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Occurrence of greenhouse gases (CO₂, N₂O and CH₄) in groundwater of the Walloon Region (Belgium)

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OUTLINE

1. Introduction

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2. Methodology

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2.2 Sampling collection

3. Results

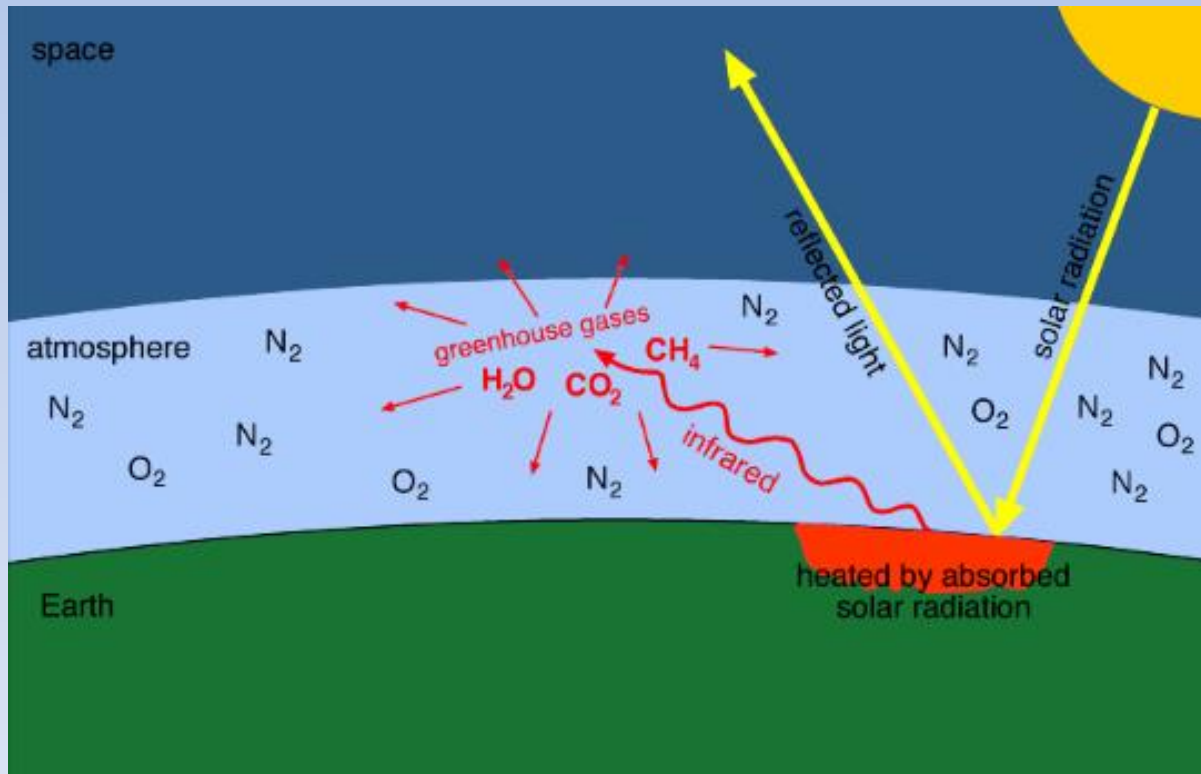
4. Assessment of the occurrence of GHGs

5. Conclusions

1. Introduction

Importance of GHGs

- ✓ GHGs are essential for life
- ✓ Without GHGs temperatures on Earth surface would fall from 15°C to -18 °C



Source: <http://www.ehso.com/climatechange/climatechange-causes-greenhouseeffect.php>

1. Introduction

Importance of GHGs

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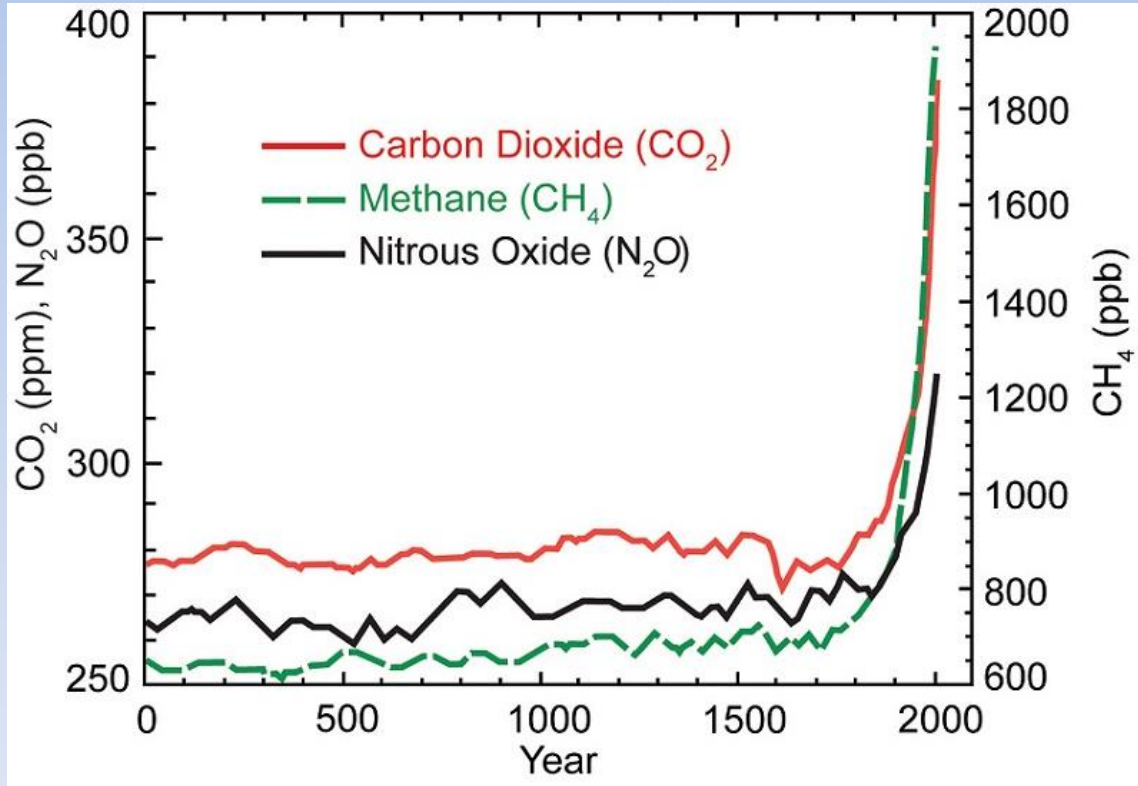
WHAT IS THE PROBLEM?

1. Introduction

Importance of GHGs

- ✓ GHGs are essential for life
- ✓ Without GHGs temperatures on Earth surface would fall from 15°C to -18 °C

WHAT IS THE PROBLEM?



Source: U.S. National Assessment (2014)

1. Introduction

Source of GHGs

CARBON DIOXIDE (CO₂)

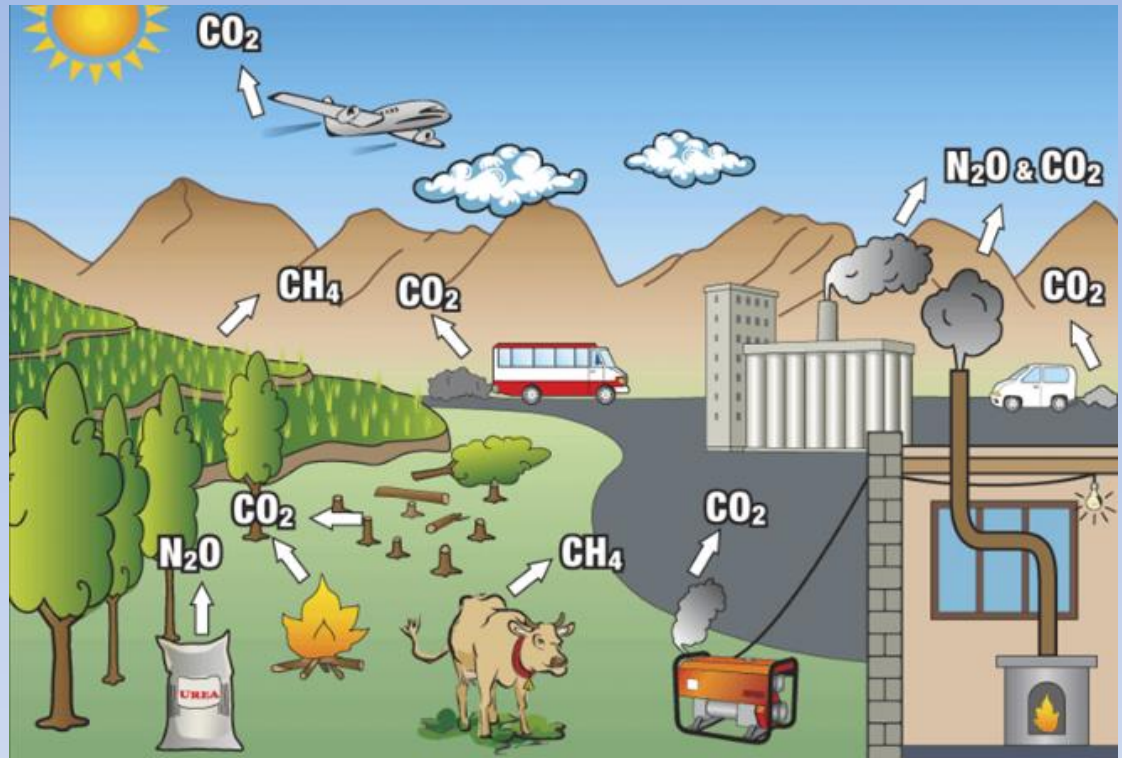
- ✓ Fossil fuel burning
- ✓ Changes in land use
- ✓ Industrial activities

NITROUS OXIDE (N₂O)

- ✓ Agricultural activities
- ✓ Fossil fuel combustion and industrial processes
- ✓ Natural processes (i.e soils)

METHANE (CH₄)

- ✓ Fossil fuel production, distribution and use
- ✓ Livestock farming
- ✓ Landfills and waste
- ✓ Wetlands

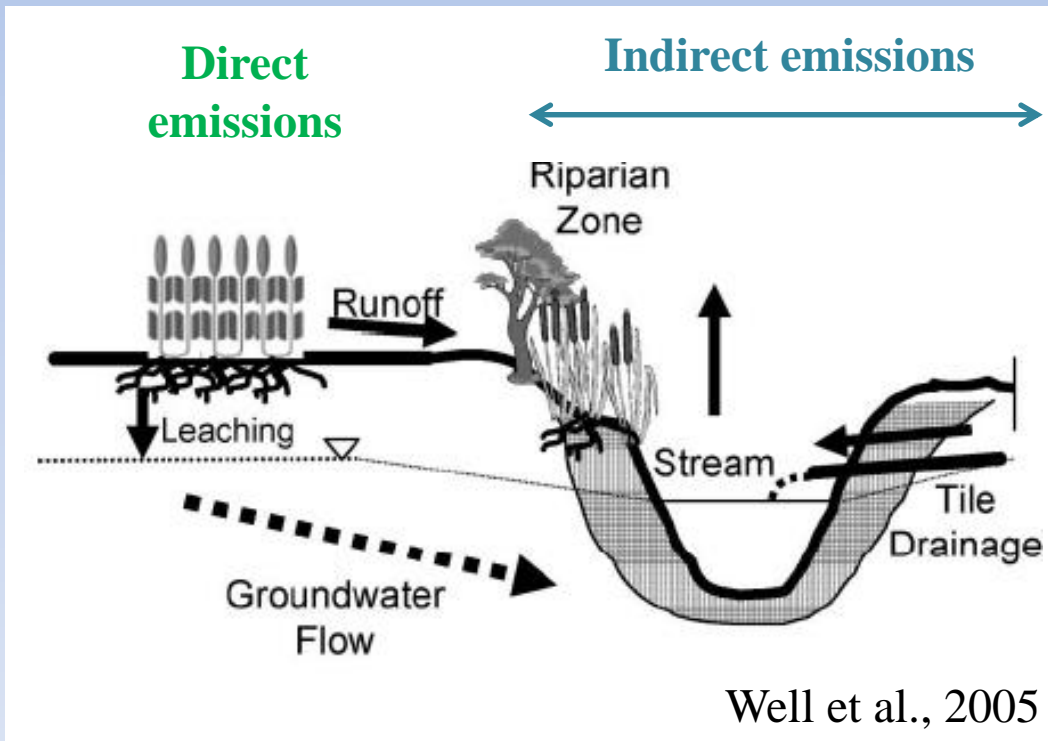


1. Introduction

Groundwater as a source GHGs

Groundwater has been proposed as a potential indirect source of GHGs to the atmosphere.

Agricultural areas (Anderson et al., 2014; Jahangir et al., 2012; Minamikawa et al., 2011)



Some examples...

Jahangir et al. (2012) → **Groundwater indirect N₂O emissions via denitrification represented the 3–11% of total N₂O emissions.**

Anderson et al. (2014) → **20 % of total N loss from a riparian area may be attributed to N₂O emissions from shallow groundwater via denitrification.**

1. Introduction

Groundwater as a source GHGs

Groundwater has been proposed as a potential indirect source of GHGs to the atmosphere.

Riverine areas (Beaulieu et al., 2010, Hotchkiss et al., 2015)

10% of the global anthropogenic N₂O emission rate was due to microbial transformations in river networks

Average N₂O fluxes estimated

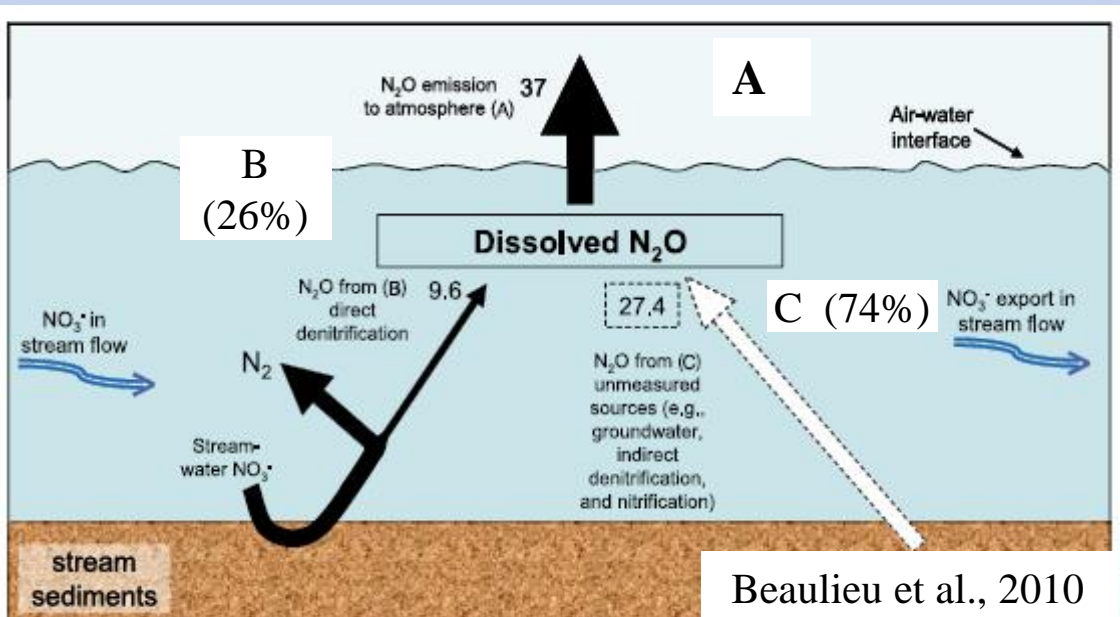
$$A=B+C$$

(A) N₂O produced in the stream temporarily resides in a pool of dissolved N₂O before being emitted to the atmosphere.

(B) In-situ N₂O produced by denitrification in stream

(C) Other **unmeasured sources** N₂O sources:

- ✓ **Inputs supersaturated GW**
- ✓ **indirect Nitrif/Denitrif from soils**



1. Introduction

Aims of the research

Investigate the occurrence GHGs in groundwater of the Walloon
Region (Belgium)

- ✓ Identification of the hydrogeological contexts and in situ conditions
- ✓ Identification of the geochemical processes

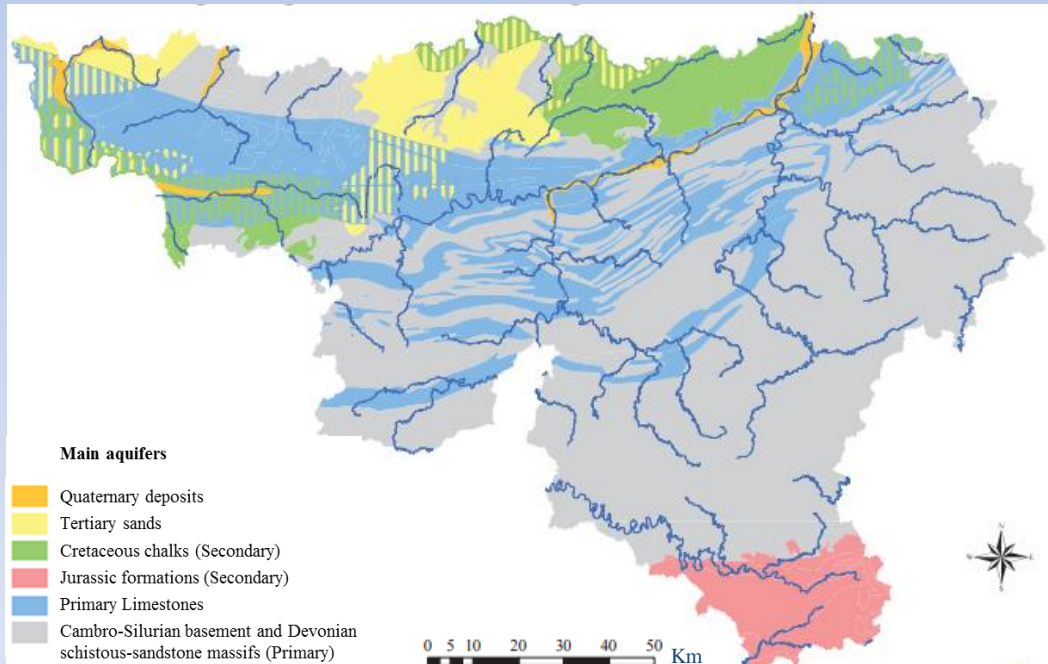
2. Methodology

Wallon Region (Belgium)

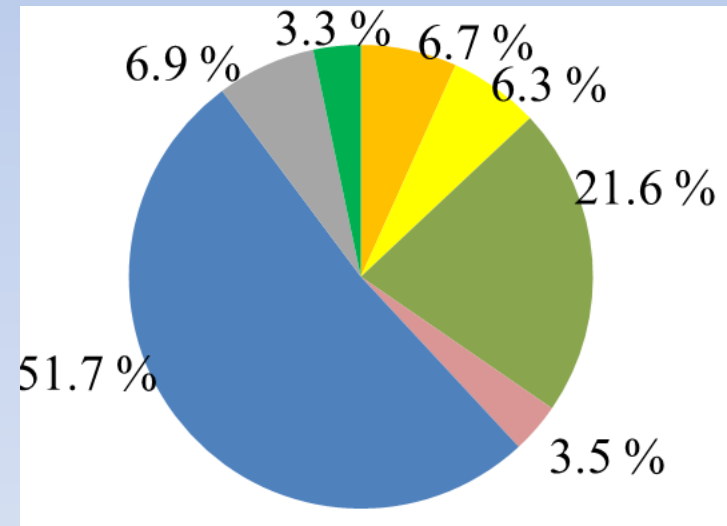


- Extension: 16844 Km²
- Land use: agricultural (51,8%) > forests (29,4%) > urban (14,3%)
- Groundwater represents the 78 % of water supply (297,5 million m³)

Main aquifers



Groundwater abstraction (% , 2012)



2. Methodology

Sampling campaigns

GHGs (C1-C3)

- ✓ CO₂, N₂O, CH₄

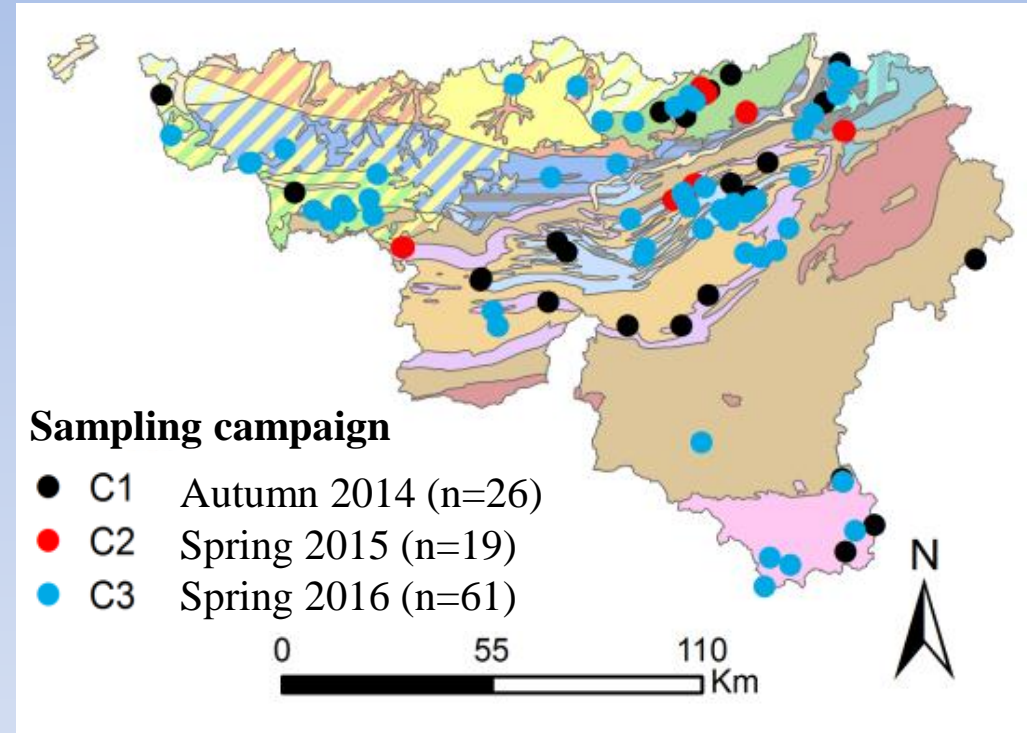
General analysis

- ✓ Minor and major elements (C1-C3)
- ✓ Metals (Fe/Mn)
- ✓ **Environmental isotopes (C3)**
- ✓ 34S and 18O from sulphate
- ✓ 15N and 18O from nitrate
- ✓ 18O and D from water

In situ parameters (C1-C3)

- ✓ O₂/EC/PH/Temp

Spatial distribution of the sampling points



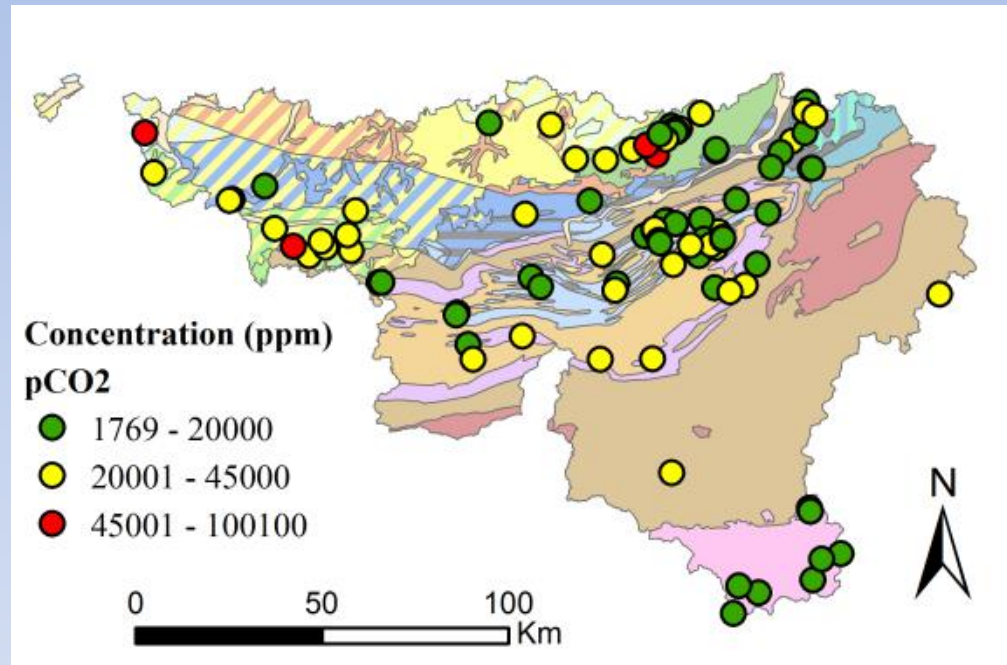
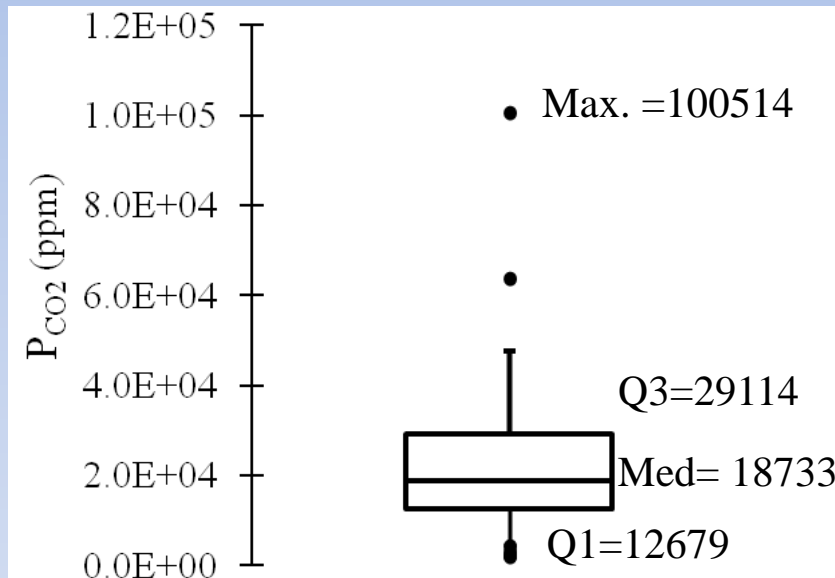
3. Results

Concentrations of Carbon dioxide ($p\text{CO}_2$)

Range \rightarrow 1769-100514 ppm

Average \rightarrow 22003 ppm

Spatial distribution of the sampling points



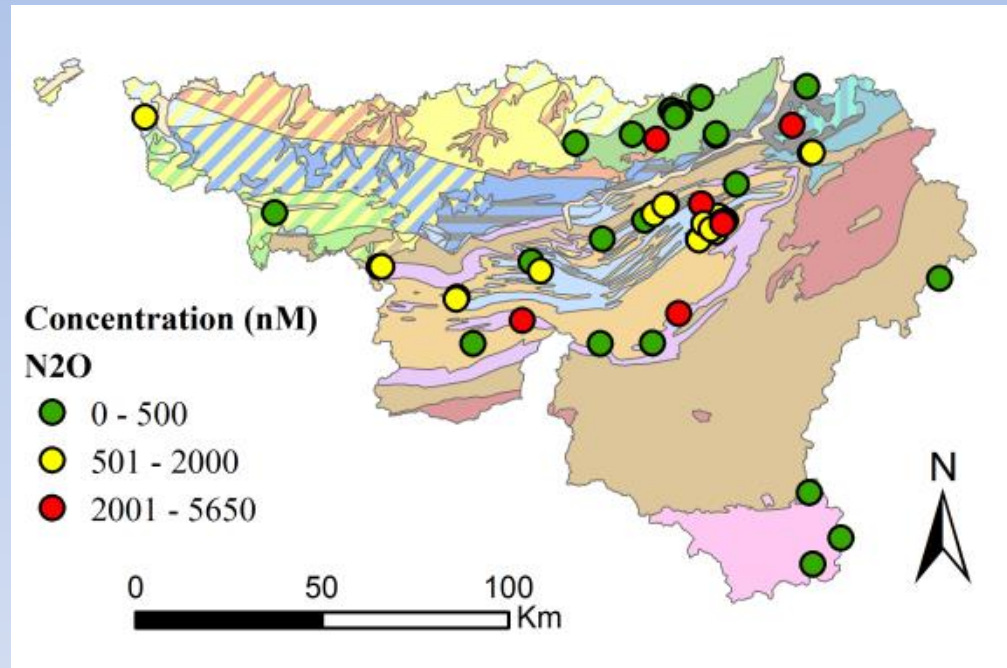
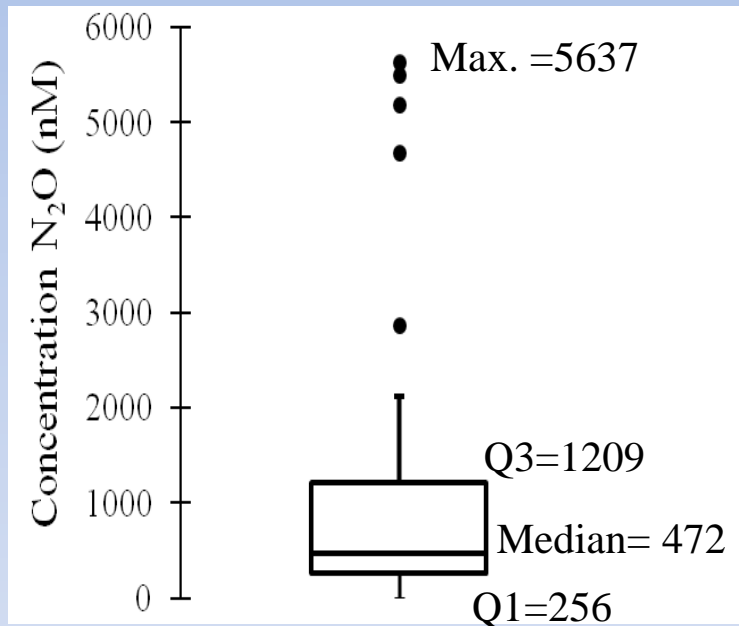
3. Results

Concentrations of Nitrous oxide (N₂O)

Range → 1-5637 nM

Average → 996 nM

Spatial distribution of the sampling points

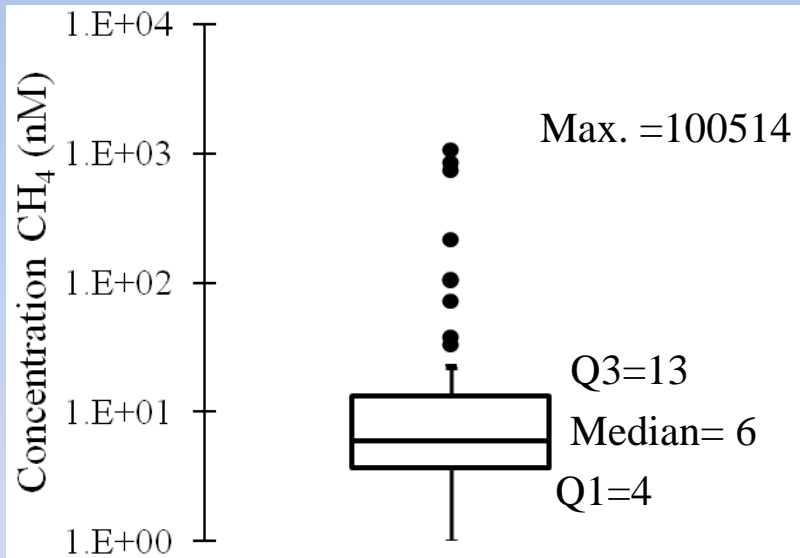


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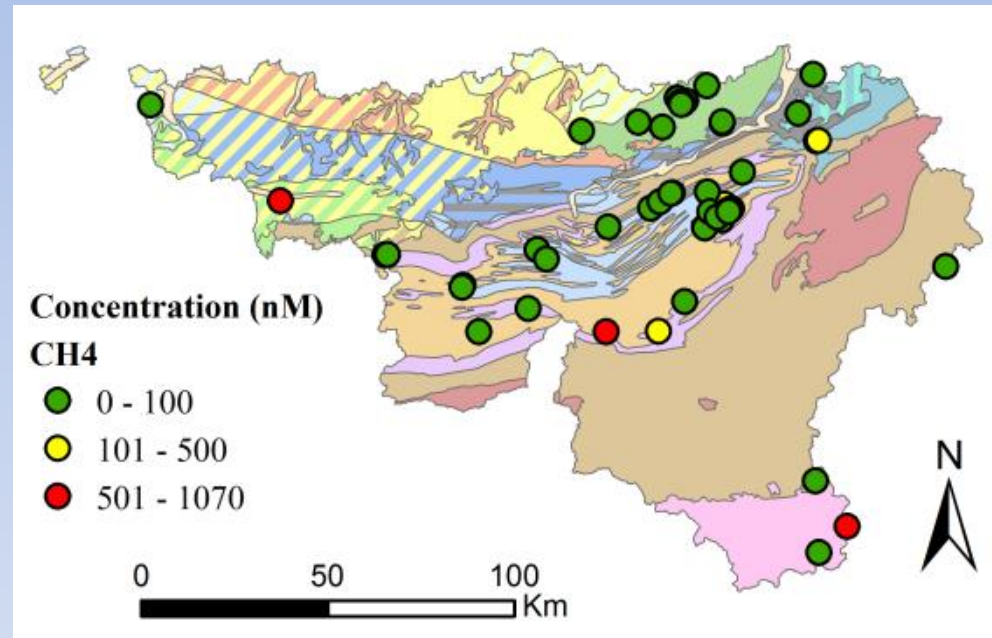
Concentrations of Methane (CH₄)

Range → 0-1064 nM

Average → 64 nM



Spatial distribution of the sampling points



4. Discussion

Occurrence of N_2O in groundwater

Denitrification: $\text{NO}_3^- \rightarrow \text{NO}_2^- \rightarrow \text{NO} \rightarrow \text{N}_2\text{O} \rightarrow \text{N}_2$

N_2O



Nitrification: $\text{NH}_4^+ \rightarrow \text{NO}_2^- \rightarrow \text{NO}_3^-$

4. Discussion

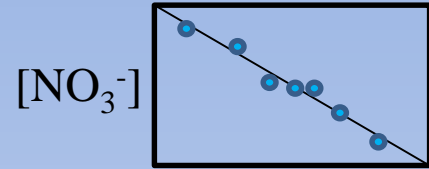
Occurrence of N_2O in groundwater

Denitrification: $NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$

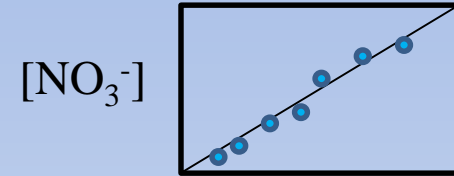
N_2O



Nitrification: $NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$



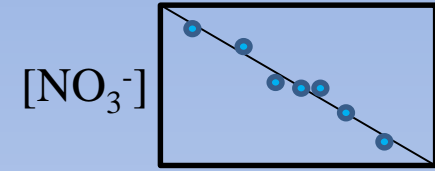
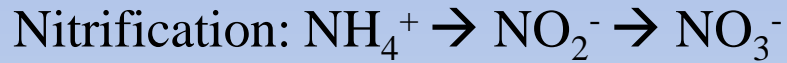
$[N_2O]$



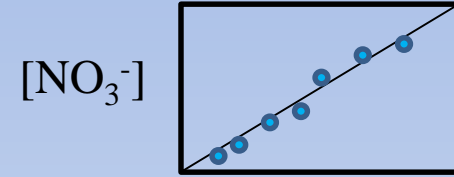
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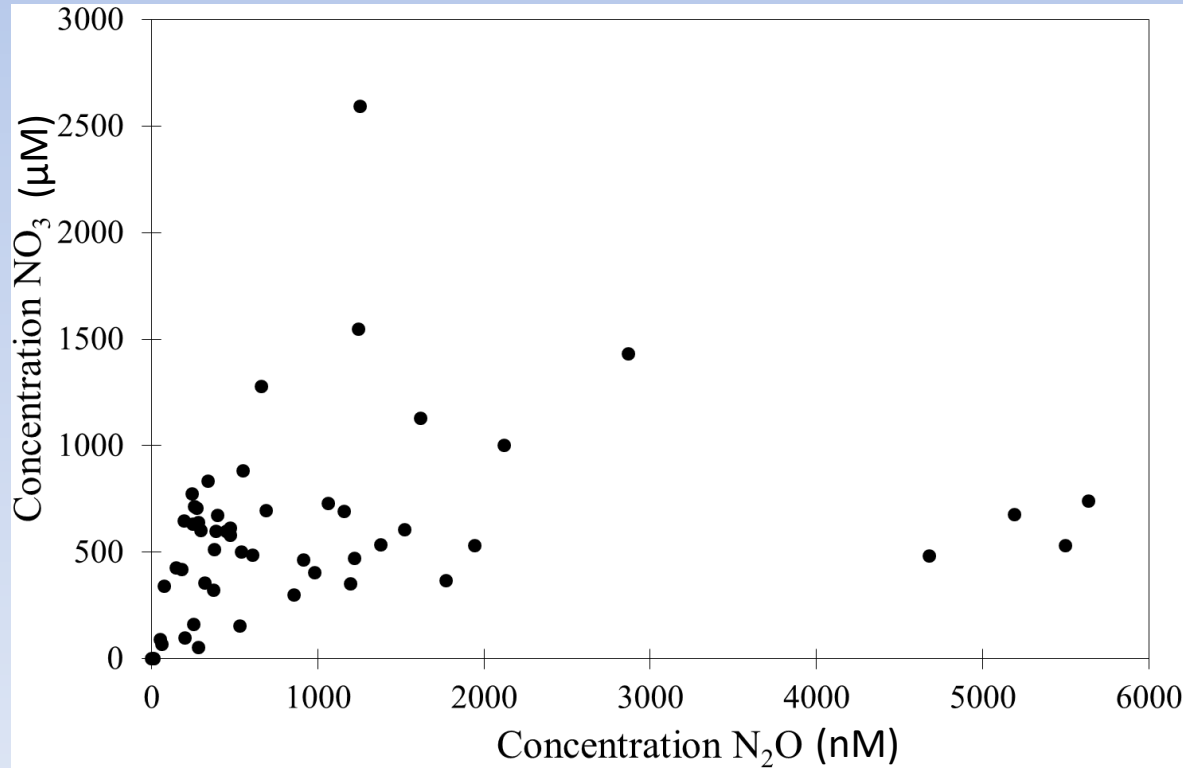
Occurrence of N₂O in groundwater



[N₂O]

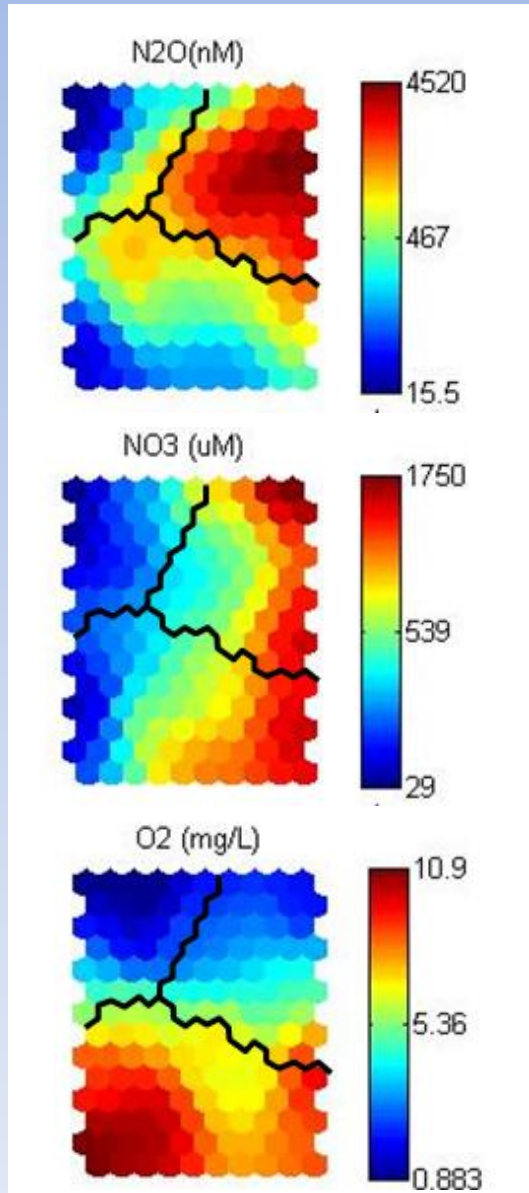


[N₂O]

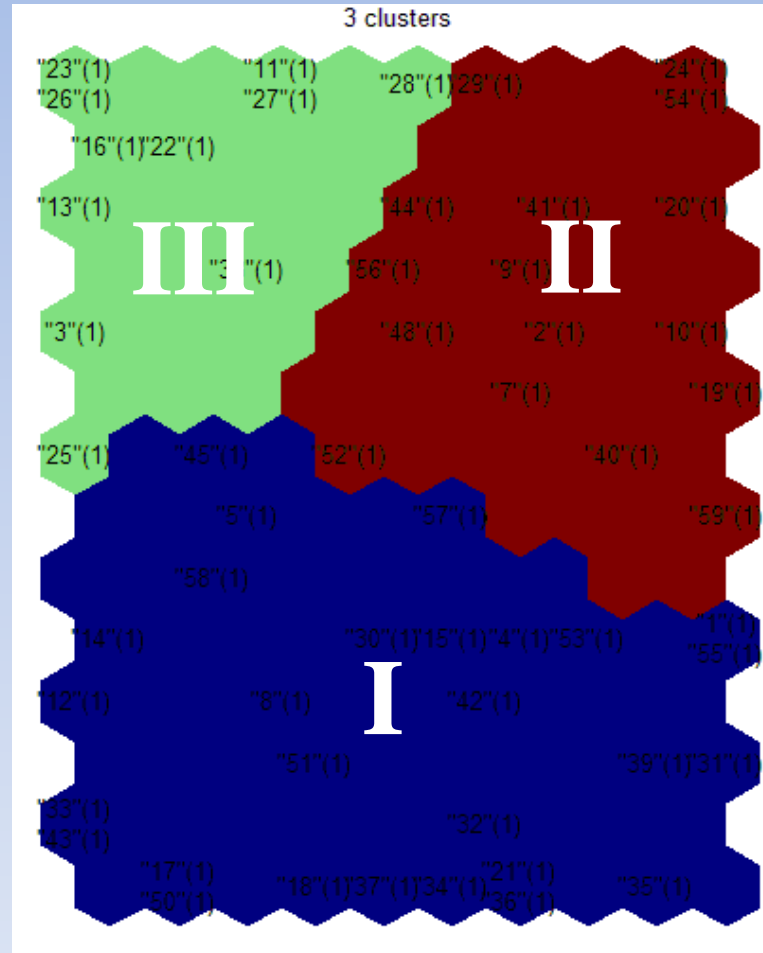


4. Discussion

Occurrence of N₂O in groundwater

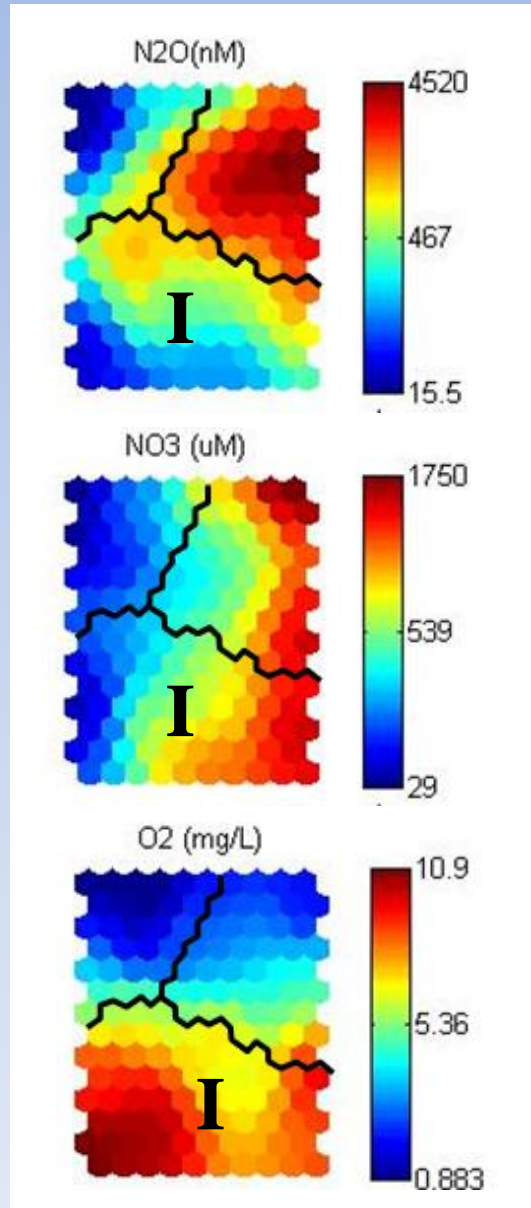


Self-Organizing Maps (SOMs)



4. Discussion

Occurrence of N₂O in groundwater



Average concentrations

Group	N ₂ O (nM)	O ₂ (mg/L)	NO ₃ (μM)
I	516.55	7.51	564.37
II	2377.31	3.64	831.28
III	188.15	1.51	215.04

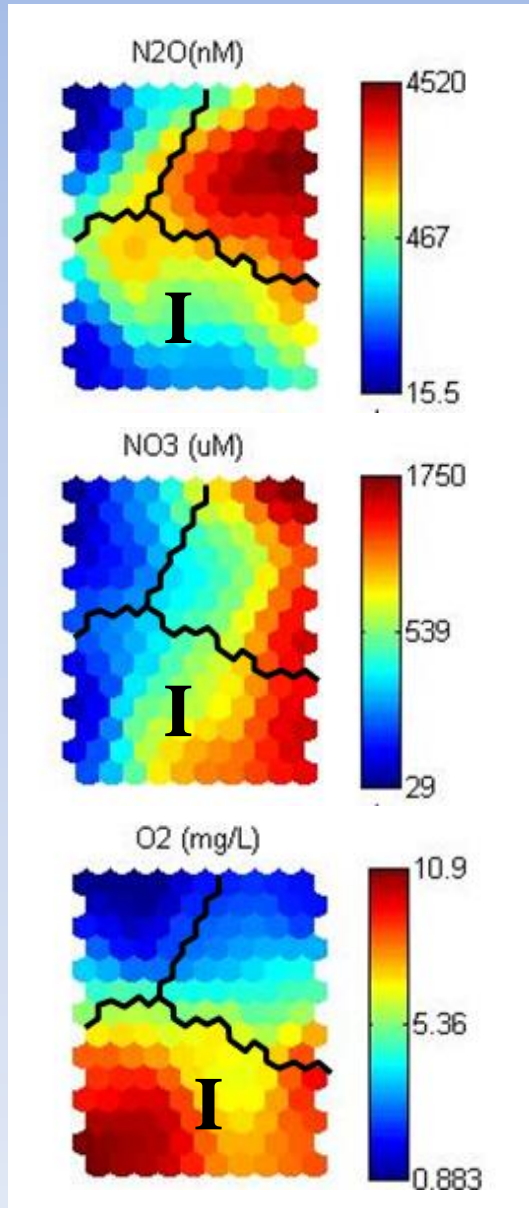
Group I

High concentrations of O₂

Medium concentrations of N₂O and NO₃⁻

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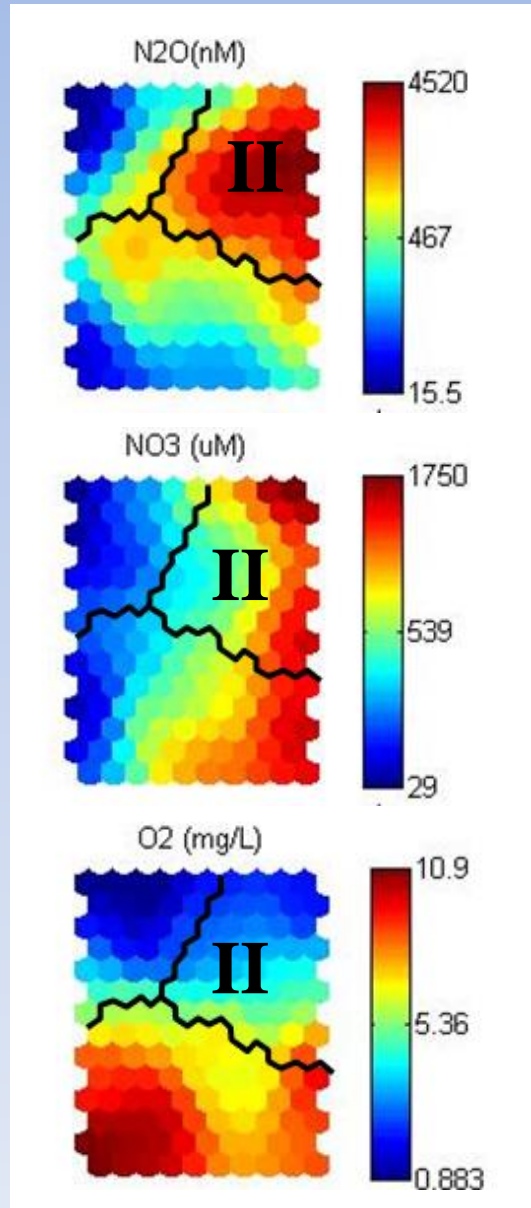
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NITRIFICATION

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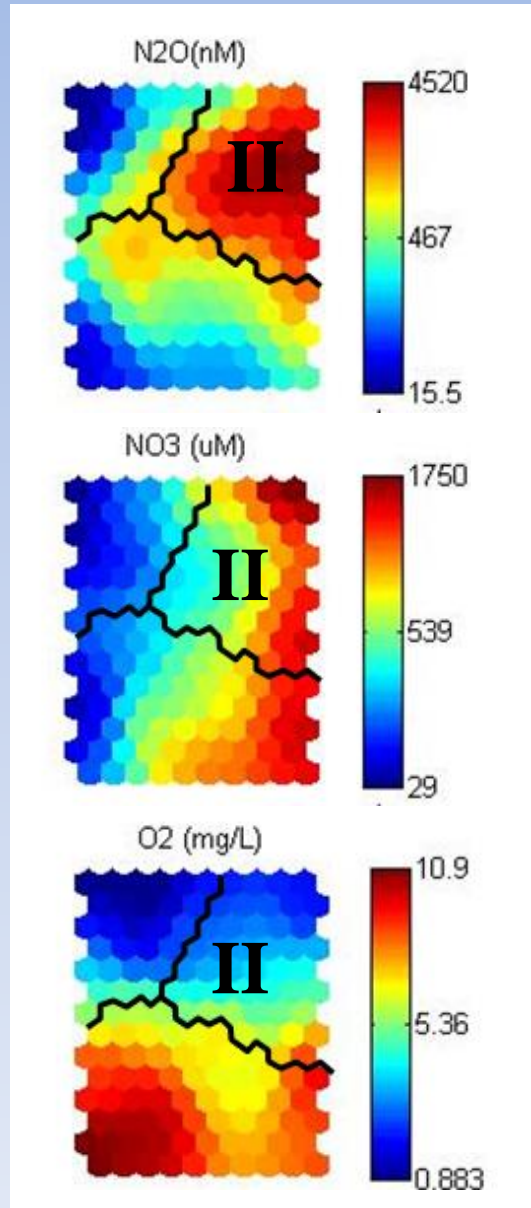
Group II

Moderate O₂

High concentrations of N₂O and NO₃⁻

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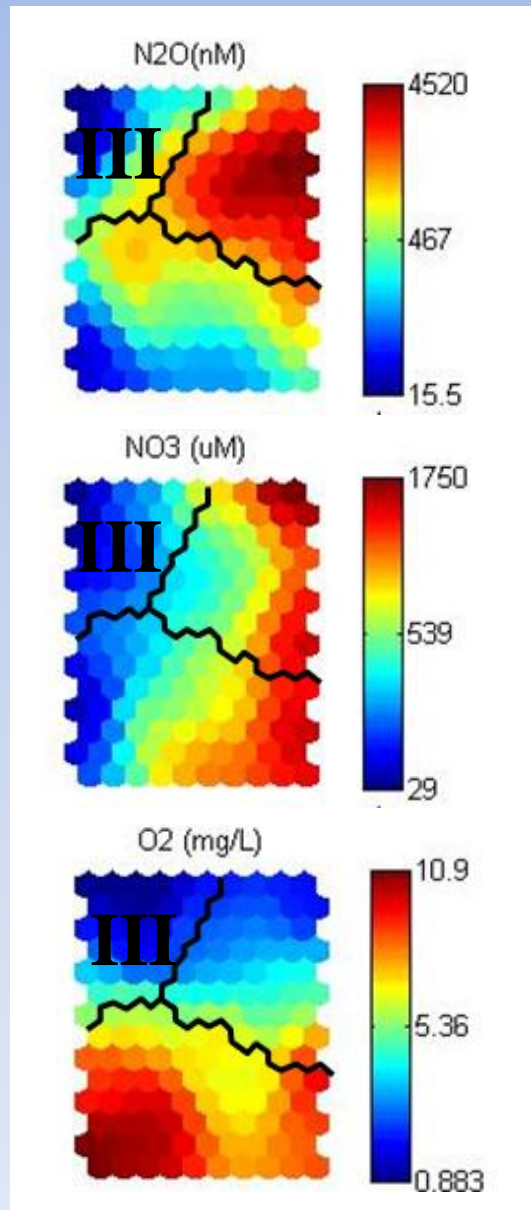


DENITRIFICATION



4. Discussion

Occurrence of N₂O in groundwater



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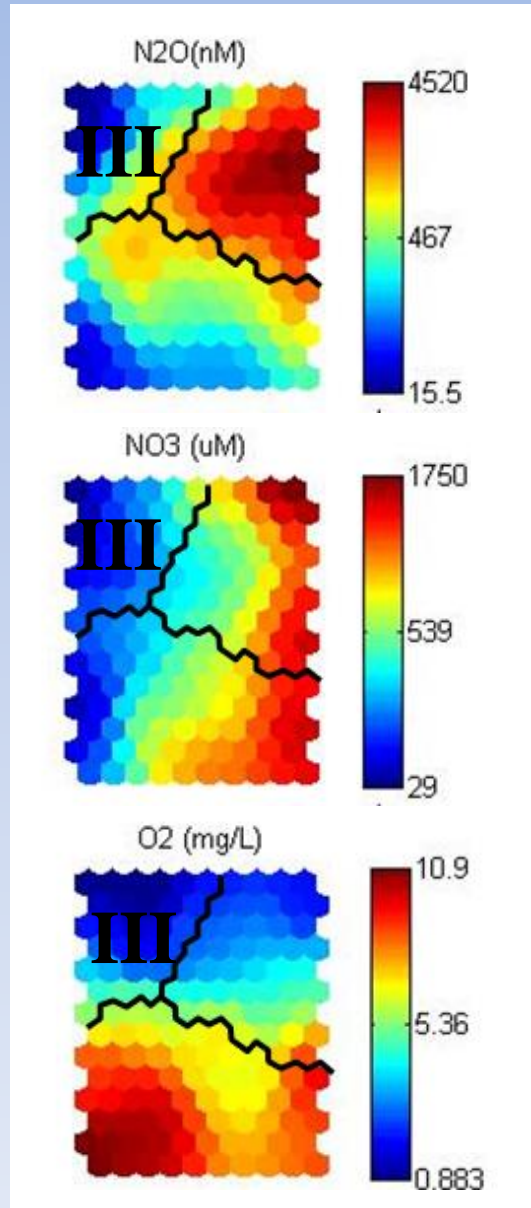
Group III

Low concentrations of O₂

Low concentrations of N₂O and NO₃⁻

4. Discussion

Occurrence of N₂O in groundwater



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DENITRIFICATION



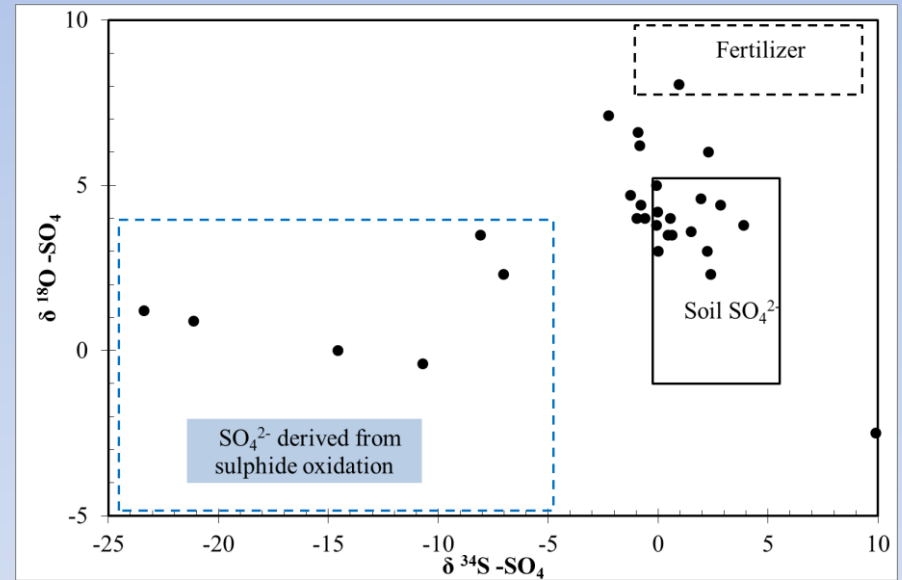
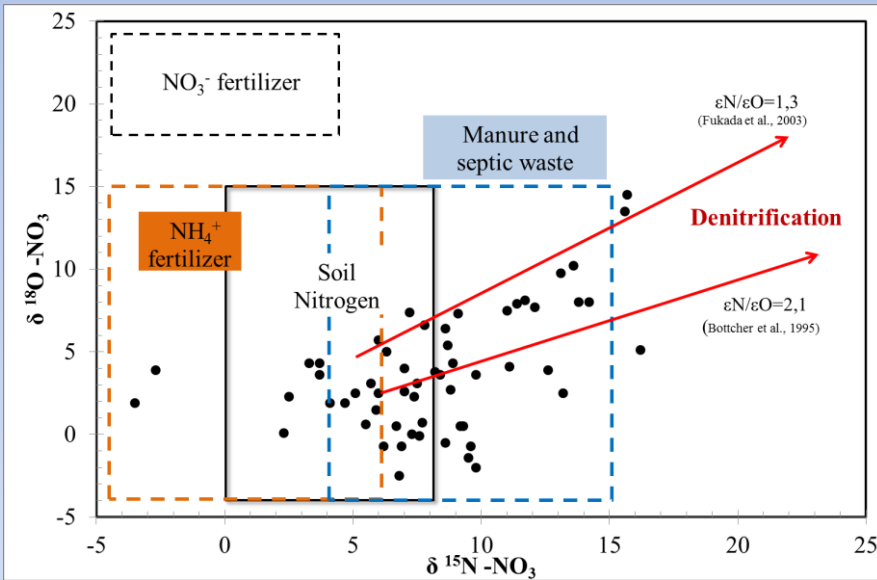
4. Discussion

Occurrence of N₂O in groundwater

Environmental isotopes coupled with hydrochemistry data

Identify origin of nitrogen

Processes that produce/consume N₂O



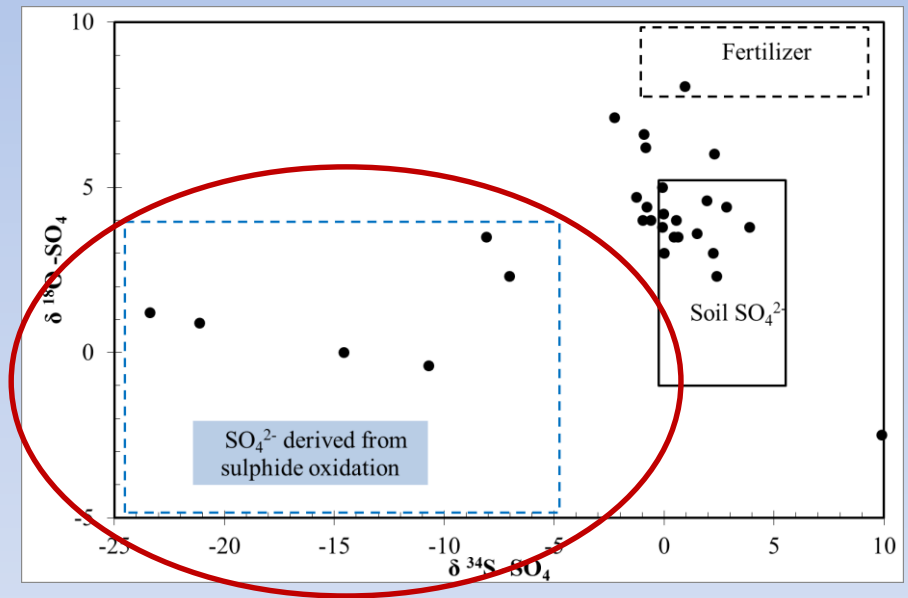
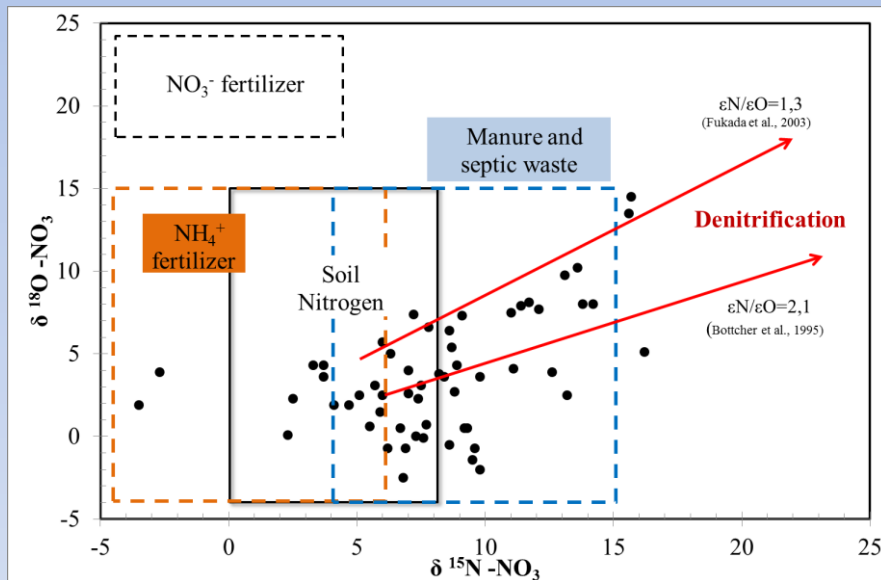
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Autotrophic denitrification (Pyrite as electron donor):



5. Conclusions

1. Groundwater of Walloon Region is oversaturated in CO_2 and N_2O relative to the atmospheric concentrations.
2. Preliminary results show that N_2O is produced by nitrification and denitrification and also consumed by denitrification.
3. Most favourable conditions for the accumulation of N_2O in groundwater seems to occur when NO_3^- is available and at medium oxygen concentrations.

Future work :

Integrate all the data available (environmental isotopes)
Investigate the occurrence of CO_2 and CH_4

Thank you for your attention

Acknowledgements. A. Jurado gratefully acknowledge the financial support from the University of Liège and the EU through the Marie Curie BeIPD-COFUND postdoctoral fellowship programme (2015-2017 from FP7-MSCA-COFUND, 600405).

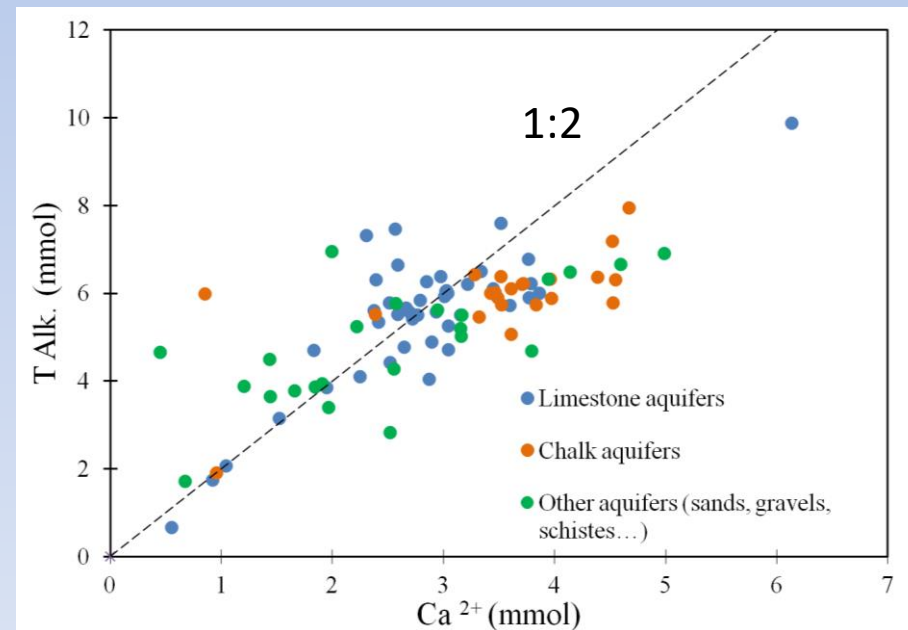
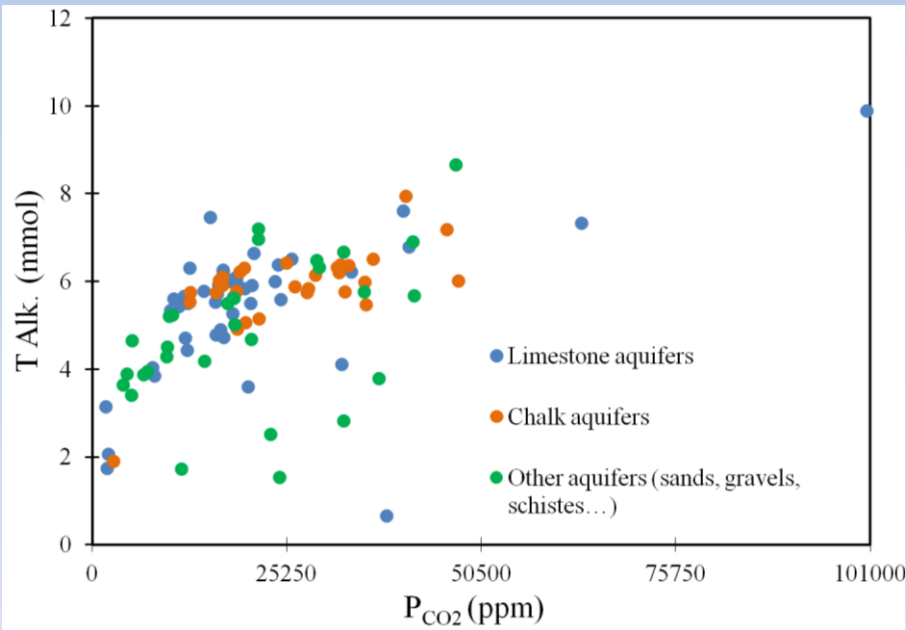
4. Discussion

Occurrence of CO₂ in groundwater

High PCO₂ in groundwater

Water percolating through the soil becomes enriched in CO₂

High PCO₂ can contribute to the dissolution of carbonate formations



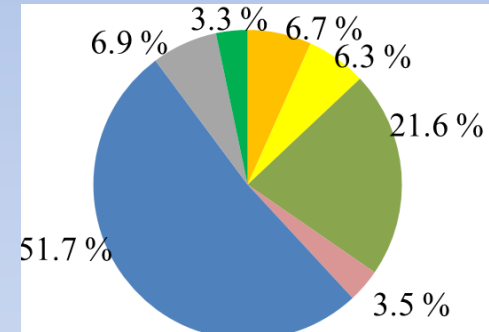
2. Methodology

Walloon Region (Belgium)

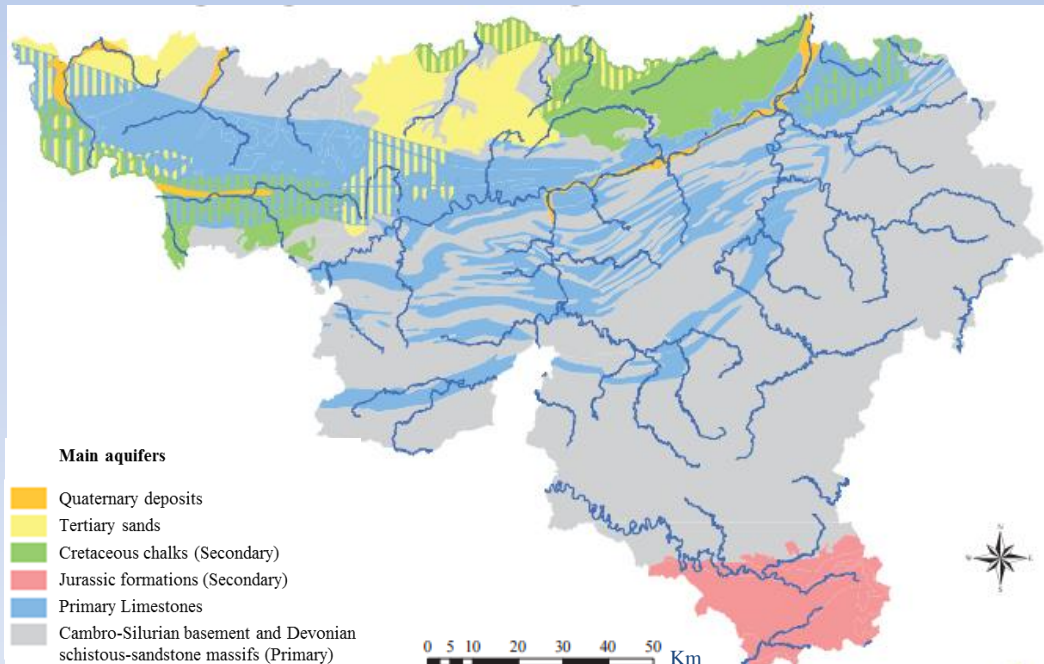
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Groundwater abstraction (% , 2012)



Main aquifers



Land use

