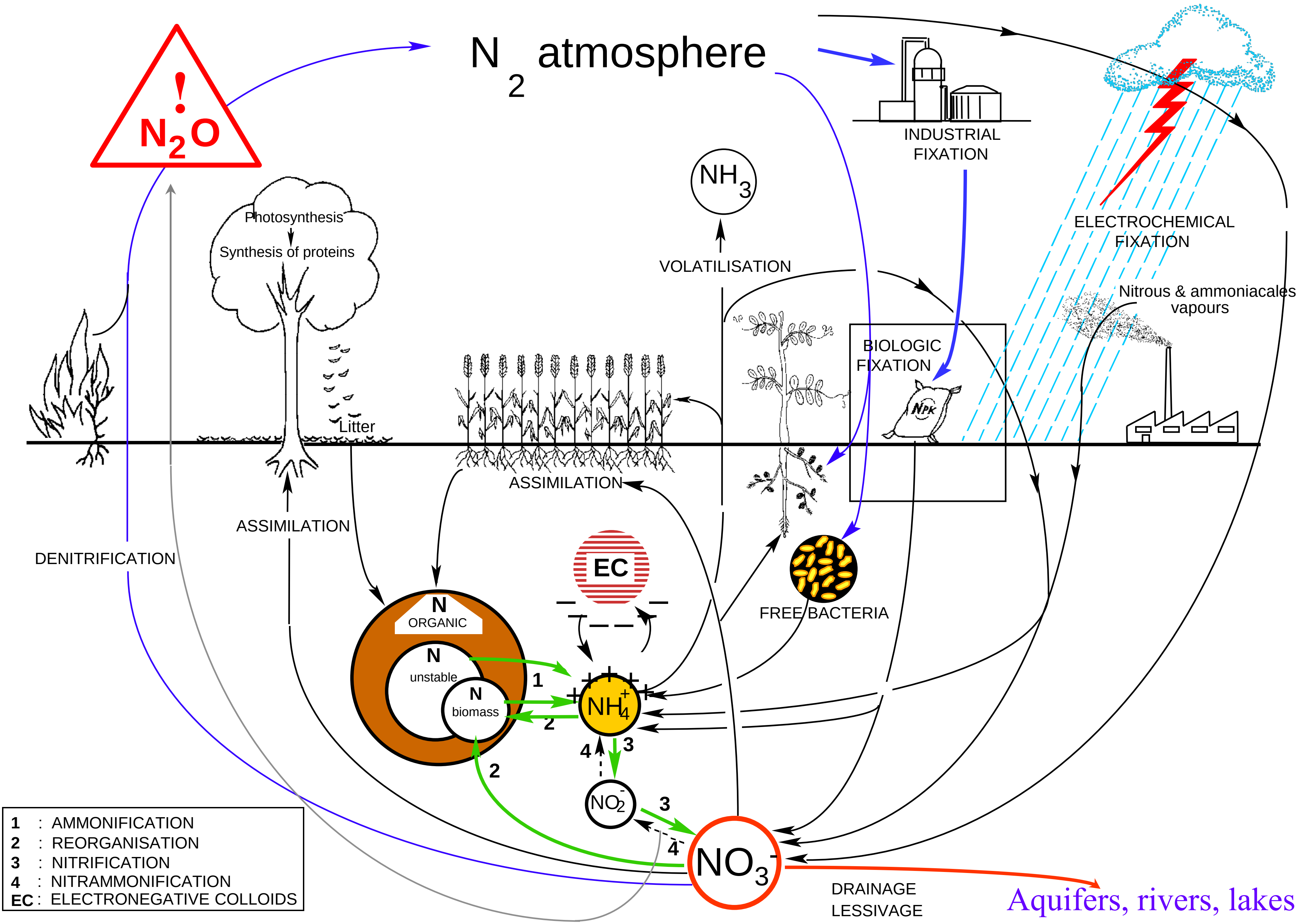
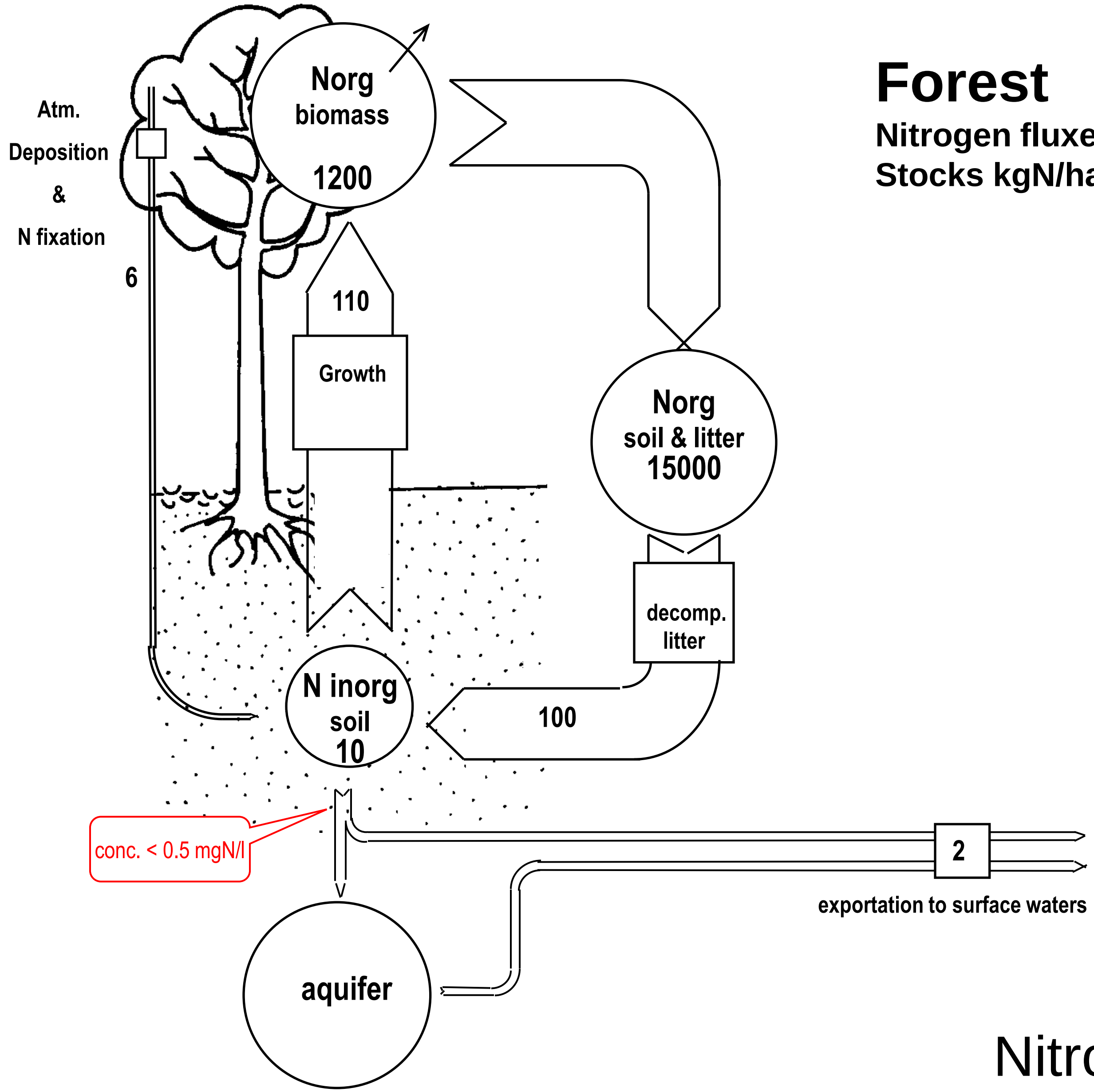
Dynamic of nitrogen at the scale of the Seine catchment (France) : Use of isotopic biogeochemistry



Mariotti, comm. pers.

Nitrates in forested areas

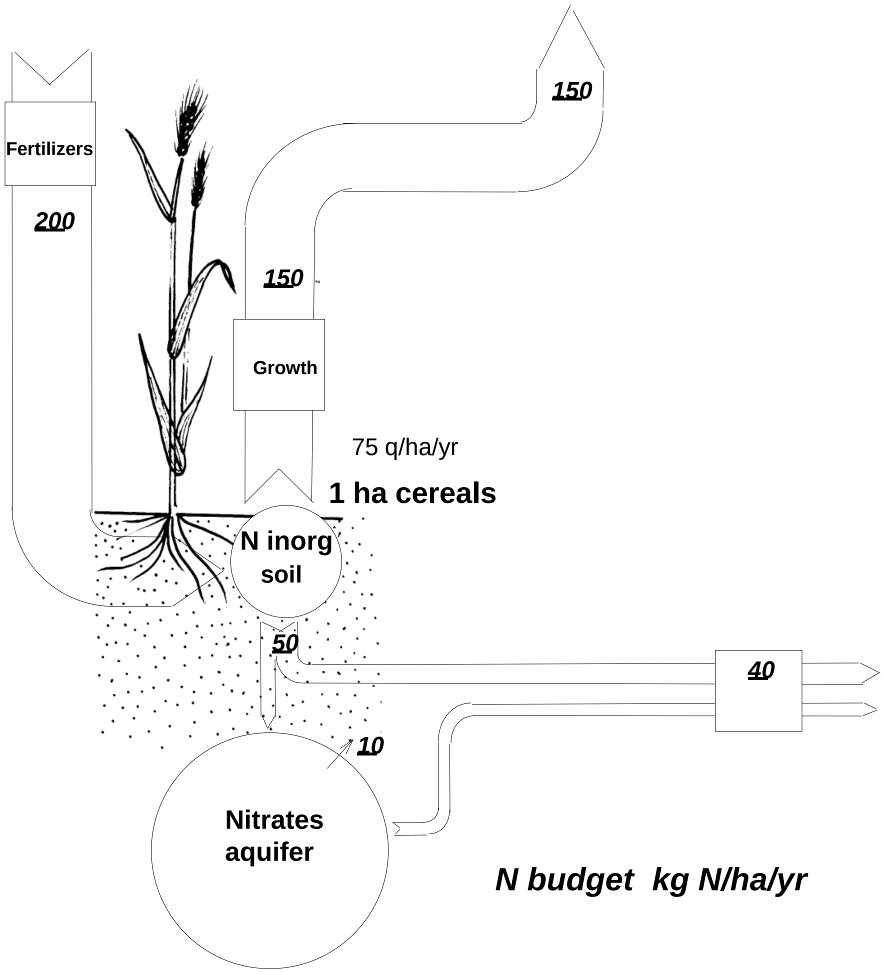


Forest

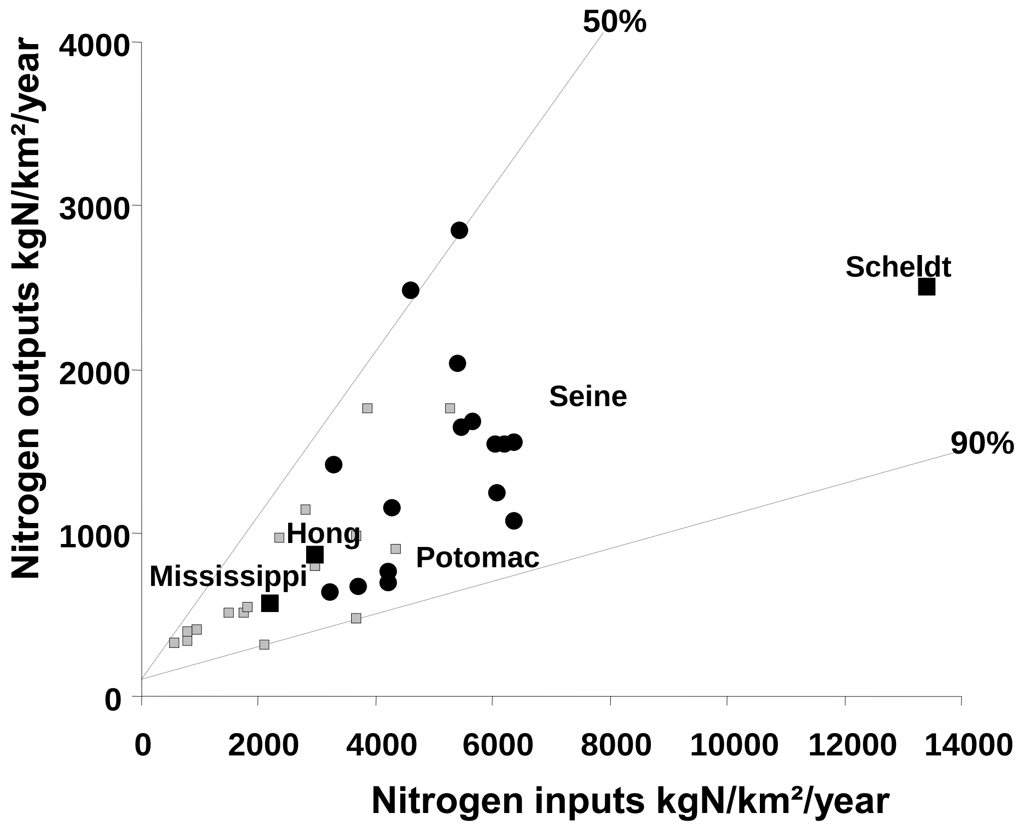
Nitrogen fluxes kgN/ha/year
Stocks kgN/ha

Nitrogen cycle closed

Nitrogen budget



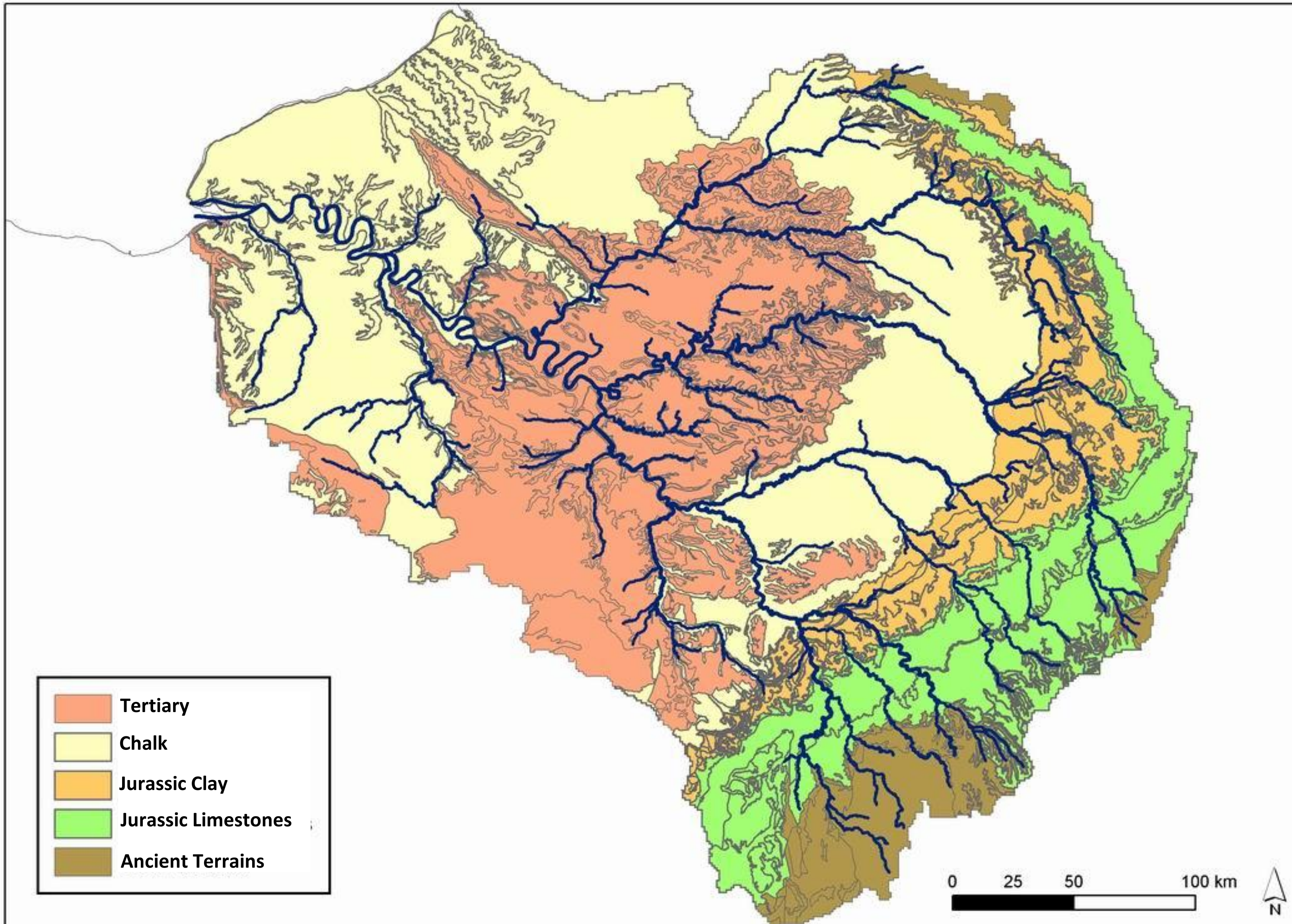
N budget kg N/ha/yr



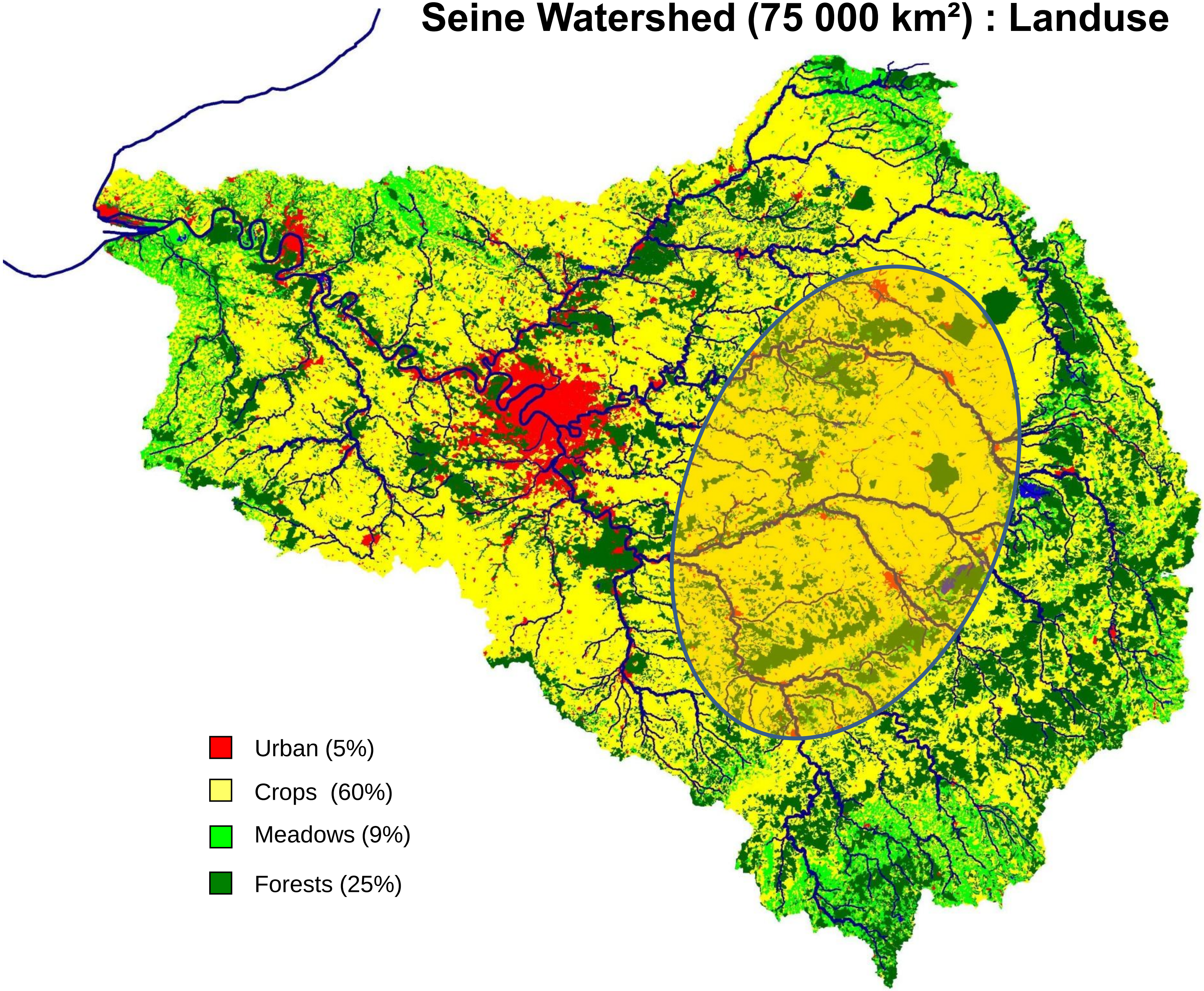
<u>Nitrogen Retention</u>: - Storage processes: uptake by plants, in groundwaters, assimilation in soil organic matter (SOM)

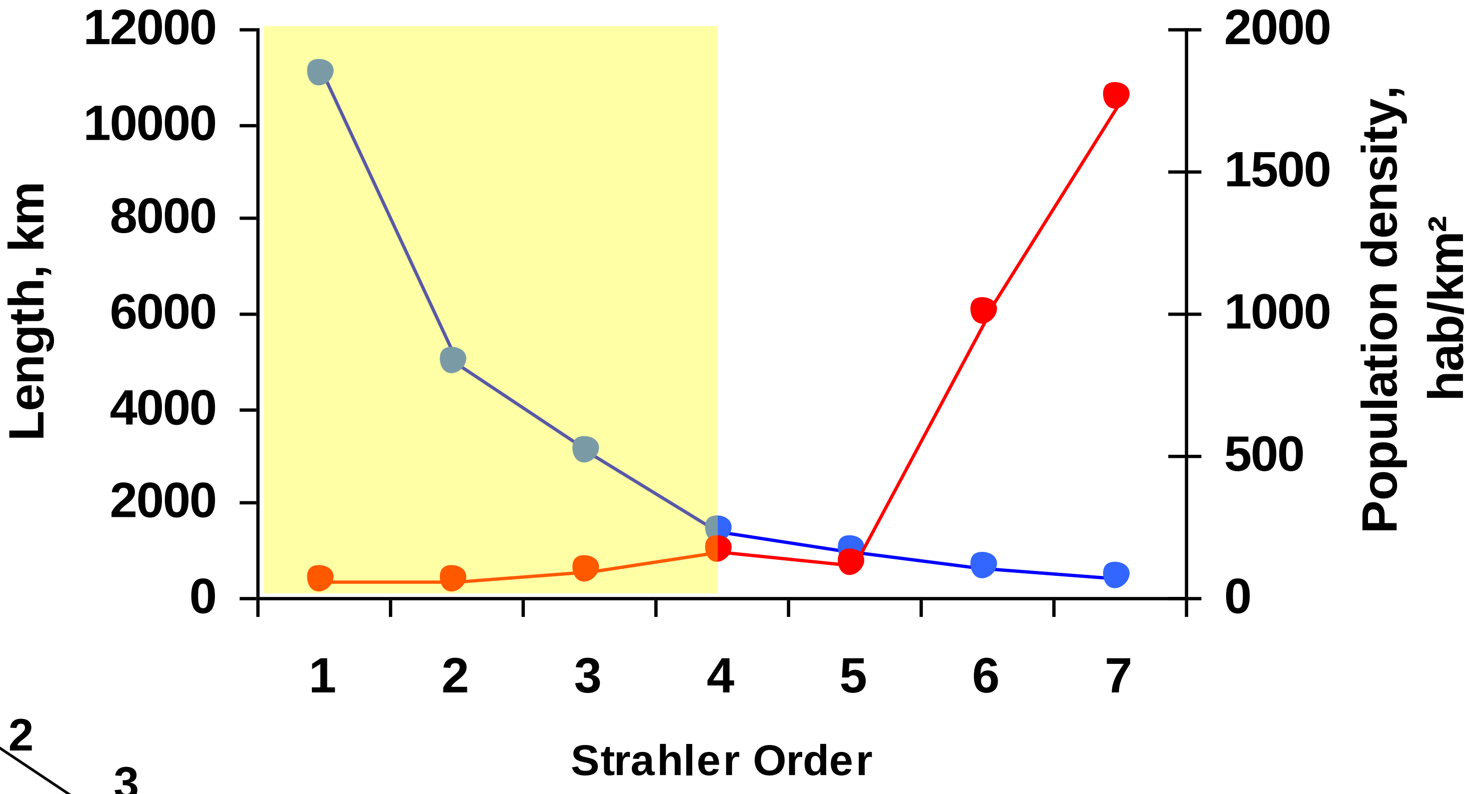
- Removing (gases production): denitrification, volatilization

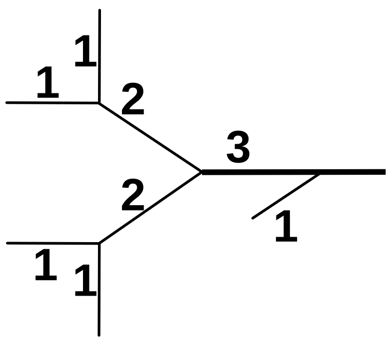
Seine Watershed (75 000 km²) : Geology



Seine Watershed (75 000 km²) : Landuse




12000
10000
8000
6000
4000
2000
0
Length, km
2000
1500
1000
500
0
Population density, hab/km²
1
2
3
4
5
6
7
Strahler Order


1
1
2
3
2
1
1
1

Isotopic Abundance

^{1}H 99.985%	^{12}C 98.9%	^{14}N 99.63%	^{16}O 99.75%
^{2}H 0.015%	^{13}C 1.1%	^{15}N 0.37%	^{17}O 0.038%
			^{18}O 0.21%

Isotopic Ratio

$$R^{18} = \frac{^{18}O}{^{16}O}$$

$$R^{15} = \frac{^{15}N}{^{14}N}$$

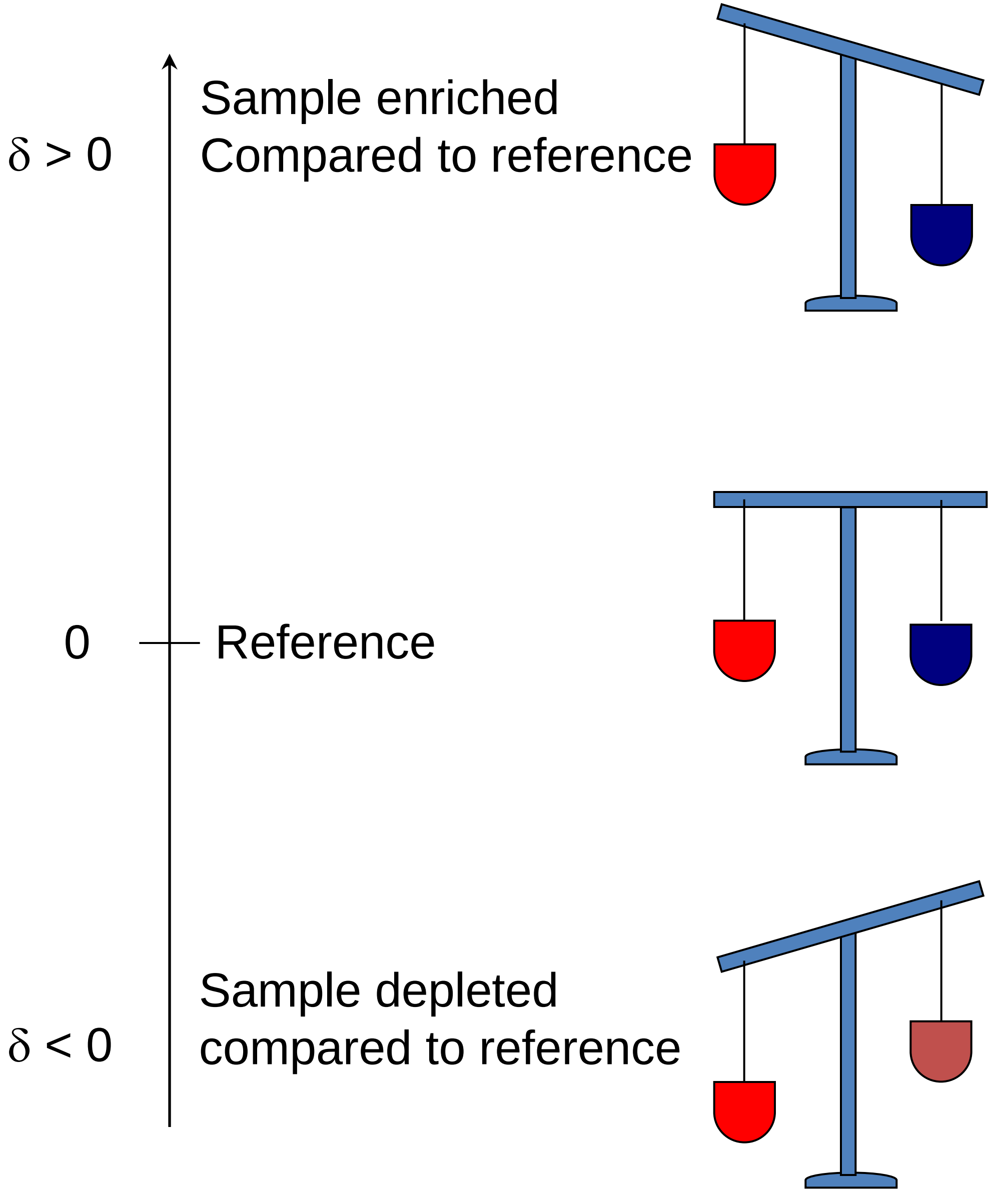
δ-Notation

$$\delta^{18}O = \left[\frac{R^{18}_{SA}}{R^{18}_{STD}} - 1\right] * 1000\ ‰$$

$$\delta^{15}N = \left[\frac{R^{15}_{SA}}{R^{15}_{STD}} - 1\right] * 1000\ ‰$$

$$\delta = \left[\frac{R_{sample} - R_{reference}}{R_{reference}} \right] . 1000$$

$$R = \frac{\text{Amount heavy isotope}}{\text{Amount light isotope}}$$



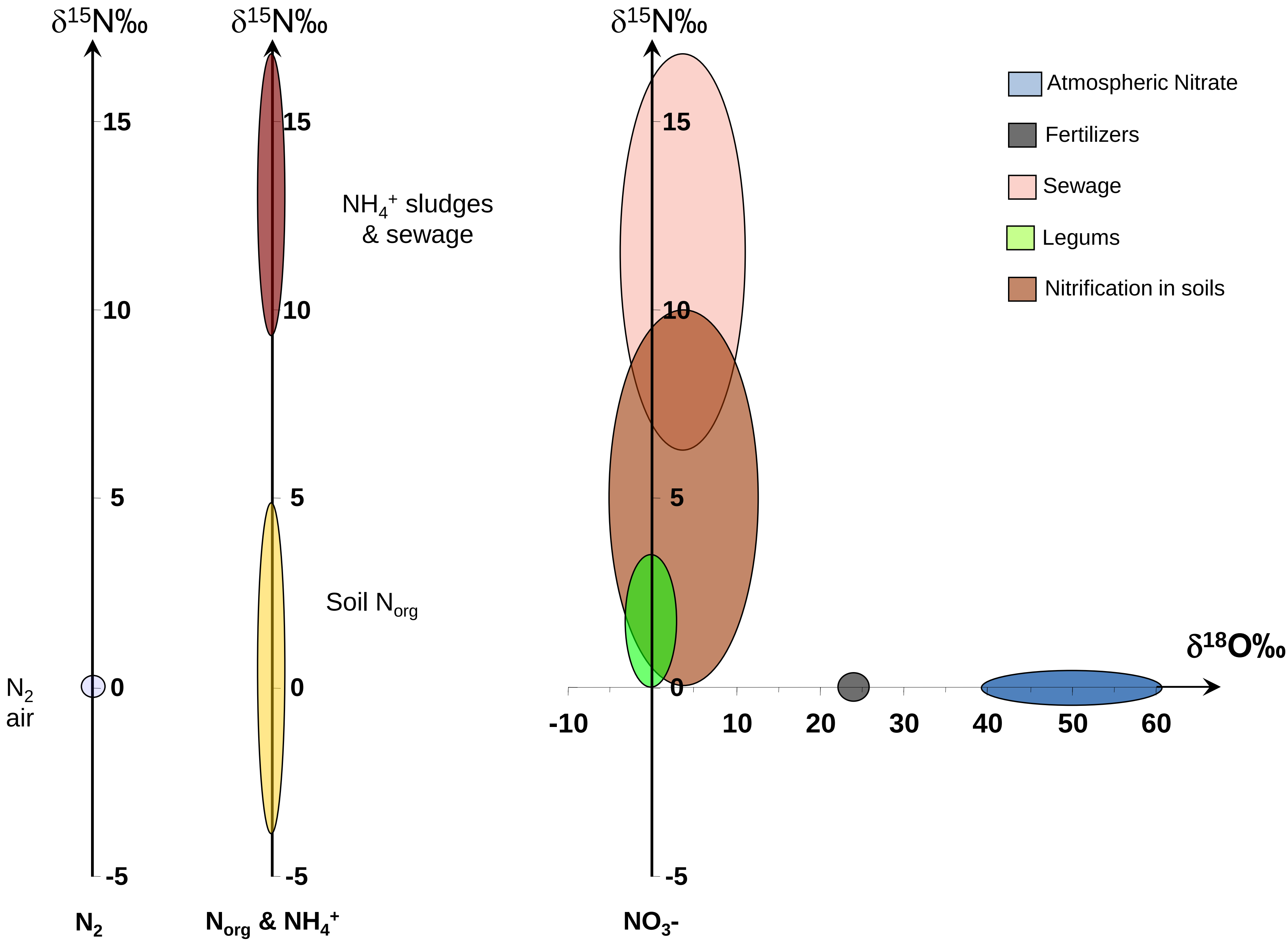
Isotopic Biogeochemistry : integrating tool

Basic Idea:

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

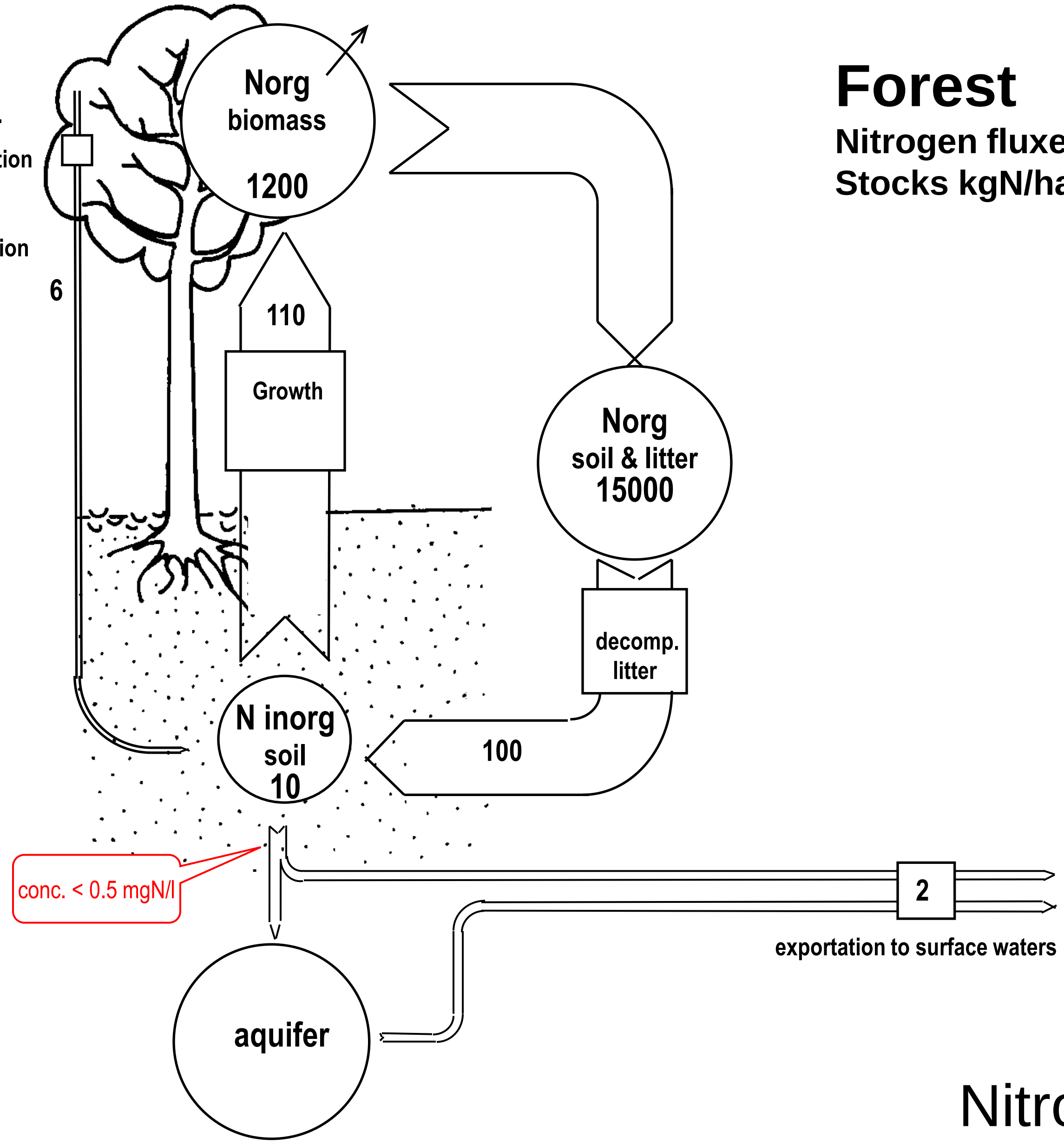
(1) Its various sources

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



δ15N‰
15
10
5
0
-5
N2 air
N2
δ15N‰
NH4+ sludges & sewage
Soil Norg
Norg & NH4+
δ15N‰
NO3-
δ18O‰
-10
10
20
30
40
50
60
Atmospheric Nitrate
Fertilizers
Sewage
Legums
Nitrification in soils

Nitrates in forested areas



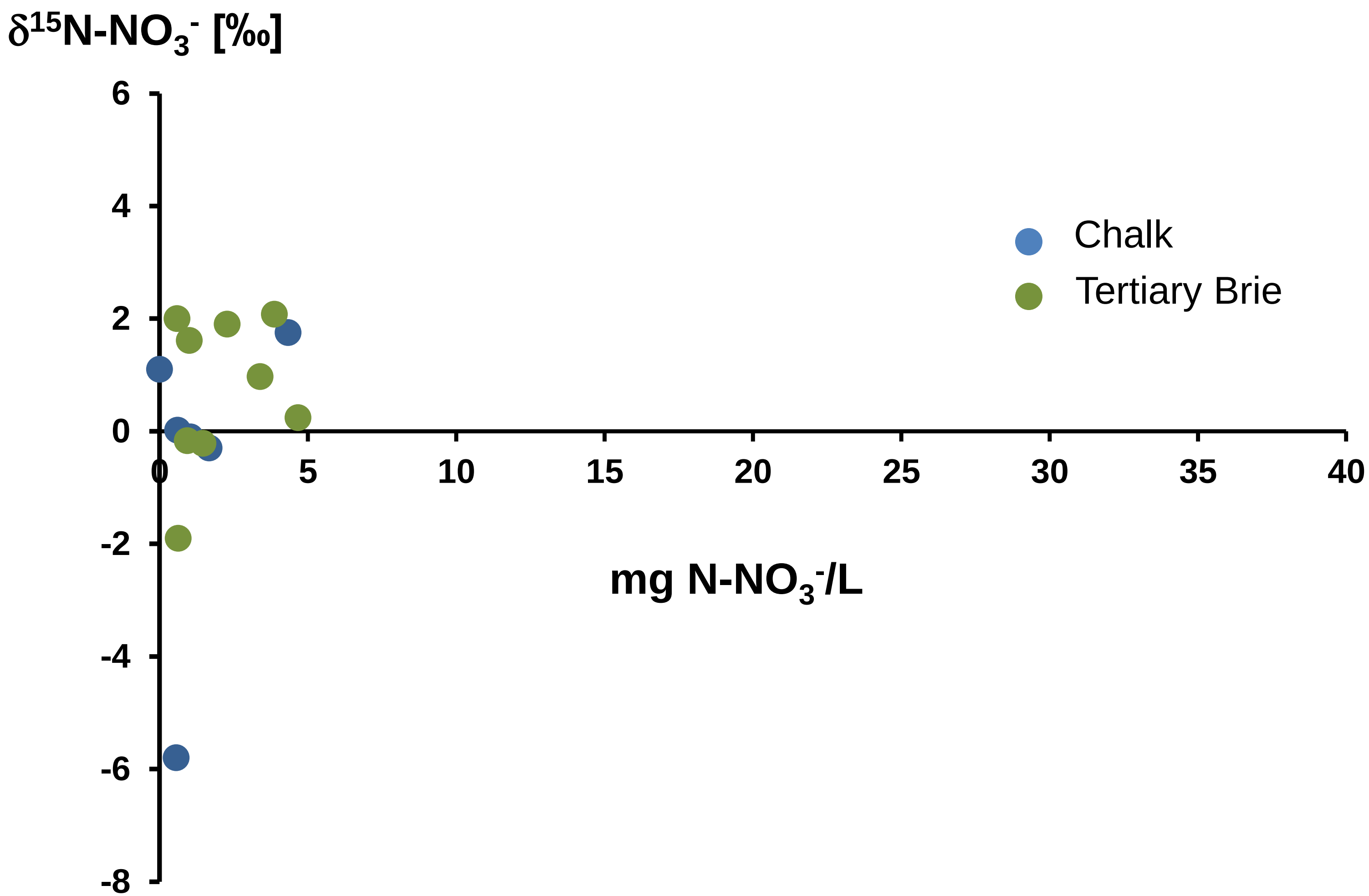
Forest

Nitrogen fluxes kgN/ha/year
Stocks kgN/ha

$\delta^{15}N\text{-}NO_3^-$?

Nitrogen cycle closed

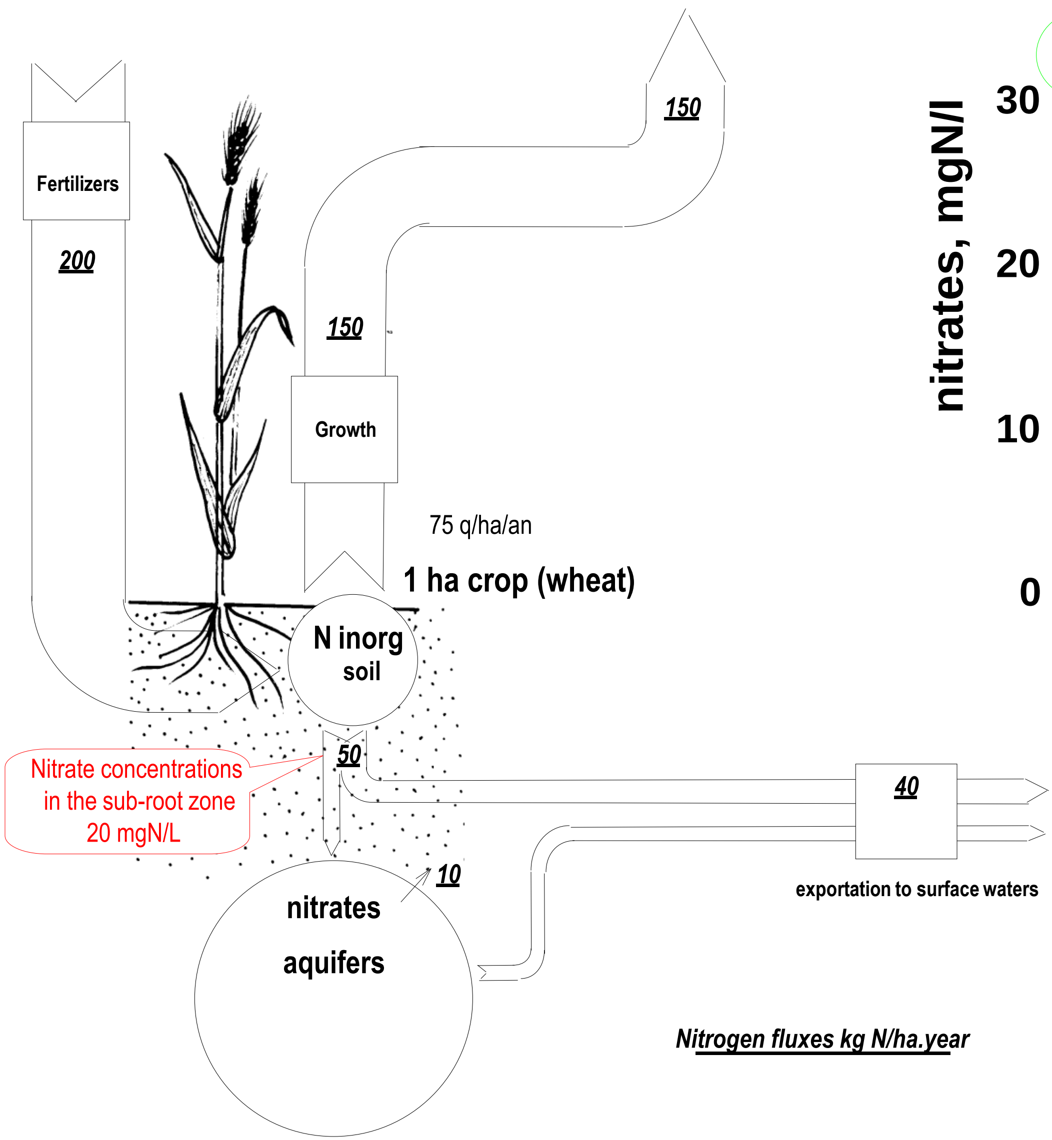
Forested areas : nitrate concentrations & $\delta^{15}N\text{-}NO_3^-$

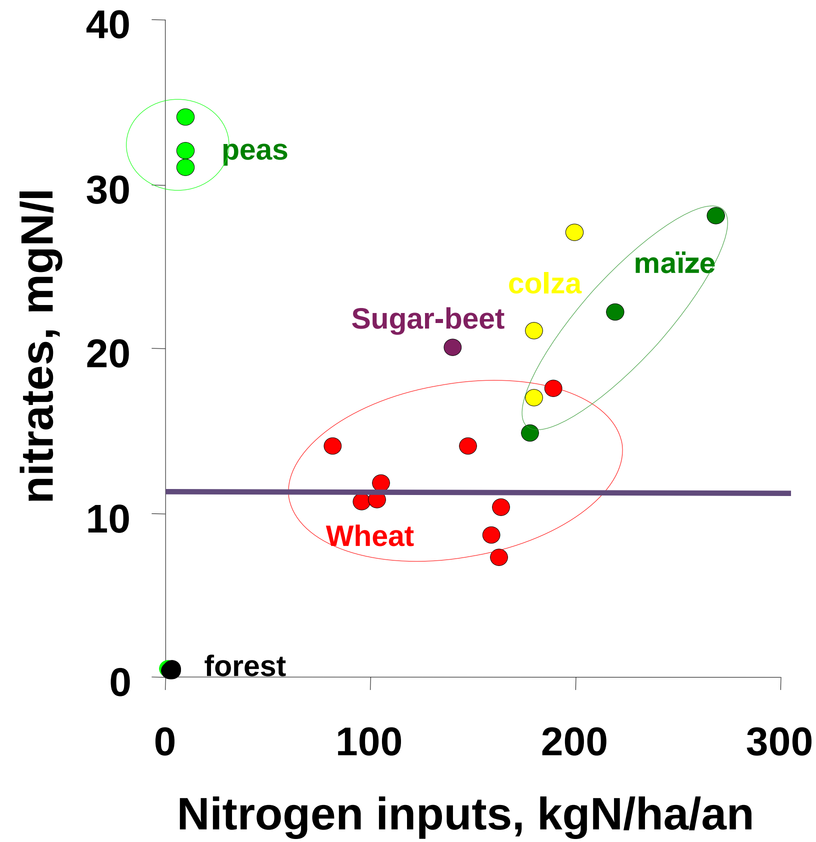


Crops : Use of inorganic fertilizers

Net exportation of nitrogen

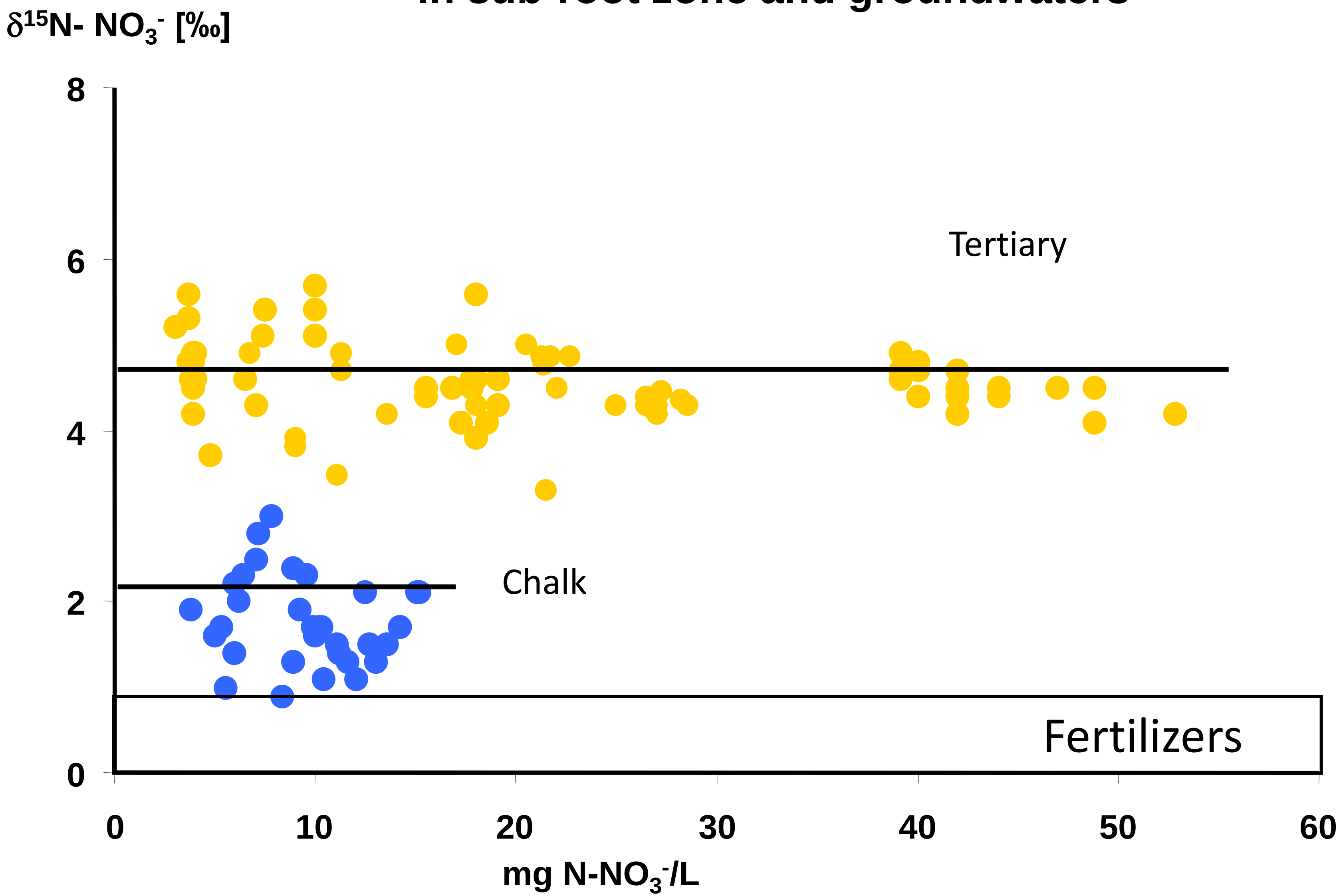
Significant part of nitrogen remains in soil

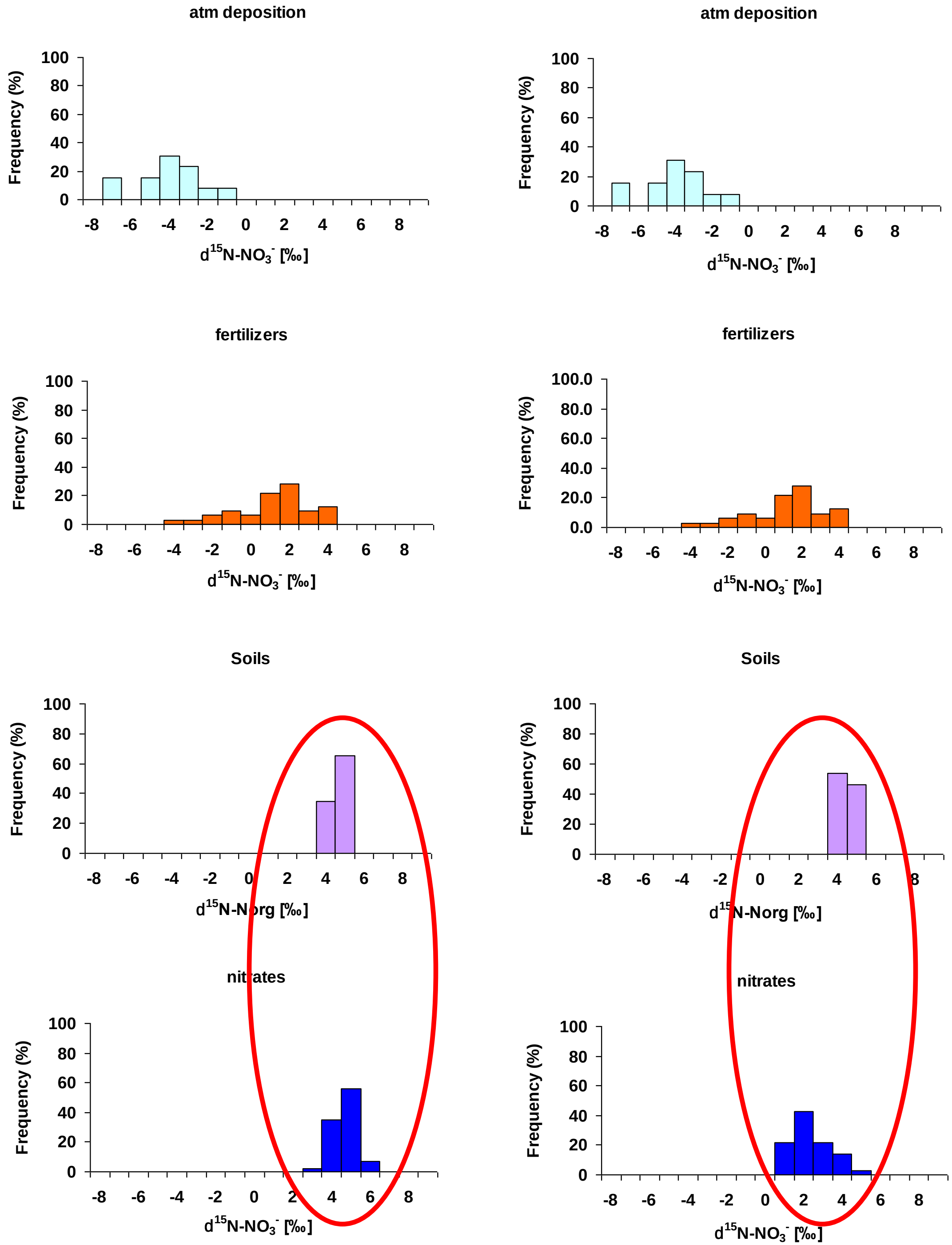




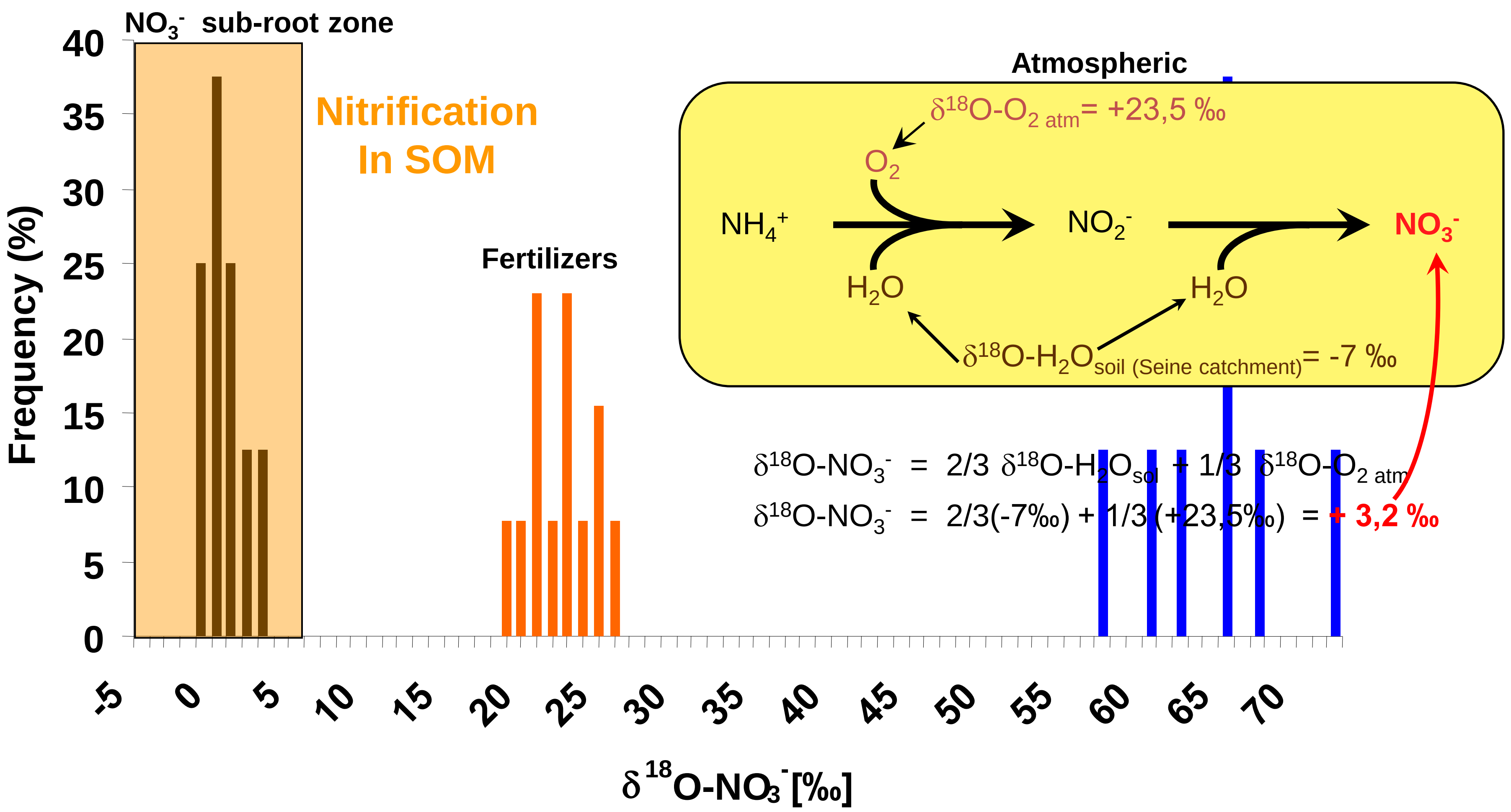
Nitrogen cycle opened

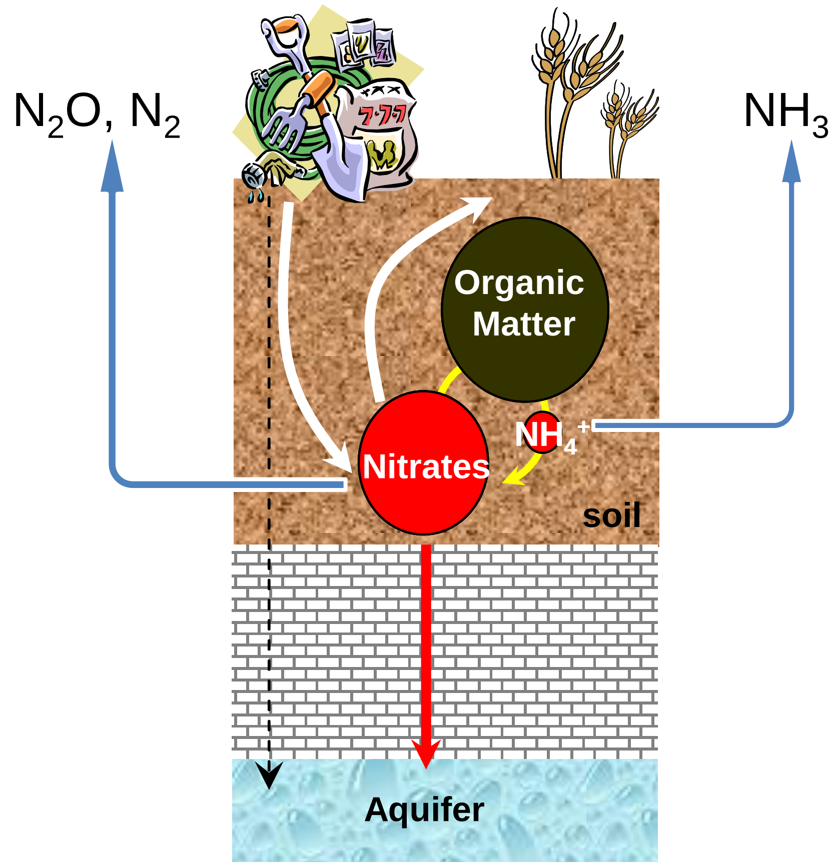
Nitrate concentrations and $\delta^{15}N-NO_3^-$ in sub-root zone and groundwaters




atm deposition
Frequency (%)
d15N-NO3- [‰]
atm deposition
Frequency (%)
d15N-NO3- [‰]
fertilizers
Frequency (%)
d15N-NO3- [‰]
fertilizers
Frequency (%)
d15N-NO3- [‰]
Soils
Frequency (%)
d15N-Norg [‰]
Soils
Frequency (%)
d15N-Norg [‰]
nitrates
Frequency (%)
d15N-NO3- [‰]
nitrates
Frequency (%)
d15N-NO3- [‰]

Natural stable isotopic composition : $\delta^{18}O- NO_3^-$





. 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

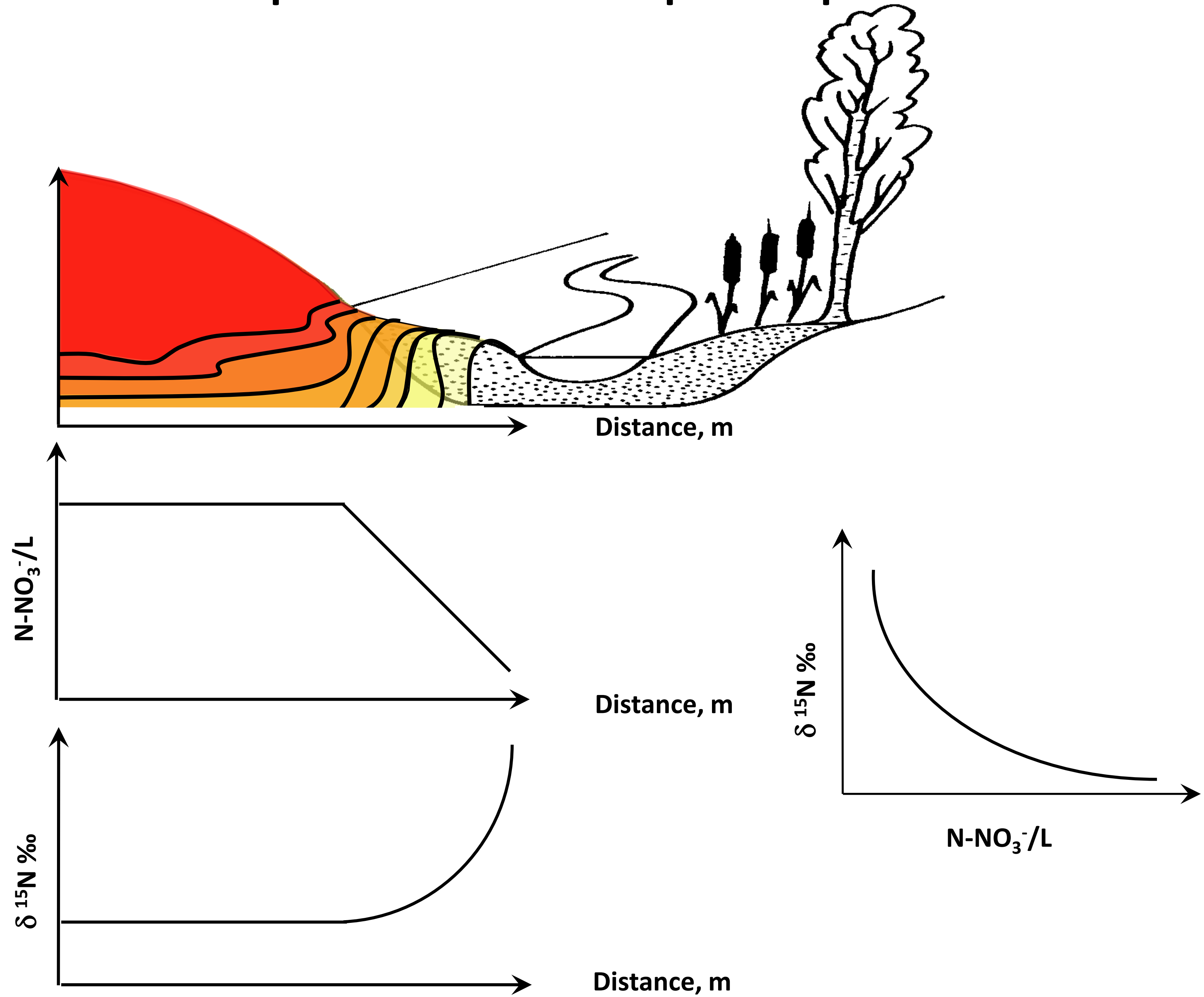
Basic Idea:

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

1. **Its various sources**
2. **the processes which affects it**

$$\textbf{Substrate} \rightarrow \textbf{Product}$$

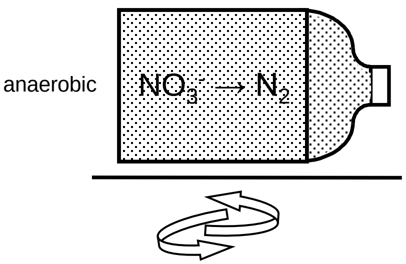
Denitrification in riparian zone & isotopic composition



Riparian vs in stream denitrification
Isotopic biogeochemistry useful?

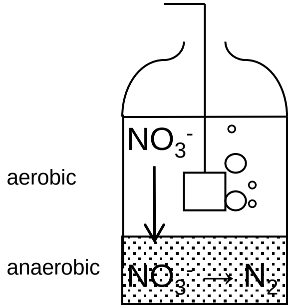
one phase denitrification

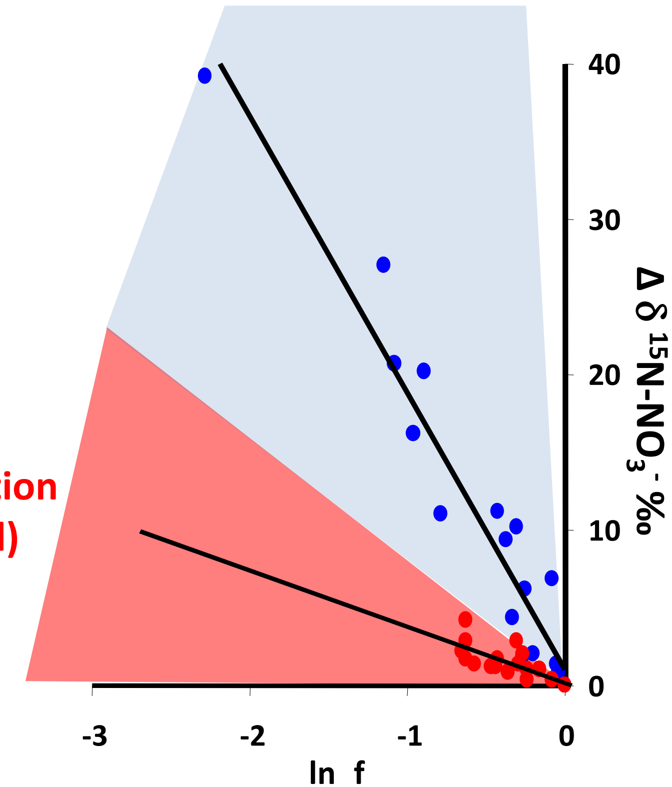
ε = -18 ‰



two phases denitrification (diffusion controlled)

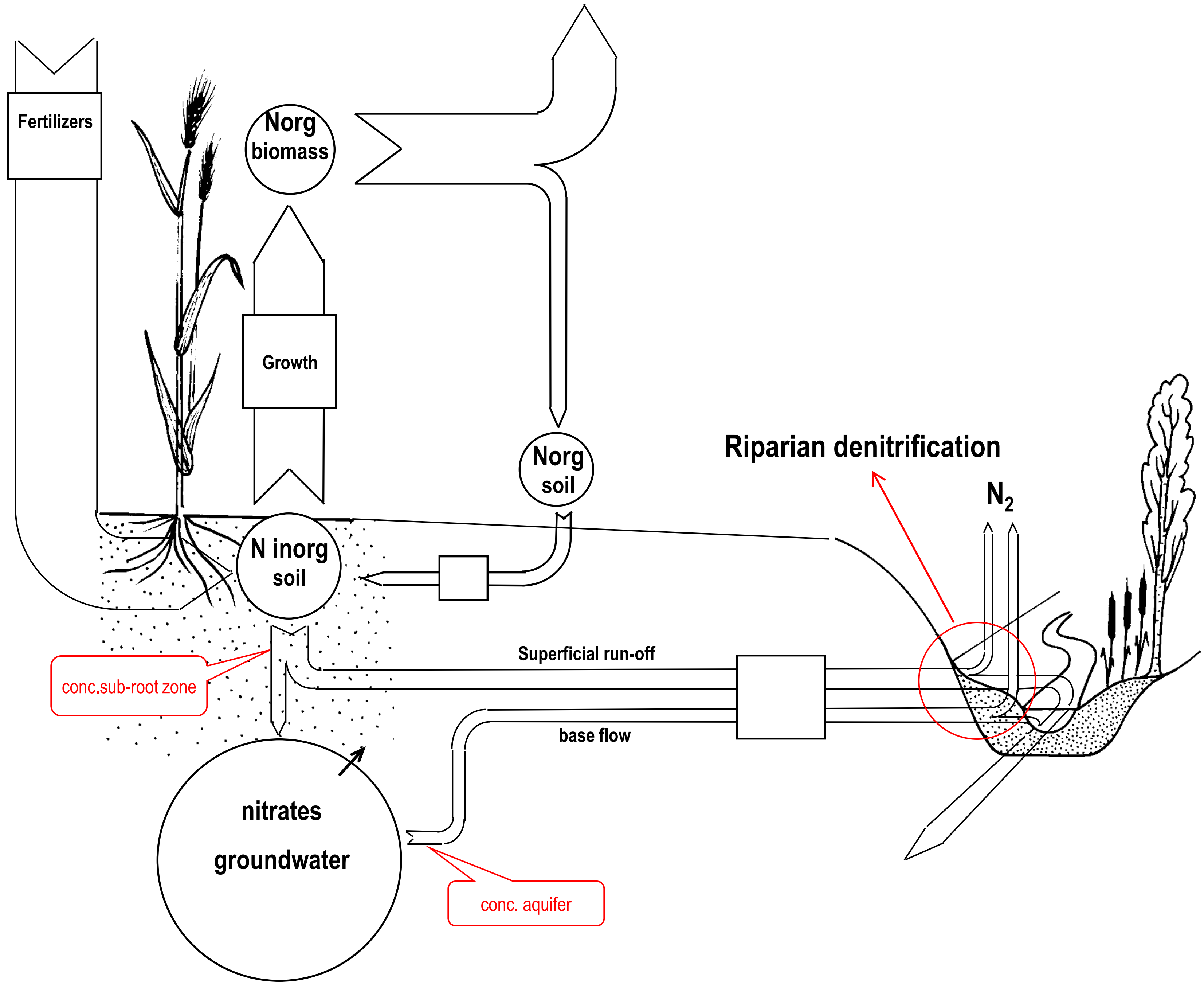
ε = - 4 ‰



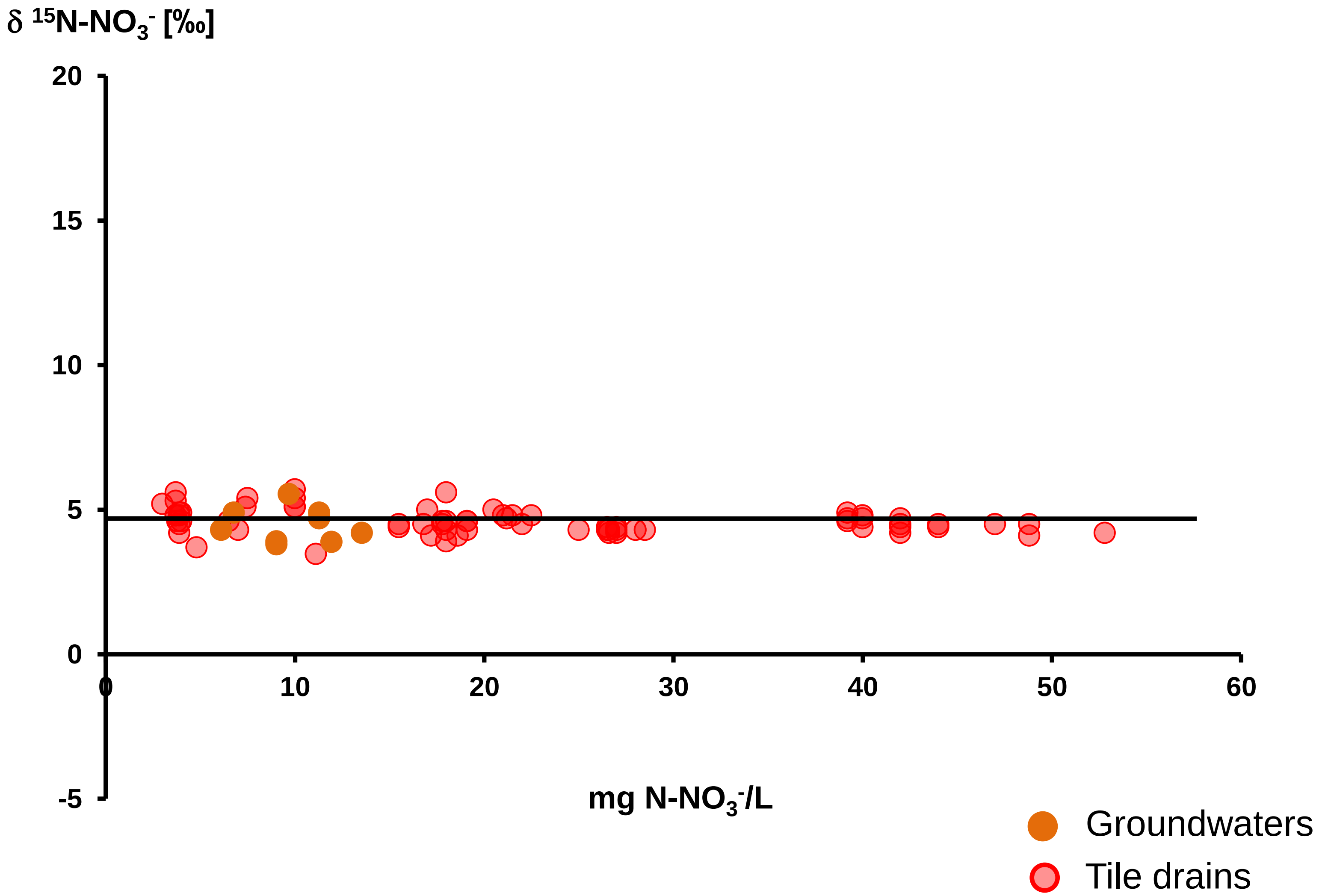


Site	ε^{15}N ‰	Authors
Culture	-28,6	Barford *et al.*, 1999
Culture	-12,3 to - 13,3	Blackmer&Bremner 1977
Culture	-13,4 to - 20,8	Delwiche & Steyn 1970
Culture	-24,6 to - 29,4	Mariotti *et al.*, 1980
Culture	-20	Myake & Wada 1971
Culture	-30	Olleros 1983
Culture	-19 to - 20	Wellman *et al.*, 1968
Culture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

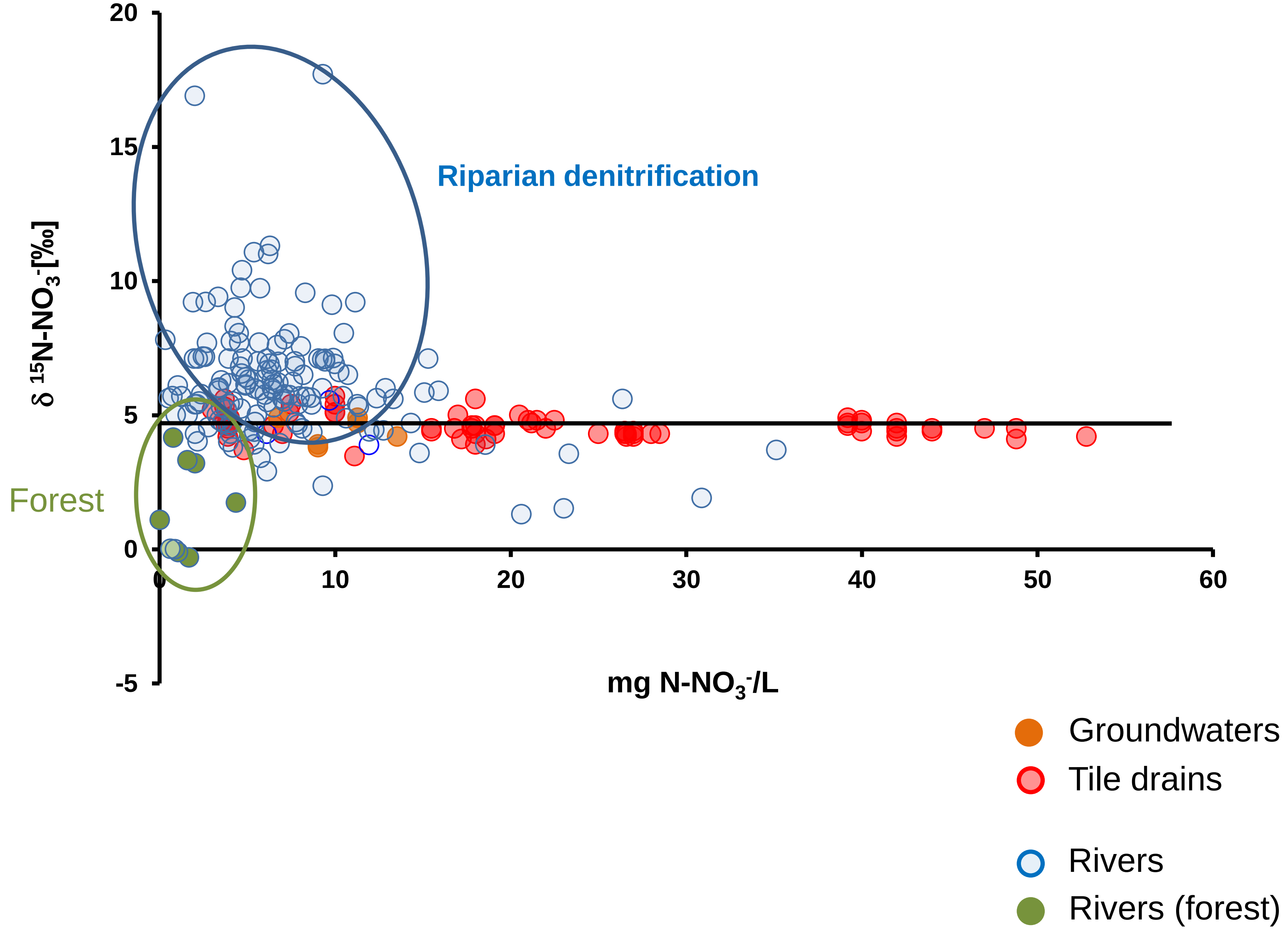
Sebilo et al., Biogeochemistry, 2003
Sebilo et al., Ecosystems, 2006

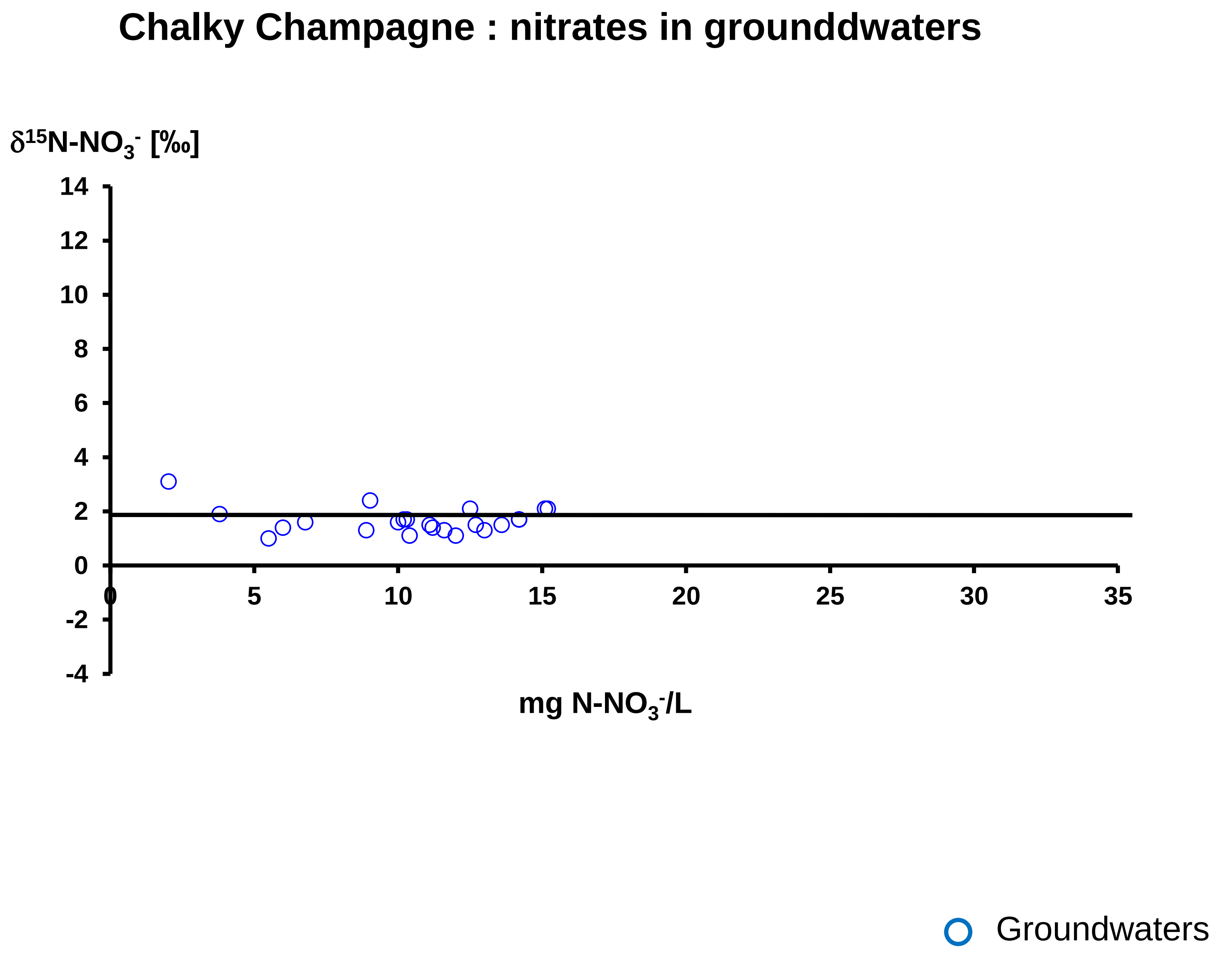

Fertilizers
Norg
biomass
Growth
Norg
soil
N inorg
soil
Riparian denitrification
N_2
Superficial run-off
base flow
conc.sub-root zone
nitrates
groundwater
conc. aquifer

Tertiary Brie : nitrates in sub-root zone and groundwaters

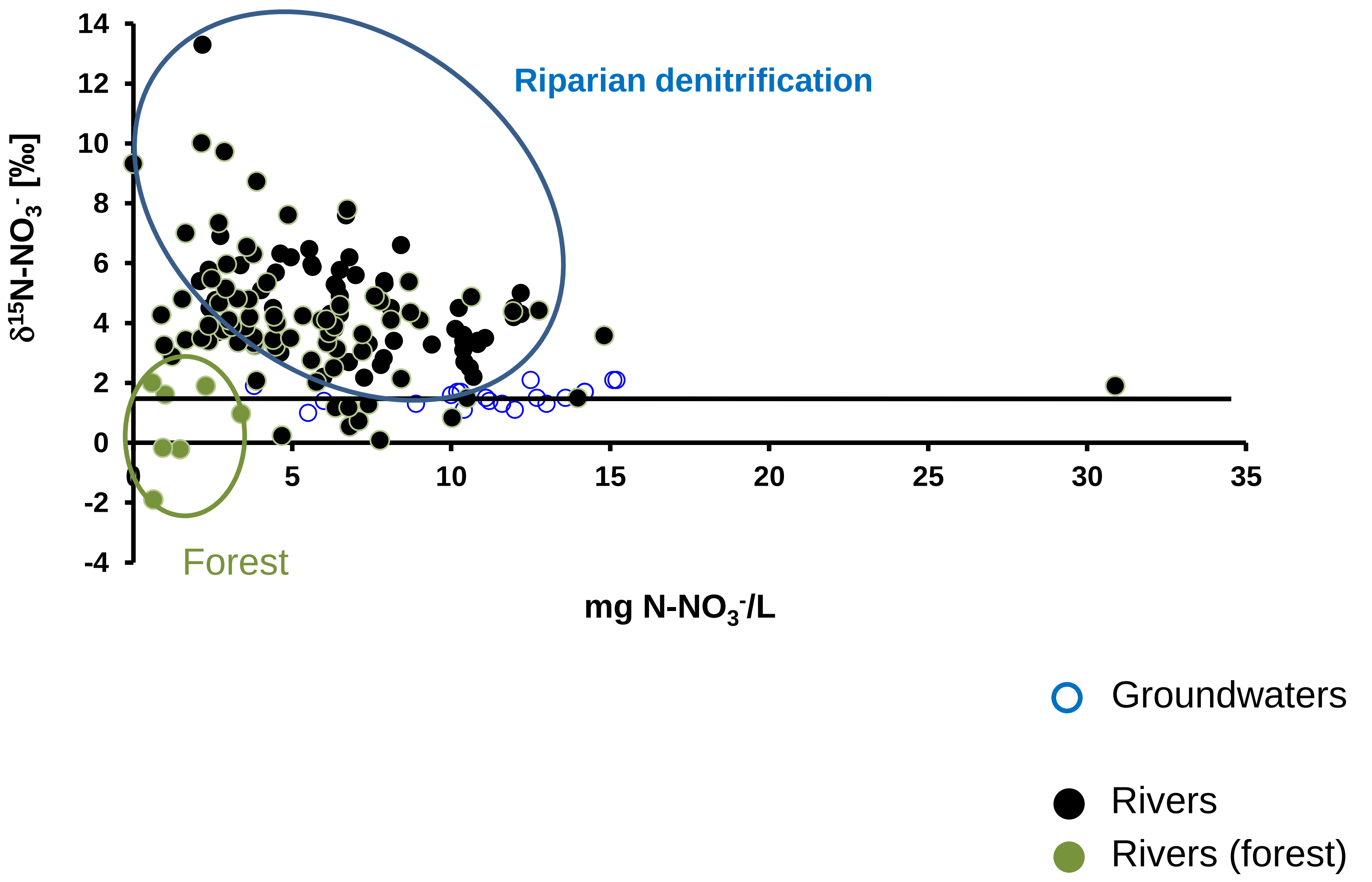


Riparian denitrification in the tertiary Brie




Chalky Champagne : nitrates in grounddwaters
δ15N-NO3- [‰]
14
12
10
8
6
4
2
0
-2
-4
0
5
10
15
20
25
30
35
mg N-NO3-/L
Groundwaters

Riparian denitrification in the chalky Champagne



Isotopic composition of nitrates at regional scale