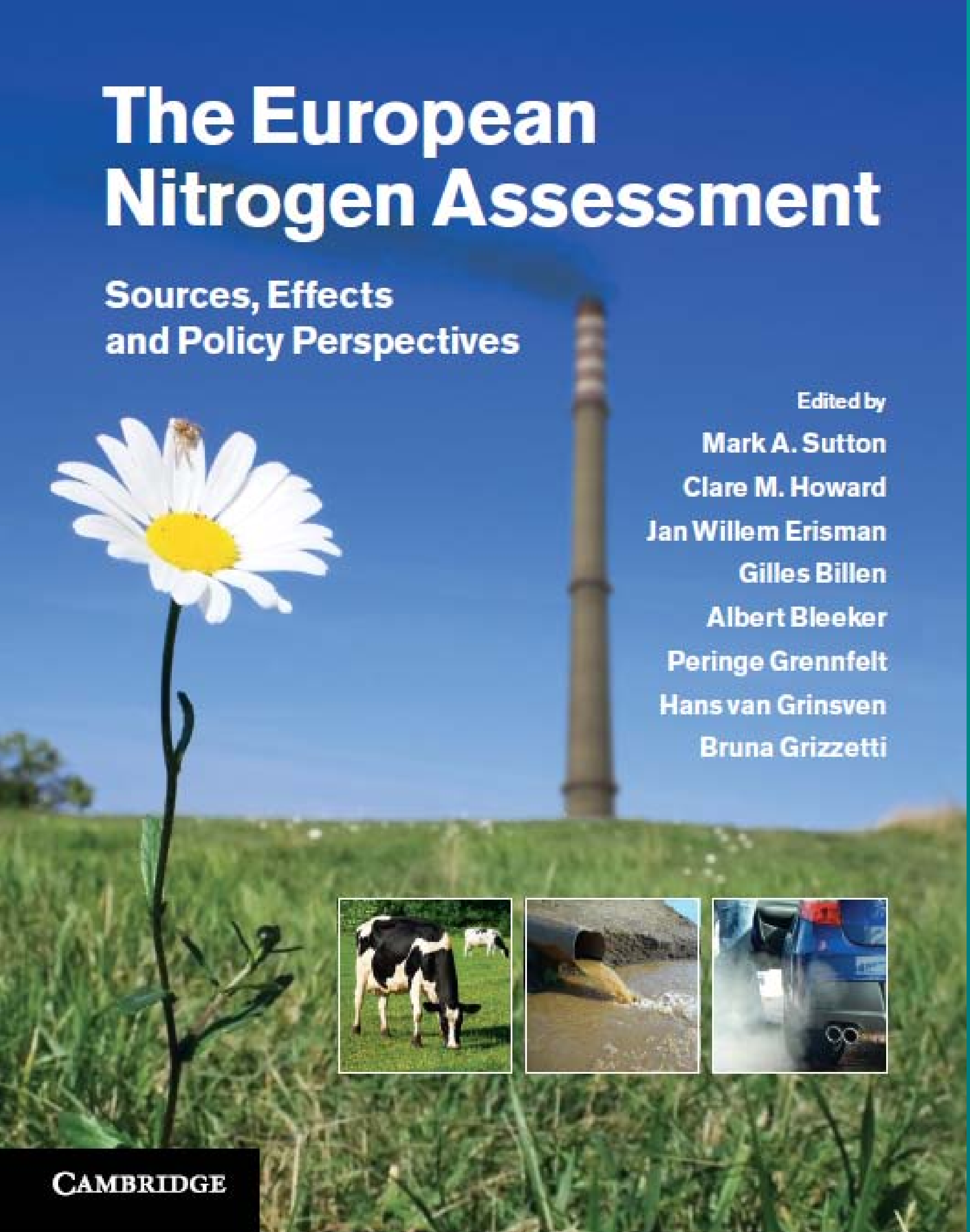
Erisman, Sutton, Galloway, Klimont & Winiwarter
Nature Geoscience (2008)

Conclusions

- Nitrogen fertilisers support around 48% of world population
- Many +/- effects: European N has a net cooling effect on climate
- Important effects of nitrogen on water and air quality, human health and biodiversity
- Smart management of the nitrogen cycle
  - Meet pollution targets with climate co-benefits
  - Our ambition for food & energy consumption

Policies & People

- As NO_x emissions decrease, NH_3 will increasingly dominate future N_r emissions. NH_3 reductions are key improving NUE and reducing N_2O emissions.
- International conventions need to work together more effectively; an inter-convention agreement should be explored
- Societal choice and behavioural change provide major opportunities.
- *"Eat right: improve your health and help protect the environment at the same time."*



ENA Launch

11-15 April 2011
Edinburgh
International Conference
“Nitrogen & Global Change

www.nitrogen2011.org