Characterizing origin and fate of groundwater nitrate pollution using multi-isotopic data.

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2000 — (^{15}N, ^{18}O) to trace sources of NO_3^-

2004 — (^{15}N, ^{18}O, ^{13}C, ^{34}S, $^{87}Sr/^{86}Sr$) to trace processes (denitrification)

2006 — Induced attenuation experiments (pyrite)
Application to 5 vulnerable areas in Catalunya

2008 — Induced NO_3^- attenuation pilot plant (ethanol)

2009 — Demonstration (^{15}N, ^{18}O) to 10 NVZ in Spain

2011 — Induced attenuation (glucose)

2013 — Set up Cd technique

2014 — Demonstration (N, B, S, C, O) to 10 NVZ in Spain

17 SCI

- Geology
- Hydrogeology
- Soil uses
- Farming and livestock pressures
- Geochemistry

$\delta^{15}N_{NO3}$ $\delta^{18}O_{NO3}$

$\delta^{11}B$

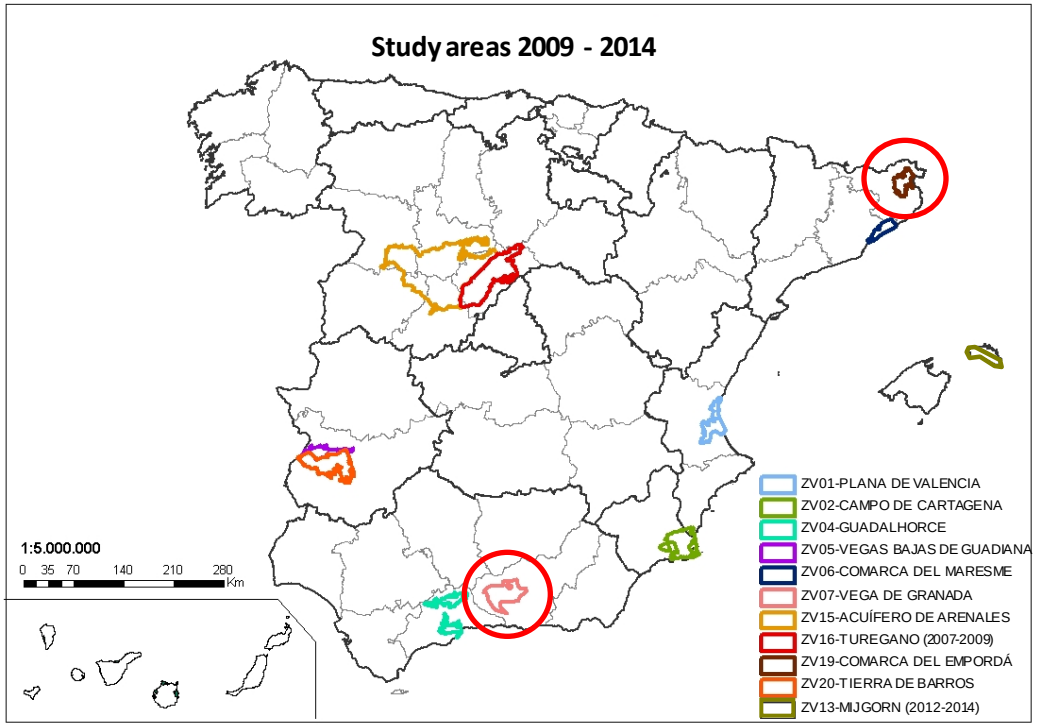
$\delta^{34}S_{SO4}$ $\delta^{18}O_{SO4}$

$\delta^{13}C_{DIC}$

$\delta^{15}N_{NH4}$

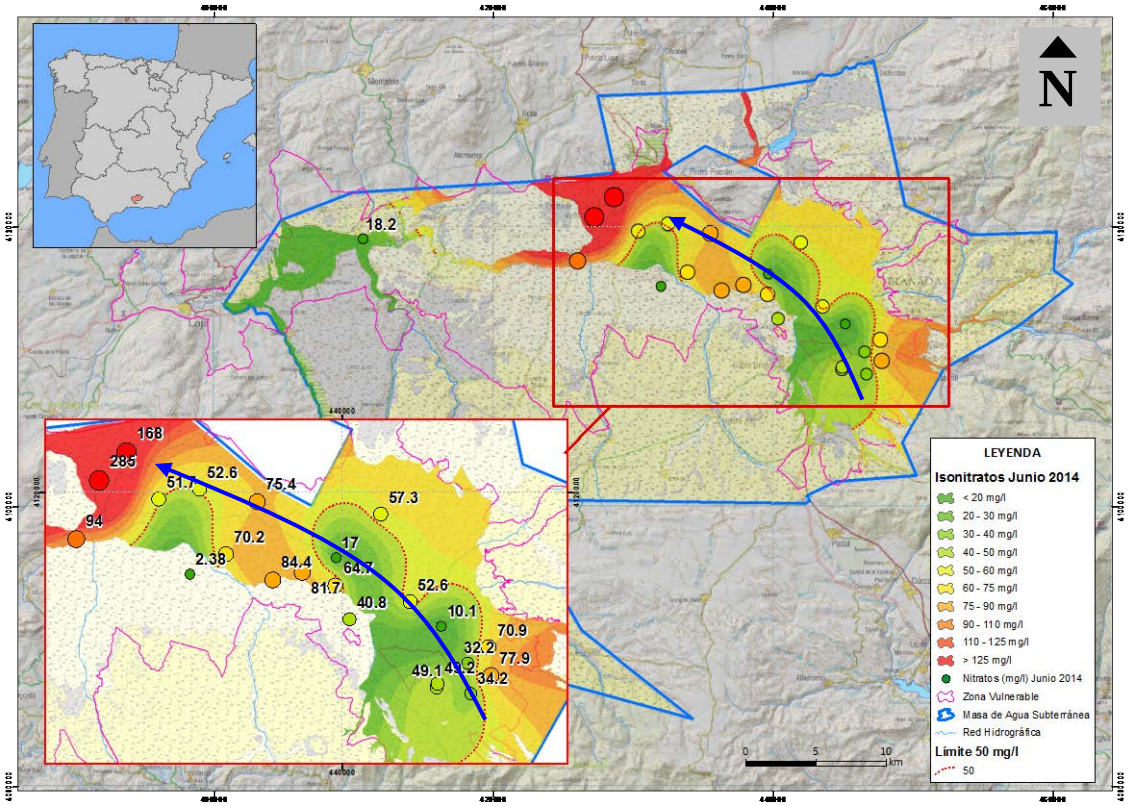
$\delta^{2}H_{H2O}$ $\delta^{18}O_{H2O}$

$\delta^{15}N_{solids}$



- Sources of nitrate pollution in groundwater
- Identification of nitrate attenuation processes
- Heterotrophic / Autotrophic denitrification
- Temporal evolution of nitrate pollution

Study case: Vega de Granada

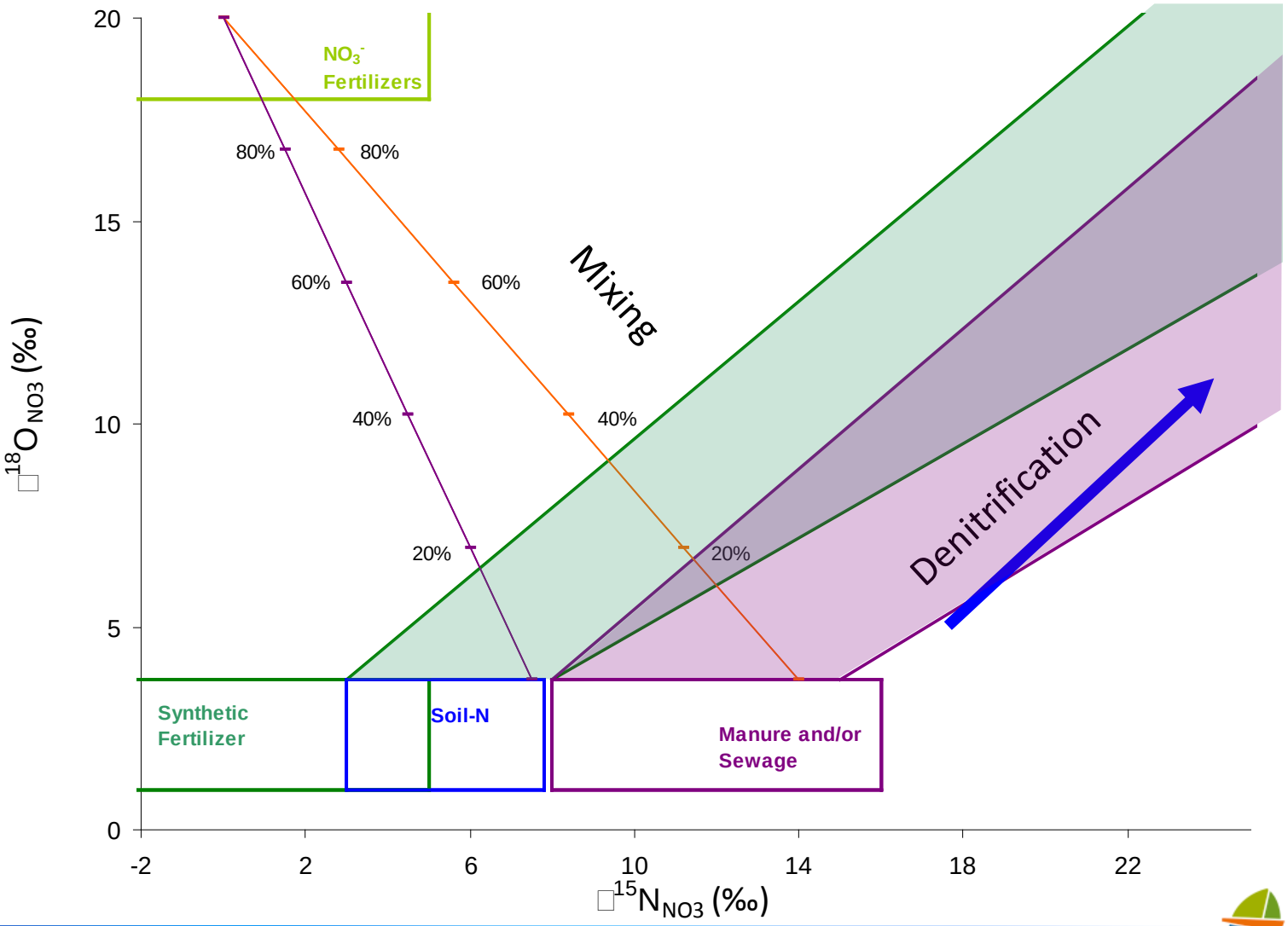


Groundwater flow

NO_3^- sources:

- % Fertilization of agricultural fields:
  - Without fertilizer: 4%
  - Organic Fert. 15%
  - Organic + Inorganic: 20%
  - Inorganic Fert. 61%
- 300 Intensive Livestock
- Wastewater from 34 cities (included Granada)

Characterizing origin and fate of groundwater nitrate pollution



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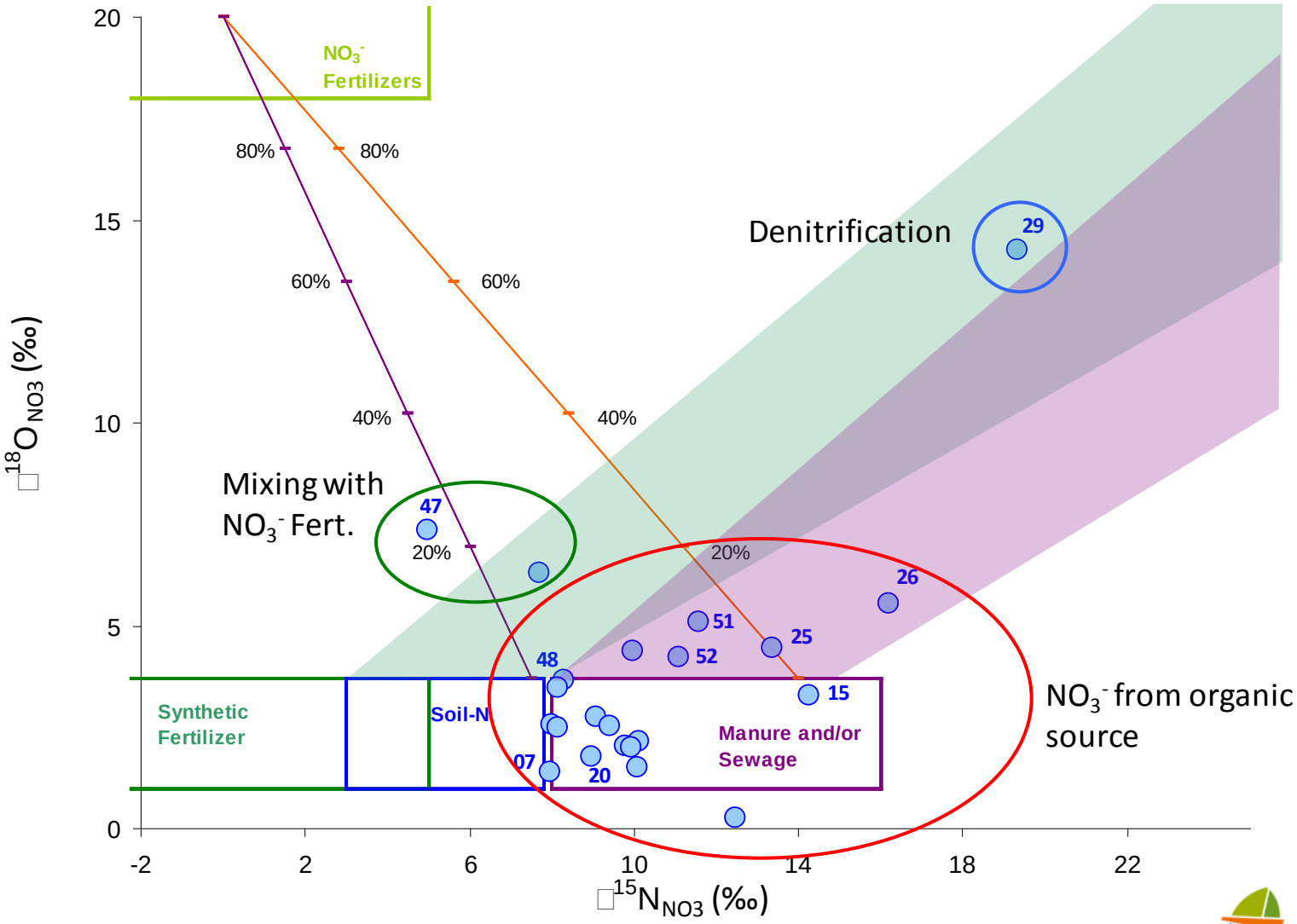
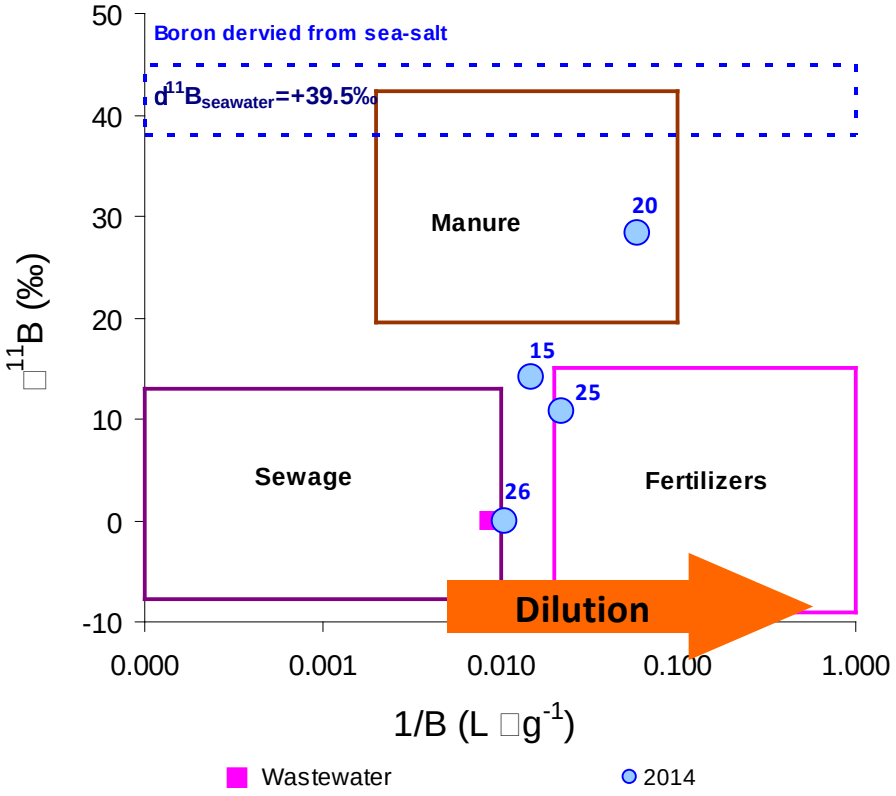
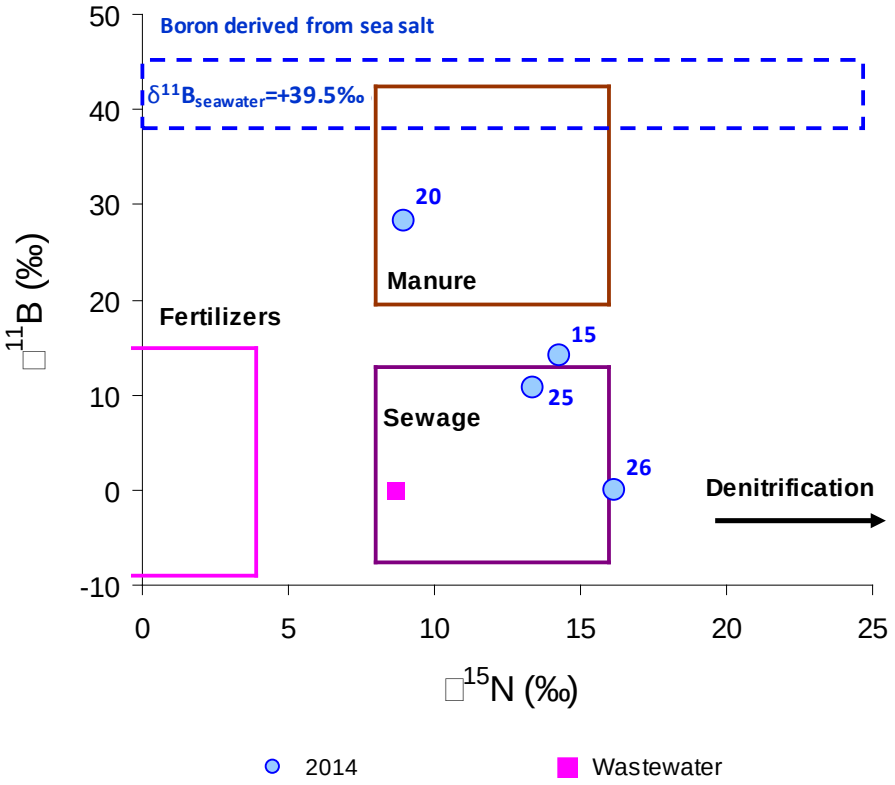
Nitrate pollution mainly related with organic nitrate: sewage/manure (e.g. Vega de Granada)

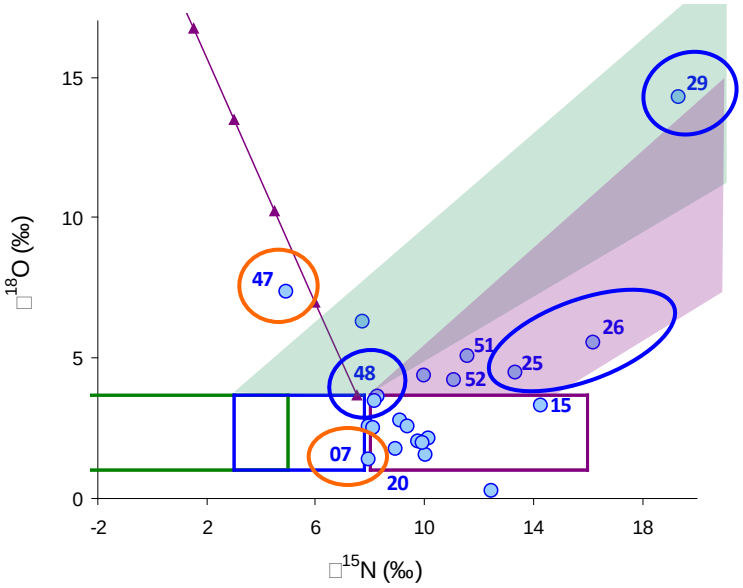


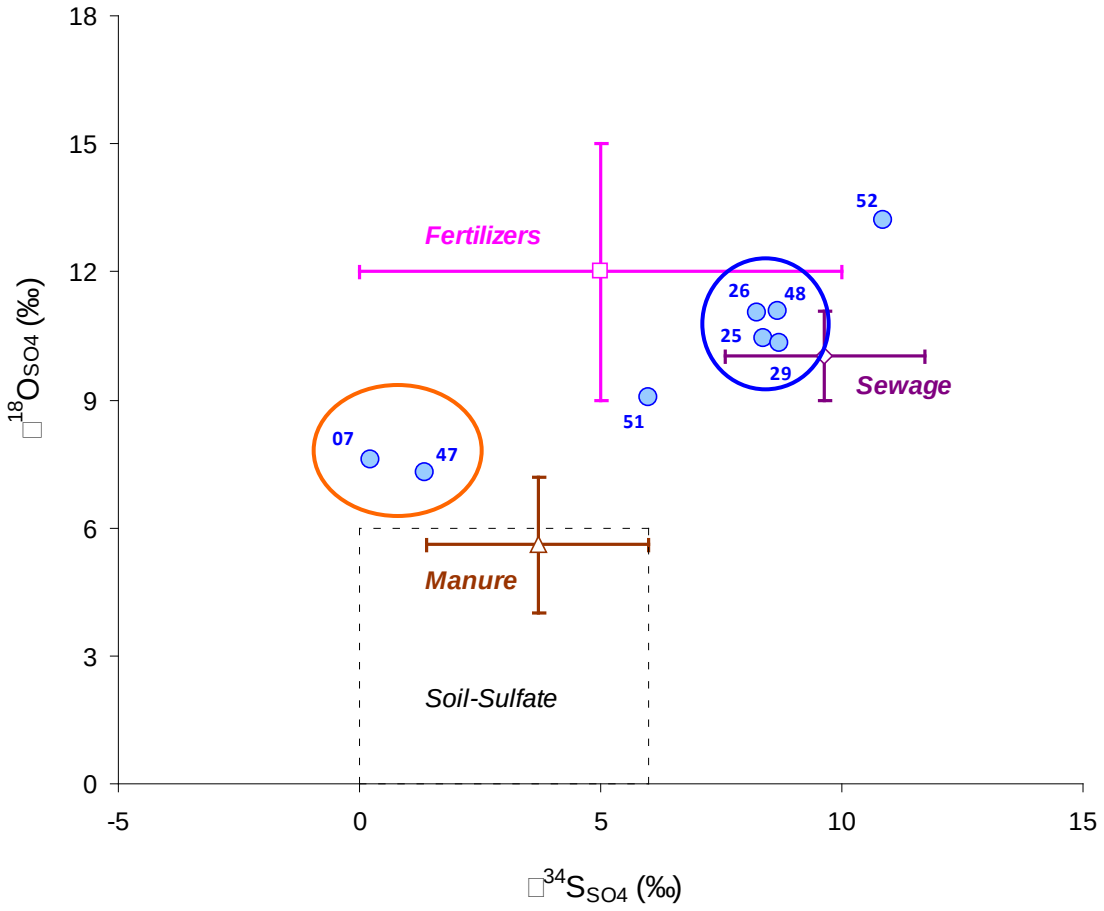
$\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ related with organic NO_3^- → sewage and/or manure? → $\delta^{11}B$



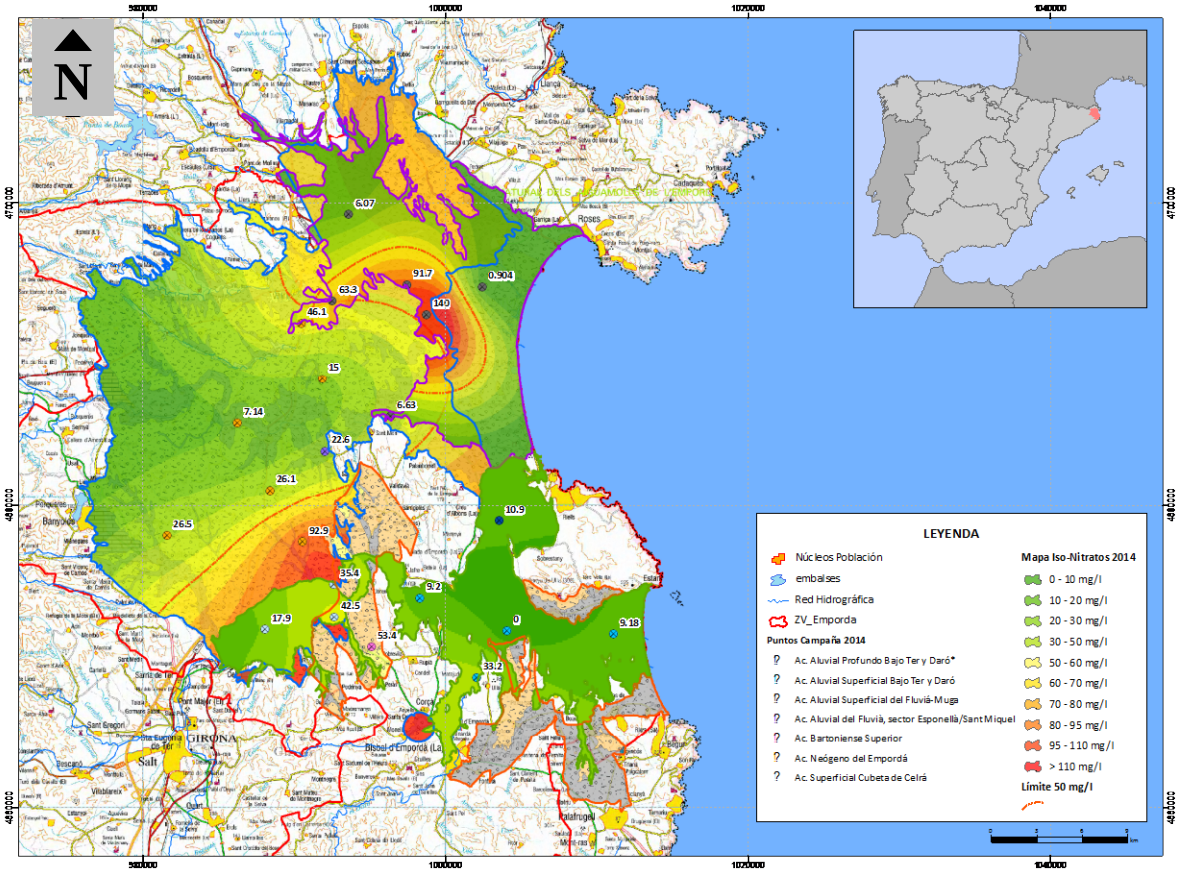


Sewage as source of nitrate? → Sulfate isotopes





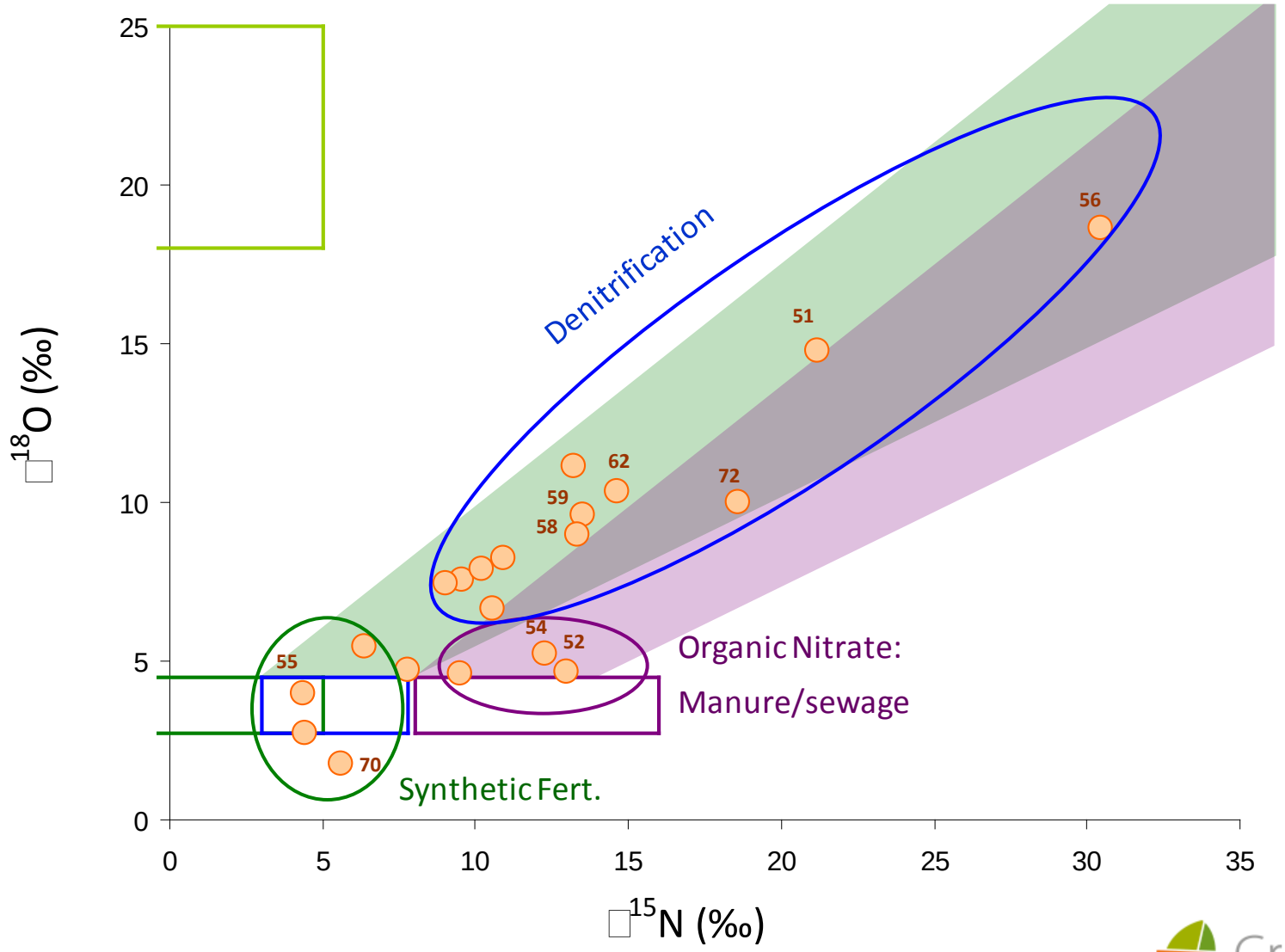
Study case coastal area: Empordá



NO_3^- sources:

- 65.000 ha of agricultural field:
  - Organic Fert. ≈ 40%
  - Organic + Inorganic Fert. ≈50%
  - Inorganic Fert. ≈ 10%
- >1000 Intensive Livestock
- Wastewater from cities

E.g. Coastal area: Empordá



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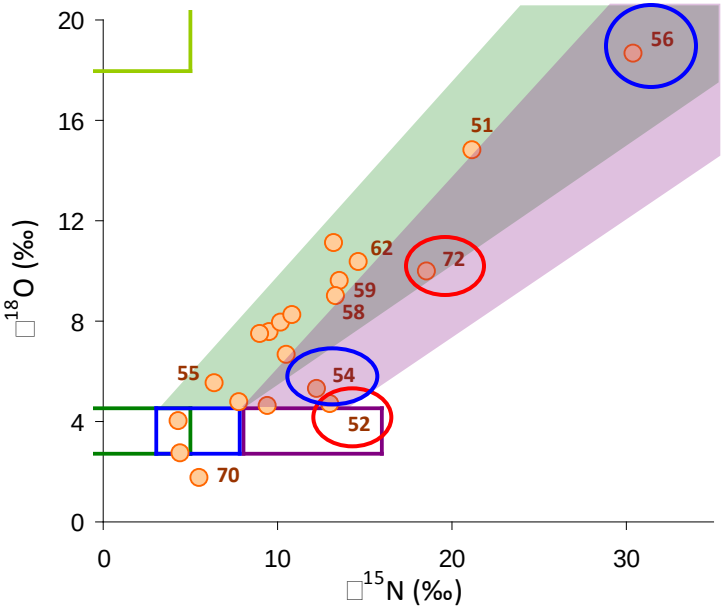
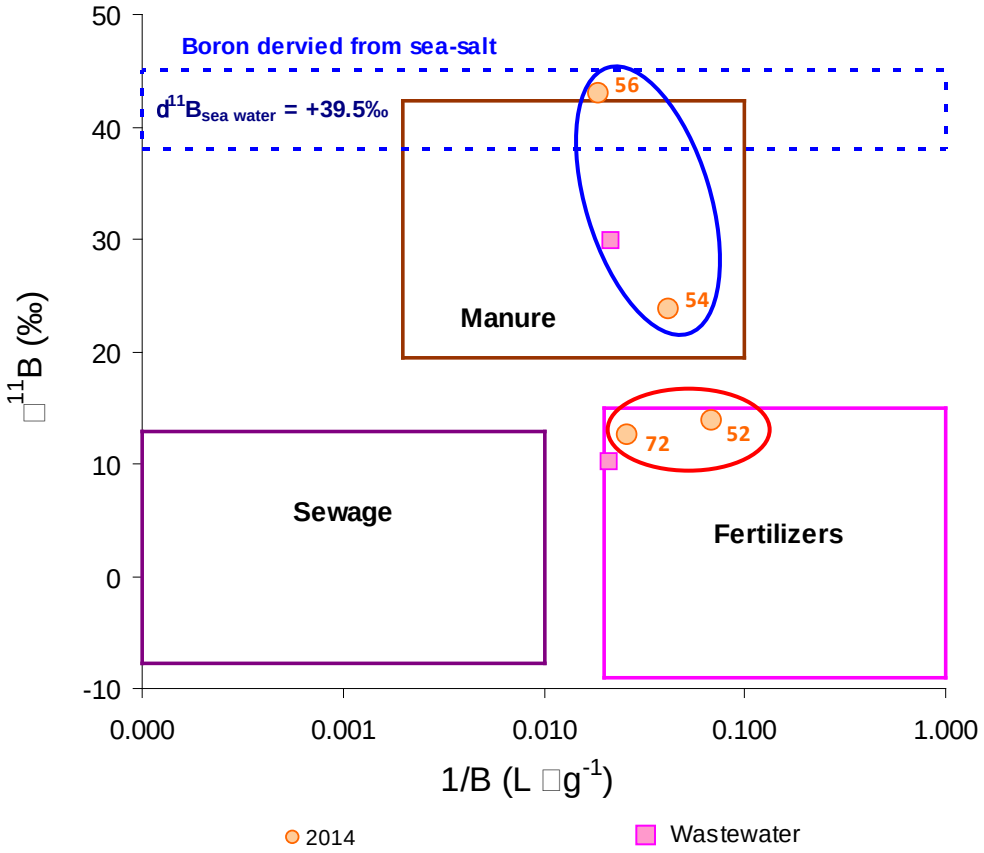
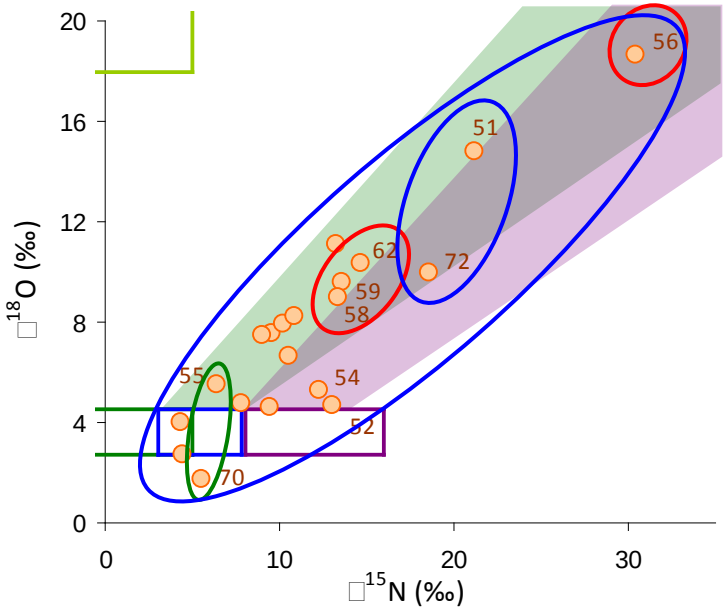
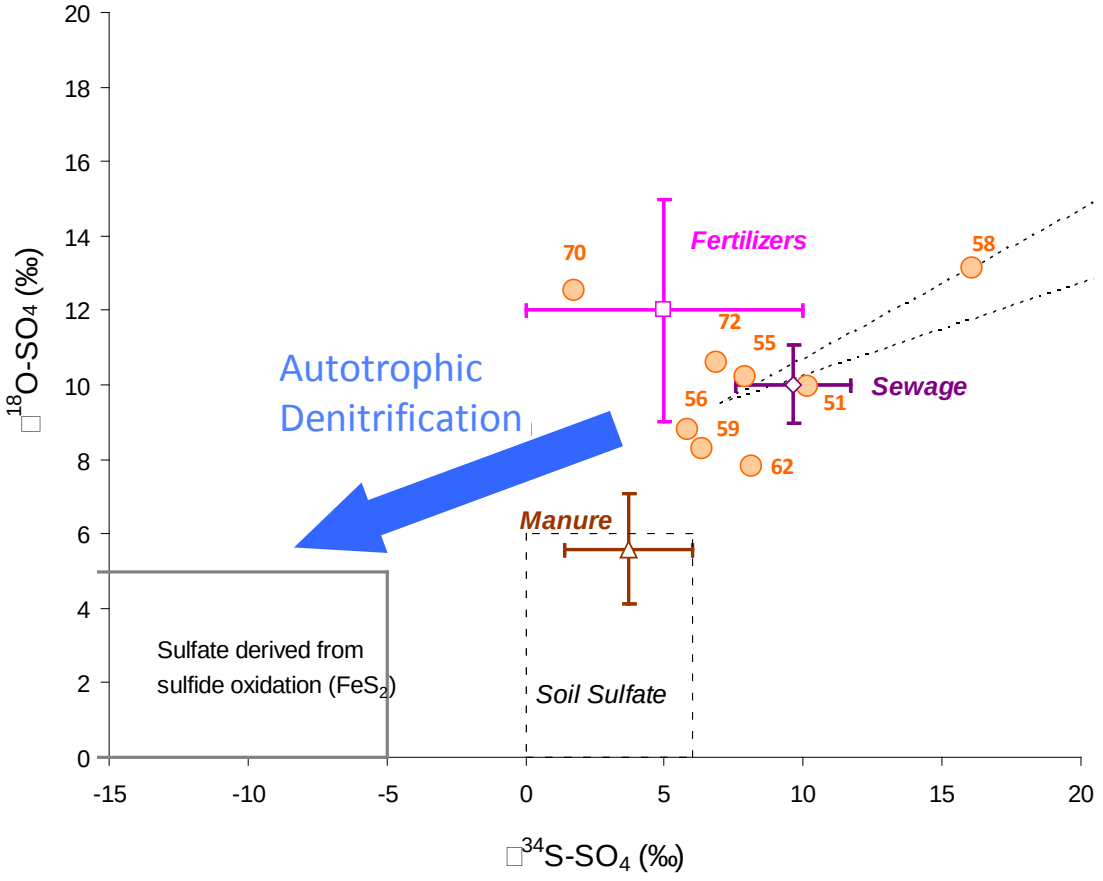
E.g. Coastal area: Empordá





Sewage/manure as source of nitrate → Sulfate isotopes





	ZV01 Valencia	Z02 Cartagena	ZV04 Guadalhorce	ZV05 Guadiana	ZV06 Maresme	ZV07 Granada	ZV13 Menorca	ZV15 Arenales	ZV19 Empordá	ZV20 Tierra de Barros	
$\delta^{15}N_{NO3}$ $\delta^{18}O_{NO3}$	🙂	🙂	🙂	🙂	🙂	🙂	🙂	🙂	🙂	🙂	**Source/ Denitrif.**
$\delta^{11}B$	☹	☹	🙂	🙂	☹	🙂	☹	😐	😐	🙂	**Source**
$\delta^{34}S_{SO4}$ $\delta^{18}O_{SO4}$	😐	🙂	🙂	🙂	😐	🙂	😐	🙂	🙂	🙂	**Source/ Denitrif.**
$\delta^{13}C_{DIC}$	-	-	🙂	🙂	☹	-	-	☹	☹	☹	**Denitrif.**

$\delta^{15}N_{NO3}$ $\delta^{18}O_{NO3}$	Identificazione delle principali fonti di inquinamento da NO_3^- nelle acque sotterranee Identificazione dei processi di attenuazione di NO_3^- Quantificazione dell' attenuazione di NO_3^- Evoluzione temporale dell' inquinamento da NO_3^-	Distinguere tra reflui e letame Origine dei nitrati in campioni denitrificati
$\delta^{11}B$	Distinguere tra reflui e letame	I valori possono essere mascherati in zone costiere
$\delta^{34}S_{SO4}$ $\delta^{18}O_{SO4}$	Identificazione delle fonti di inquinamento da SO_4^{2-} Identificazione della denitrificazione autotrofa Identificazione dei processi di solfato-riduzione	Fonti secondarie di solfato: Gessi, origine marina, miniere
$\delta^{13}C_{DIC}$	Identificazione della denitrificazione eterotrofa	I valori possono essere mascherati dalla presenza di carbonati

Grazie per l'attenzione

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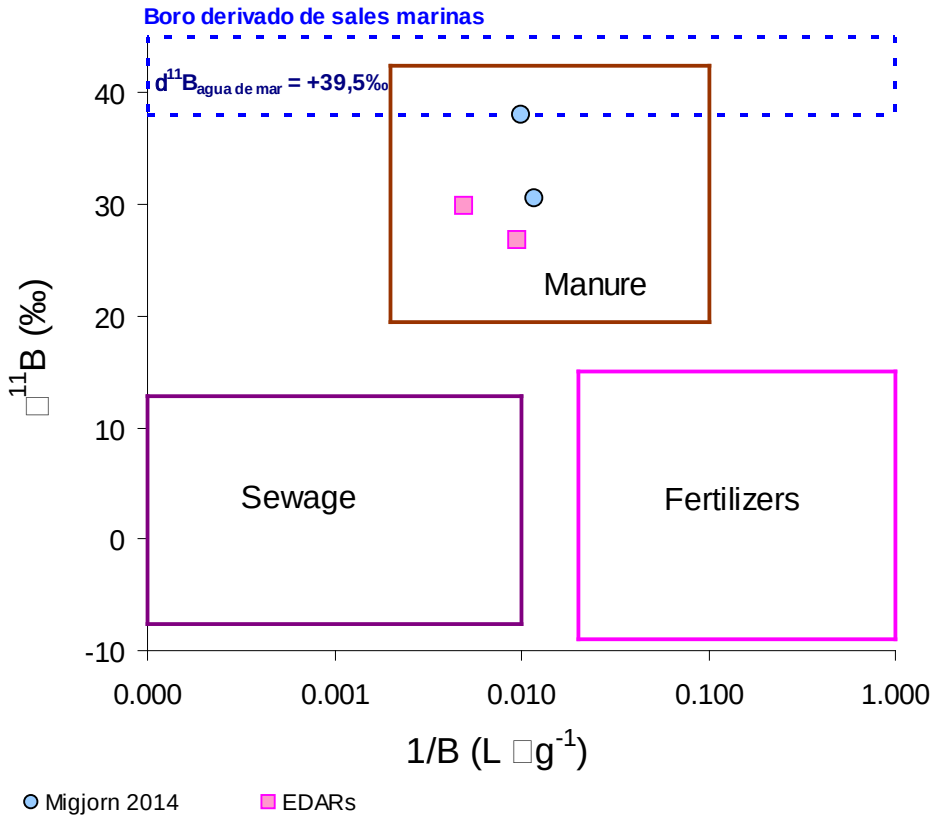
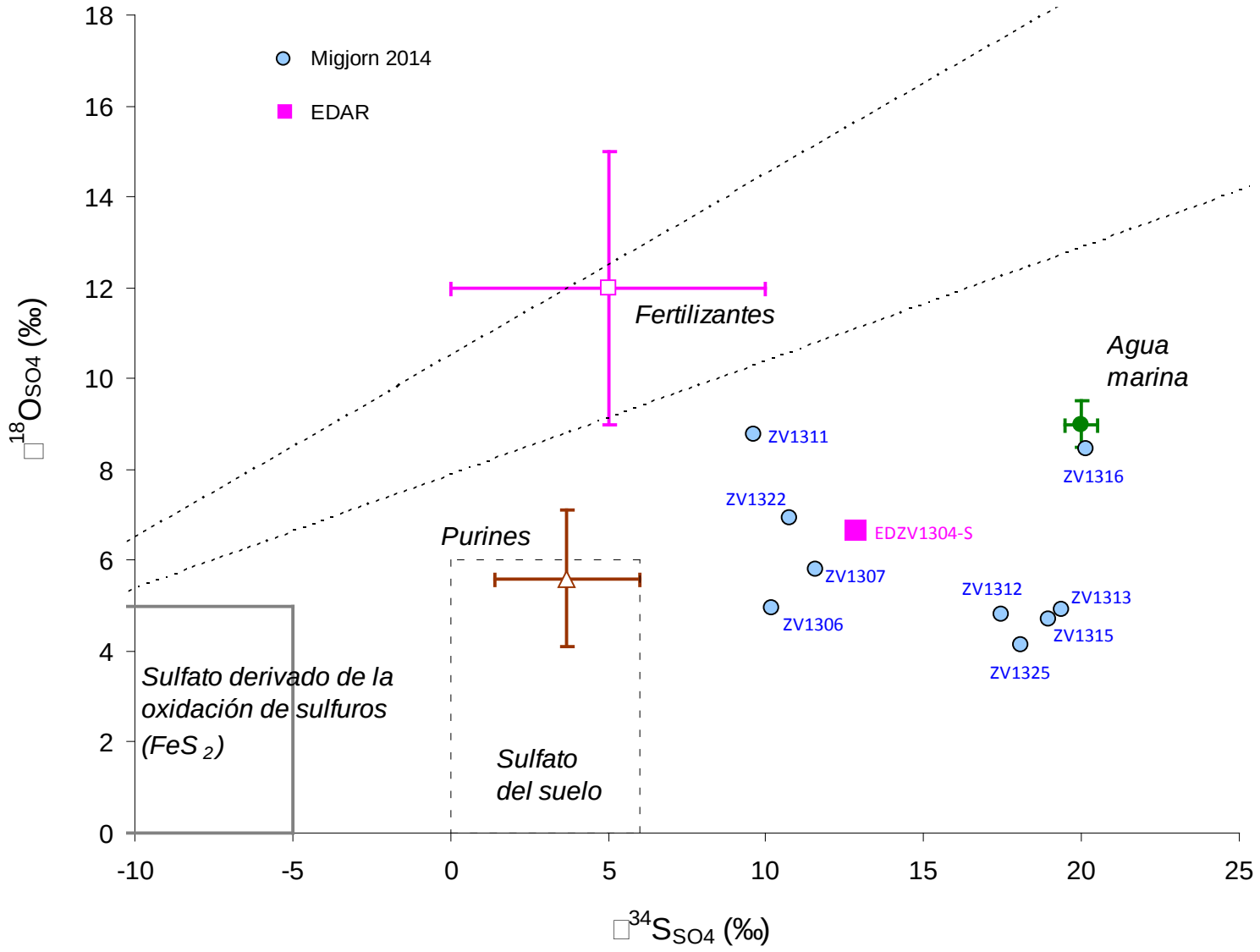
$\delta^{15}N_{NO3}$ $\delta^{18}O_{NO3}$	Identification of main NO_3^- pollution sources Identification of NO_3^- attenuation processes Quantification of nitrate attenuation Temporal evolution of nitrate pollution	Distinguish sewage and manure Source of nitrate in denitrified samples
$\delta^{11}B$	Distinguish between sewage and manure	Values may be masked in coastal areas
$\delta^{34}S_{SO4}$ $\delta^{18}O_{SO4}$	Identification of SO_4^{2-} pollution sources Identification of autotrophic denitrification Identification of sulfate-reduction processes	Secondary sources of sulfate: Gypsums, marine, mining
$\delta^{13}C_{DIC}$	Identification of heterotrophic denitrification	Values may be masked by carbonates

Menorca

Seawater influence



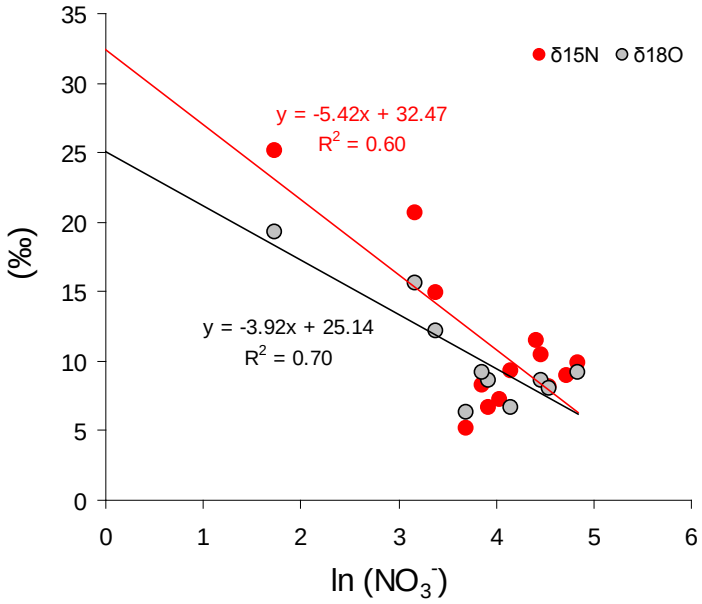
Identification of nitrate pollution sources in groundwater: multi-isotopic approach



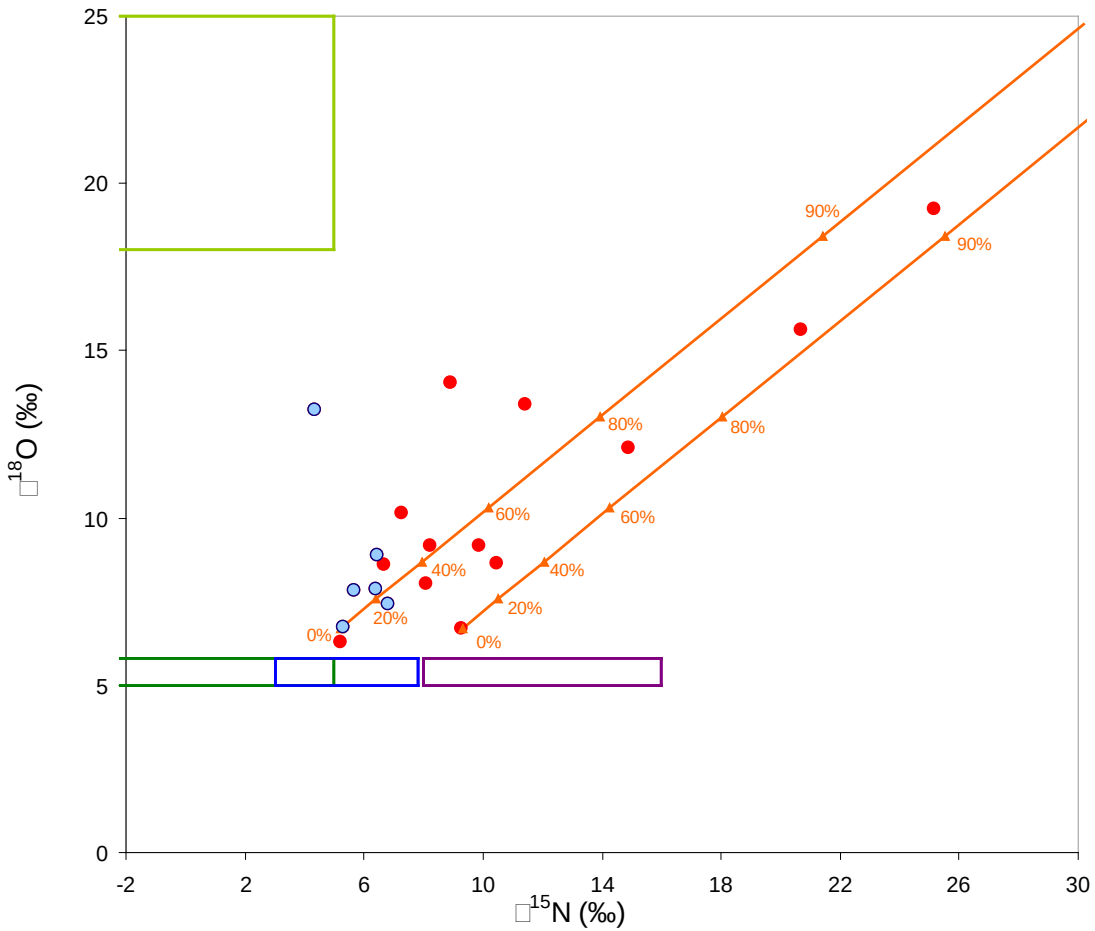
Identification of other N-reactions: (DNRA, Nitrification, ANAMMOX)

Theoretical nitrate compositional box

Vega Baja Guadiana



$$DEN(\%) = \left[1 - e^{\left(\frac{\delta_{residual} - \delta_{inicial}}{\varepsilon}\right)}\right] \times 100$$



Tierra de Barros: Temporal evolution