Nitrogen turnover processes and effects in terrestrial ecosystems

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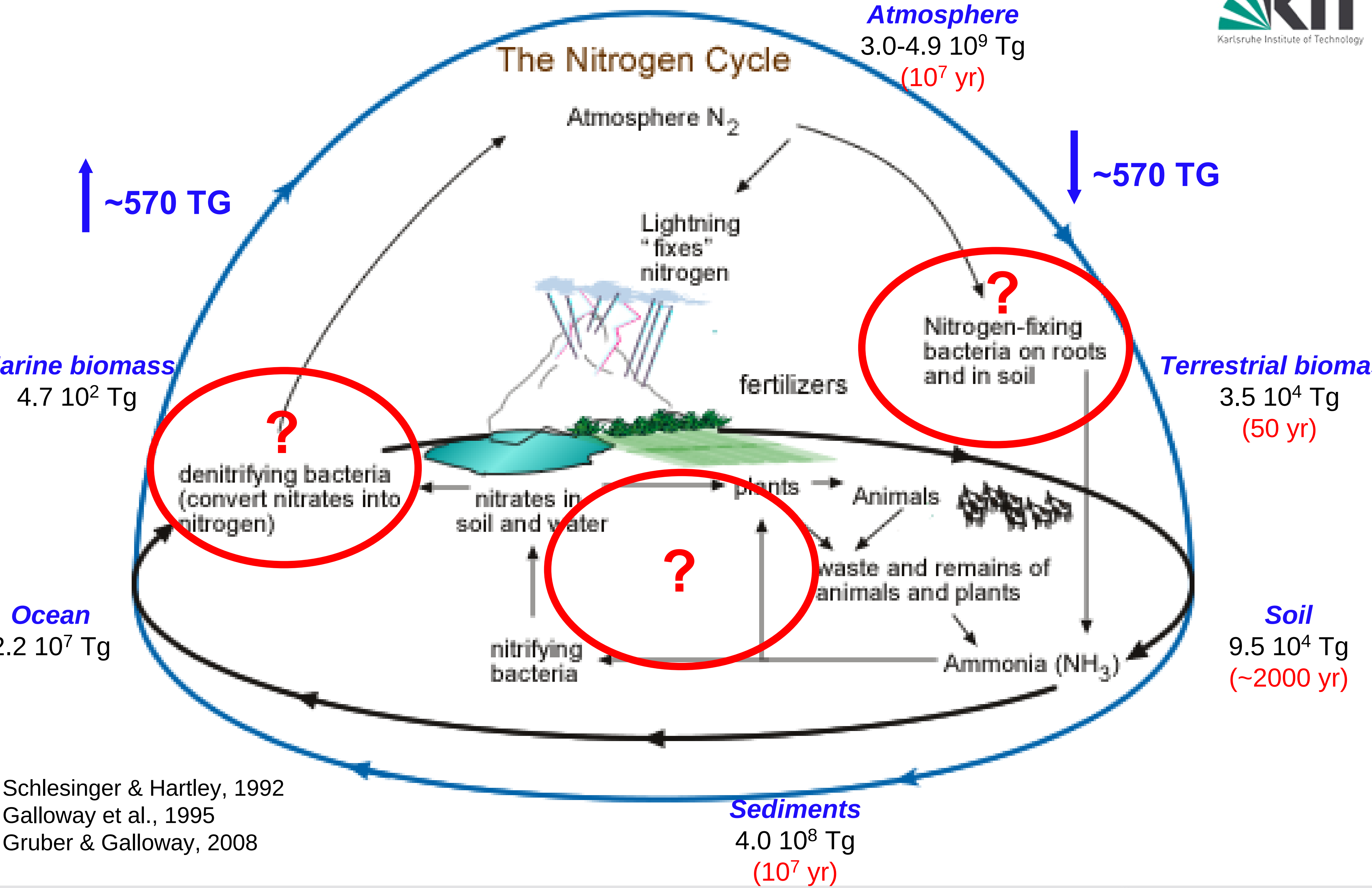
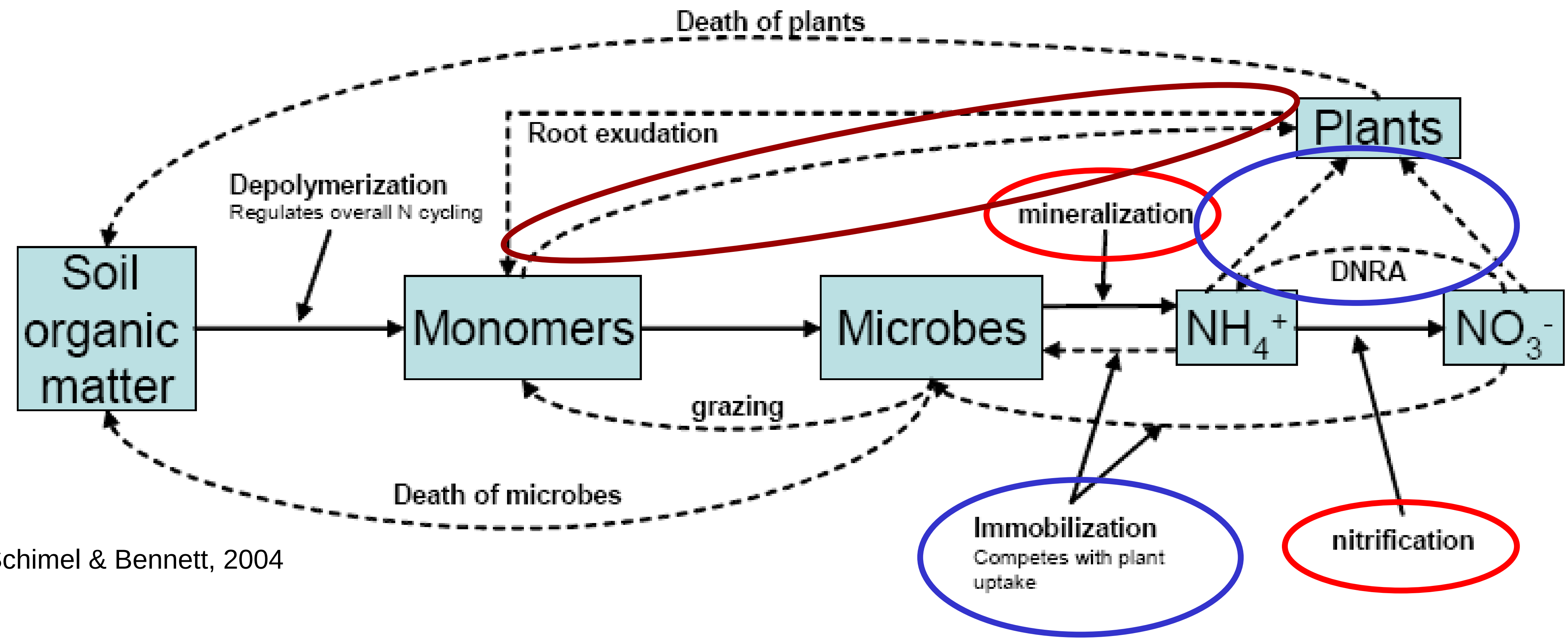


Schlesinger & Hartley, 1992
Galloway et al., 1995
Gruber & Galloway, 2008

Biological N_2-fixation (BNF)

- Major natural process to create Nr, highly energy demanding
- Different ecophysiological groups involved
  - Symbiotic association between microbes and plant roots (e.g. legumes; 10-100 kg N ha^{-1} yr^{-1})
  - Cyanobacteria (e.g. crusts in semiarid regions; 1-40 kg N ha^{-1} yr^{-1})
  - Heterotrophic N_2-fixation (upland: 1-5 kg N ha^{-1} yr^{-1} or wetland: 50-100 kg N ha^{-1} yr^{-1})
- Understanding of ecological controls of BNF is limited (except agricultural crops)
  - Cyano-bacteria: light (e.g. steppe)
  - Heterotrophic N_2 fixation: substrate (carbon) quality > substrate quantity
  - General: pH, drought, temperature, salinity
- Uncertainties:
  - Knowledge about the biology of N fixers is limited
  - Biological N_2 fixation only assessed for a few systems
  - Contribution of BNF to ecosystem N cycling highly uncertain

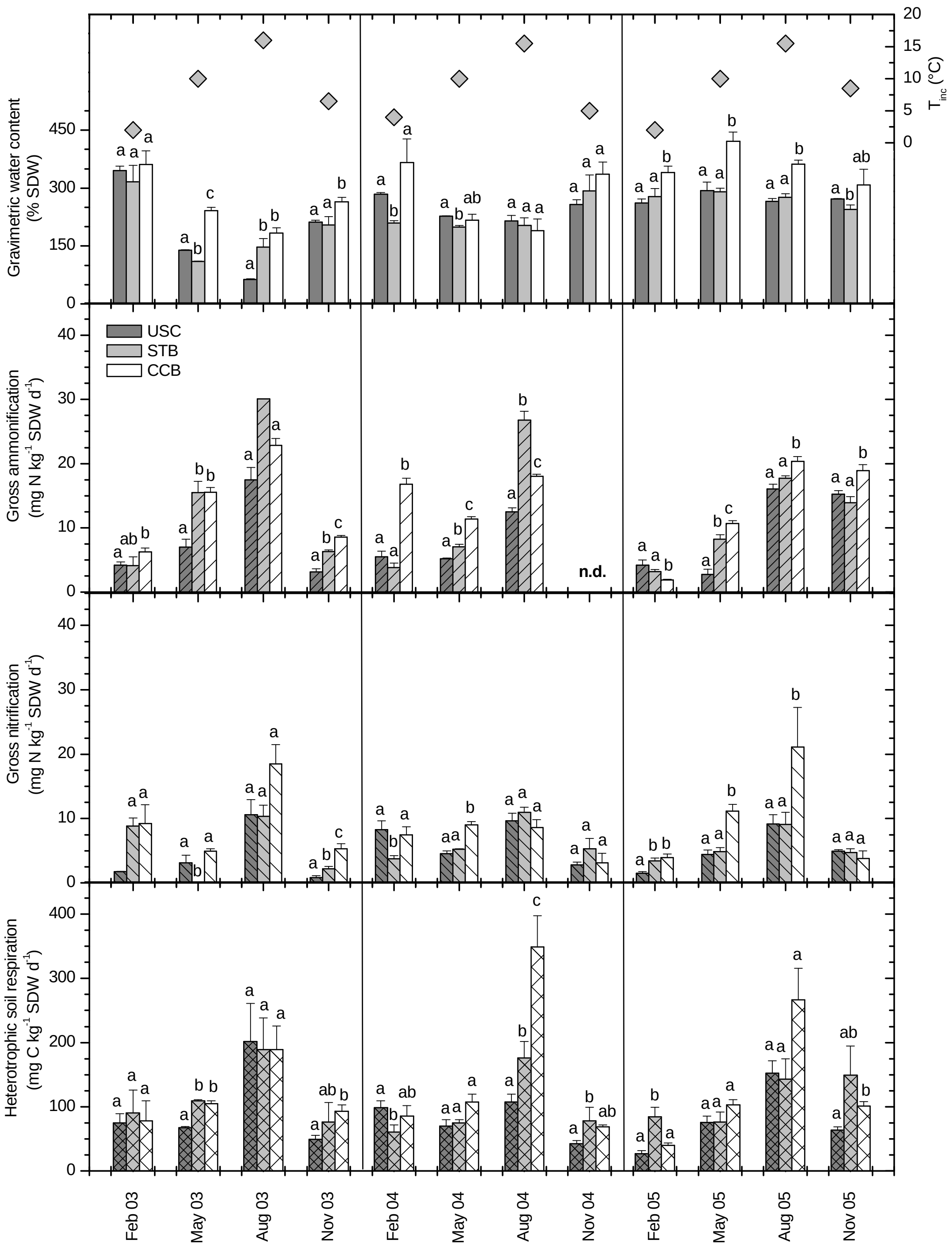
Processes involved in N-cycling



Schimel & Bennett, 2004

- Only since approx. 10 – 15 yrs we are talking about gross rates
- Competition between microbes and plants
- Role of organic N for N cycling, mediated by mycorrhiza?

N-cycling at the Höglwald Forest, Germany



Gross-Ammonification:

800 – 1000 kg N ha^{-1} yr^{-1}

Gross-nitrification:

480 – 590 kg^{-1} N ha^{-1} yr^{-1}

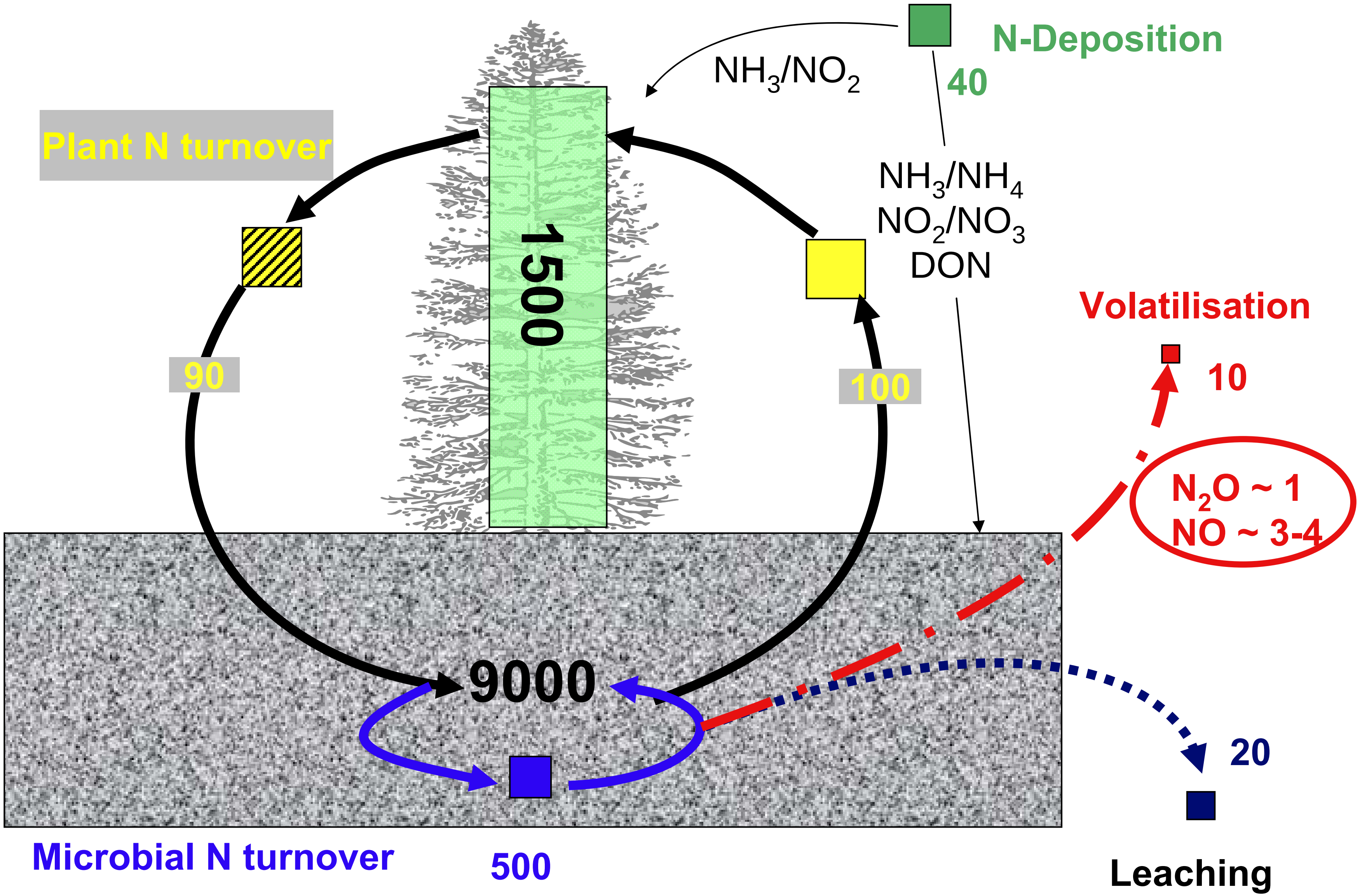
Heterotrophic respiration:

8000 – 9000 kg C ha^{-1} yr^{-1}

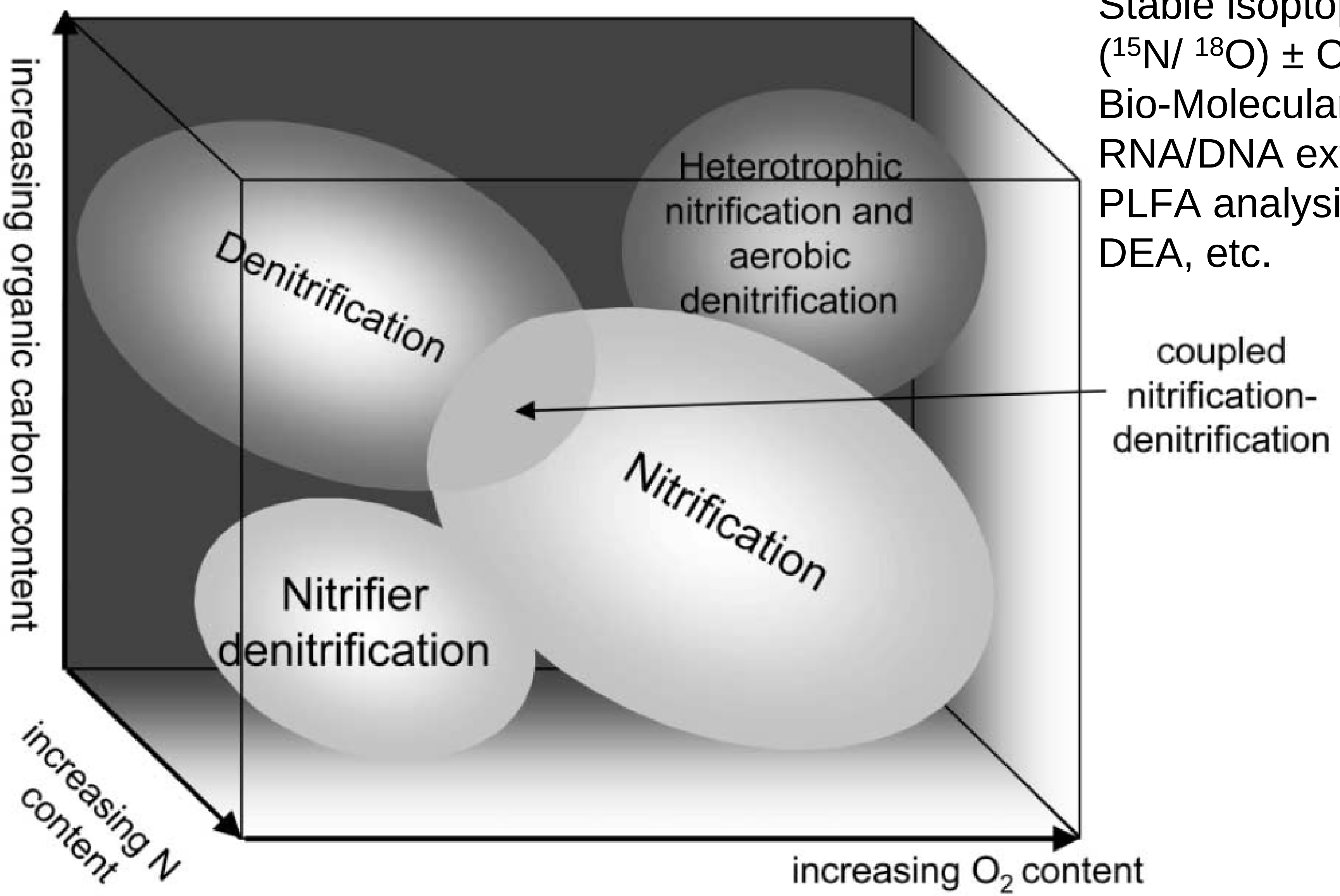
Rosenkranz et al., 2008, Biogeochem. Subm.

NitroEurope – Towards full N balance studies

Höglwald, spruce forest (Germany), N Brüggemann, H Papen, K Butterbach-Bahl (FZK



Ecological niche of nitrifier-denitrification



Wrage et al., 2001, Soil Biol. Biochem.

Tools for process identification:

Stable isoptope techniques (^{15}N/ ^{18}O) ± C_2H_2

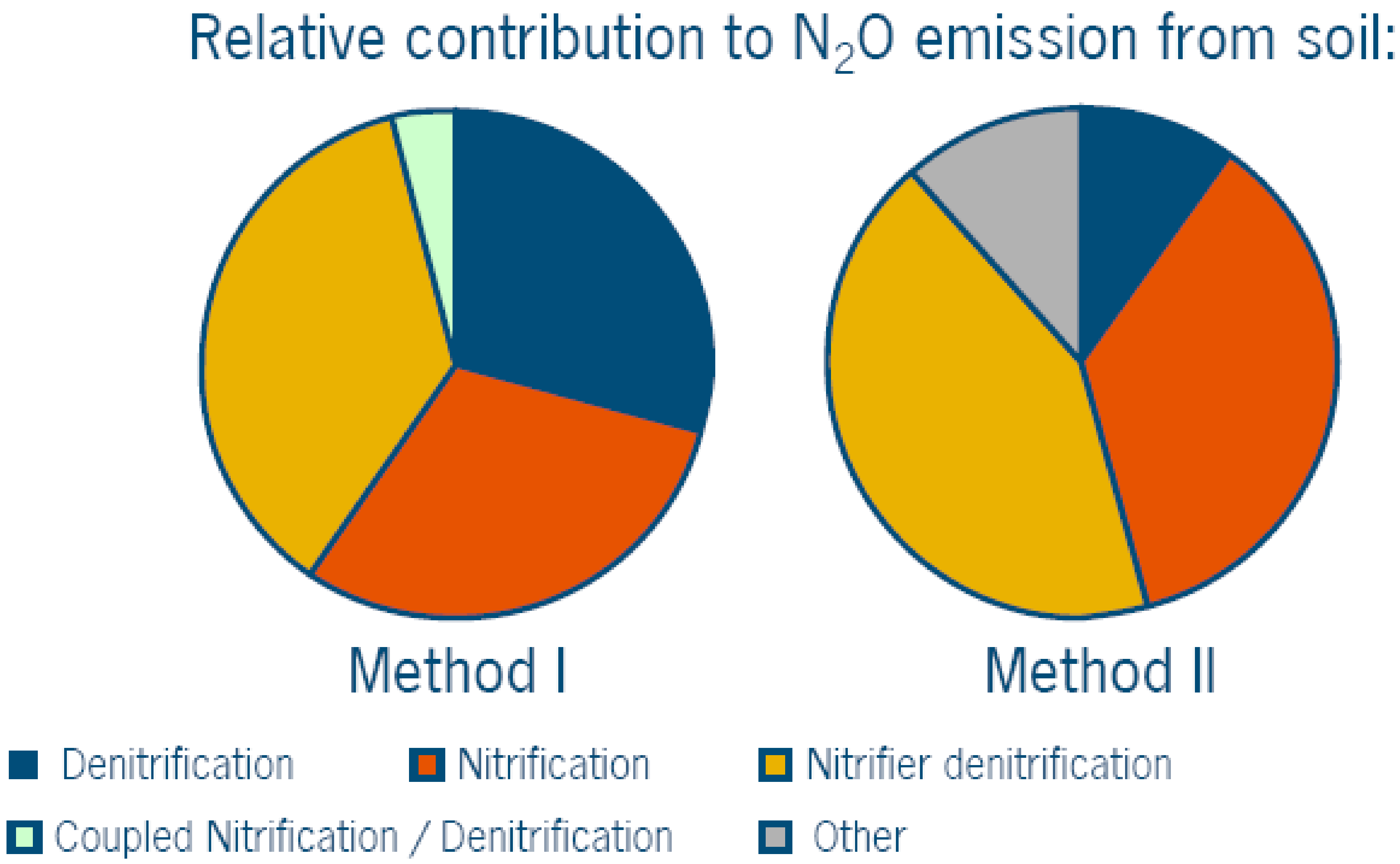
Bio-Molecular techniques

RNA/DNA extractions

PLFA analysis

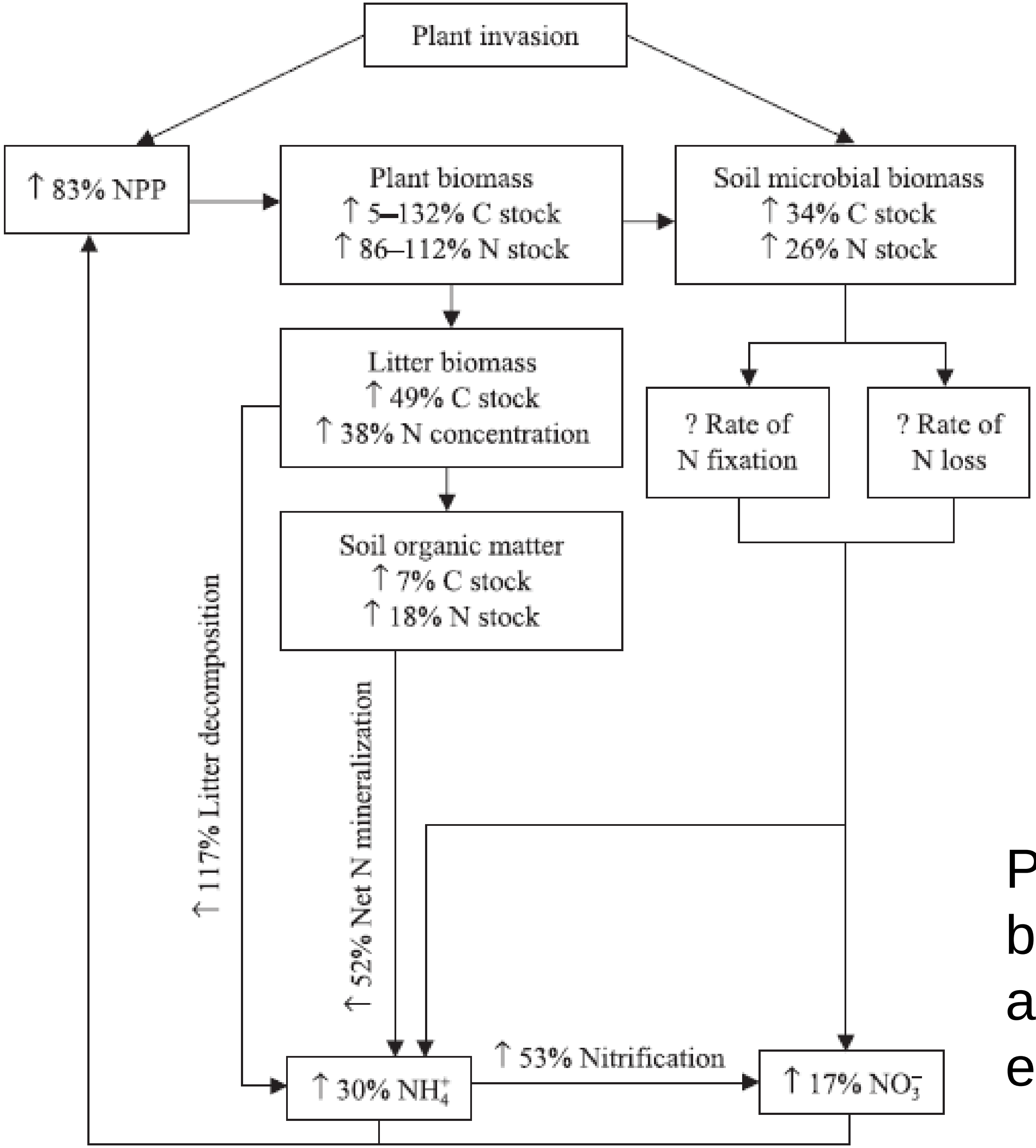
DEA, etc.

Importance of nitrifier denitrification for soil N_2O emissions



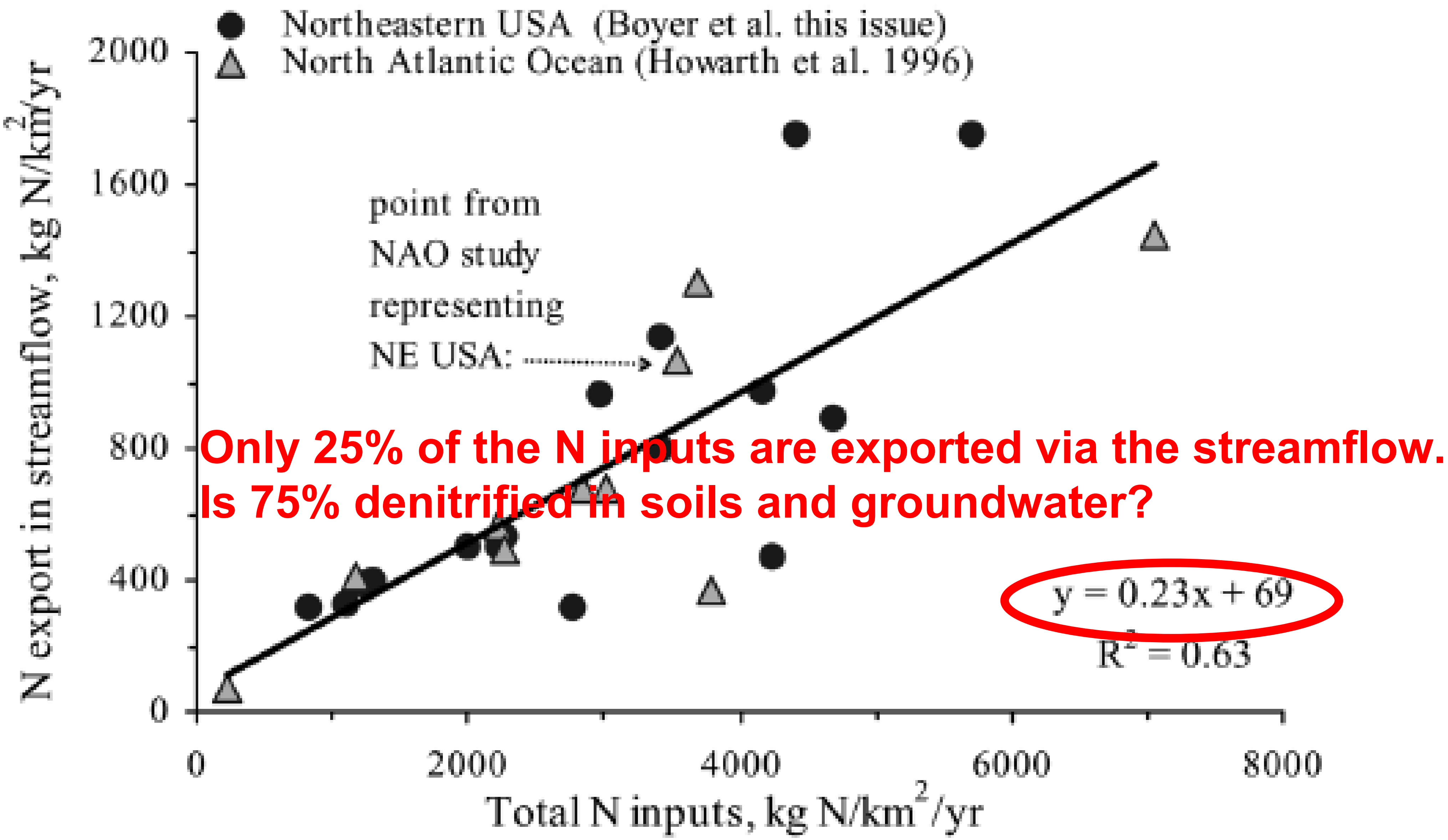
Wrage et al., 2005, RCMS

Vegetation changes and ecosystem N cycling

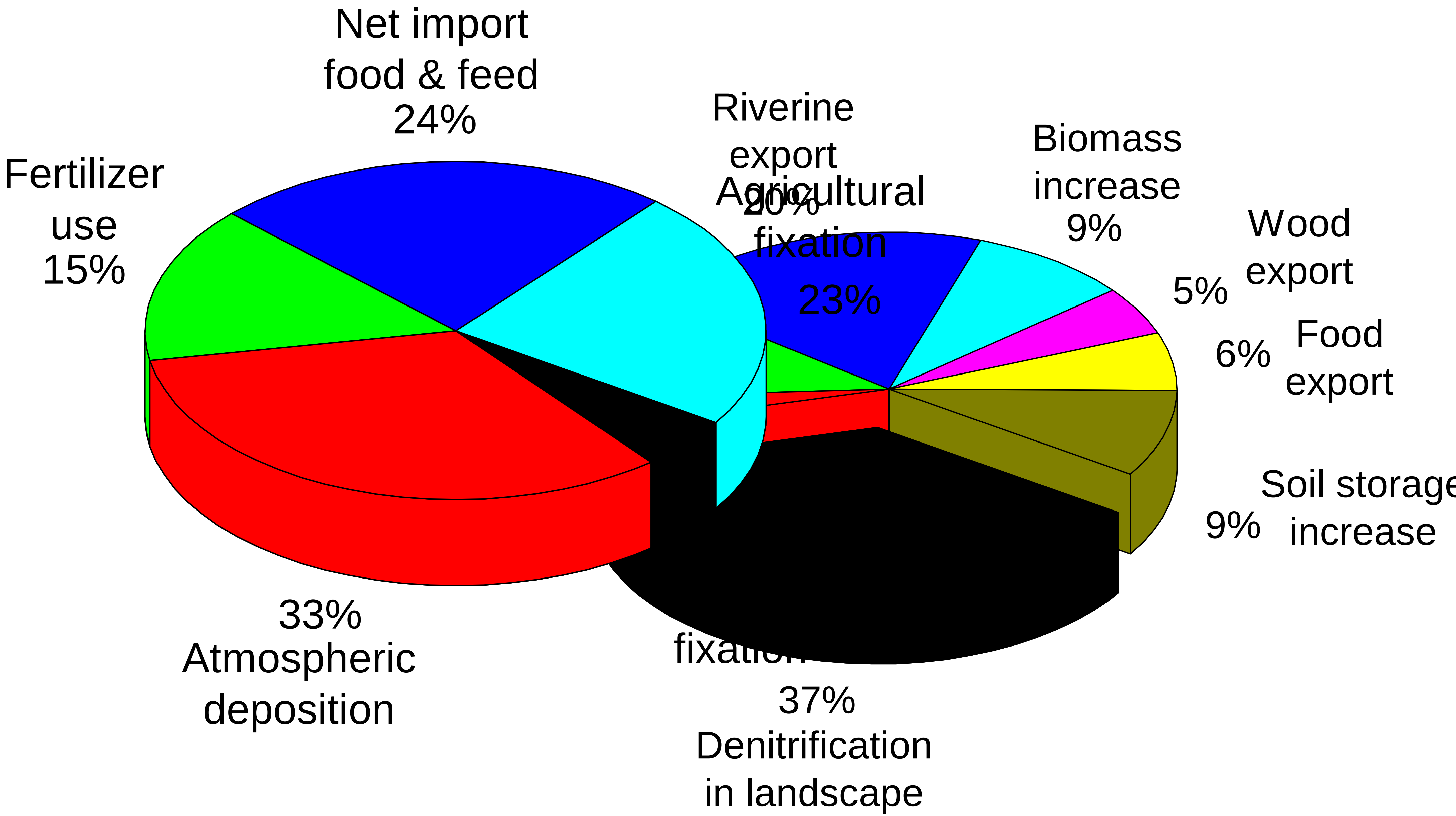


Potential positive feedbacks between plant invasion and carbon and nitrogen cycles in invaded ecosystems. Liao et al., 2008

Van Breemen et al., 2002: Where did all the nitrogen go?



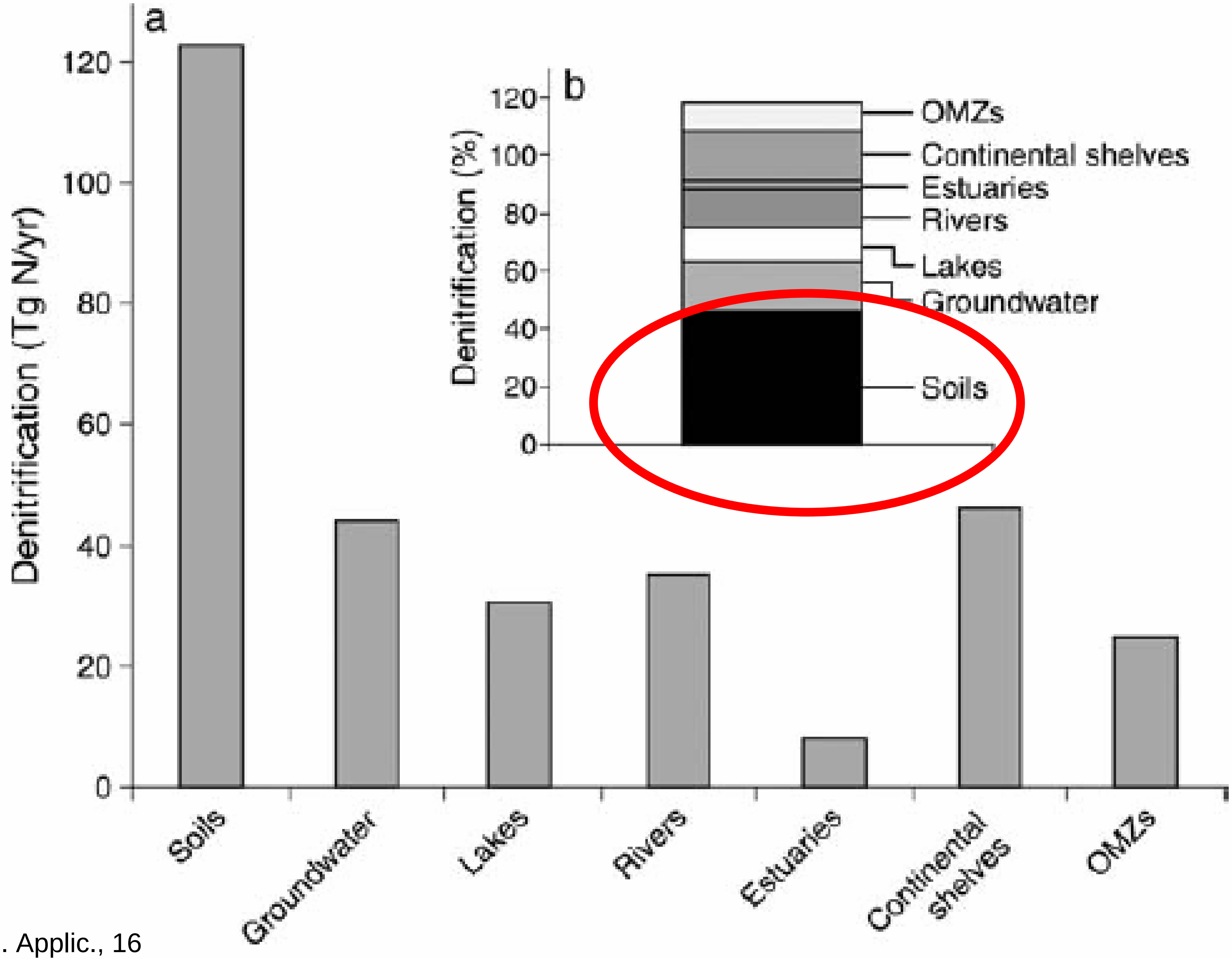
Van Breemen et al., 2002: Where did all the nitrogen go?



Van Breemen et al., 2002, Biogeochemistry

Seitzinger et al., 2006: 40% of N input is denitrified in soils

Approx. 270 Tg N_r additions to terrestrial systems



Seitzinger et al., 2006, Ecol. Applic., 16

It seems that we do know the “big” numbers quite well,

but how good is our knowledge on site and landscape scales?

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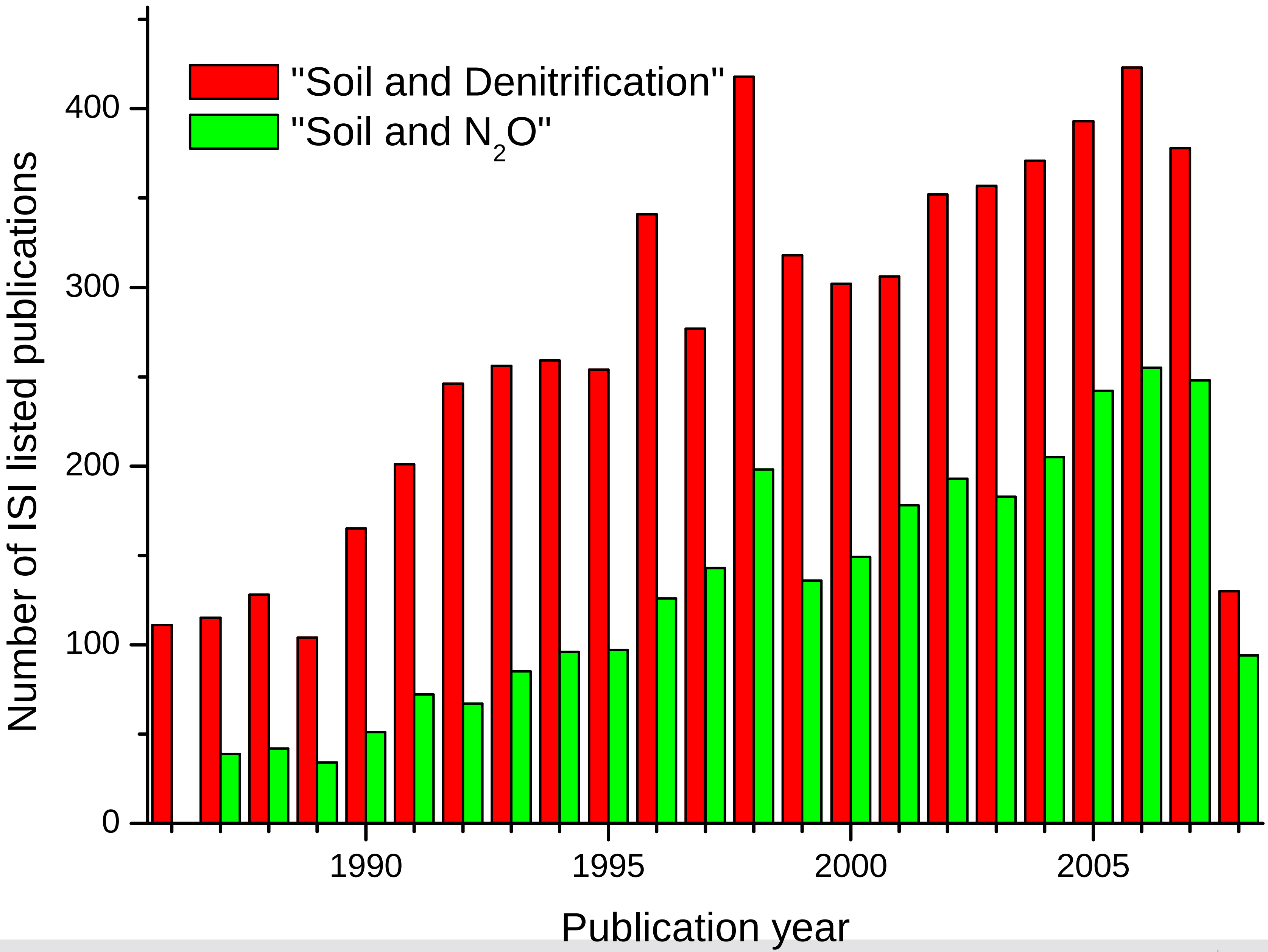
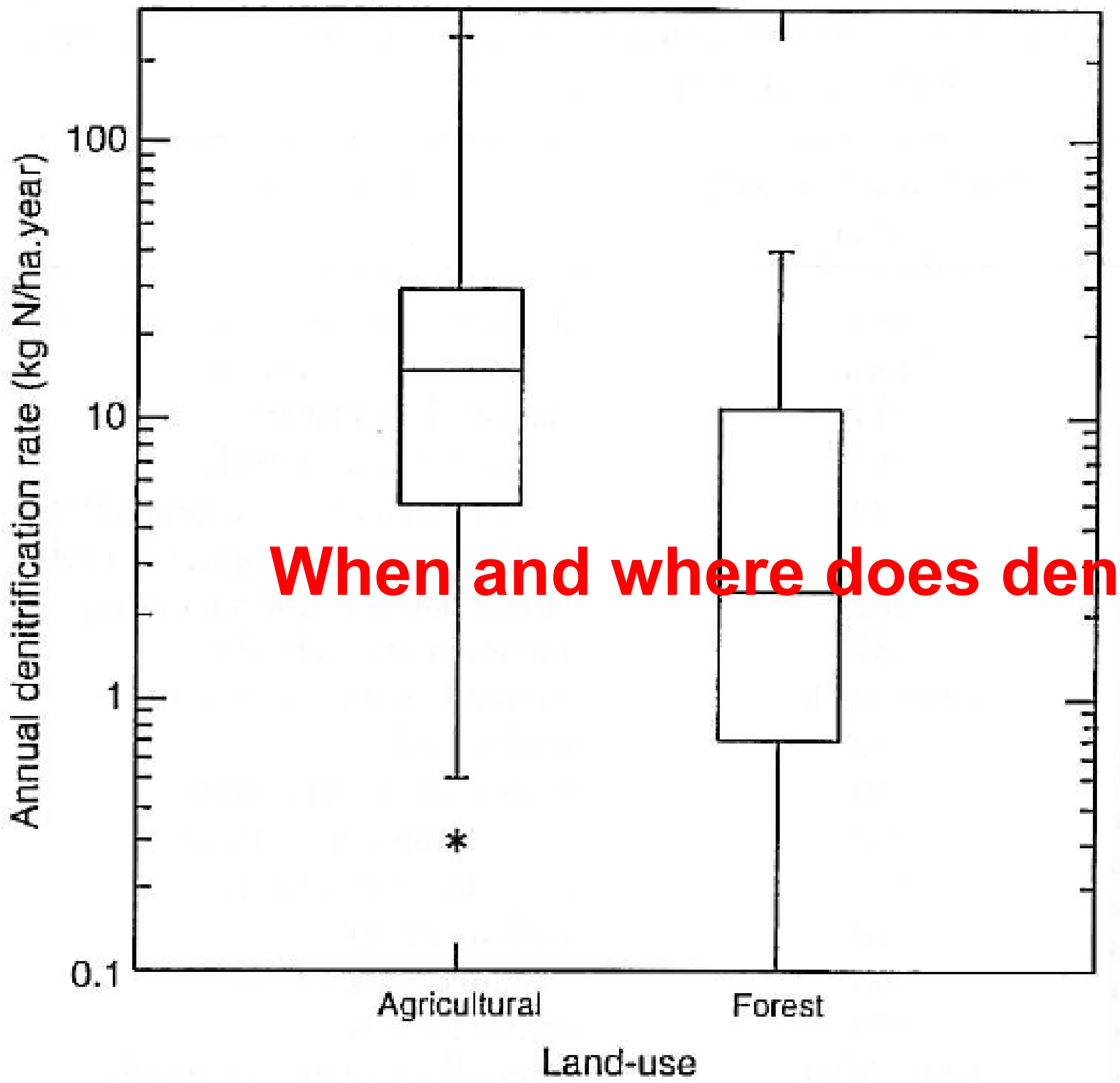
Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

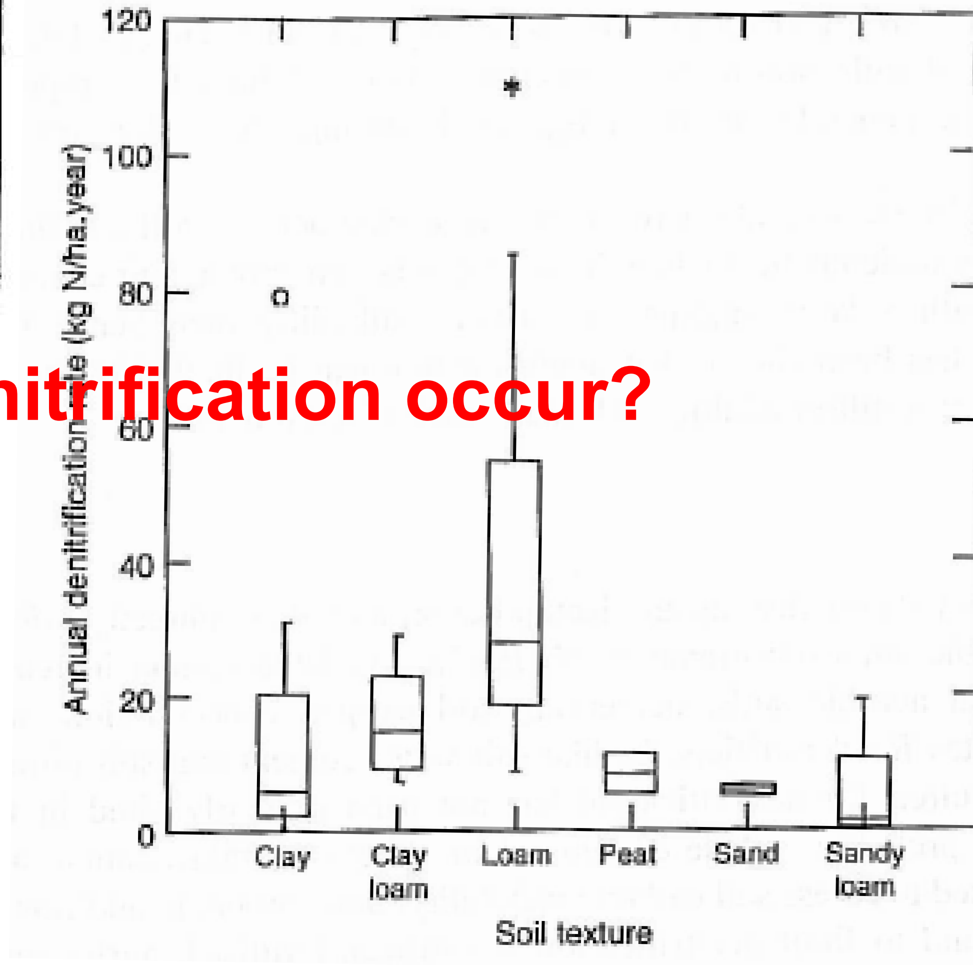
Publications on denitrification and soils increased by a factor of four within the last 20 yrs



Variability of denitrification estimates



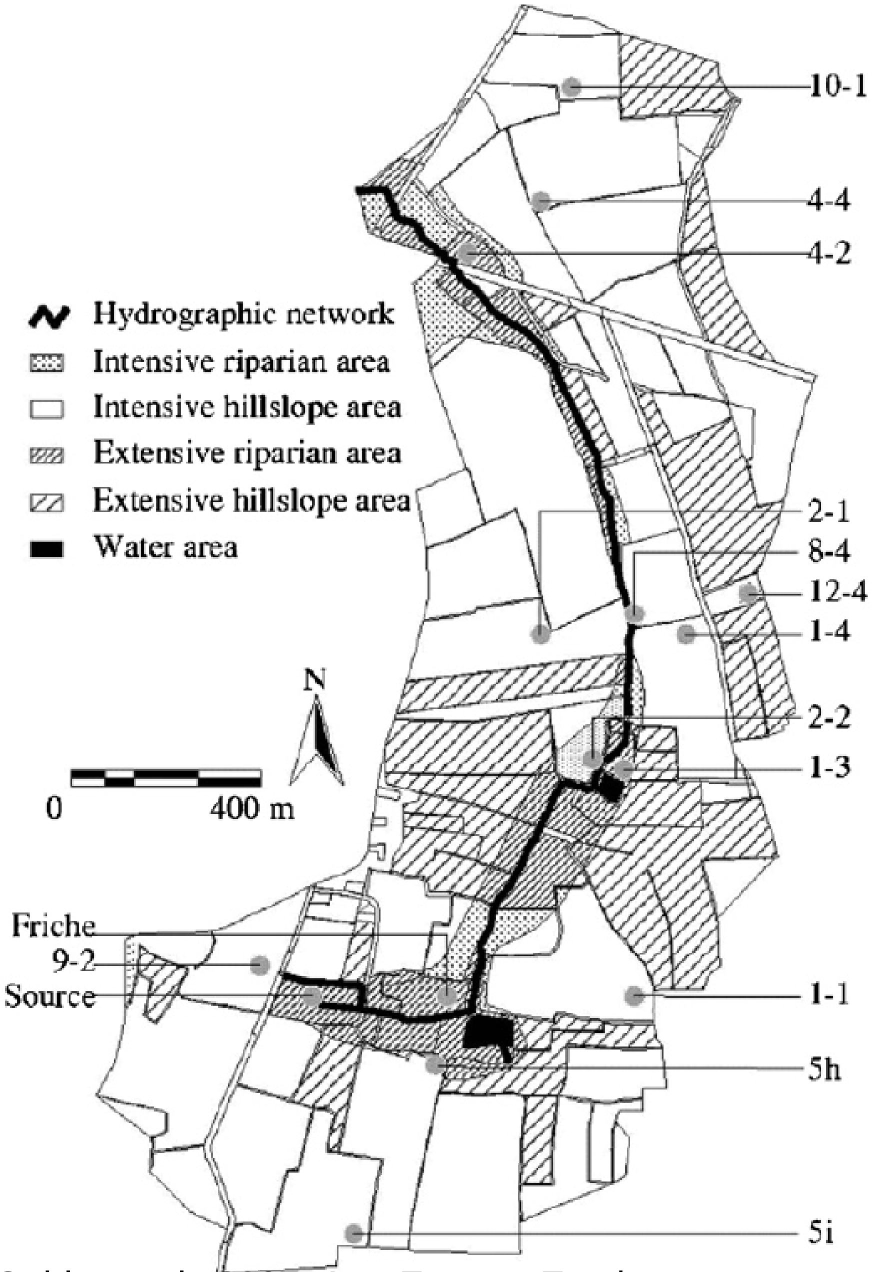
Denitrification & texture (grasslands)



When and where does denitrification occur?

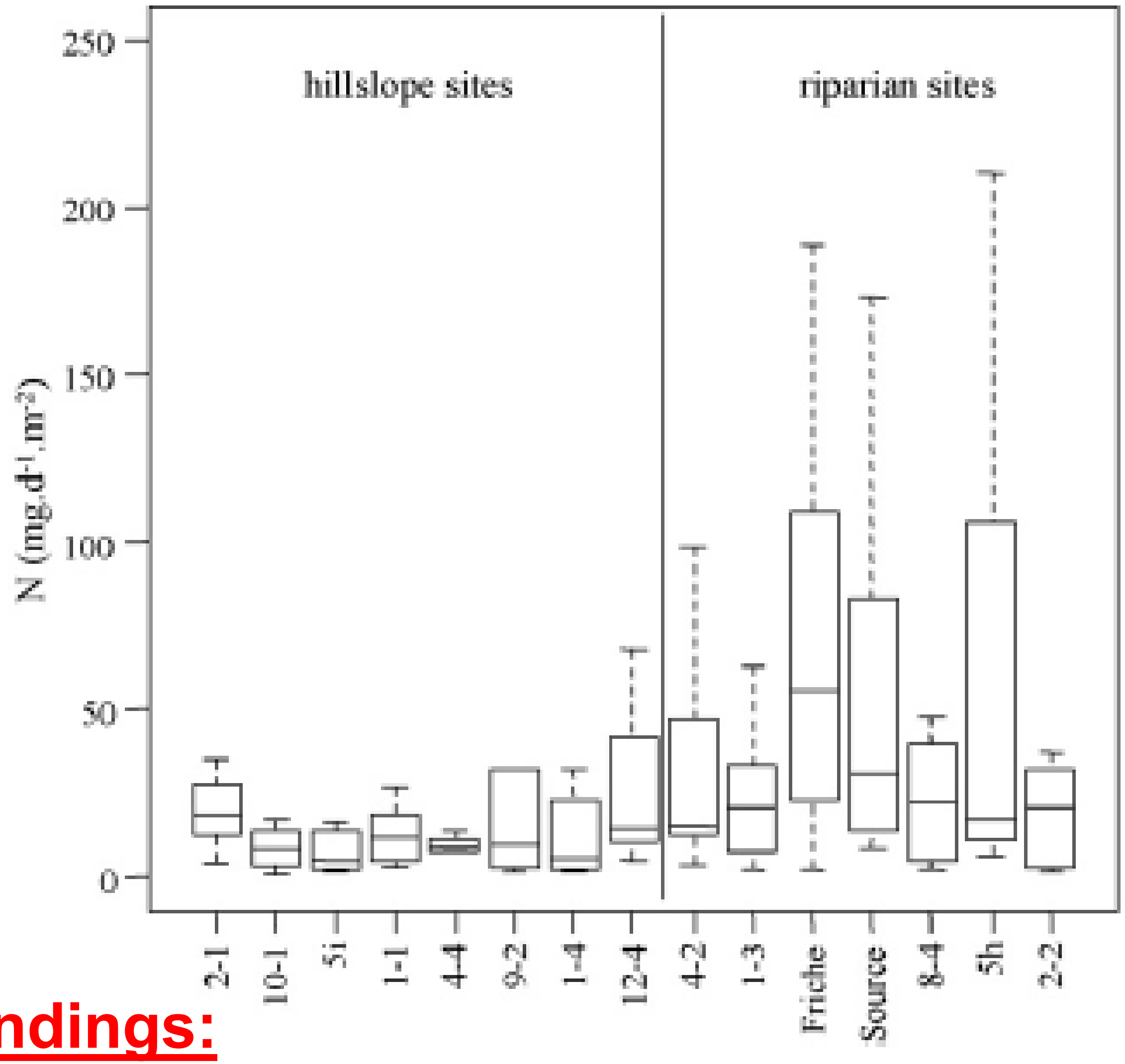
Barton et al.,1999, Aust J Soil Res

Estimating landscape scale denitrification losses



Oehler et al., 2007, Agr. Ecosys. Envrionm.

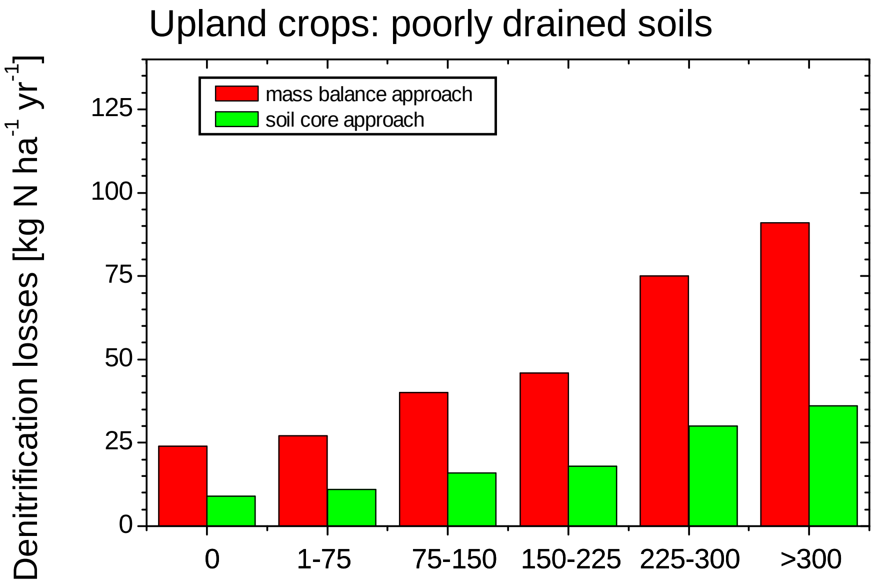
Annual mean N_2+N_2O losses



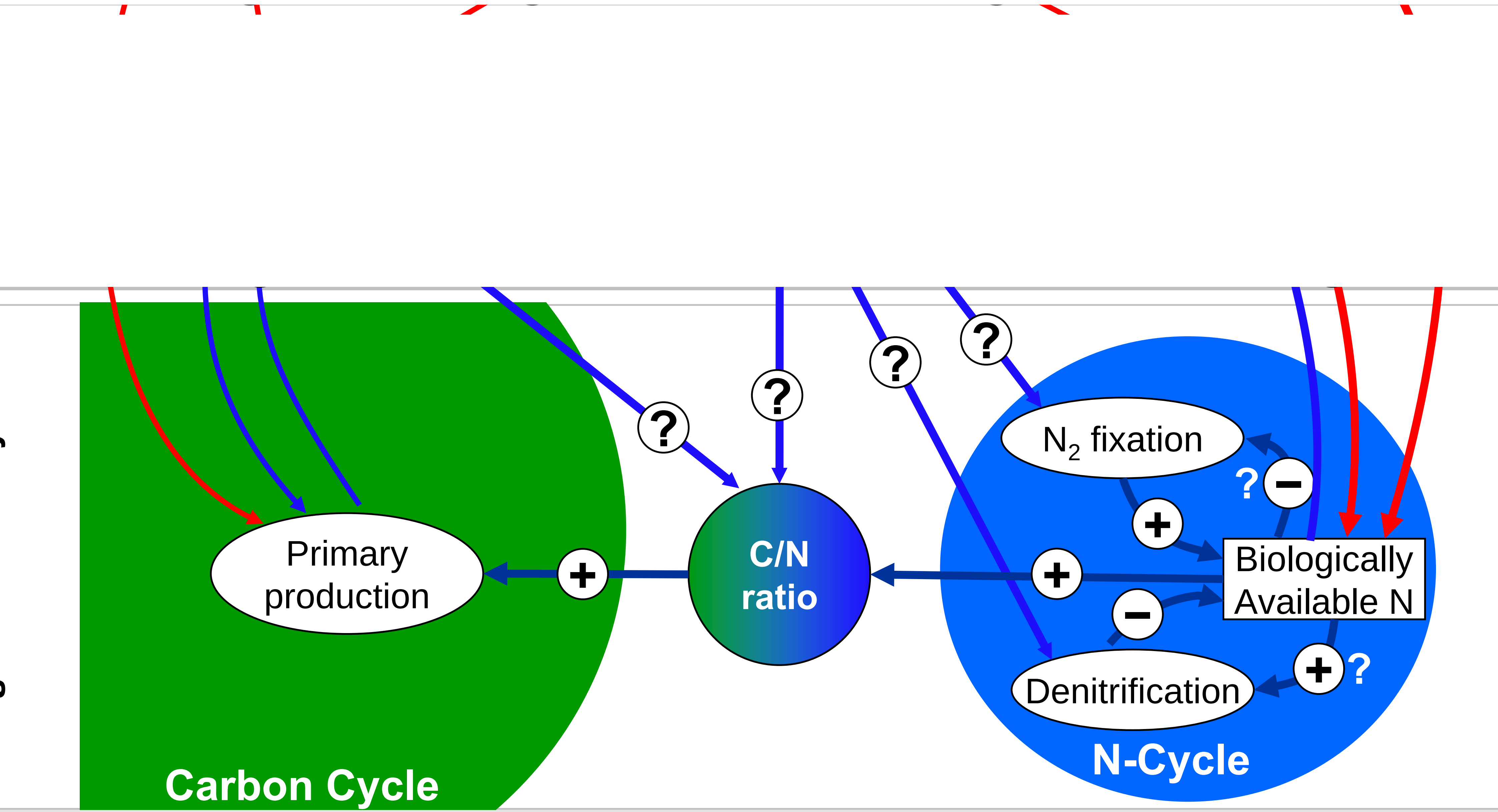
Main findings:

- 50% of denitrification occurs at hillslopes
- 20-40 cm layer contributed 50% to N losses
- N_2O:N_2 ratio approx. 1, i.e. main losses via N_2

Uncertainties of denitrification estimates



Hofstra & Bouwman, 2005, Nutr Cycl Agroecosys



Primary production
C/N ratio
N_2 fixation
Biologically Available N
Denitrification
Carbon Cycle
N-Cycle

Summary and conclusions

- Uncertainties with regard to Nr input
  - BNF not well understood
  - Dry deposition not well constrained
- Uncertainty with regard to Nr cycling
  - Microbial processes and microbial diversity
  - Plant-microbe competition and species composition
  - Organic N cycling
- Uncertainty with regard to Nr output
  - Denitrification (when and where?)
  - Changes in stocks versus external losses
- Uncertainties with regard to feedbacks to global changes