

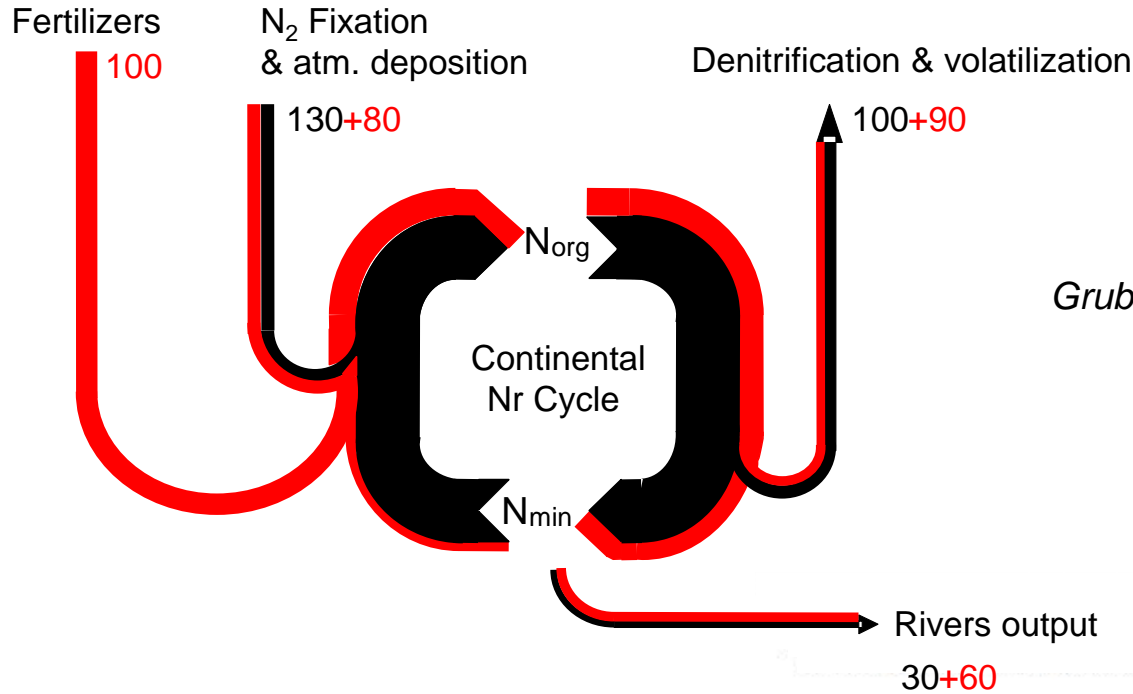
Organic Nitrogen pool and nitrat leaching from agricultural soils : Isotopic tracing ($\delta^{15}\text{N}$ & $\delta^{18}\text{O}-\text{NO}_3^-$)

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UFR 918 Terre, Environnement, Biodiversité

Nitrogen cycle : changes with anthropogenic activities



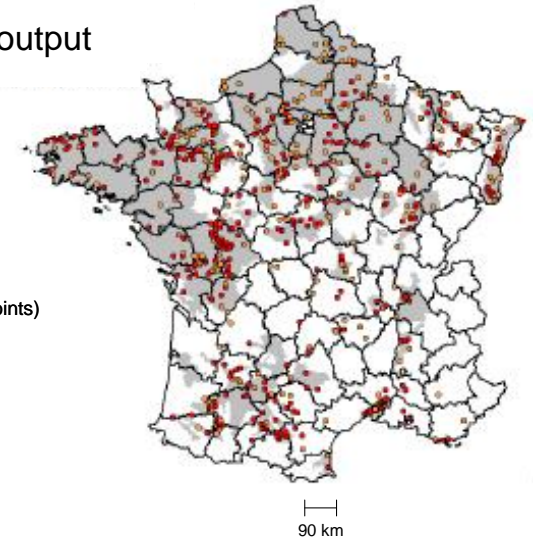
Gruber et Galloway, 2008;
TgN/year

- Human Activities: nitrogen inputs doubled in 50 years (Van Breemen et al., 2002, Galloway et al., 2003; 2004; Gruber et Galloway, 2008)

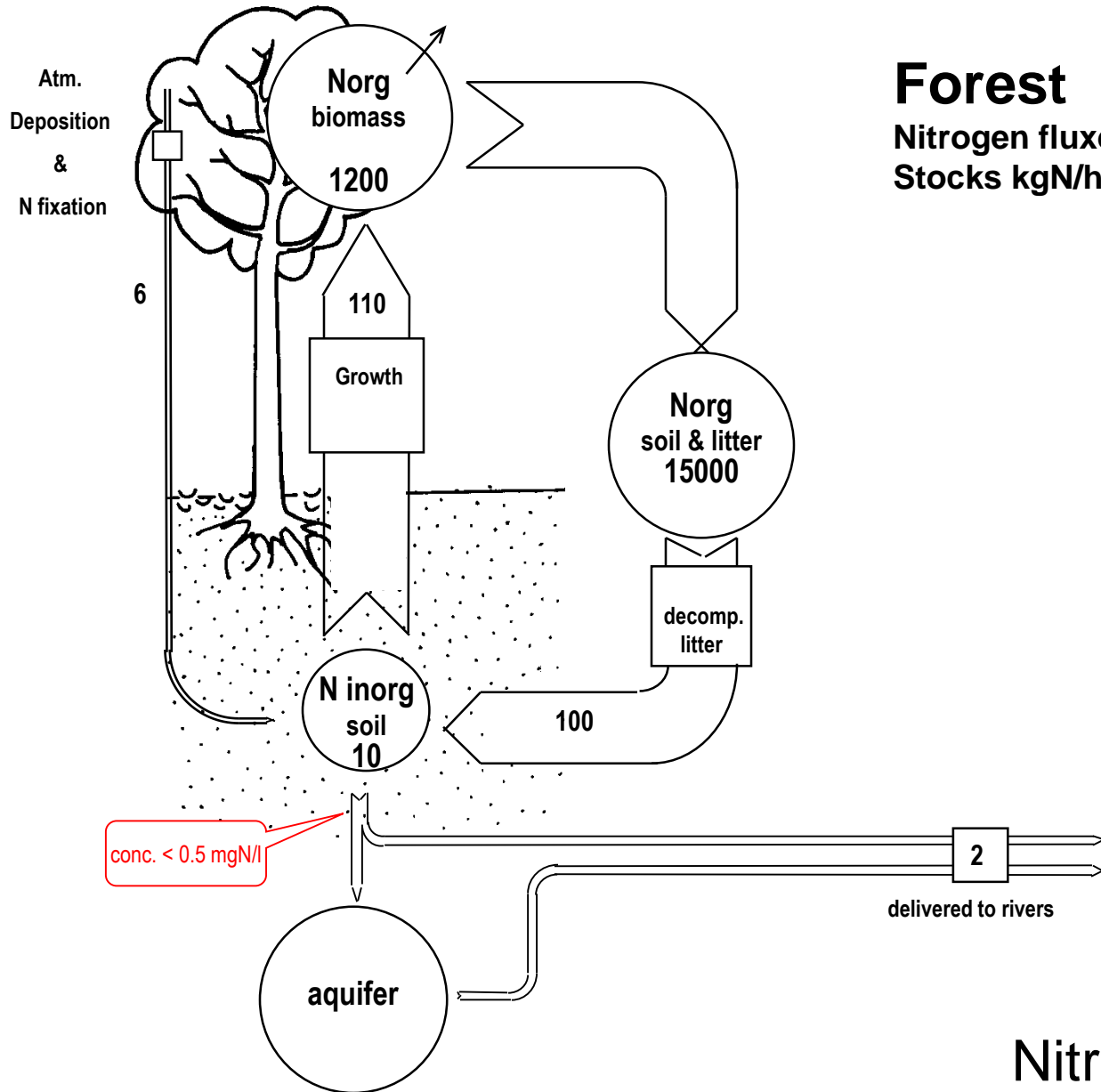
- Nitrogen cycle disturbed, fertilizers used for agriculture activities

- Strong increase of nitrate concentrations in groundwaters and rivers

- De 40 à 50 mg/l (273 points)
- > 50 mg/l (346 points)



Nitrates in forested areas



Forest

Nitrogen fluxes kgN/ha/year
Stocks kgN/ha

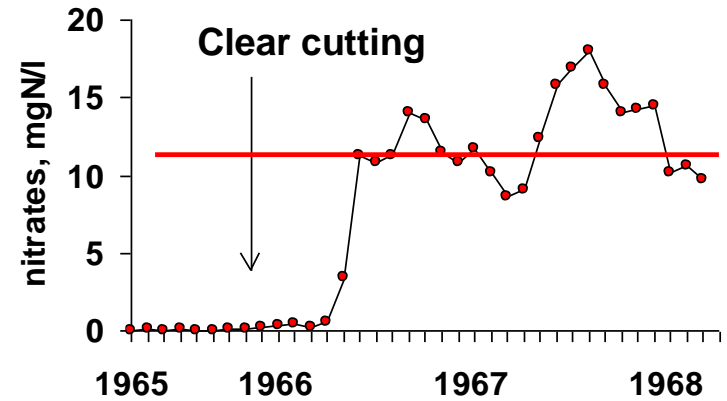
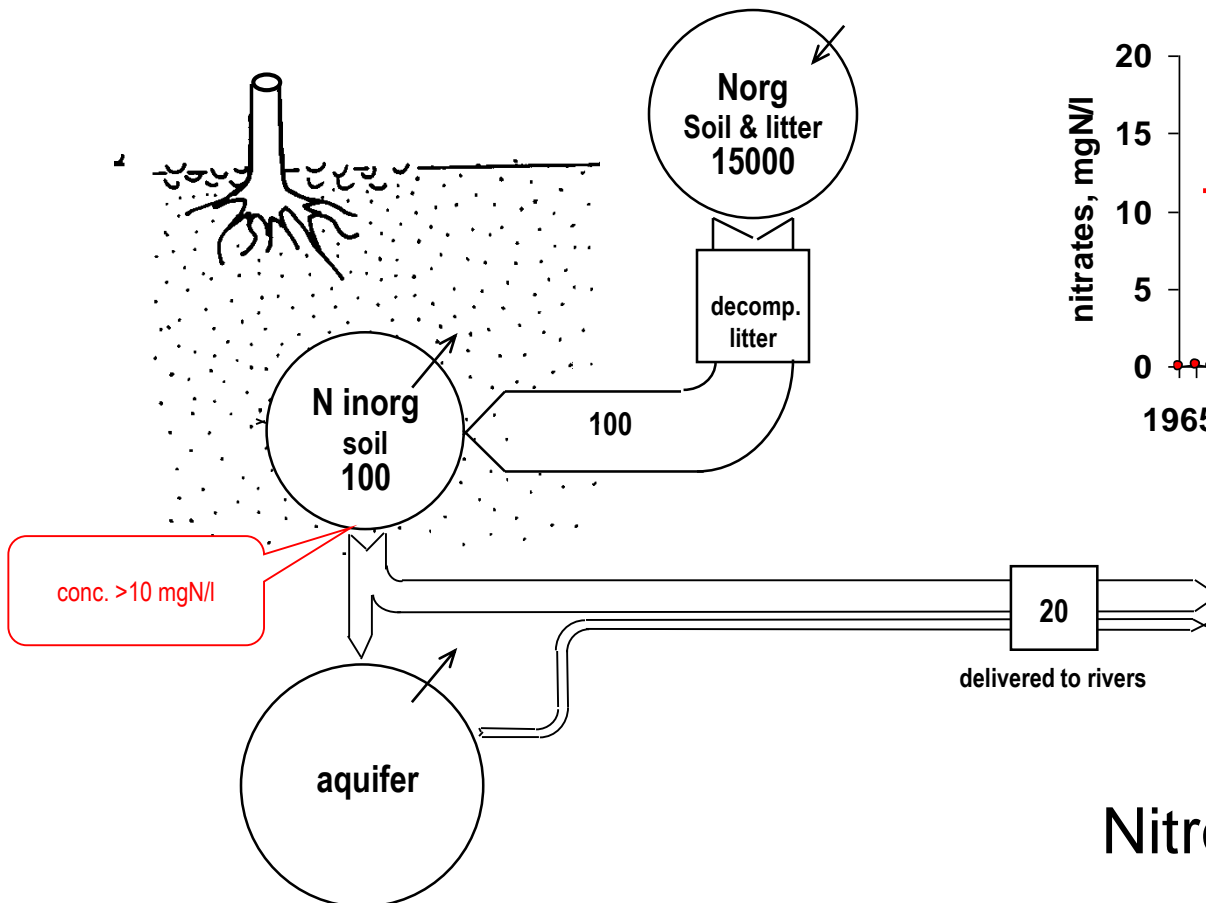
Nitrogen cycle closed

Cutting

Nitrogen fluxes kgN/ha/year

Stocks kgN/ha

Hubbard Brook (Likens & Bormann, 1972)

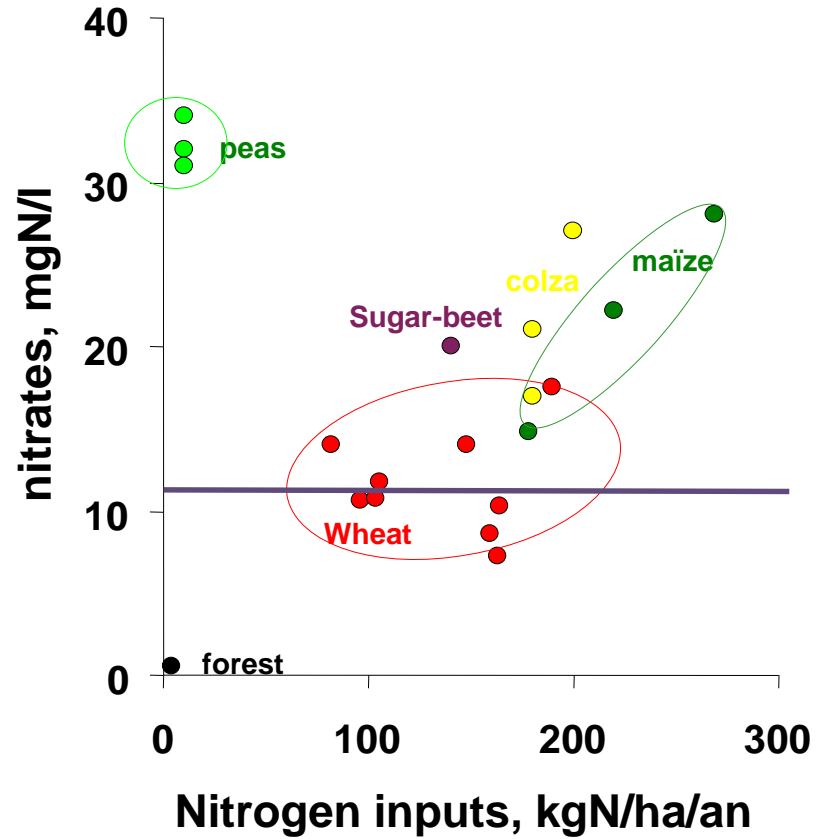
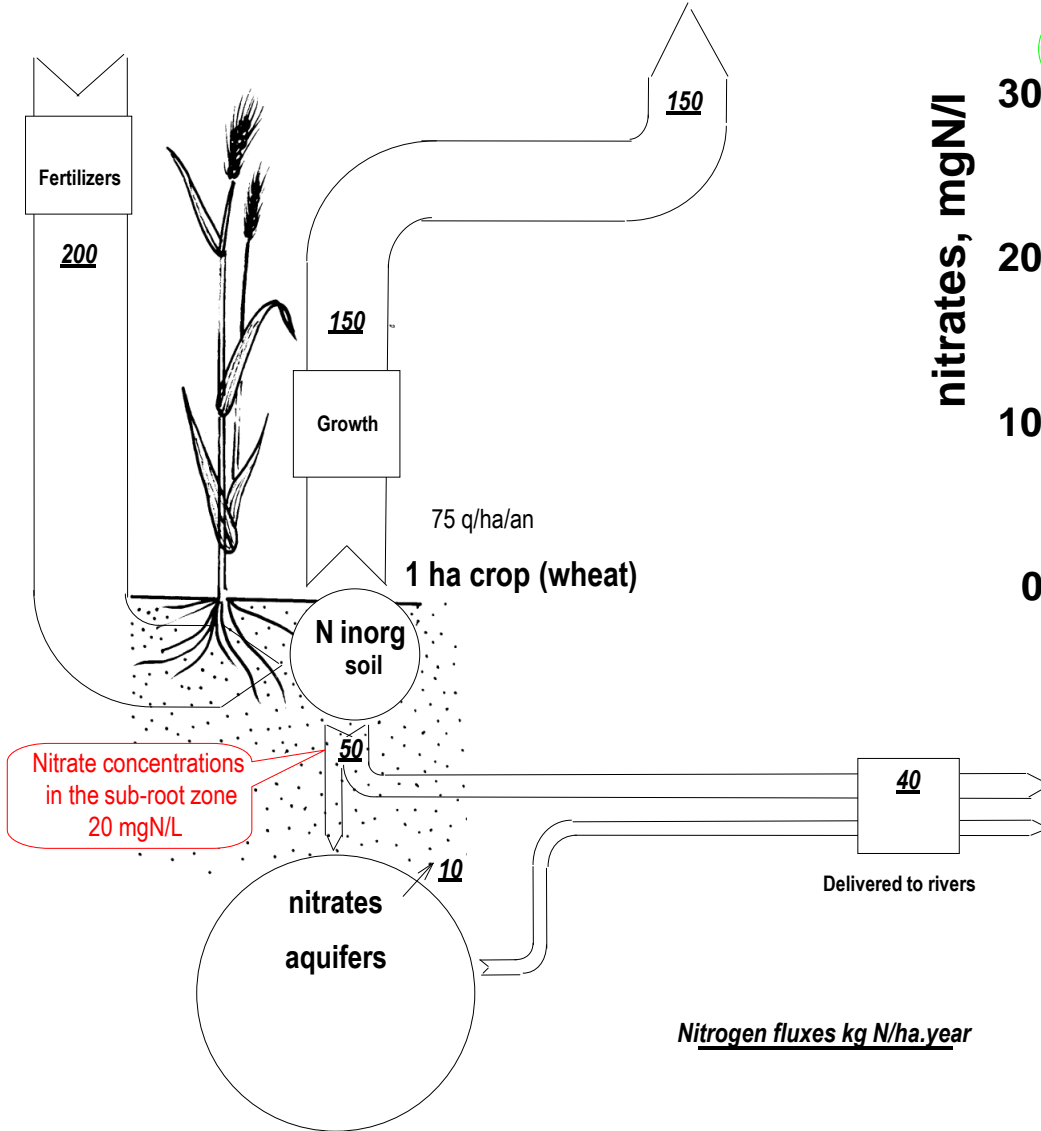


Nitrogen cycle opened

Crops : Use of inorganic fertilizers

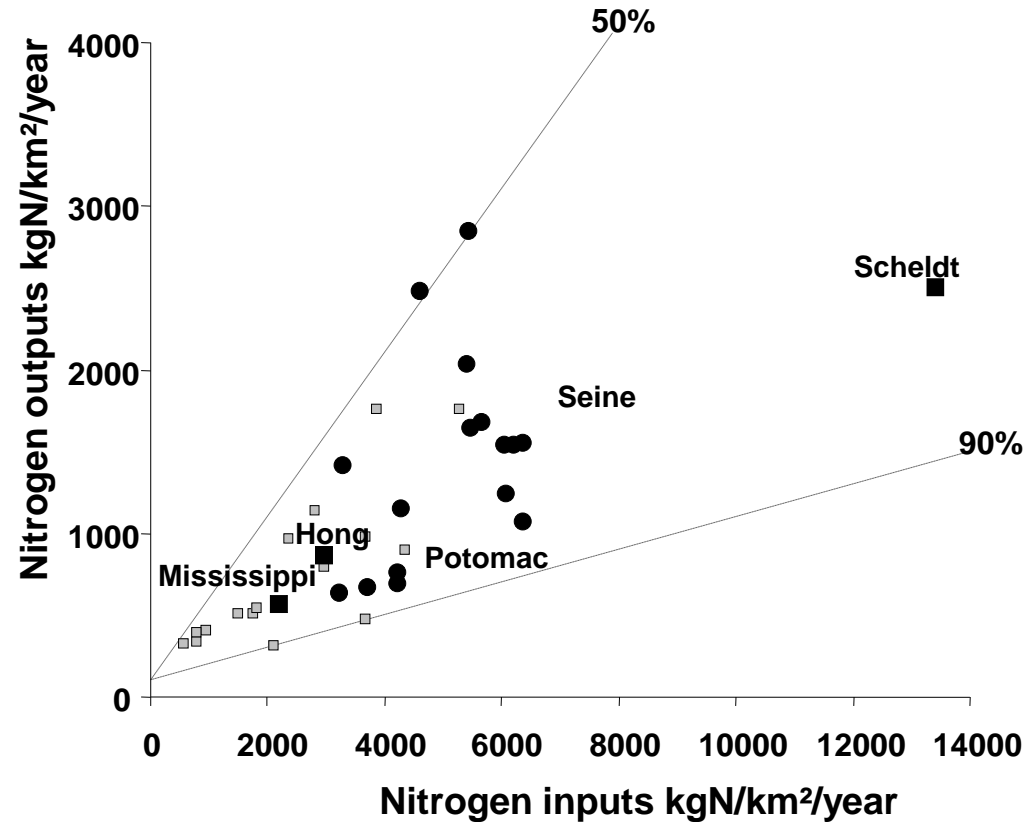
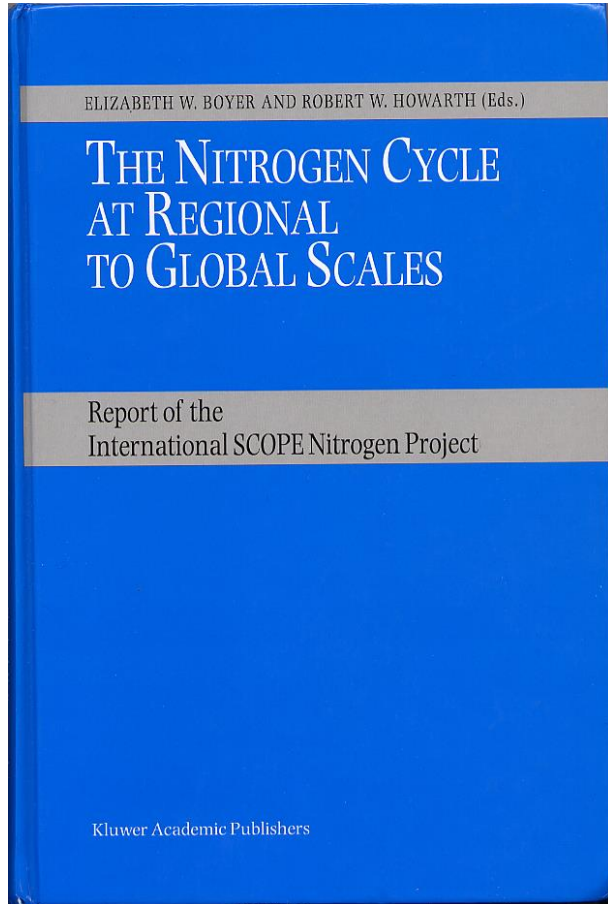
Net exportation of nitrogen

Significant part of nitrogen remains in soil



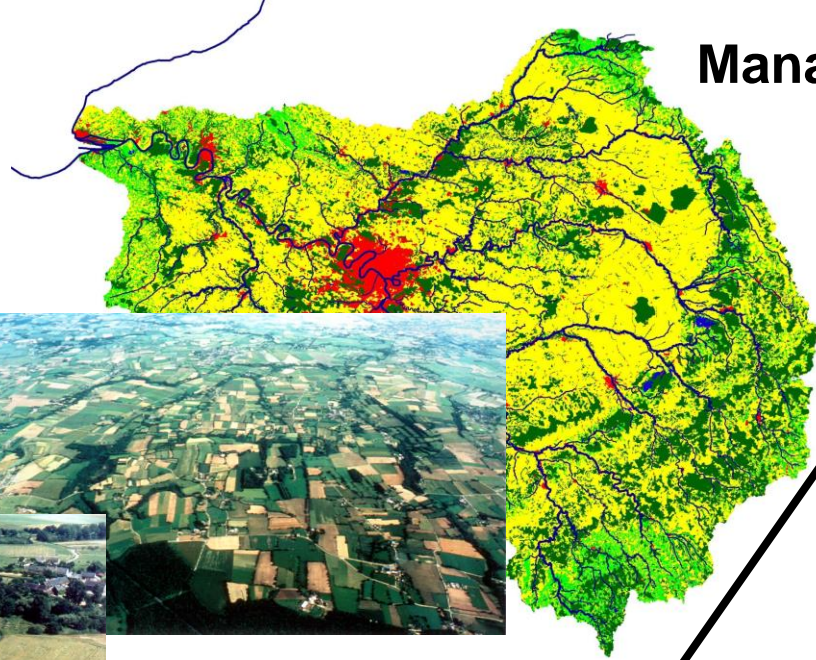
Nitrogen cycle opened

Nitrogen budget

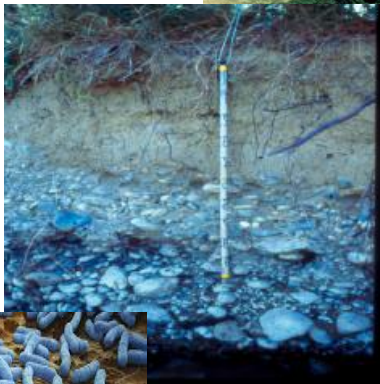


Nitrogen Retention: - **Storage processes:** uptake by plants, in groundwaters, assimilation in soil organic matter (SOM)
- **Removing (gases production):** denitrification, volatilization

Management ?



Where ?



Efficiency ?



**Hot spots ?
Hot moments?**

Scale

Isotopic Biogeochemistry

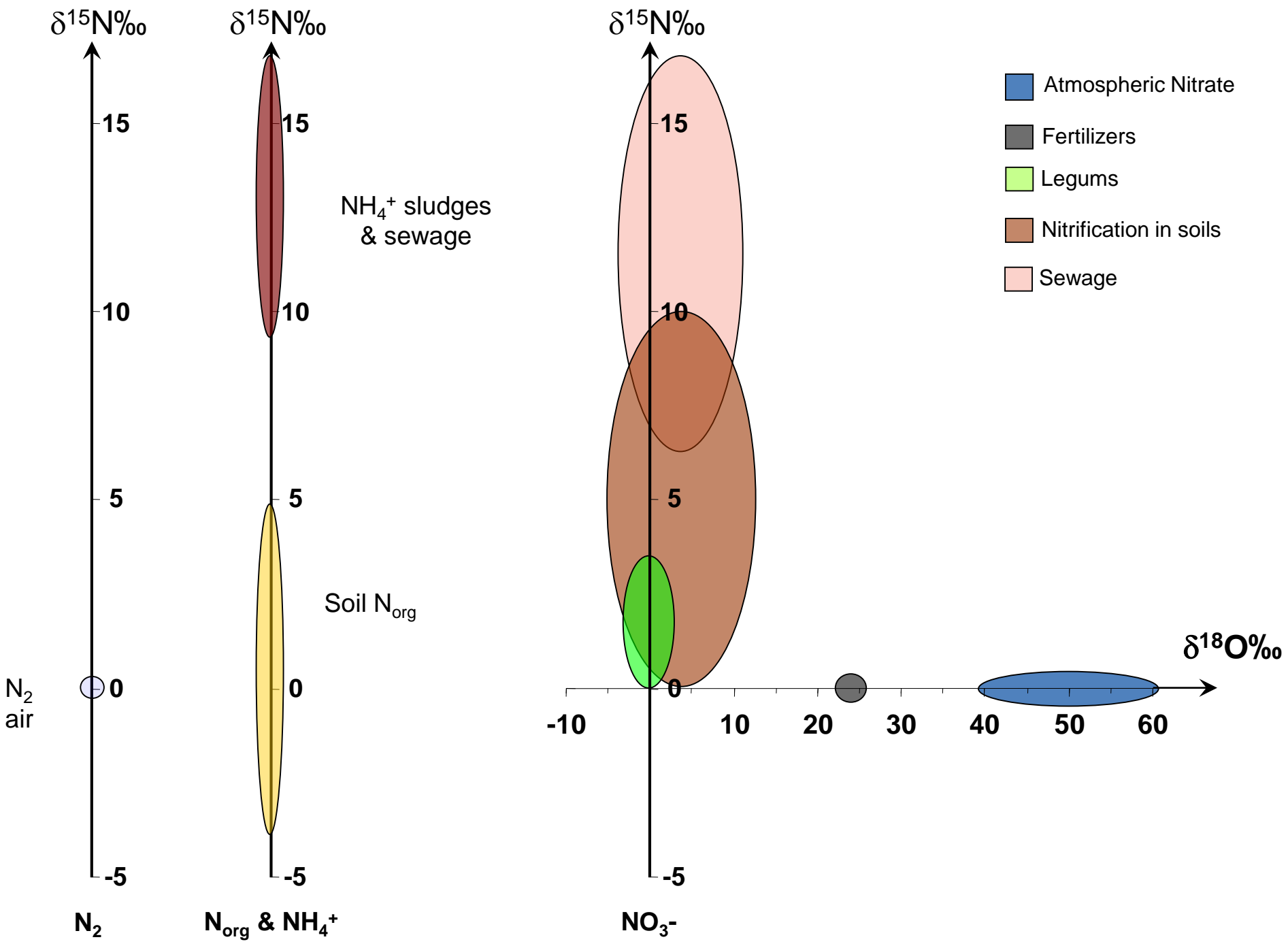
Isotopic Biogeochemistry : integrating tool

Basic Idea:

Isotopic composition of a chemical species at a definite location reflects:

(1) Its various sources

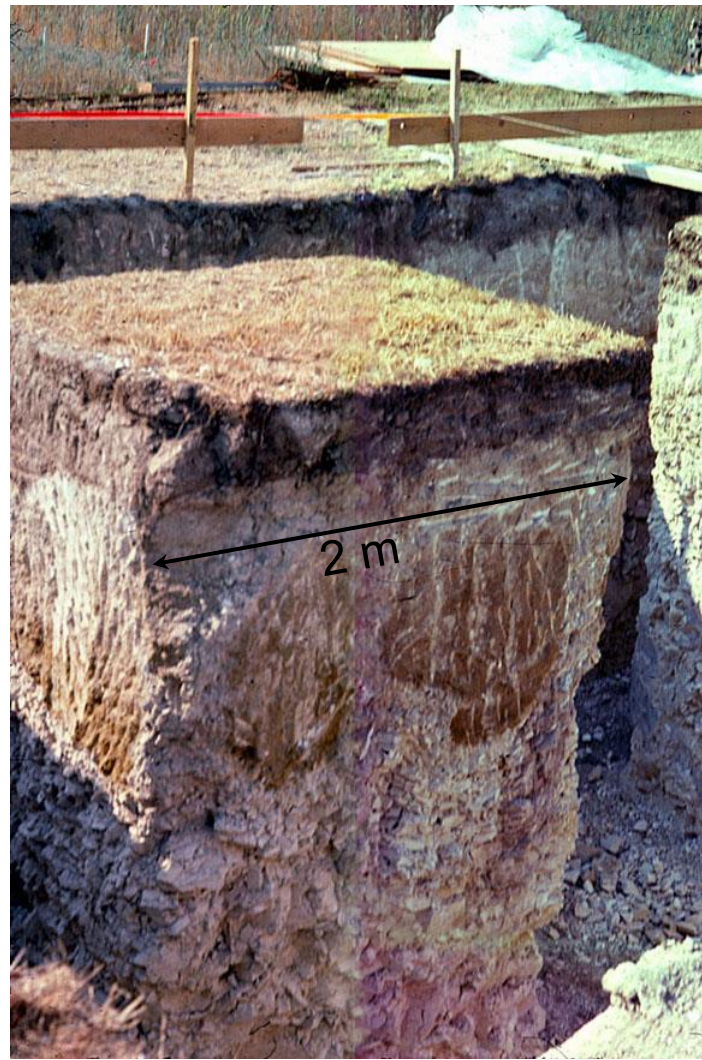
$$\delta_{\text{sample}} (\text{‰}) = \left(\frac{R_{\text{sample}} - R_{\text{standard}}}{R_{\text{standard}}} \right) \times 1000$$



Use of labeled compound and its application on lysimeters

Rotation wheat-sugar beet, 120 kgN/ha/year

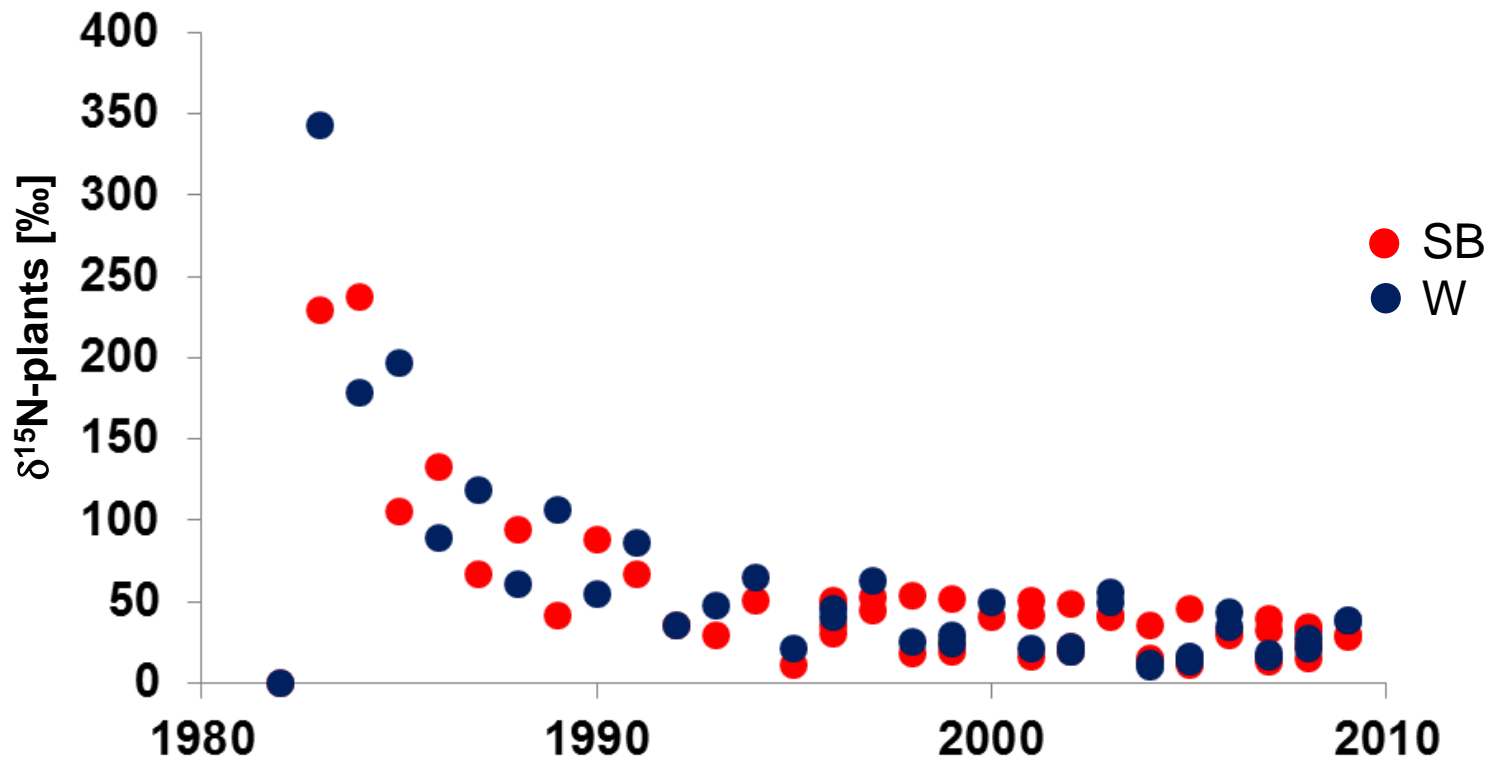
1982 $K^{15}NO_3^-$ applied



1982

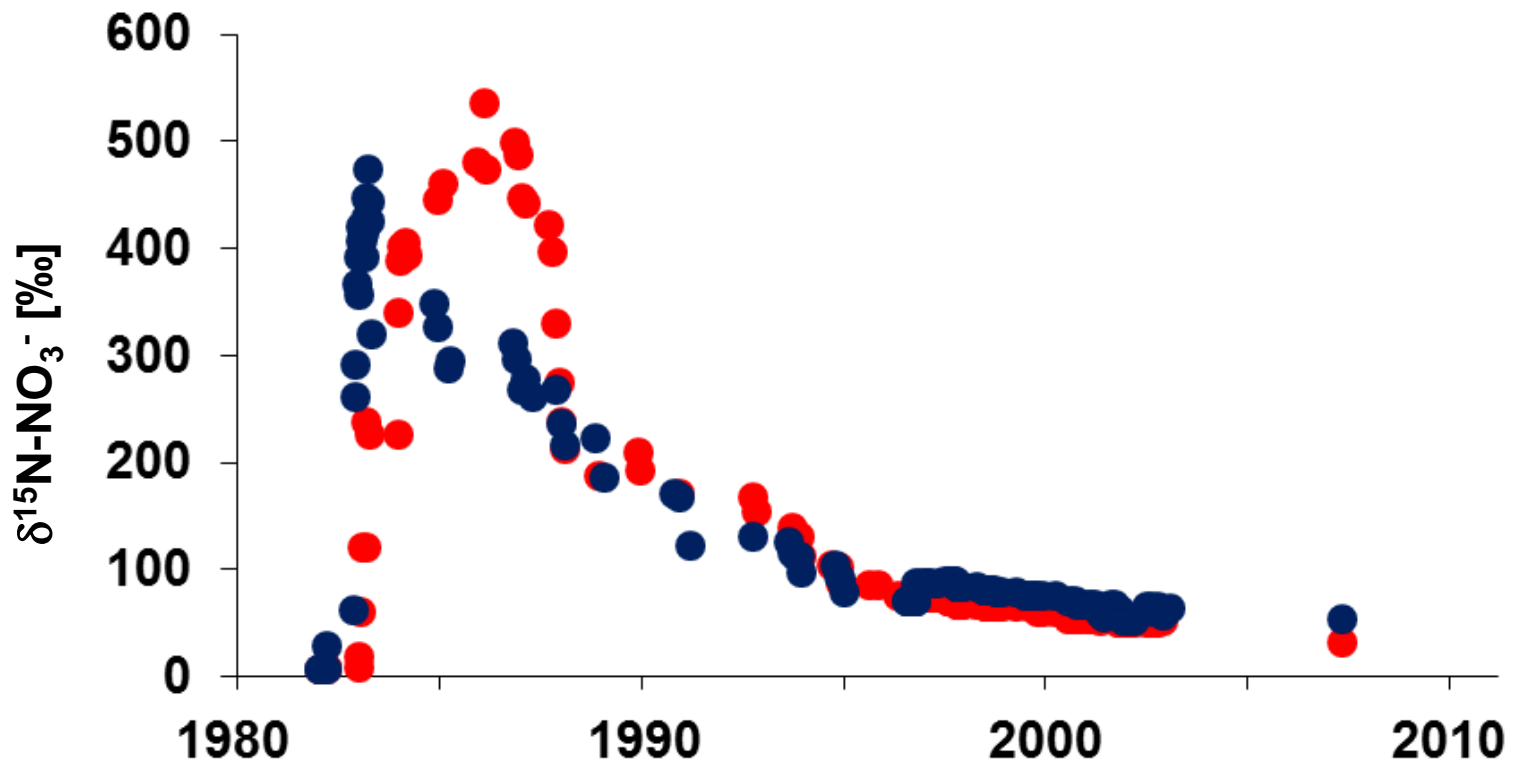
Measurements of the isotopic composition :
Plants
Soil Organic Matter
Nitrate

2010



Nitrate uptake by plants.

But the isotopic signal is still different from the natural level.

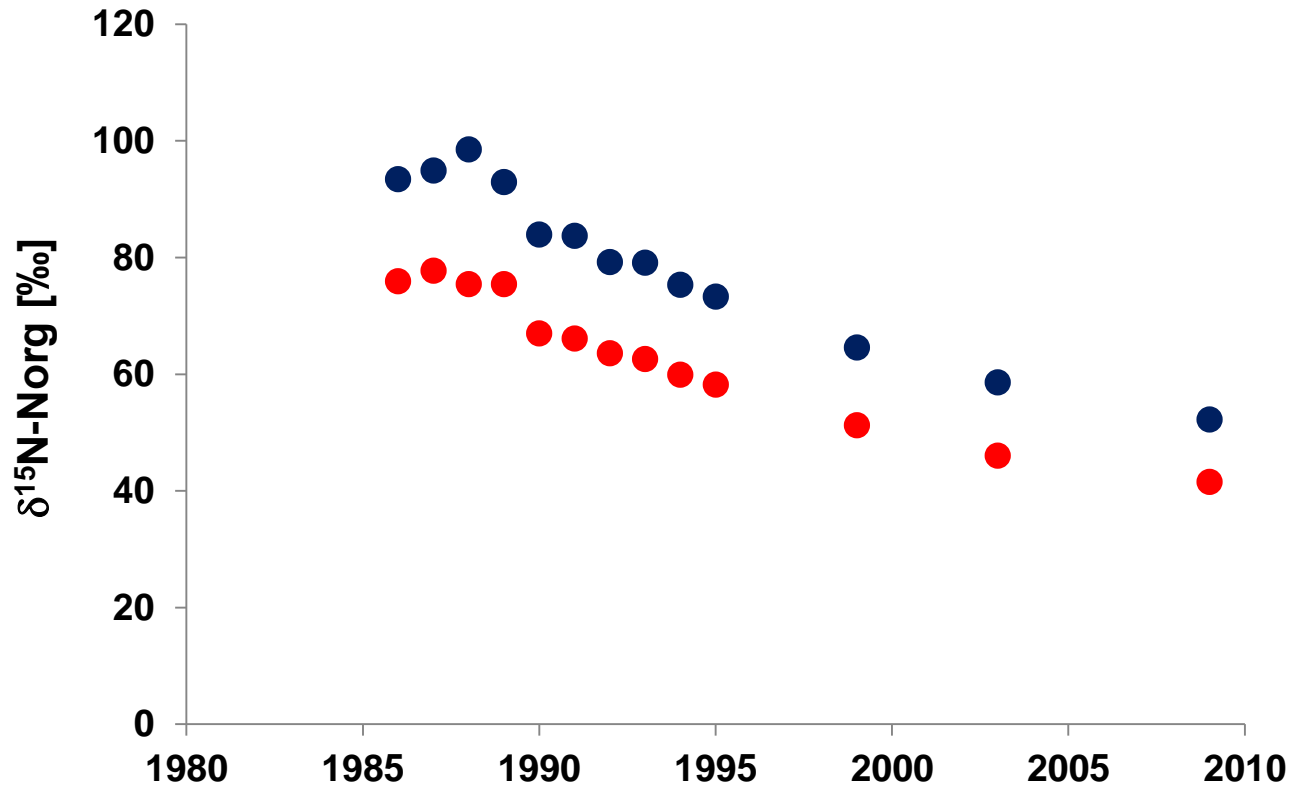


Hypothesis :

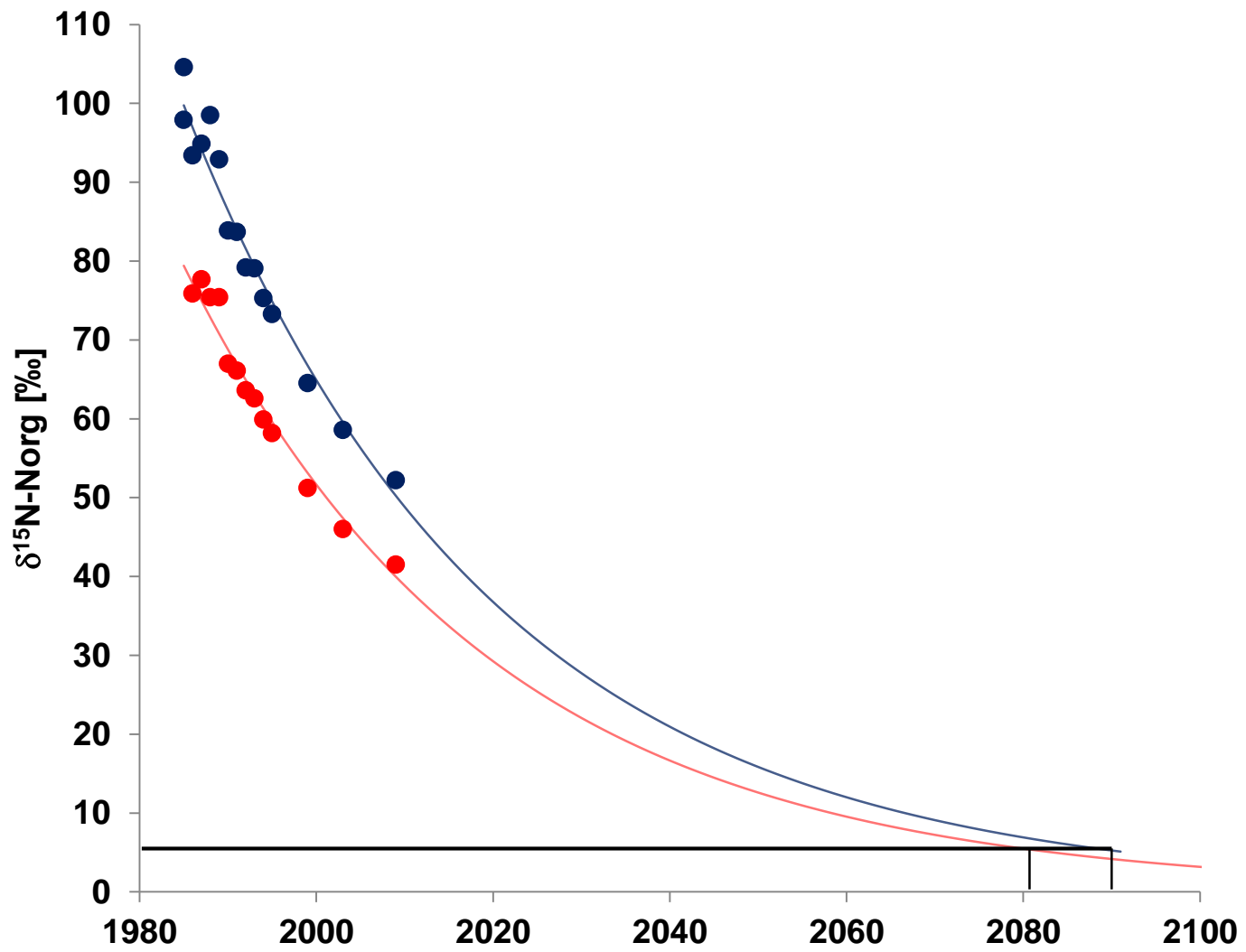
1°) Hydrological phenomenon ?

^3H measurements : infiltration 35 cm/year to 55 cm/year
cumulated volumes collected are higher than 3000 l/m²
lysimeters were purged **10 times**

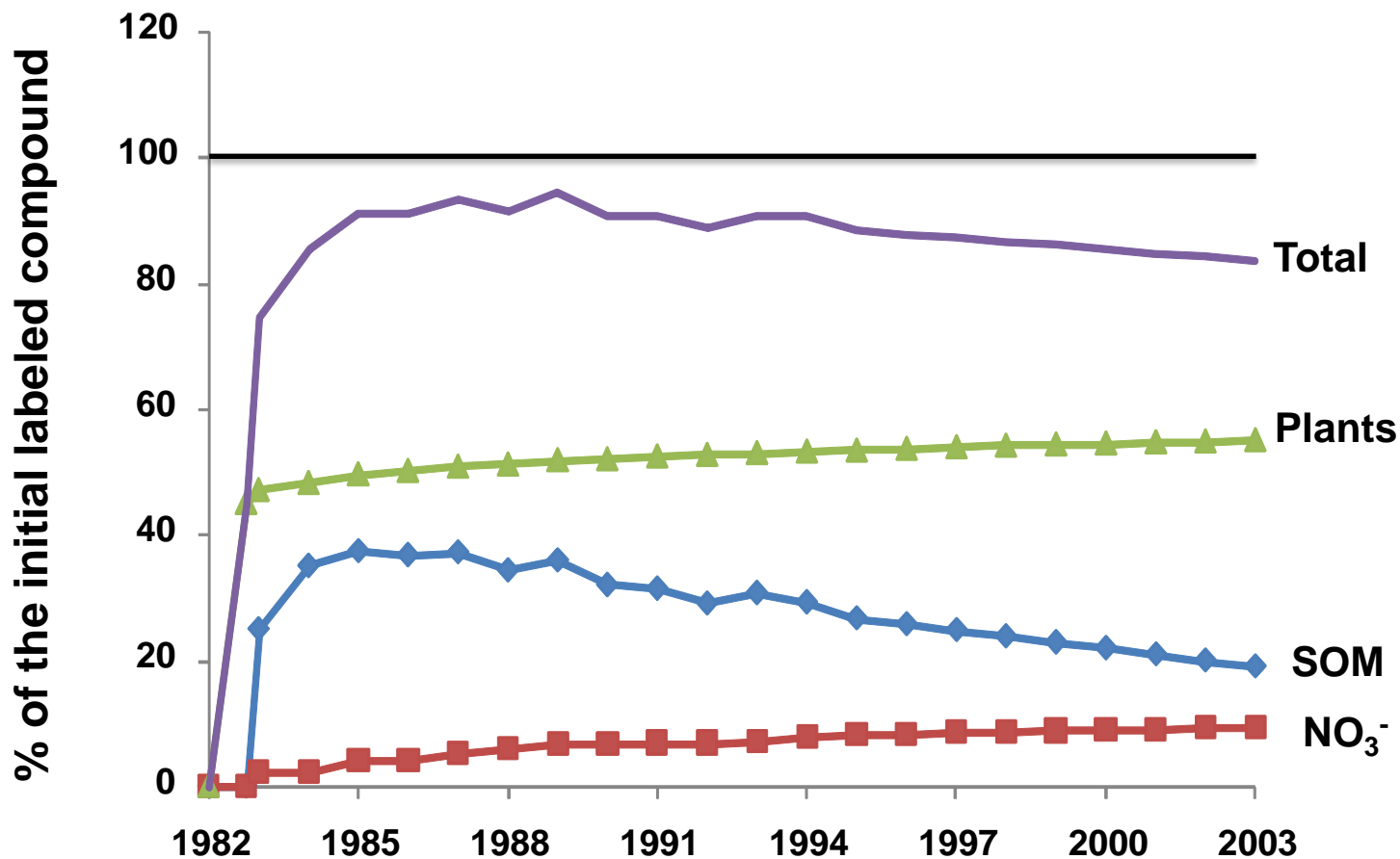
2°) Retention in the pool of soil Organic Matter?



Major role of the Soil Organic Matter



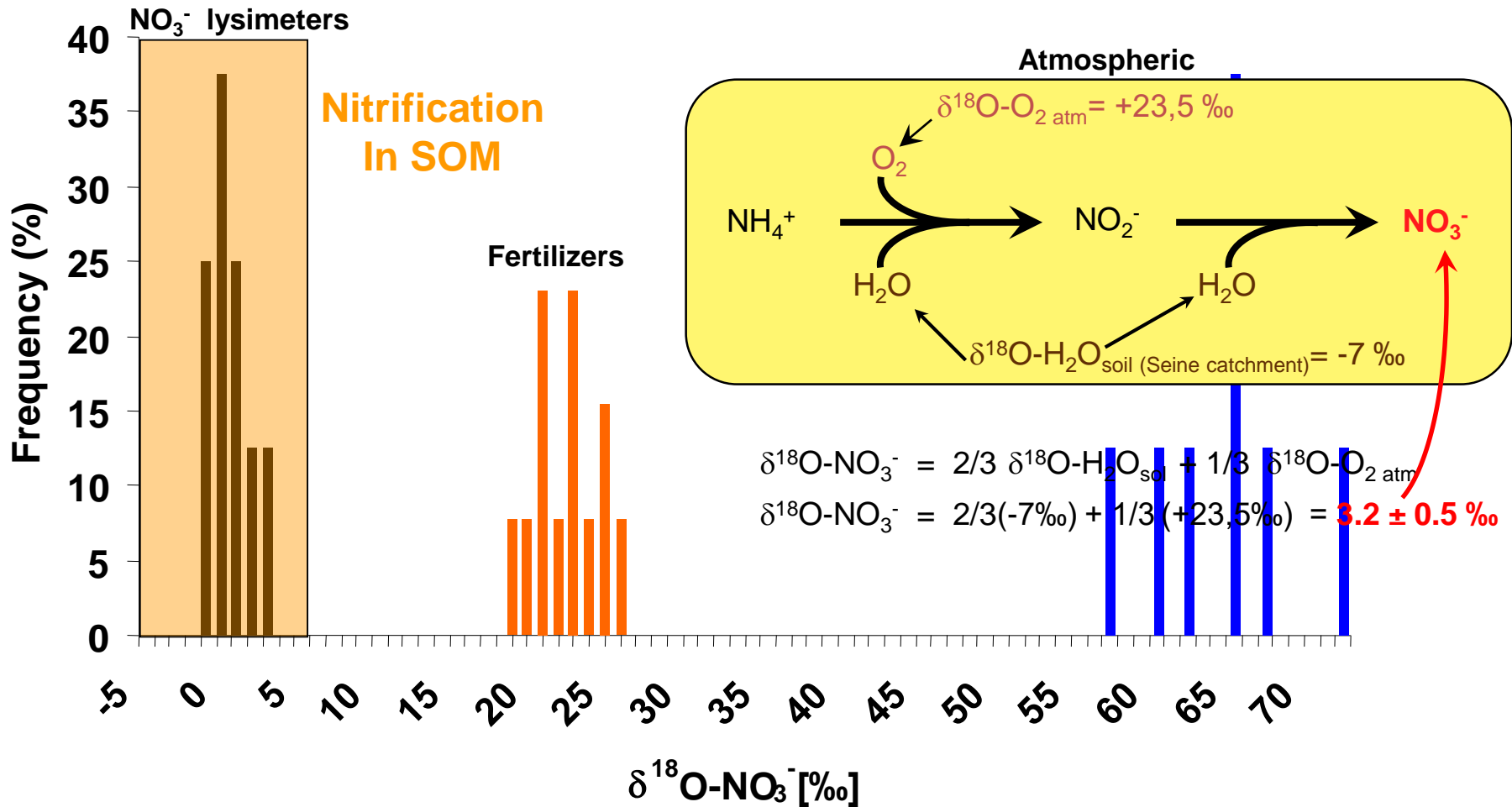
Budgets : lysimeters experiment

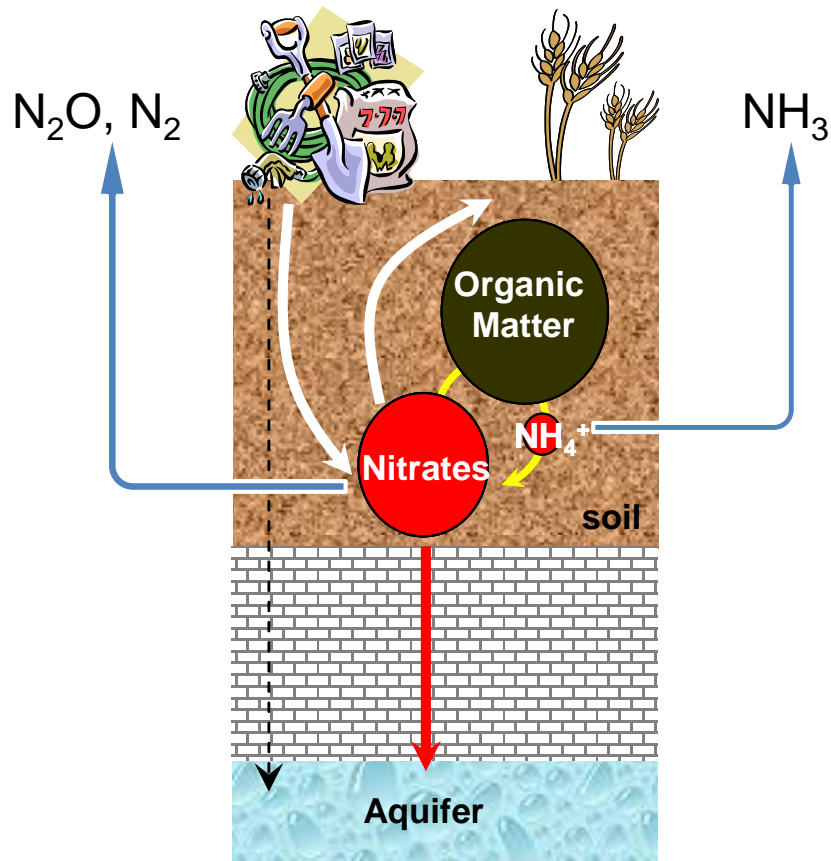


Gases production

→ **Denitrification and/or Nitrification - Volatilization**

Natural stable isotopic composition : $\delta^{18}\text{O}-\text{NO}_3^-$





- . The natural stable isotopic composition of nitrates in sub-root zone doesn't reflect the isotopic composition of the sources (atm. deposition, fertilizers), but nitrates "freshly " produced.
- . Gases production from the turn over of Soil Organic Matter

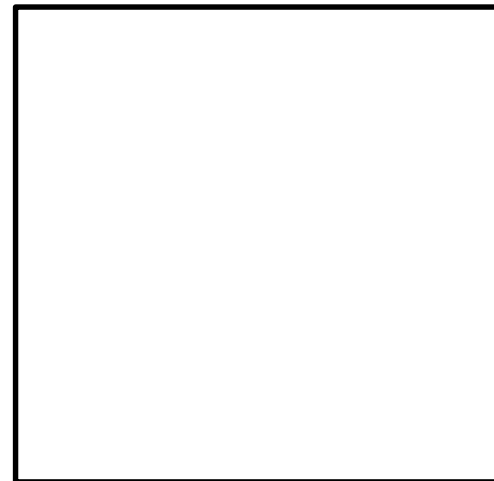
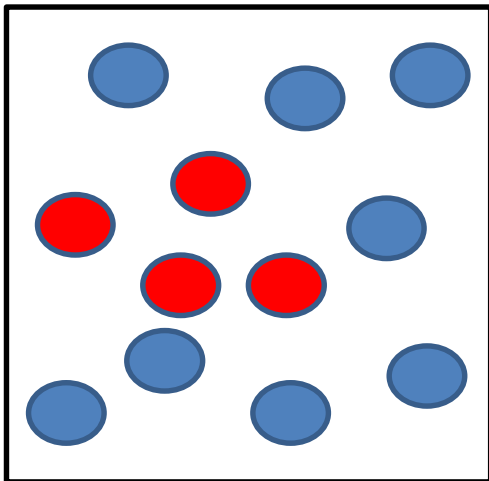
Isotopic Biogeochemistry : integrating tool

Basic Idea:

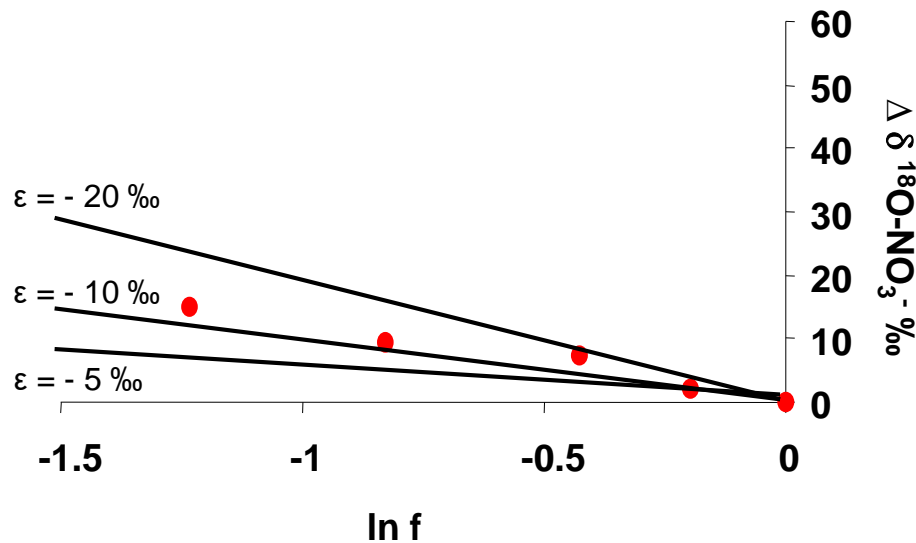
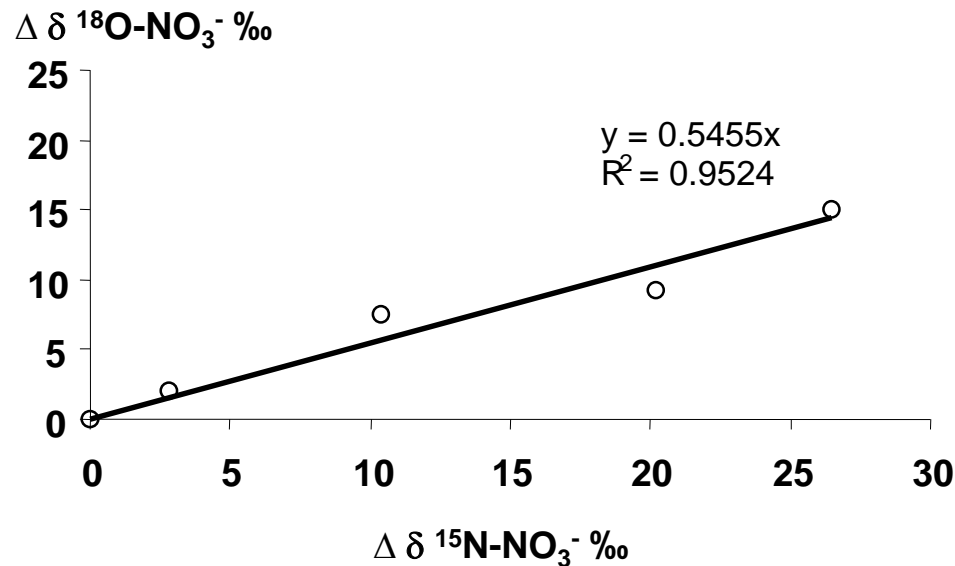
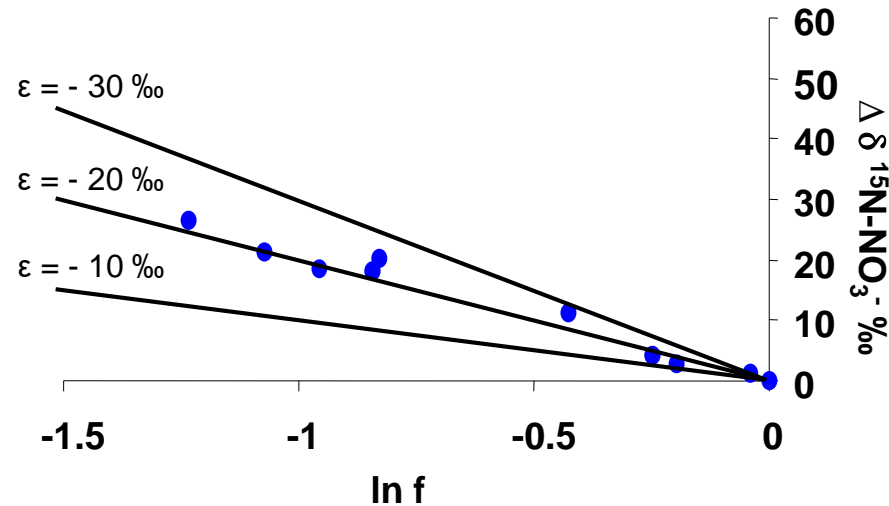
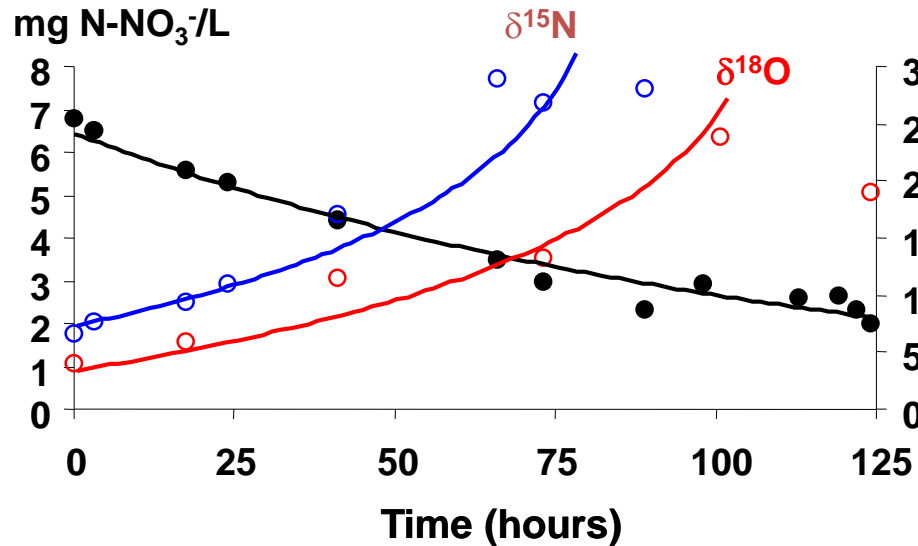
Isotopic composition of a chemical species at a definite location reflects:

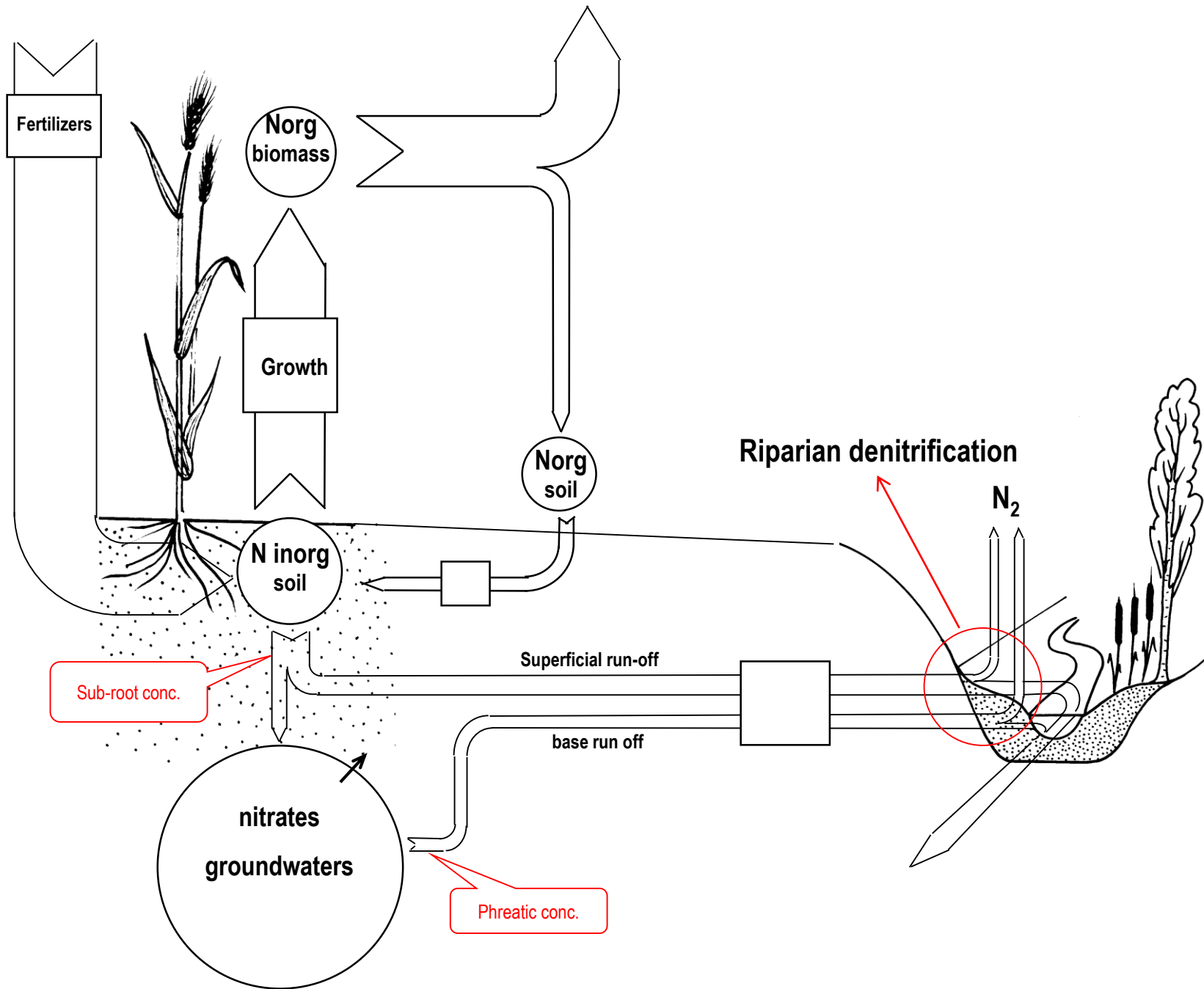
- (1) Its various sources
- (2) the processes which affects it

Substrate → Product



Denitrification and isotopic fractionation





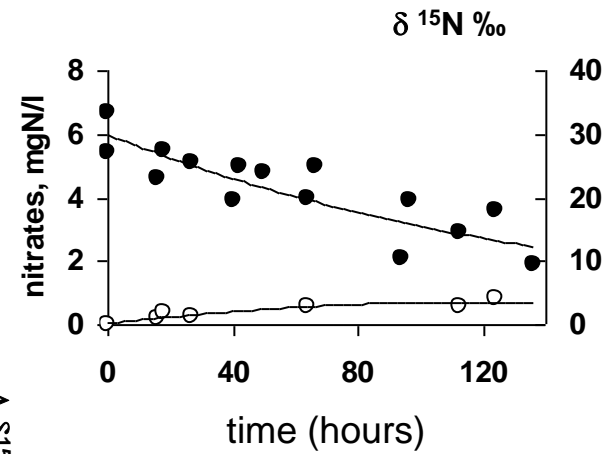
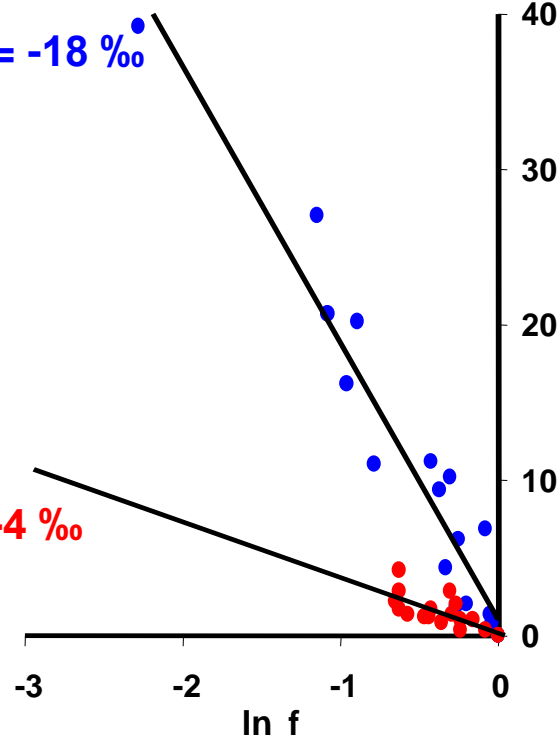
one phase denitrification

$$y = -17,836x + 1,0273$$

$$R^2 = 0,93$$

n=18

$$\varepsilon = -18 \text{ ‰}$$



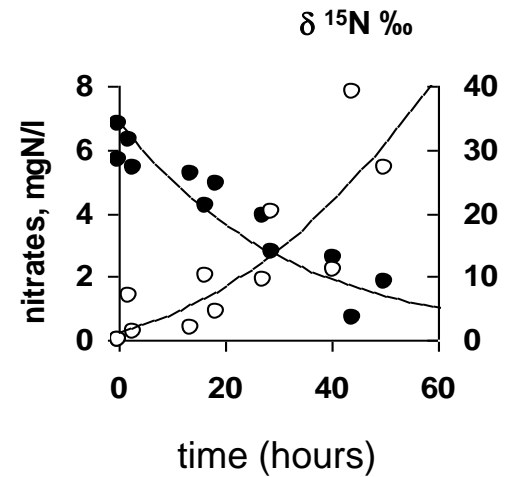
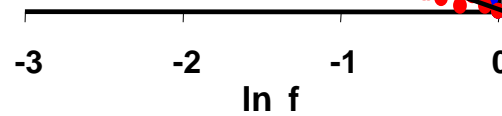
two phases denitrification

$$y = -3,653x + 0,1449$$

$$R^2 = 0,54$$

n = 19

$$\varepsilon = -4 \text{ ‰}$$

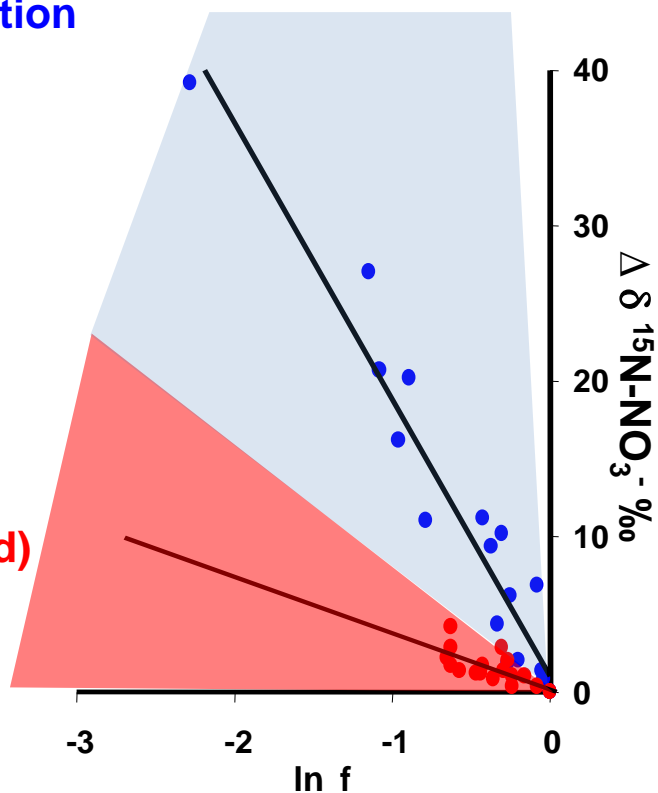


one phase denitrification

$\epsilon = -18 \text{ ‰}$

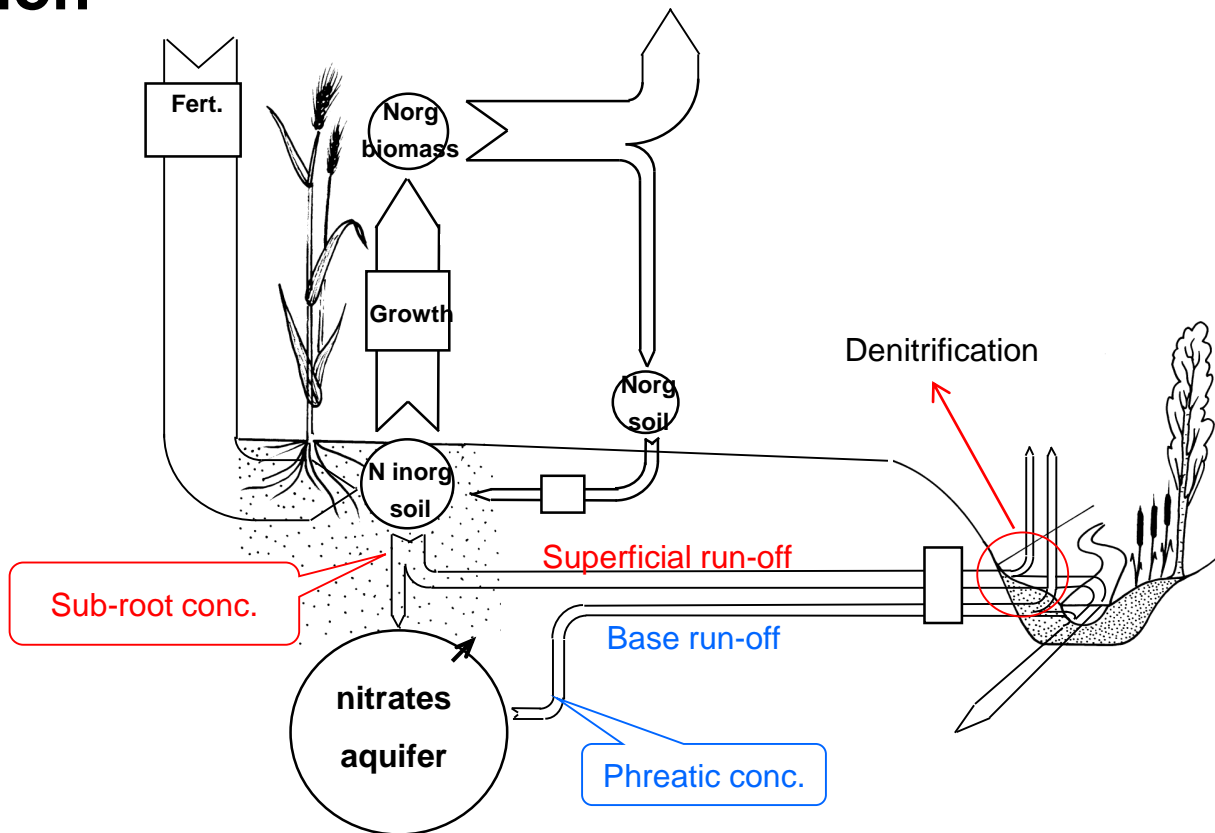
two phases denitrification
(diffusion controlled)

$\epsilon = -4 \text{ ‰}$

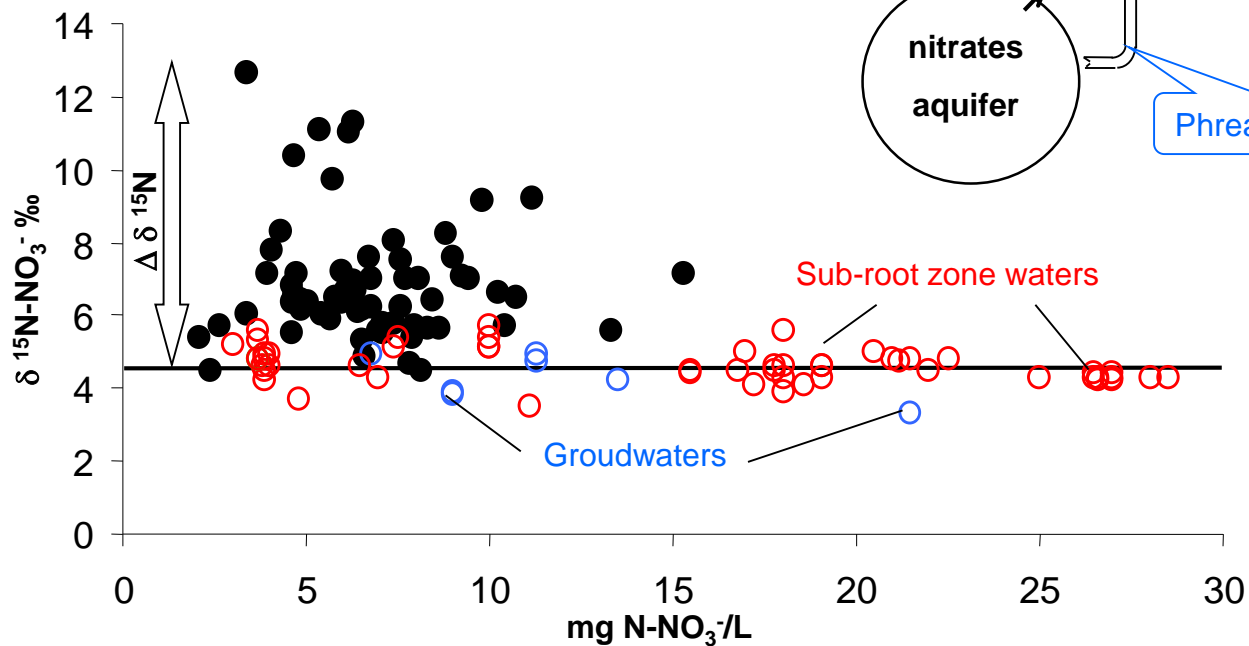


Site	$\epsilon^{15}\text{N} \text{ ‰}$	Authors
Culture	-28,6	Barford <i>et al.</i> , 1999
Culture	-12,3 to - 13,3	Blackmer&Bremner 1977
Culture	-13,4 to - 20,8	Delwiche & Steyn 1970
Culture	-24,6 to - 29,4	Mariotti <i>et al.</i> , 1980
Culture	-20	Myake & Wada 1971
Culture	-30	Olleros 1983
Culture	-19 to - 20	Wellman <i>et al.</i> , 1968
Culture	-18	Sebilo Thesis
Groundwater	-22,9	Aravena & Robertson 1998
Groundwater	-15,9	Böttcher <i>et al.</i> , 1990
Groundwater	-13,6	Fukada <i>et al.</i> , 2003
Groundwater	-27,6	Mengis <i>et al.</i> , 1999
Groundwater	-13,9	Smith <i>et al.</i> , 1991
Groundwater	-30 \pm 6	Vogel <i>et al.</i> , 1981
Arabian Sea	-22 to - 25	Brandes <i>et al.</i> , 1998
NE Pacific Ocean	-25 to - 30	Brandes <i>et al.</i> , 1998
NE Pacific Ocean	-30 to - 40	Cline & Kaplan 1975
NE Pacific Ocean	-30 \pm 7,5	Voss <i>et al.</i> , 2001
Lac de Lugano	-11	Lehmann <i>et al.</i> , 2003
Culture	-2 to - 12	Wada 1980
Groundwater	-4,7 to - 5	Mariotti <i>et al.</i> , 1988
Reservoir	-1,5	Sebilo <i>et al.</i> , 2003
Marine sediments	\pm 0	Brandes & Devol 1997
Continental sediments	0 to - 3	Brandes & Devol 2002

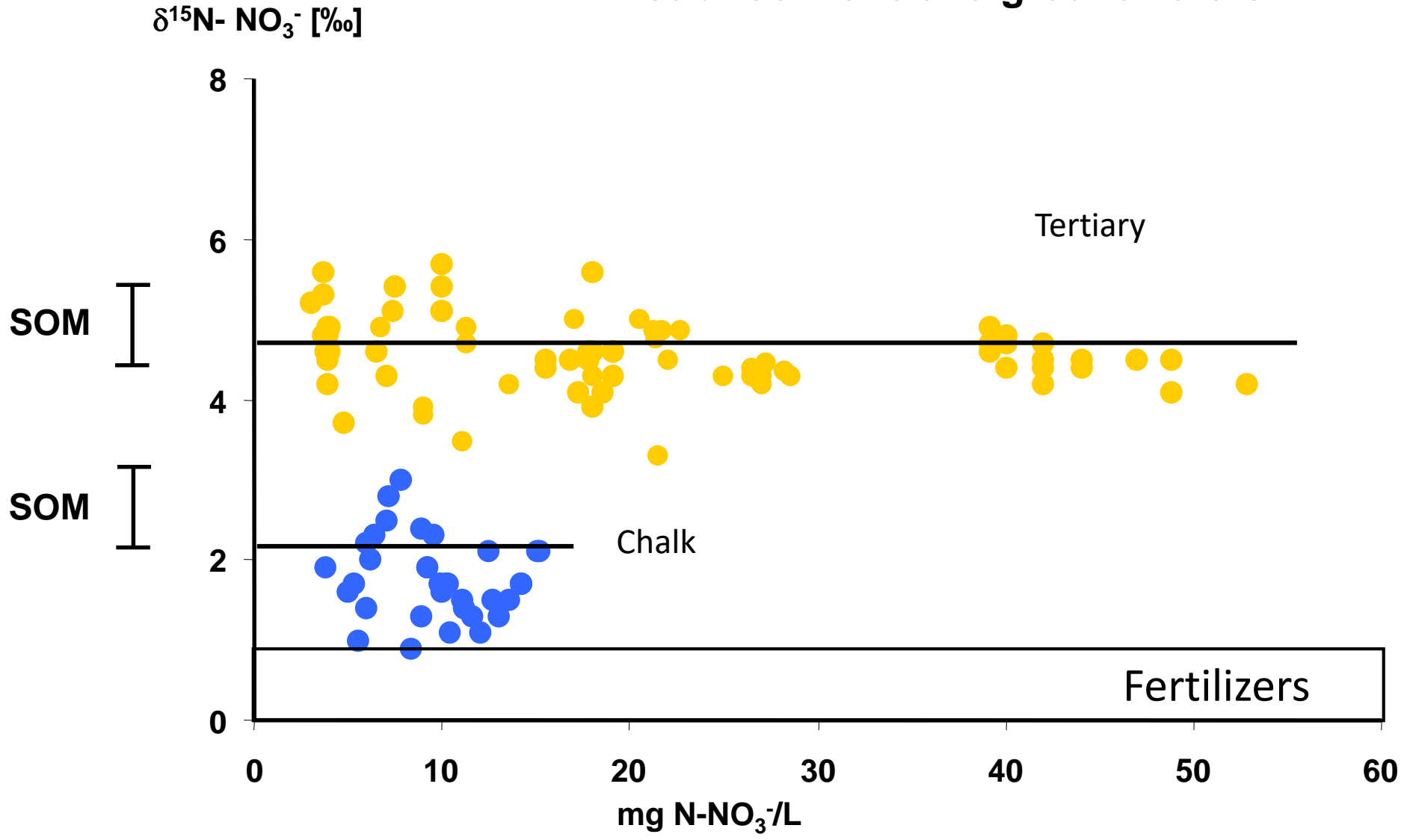
Riparian denitrification

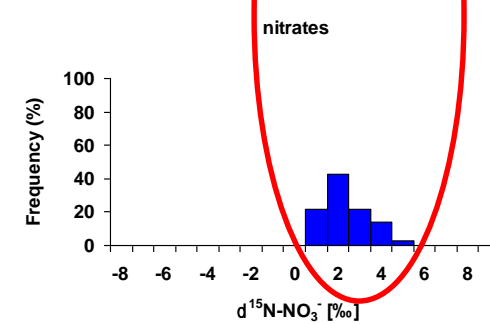
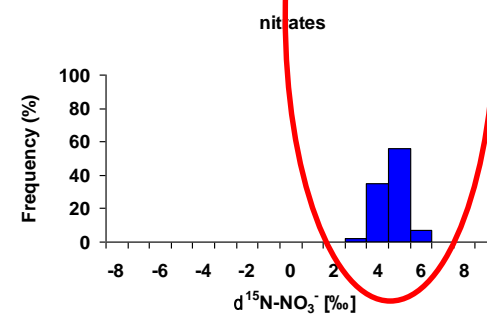
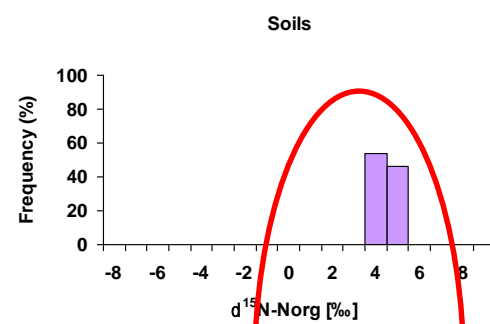
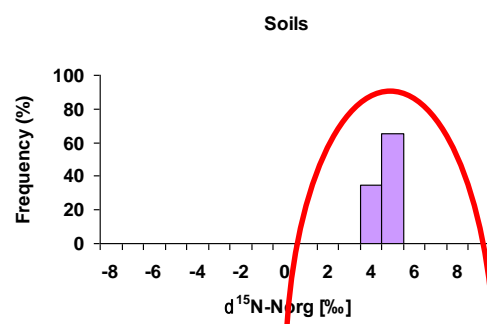
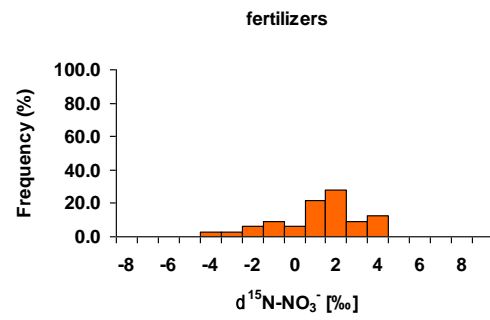
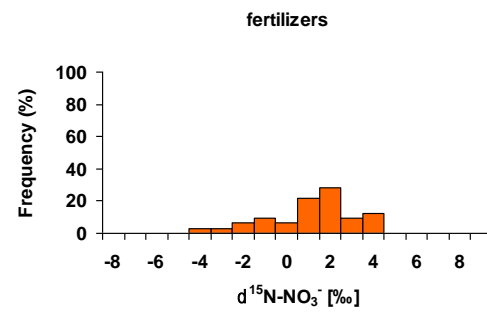
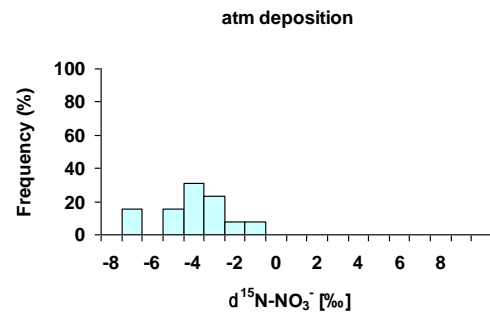
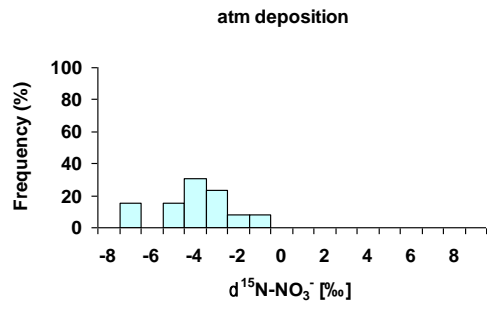


Tertiary Brie

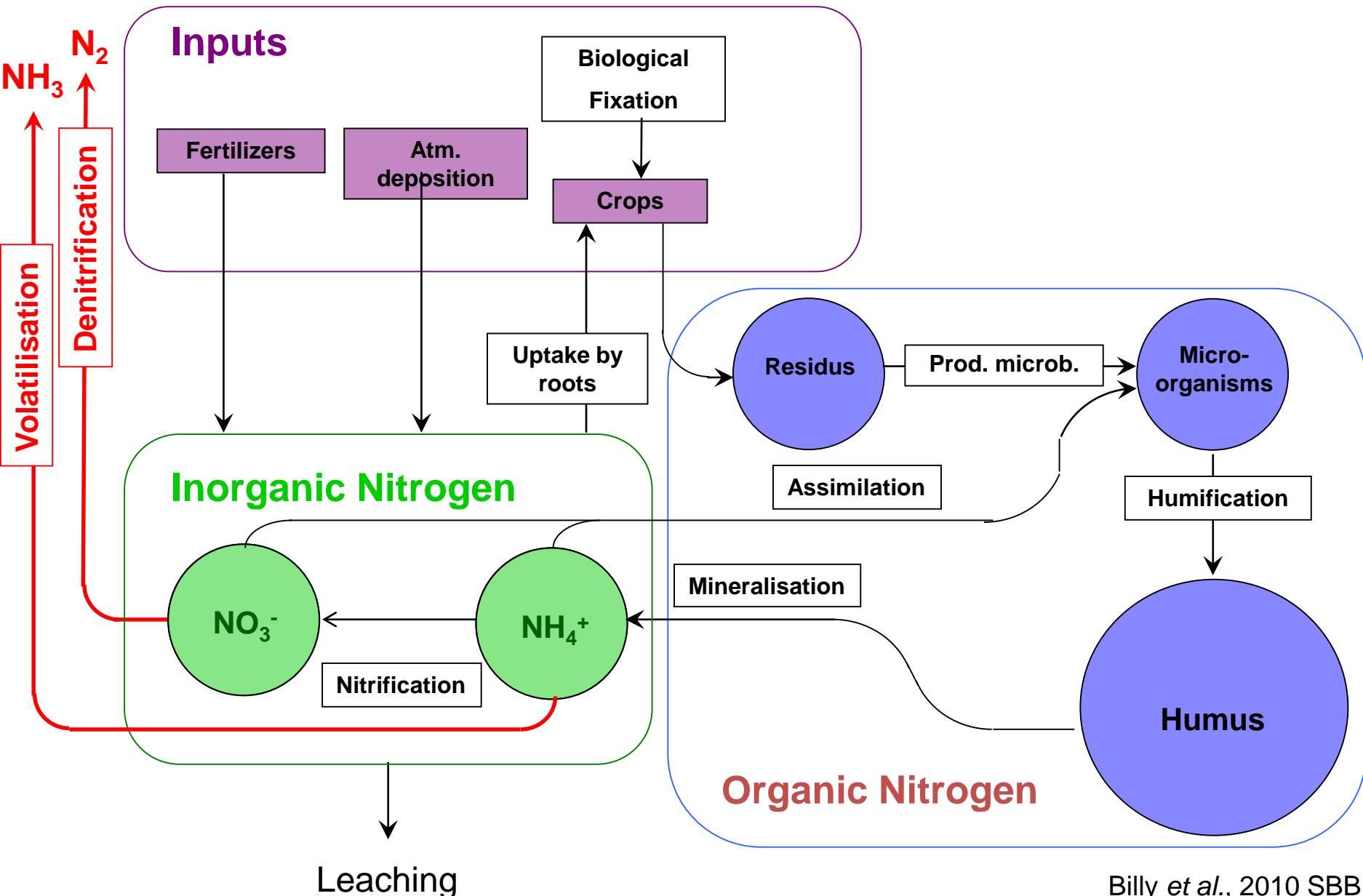


Nitrate concentrations and $\delta^{15}\text{N-NO}_3^-$ in sub-root zone and groundwaters

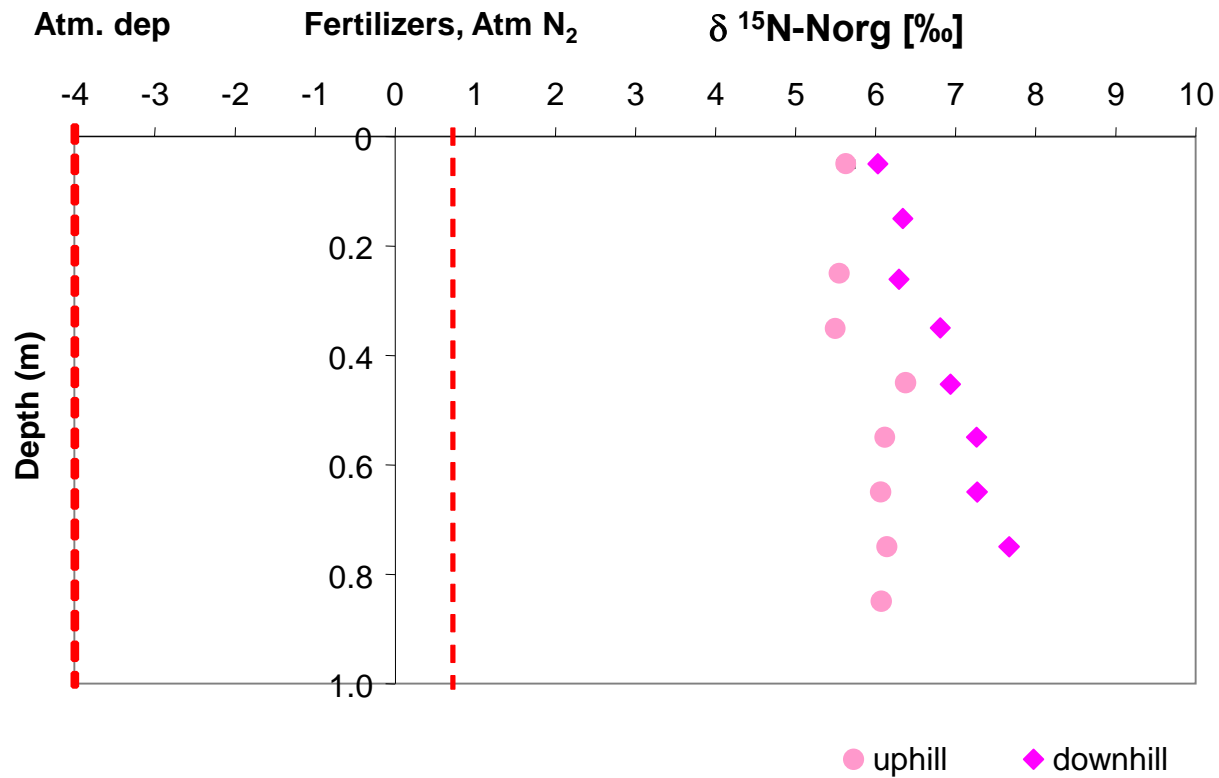




SIMSONIC Algorithm

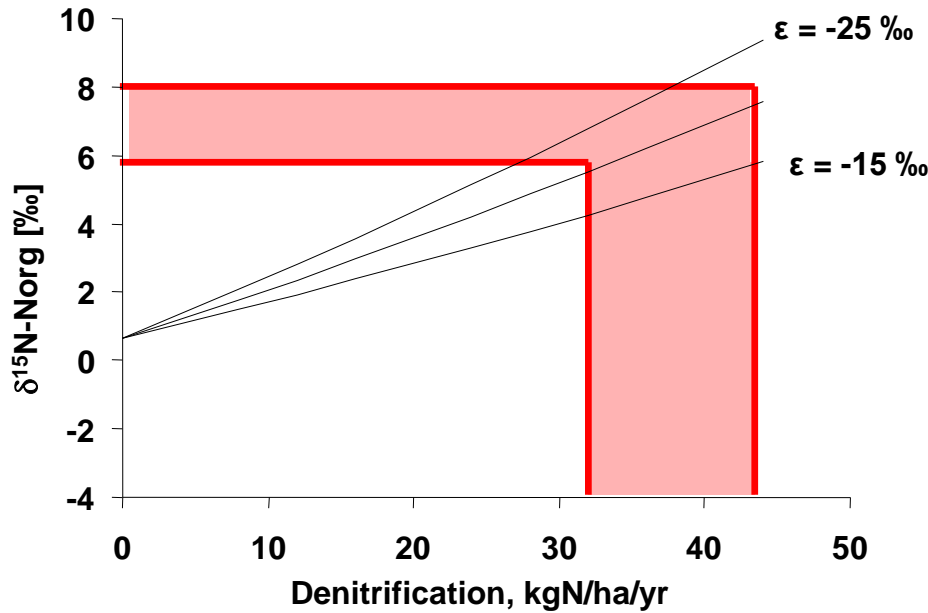


Measurements in field site (tertiary Brie)

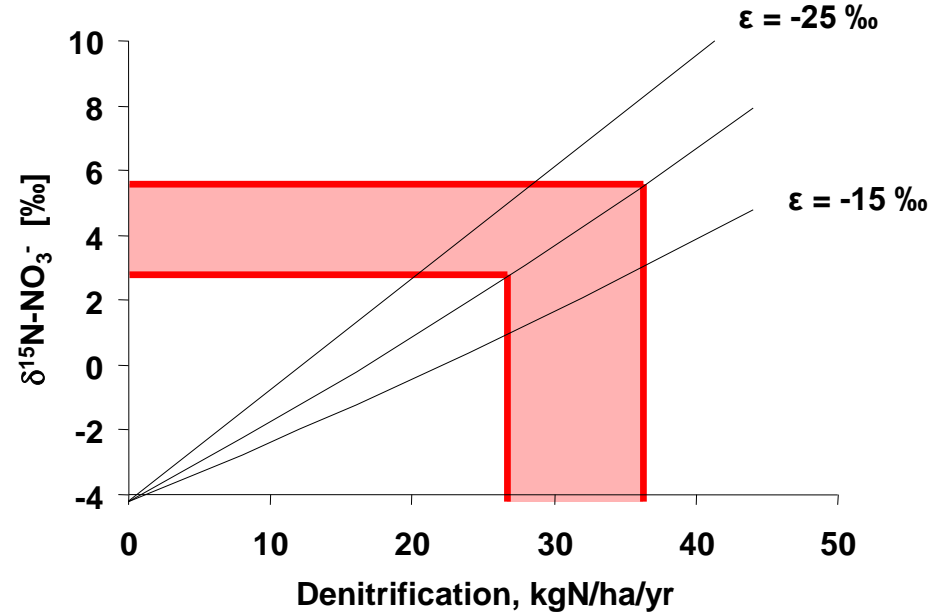


- $\delta^{15}\text{N}$ higher than external sources of nitrogen
- increase of $\delta^{15}\text{N}$ with depth
- increase of $\delta^{15}\text{N}$ uphill to downhill

Quantification of denitrification



Organic Nitrogen



Leaching Nitrates

- Denitrification explains variation of $\delta^{15}\text{N}$ in SOM and nitrate: 25 to 40 kgN/ha/yr
- Same ranges compared to those measured with acetylen block (20-30 kgN/ha/yr) and agronomic model (30-35 kgN/ha/yr)