

Impact of transfer time on trends in nitrate concentrations in mainland France.

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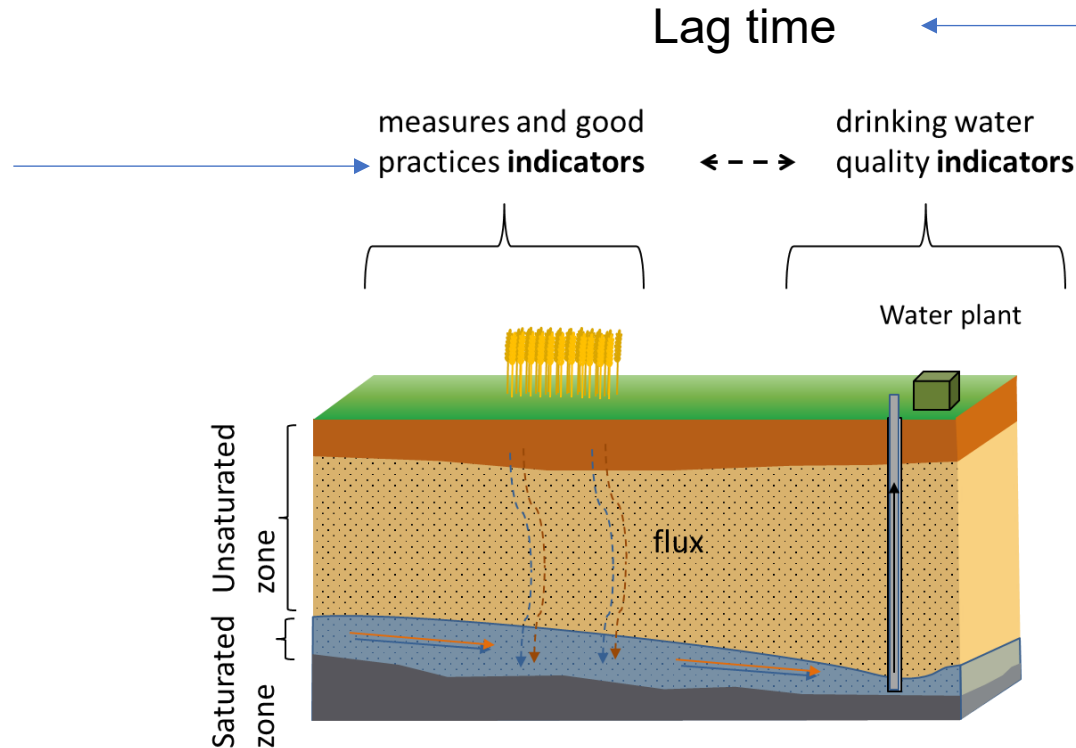
Geoscience for a sustainable Earth

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Background and challenges

Despite the fact that programmes of measures have been implemented for several years to reduce water contamination by nitrates, evaluate their effectiveness remains complex due to the interactions between farming practices, climate, and geological features.

The first challenge to overcome is that farming practices data are generally difficult to obtain



The second challenge to overcome is the delay between farming practice data and water quality data

Simplified Method for Estimating Nitrate Transfer Times

To address these challenges, we tested a simplified method to estimate nitrate transfer times using an analysis of dominant rock types and hydrogeological models at the groundwater body level.

This method does not require agricultural data.

Two steps :

- **Transfer Time Calculation**

During the first step, we estimated nitrate transfer times with a method that requires minimal data, enabling a nationwide application.

- **Comparison with Trends**

During the second step, we analyzed transfer times in relation to trends in groundwater nitrate concentrations.

Nitrate Transfer Time Calculation

Concept

- The method determines an average transfer rate at which nitrate moves through the unsaturated zone.
- The following equation is used to calculate a transfer time:

$$T_{\text{transfer}}(z) = E_{\text{zns}}(z) / V_{\text{transfer}}(z)$$

With :

$T_{\text{transfer}}(z)$: Transfer time in years

$E_{\text{zns}}(z)$: Average thickness of the unsaturated zone

$V_{\text{transfer}}(z)$: Transfer velocity

Input data

- Average thickness of the unsaturated zone
- Transfer velocity

Nitrate concentration trend

Concept

- The statistical tool HYPE was used to calculate nitrate concentration trends.
- This R-based tool is designed to characterize the evolution of time series of groundwater contaminant
- The tool automatically calculate statistics using the non-parametric Mann-Kendall test.

Period

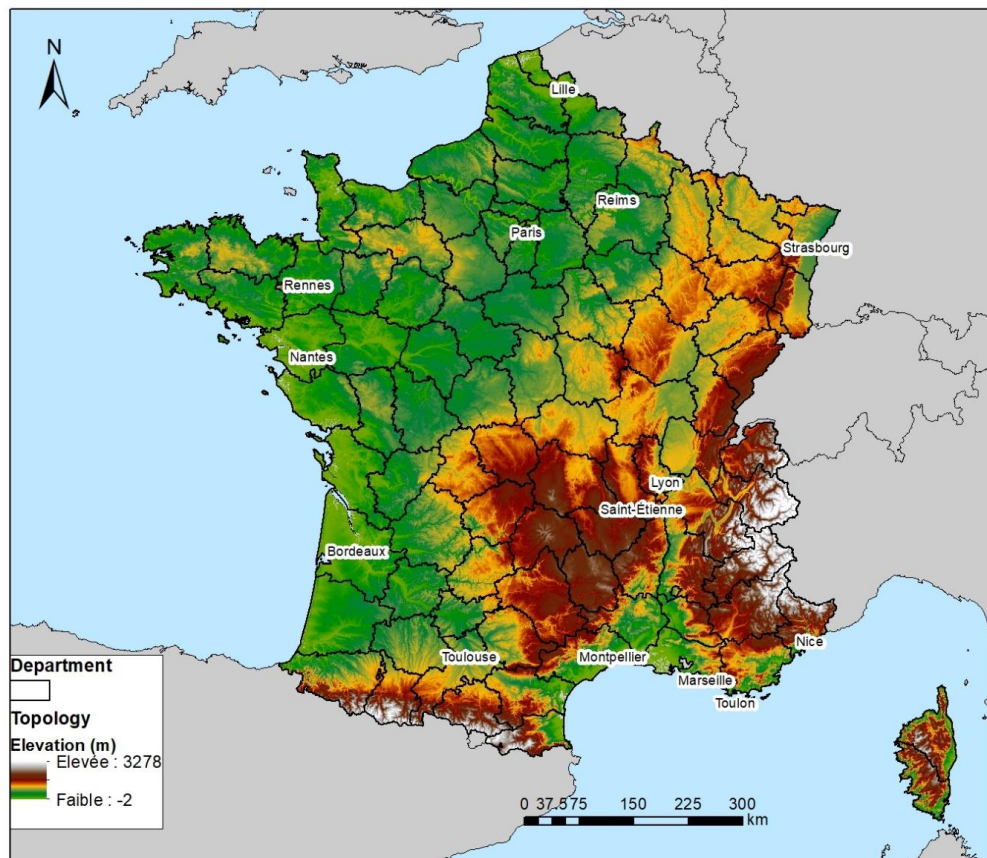
- The study includes data available from 01/01/2000 to 01/01/2023.

Input Data

- The calculation is performed for all series with at least 15 data points.
- The concentration data were obtained from the French geological database (Ades)

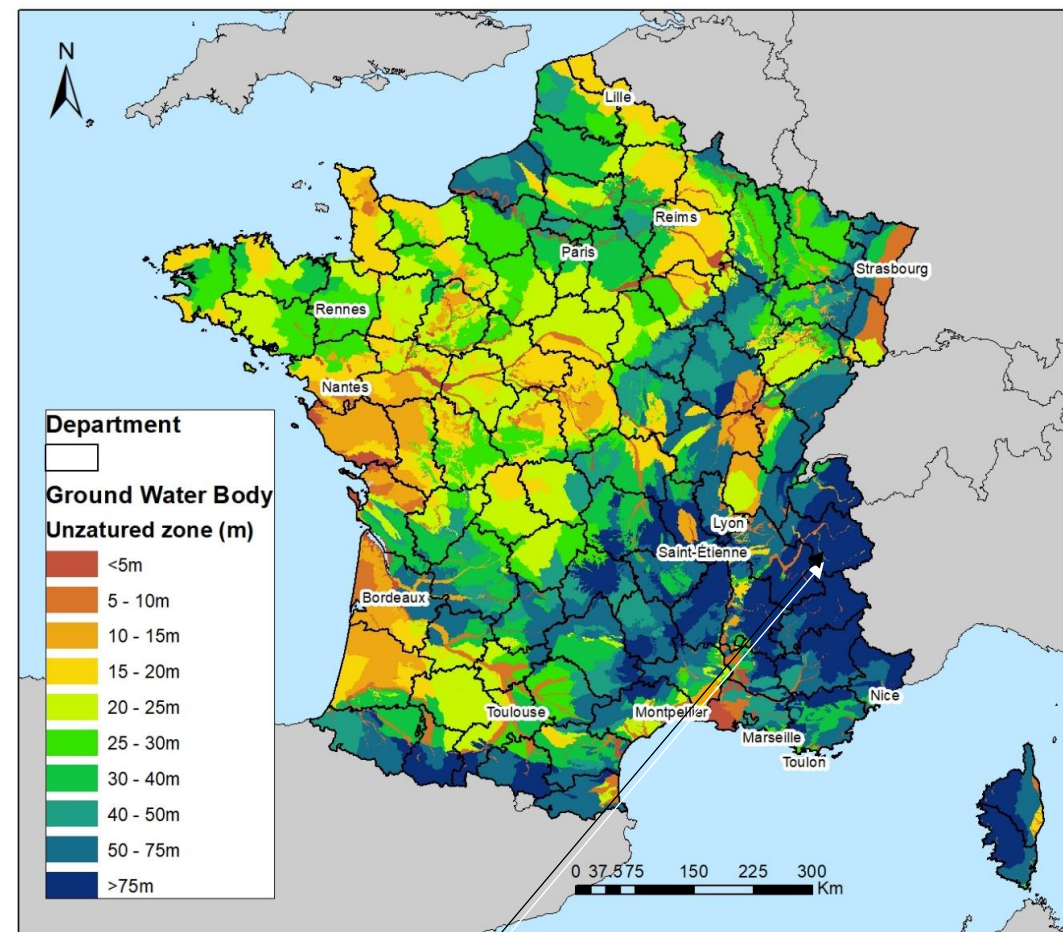
Unsaturated zone thickness

- DEM map



The unsaturated zone thickness was calculated as the difference between average groundwater levels and the ground elevation

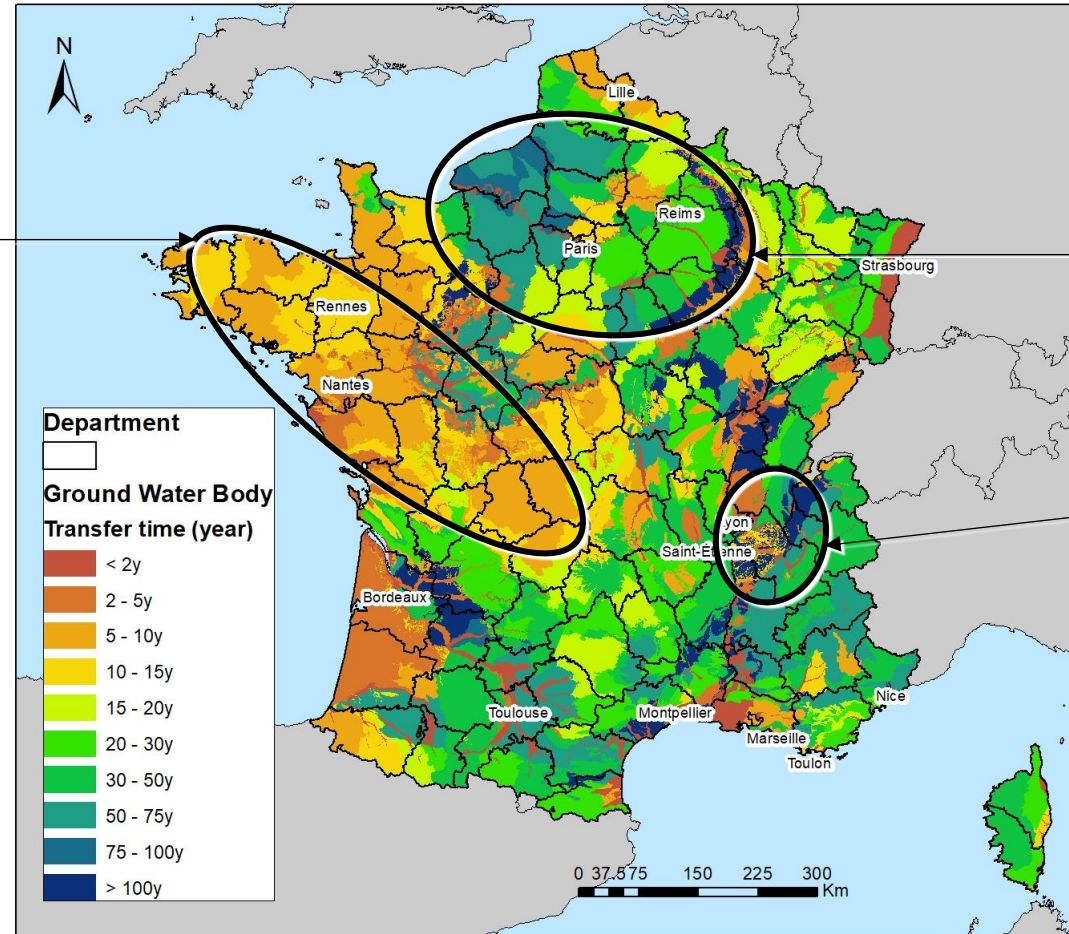
- Unsaturated Zone thickness map



The calculated value does not necessarily hold true everywhere in the groundwater body, particularly in mountainous regions

Transfer time map

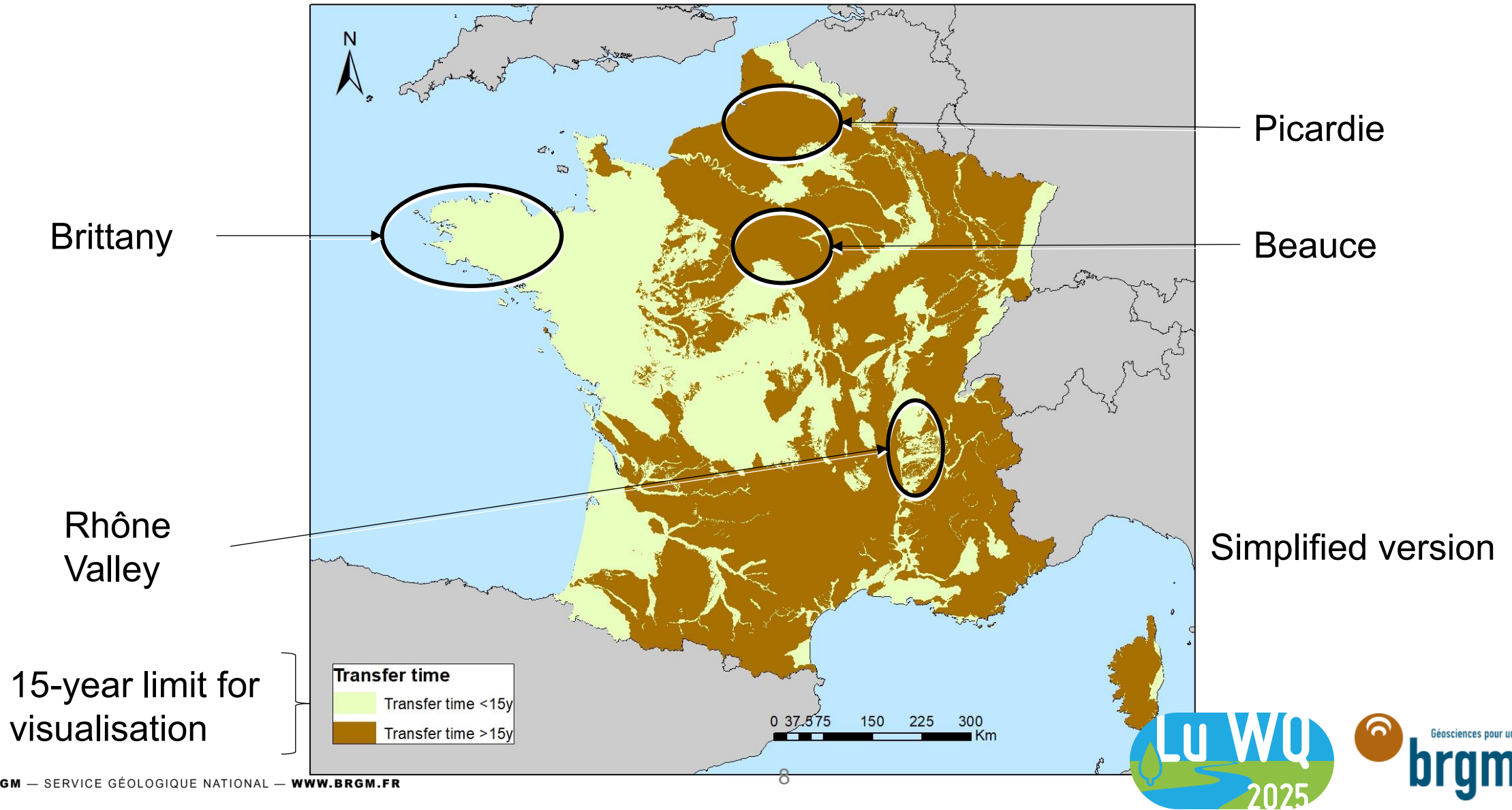
Transfer times are generally faster in western France



Transfer times tend to be slower in the north-east of France and around Paris

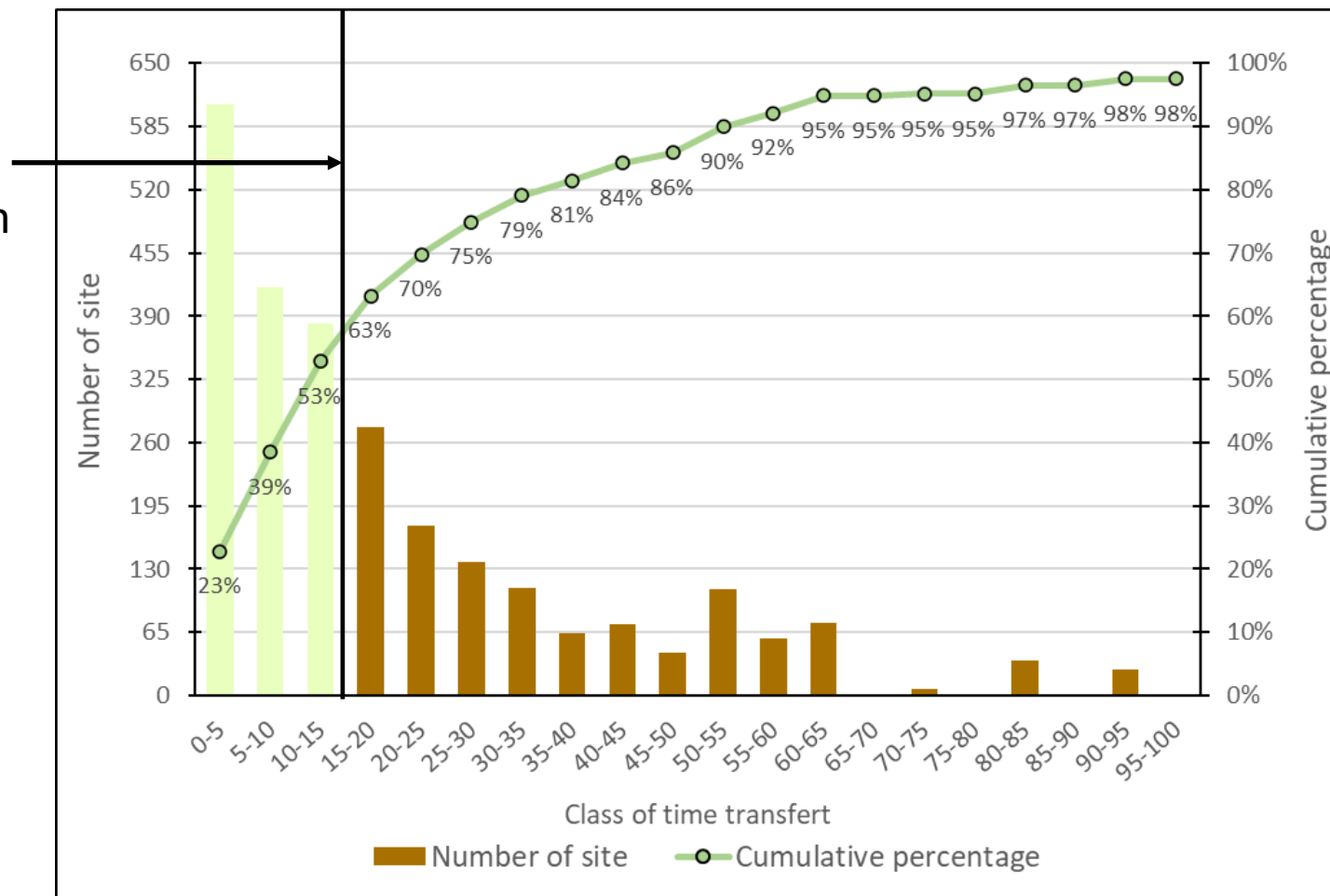
Significant variations of transfer time

Transfert time map



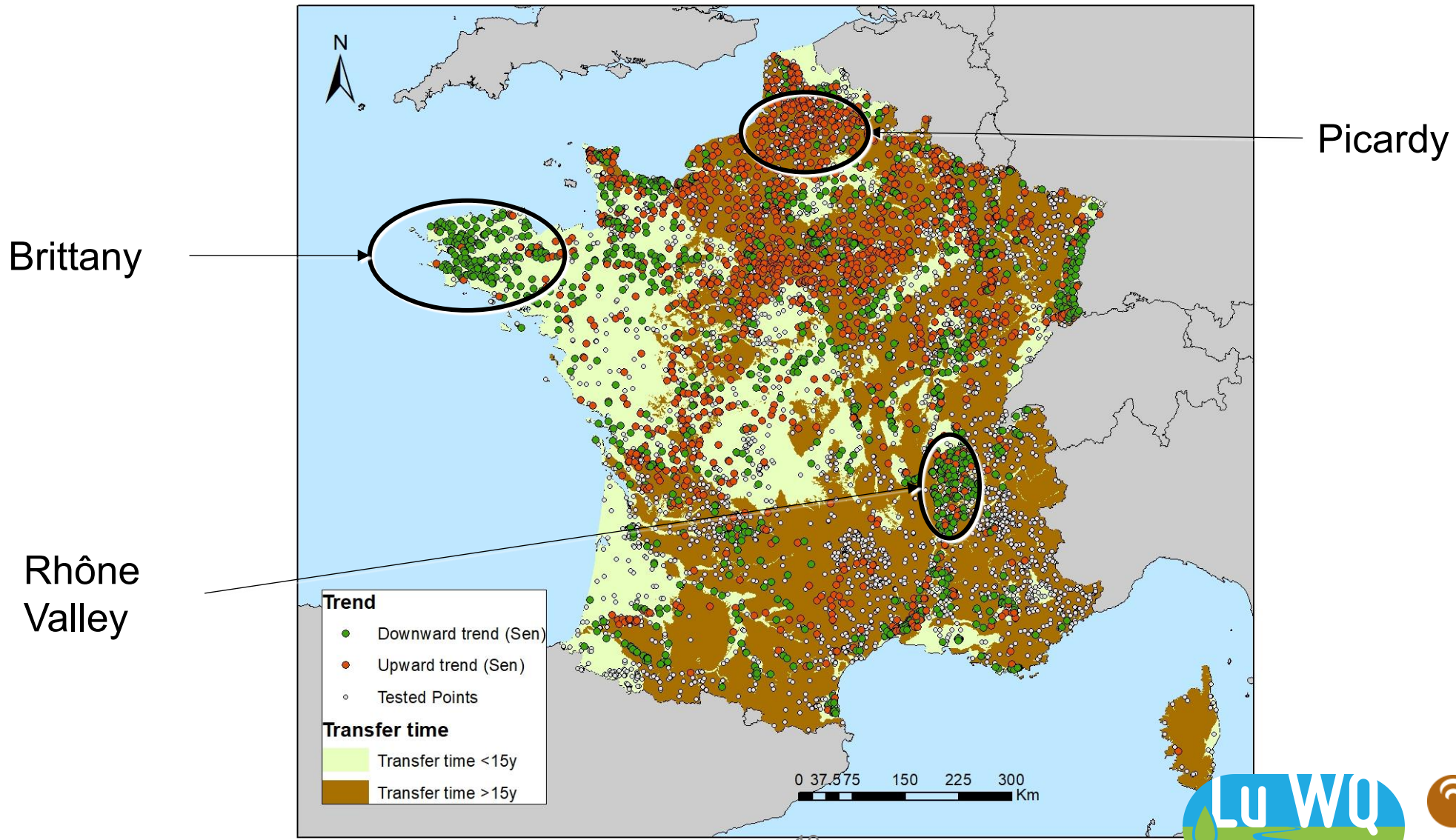
15 years limit justification

Half of the sites are situated in a groundwater body with a transfer time below 15 year



Distribution of the number of sites (monitoring well) by classes of time transfer

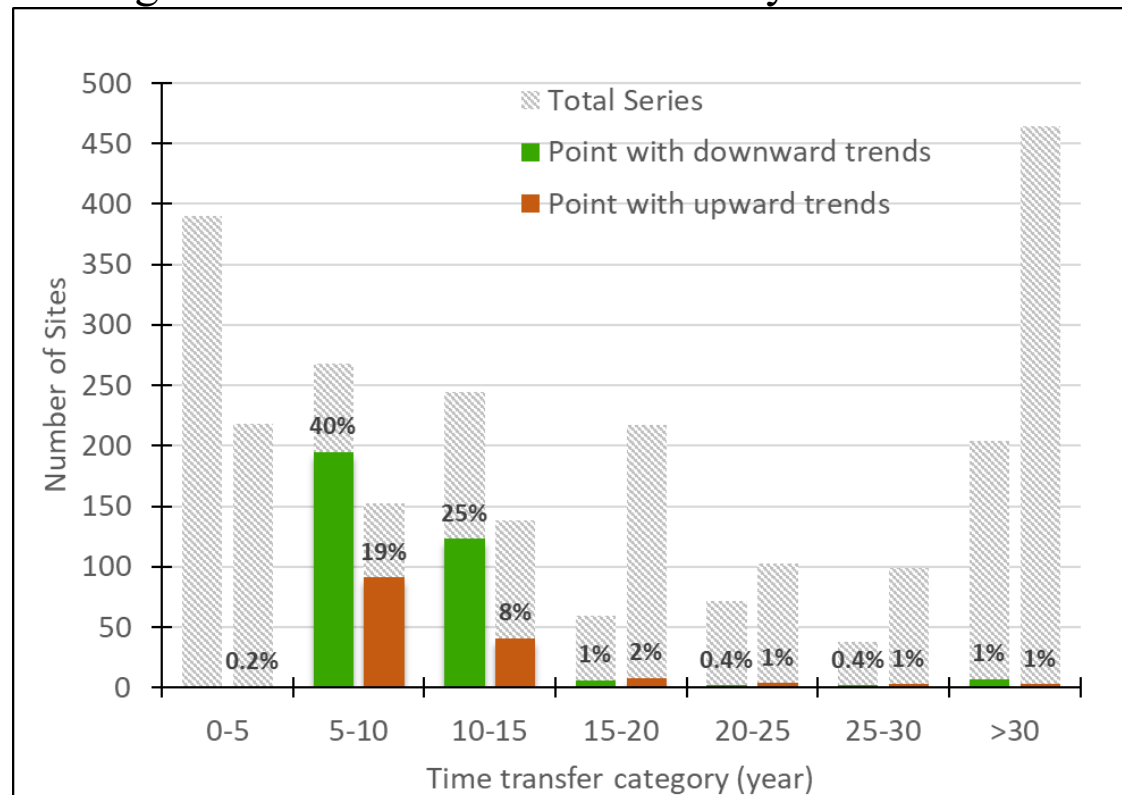
Comparaison map – spatial repartition



Relationship between trend and transfer time

groundwater bodies dominated by hardrock

Transfert time category	Frequency of point with downward trends	Frequncy of point with upward trends	
0-5		0.2%	
5-10	40%	19%	
10-15	25%	8%	
	65%	27%	93%



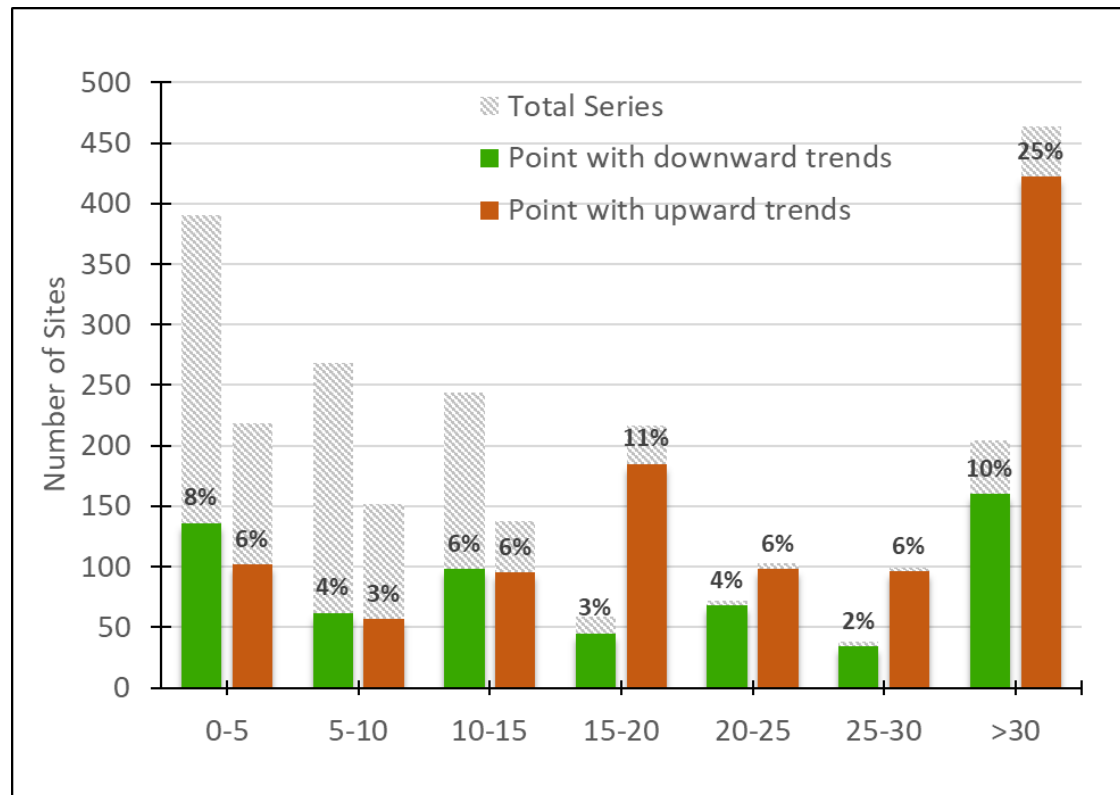
Transfert time category	Frequency of point with downward trends	Frequncy of point with upward trends	
15-20	1%	2%	
20-25	0.4%	1%	
25-30	0.4%	1%	
>30	1%	1%	
	3%	4%	7%

65% are oriented downward

Relationship between trend and transfer time

groundwater bodies dominated by sediment

Transfert time category	Frequency of point with downward trends	Frequency of point with upward trends	
0-5	8%	6%	
5-10	4%	3%	
10-15	6%	6%	
	18%	15%	33%



Transfert time category	Frequency of point with downward trends	Frequency of point with upward trends	
15-20	3%	11%	
20-25	4%	6%	
25-30	2%	6%	
>30	10%	25%	
	19%	48%	67%

48% are oriented upward

Conclusion

- This study propose a simple method for estimating nitrate transfer times through the unsaturated zone.
- Maps have been created to represent transfer rates according to different time classes
- The method allows for analysis without requiring precise data on agricultural practices, thus providing an alternative for assessing the environmental impact of agriculture.
- The results show that points with downward trends are more frequent in the west of France, while points with upward trends are mainly located in the north and east, reflecting the intrinsic properties of the groundwater bodies.

More details and additional results on this study can be found in the following article: **Surdyk N., Gourcy L., Pinson S., 2025. Geographical disparities in nitrate trends: Mapping transfer times in French aquifers, *Groundwater for Sustainable Development*. 30, Article 101467.**

<https://doi.org/10.1016/j.gsd.2025.101467>