Simplified hydrological and nitrogen transfer modeling : the case of Orgeval (France) and Porijõgi (Estonia)

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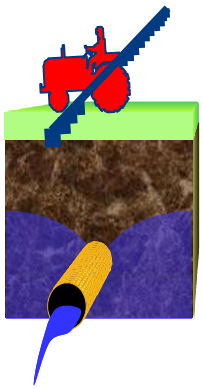
Context and objective

Problem: surface water pollution (nitrate transfer) from agricultural lands.

Regulation: Water Framework Directive (2000).

"Reduce water pollution by nitrates from agriculture"

Modelling : Characterization of main processes of nitrate transfer



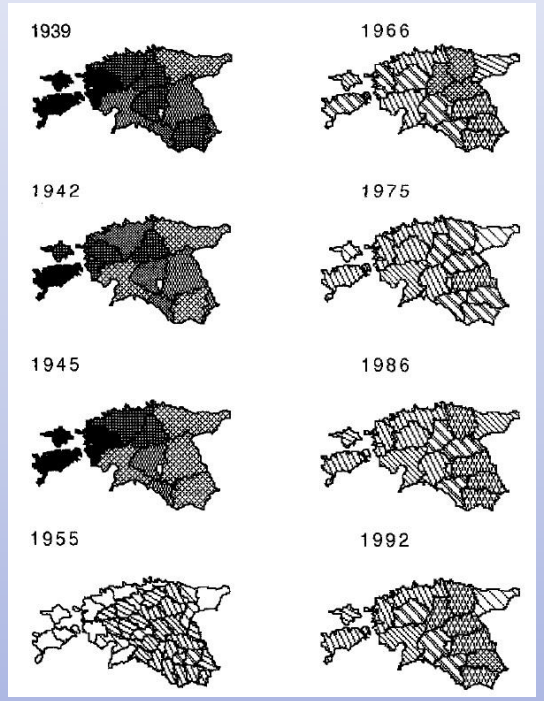
Mitigation solution like artificial wetland

Context and objective

Landuse variability vs semi-distributed models

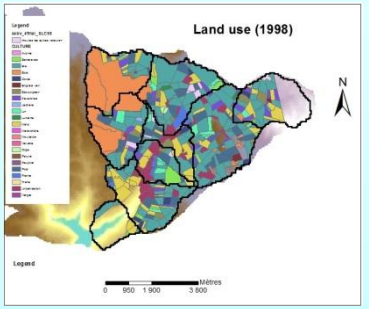
How to represent the agricultural mosaic in simplified modelling approach?

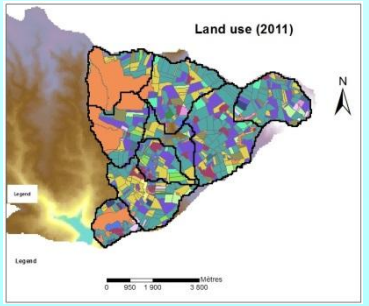
- Socio-Political Changes
Porijõgi (Estonia) (Mander, 1994)



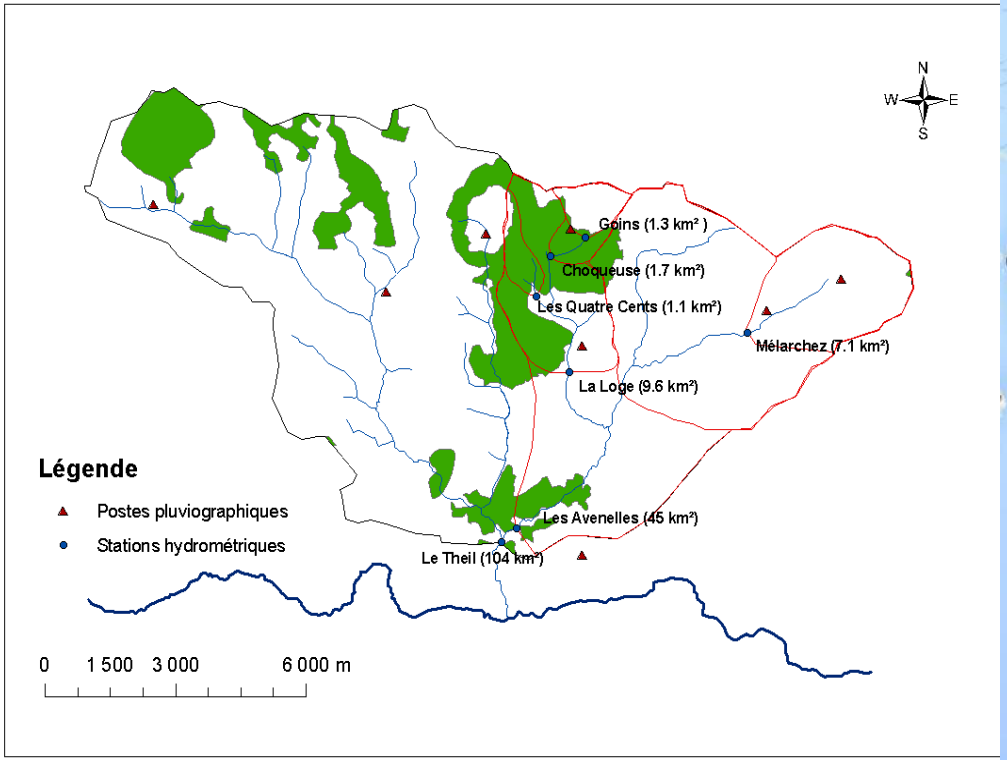
Landuse Change and modelling

- Crops rotation
Orgeval (France)

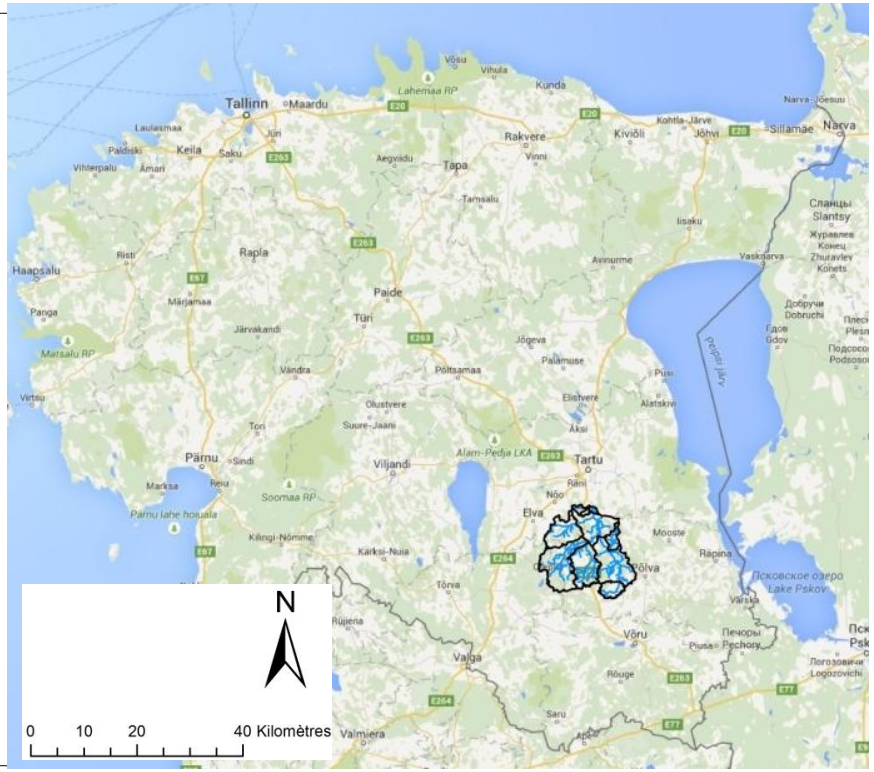




Study sites



Orgeval (France)



Porijõgi (Estonia)

Study sites : Orgeval Catchment (France)

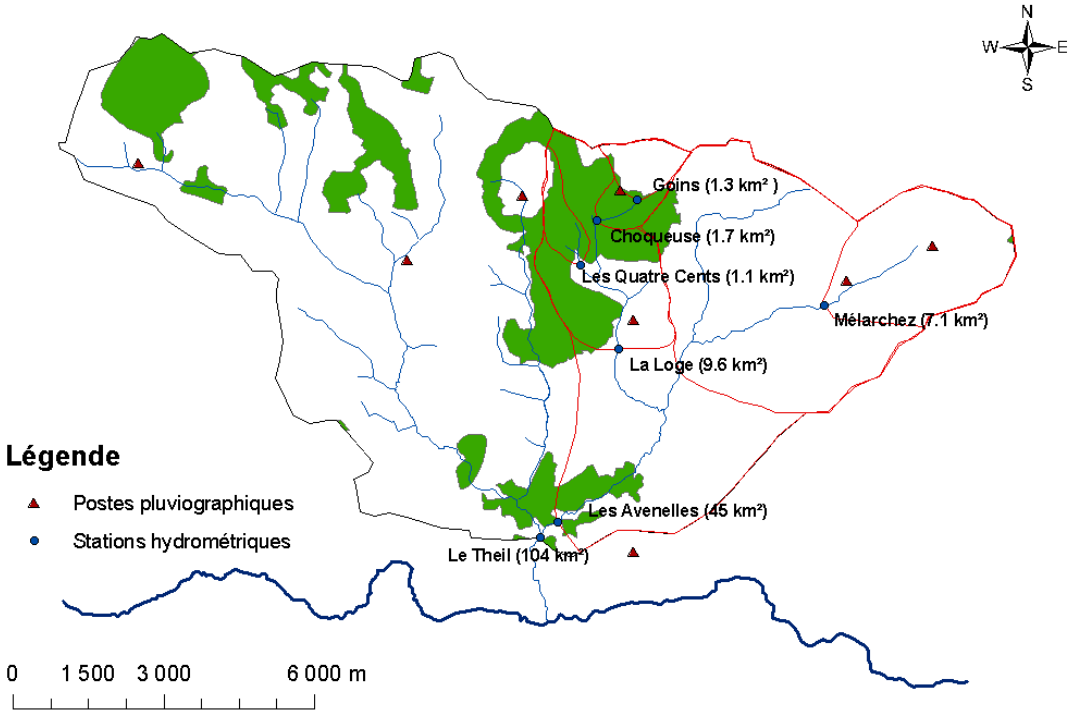
Orgeval catchment

Surface : 104 km²
Mean discharge : 0.581 m^3/s

Agriculture : 82% total area
75% artificially drained

Avenelles sub-catchment

Surface : 45 km²
Mean discharge: 0.184 m^3/s

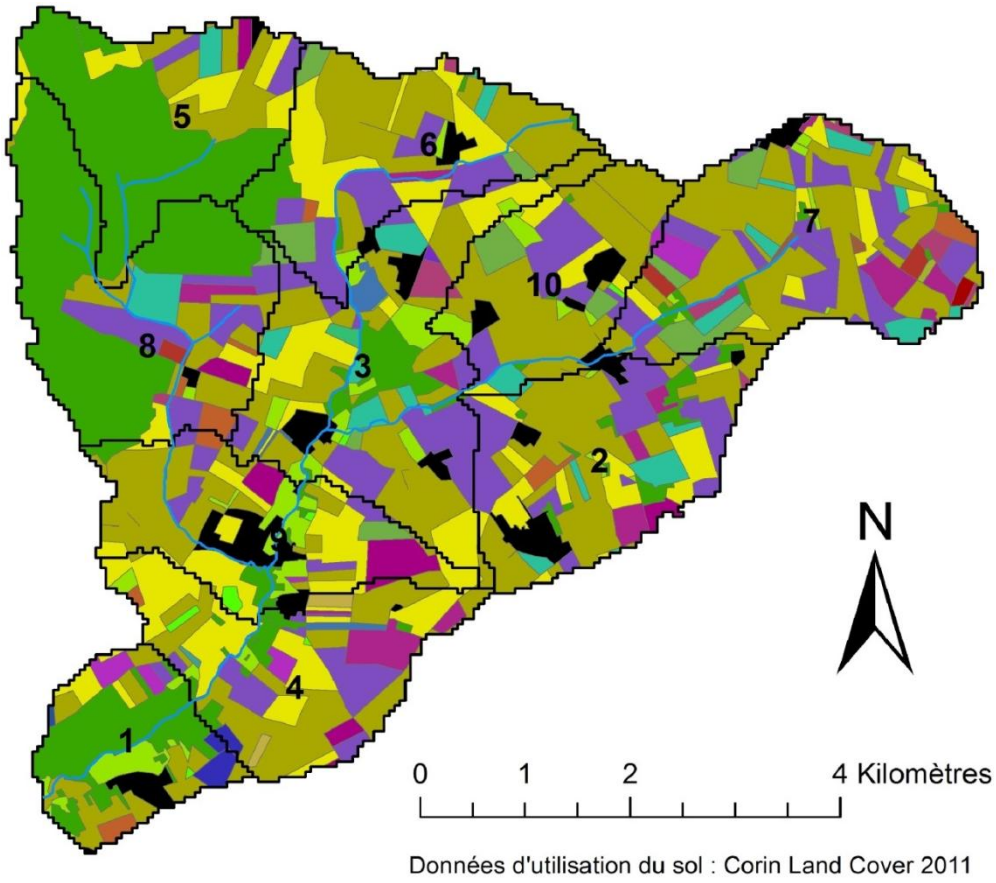


http://gisoracle.irstea.fr/

Landuse (crops rotation)

Landuse map 2011

- wheat: 33%
- Forest: 18%
- corn: 13%
- Field beans: 13%

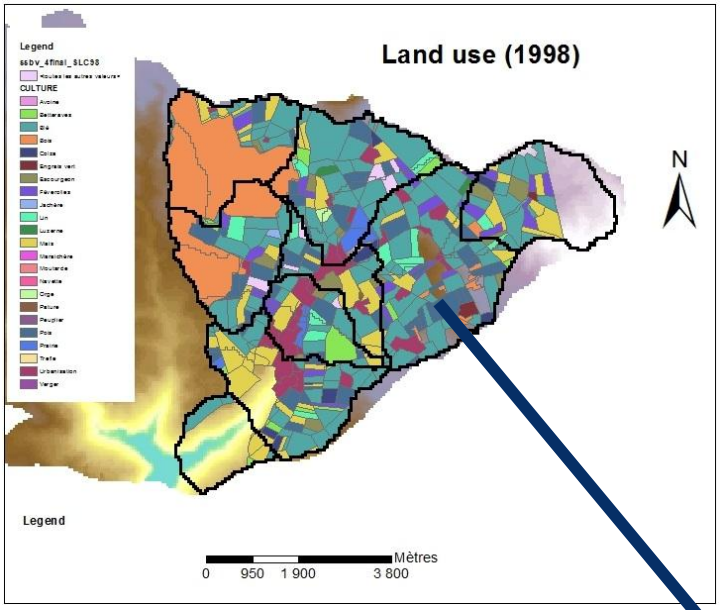


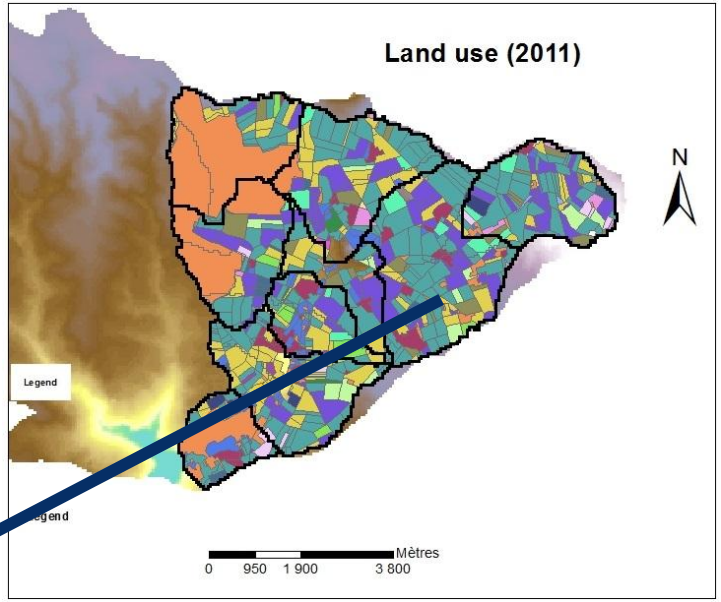
- Depends on agricultural system type (land use)
- Time variable

Nitrogen transfer modeling : Hydrological semi-distributed model

A) Landuse change and Modeling

Nitrogen transfer modeling :
Crops rotation from 1998 to 2011



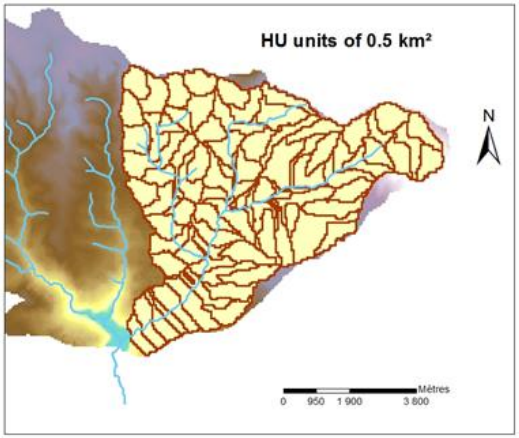


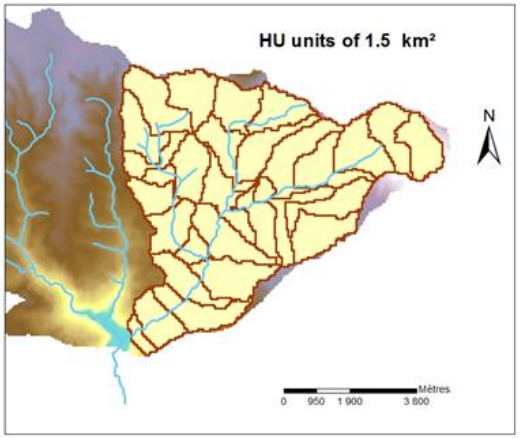
Calculate the Ratio $\frac{A_{Crop\ area}}{A}$ for each sub-catchment and per year.

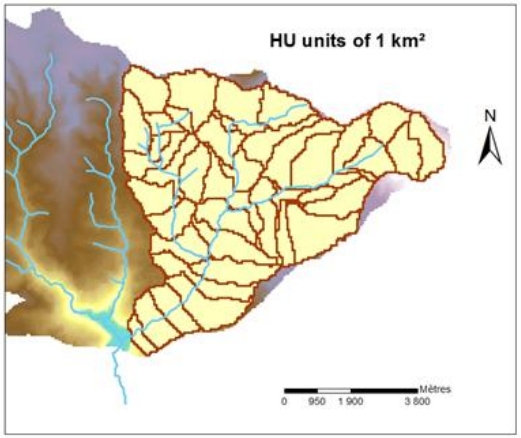
Crops variation : $\frac{crops\ number\ per\ sub-bassin}{total\ crops}$

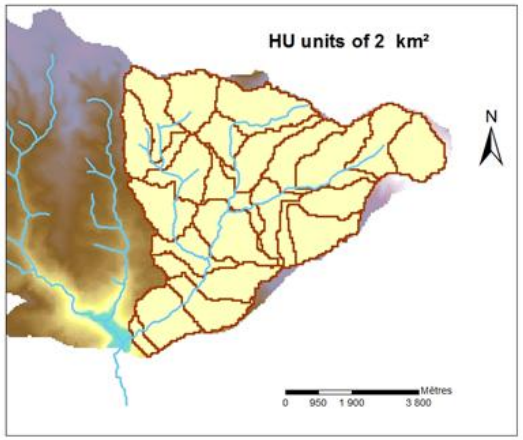
➔ Mean variation

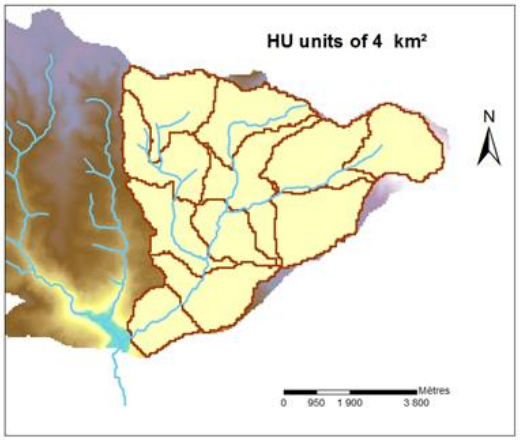
Spatial distributed model: hydrological units (sub-catchment)

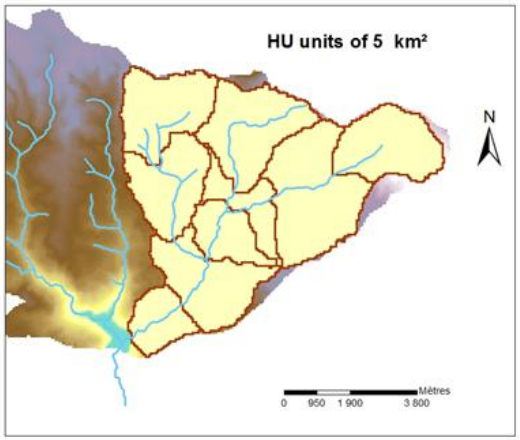






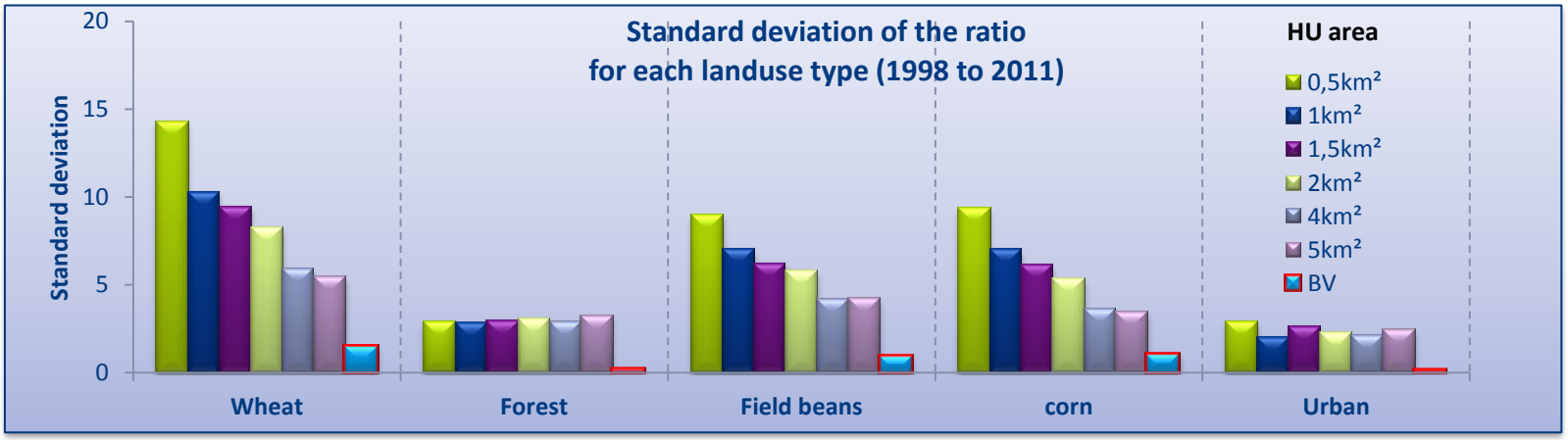


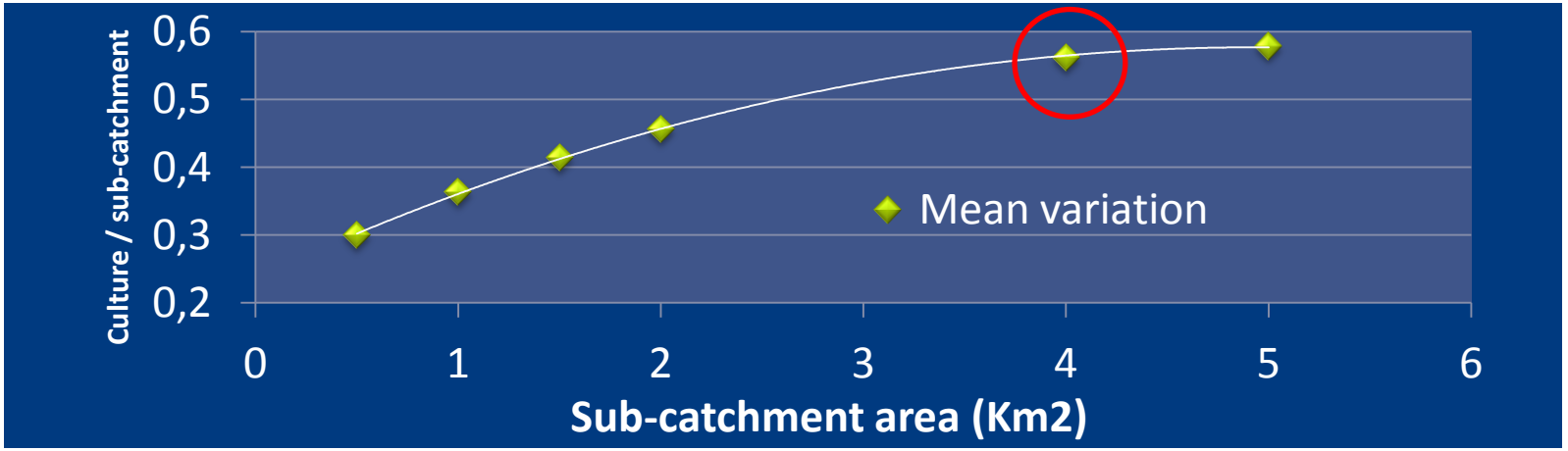




➔ Mean variation of the ratio $\frac{A_{Crop\ area}}{A}$ for each sub-division

Spatial distributed model: hydrological units (sub-catchment)





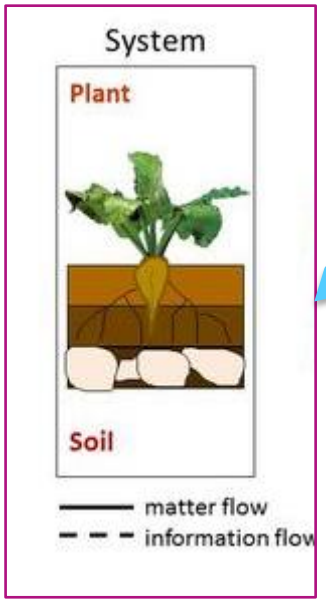
Mean crops variation for each subdivision

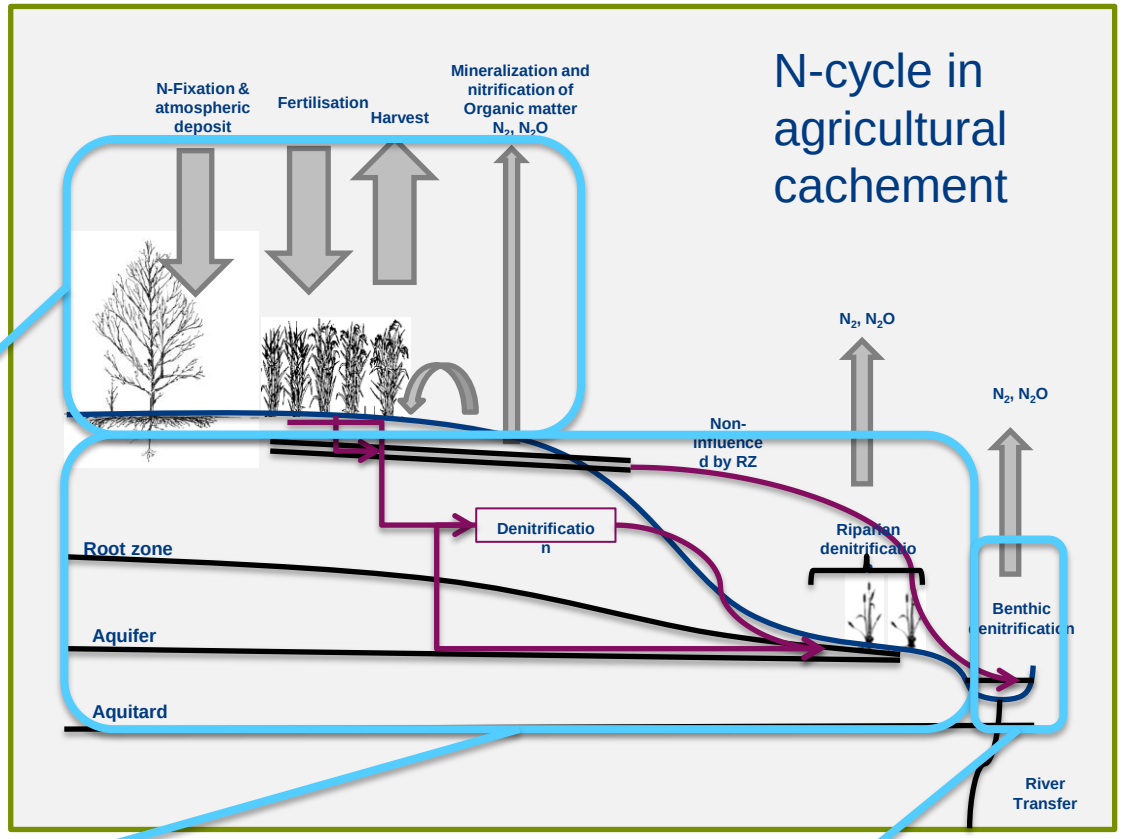
Nitrogen transfer modeling : Hydrological semi-distributed model

B) Nitrogen input data

Nitrogen transfer modeling : N-cycle at the cachement scale

Crop model





Soil transfer model

- Numerical model : (Richards equation + transport model)
- Conceptual model (reservoir model, …)

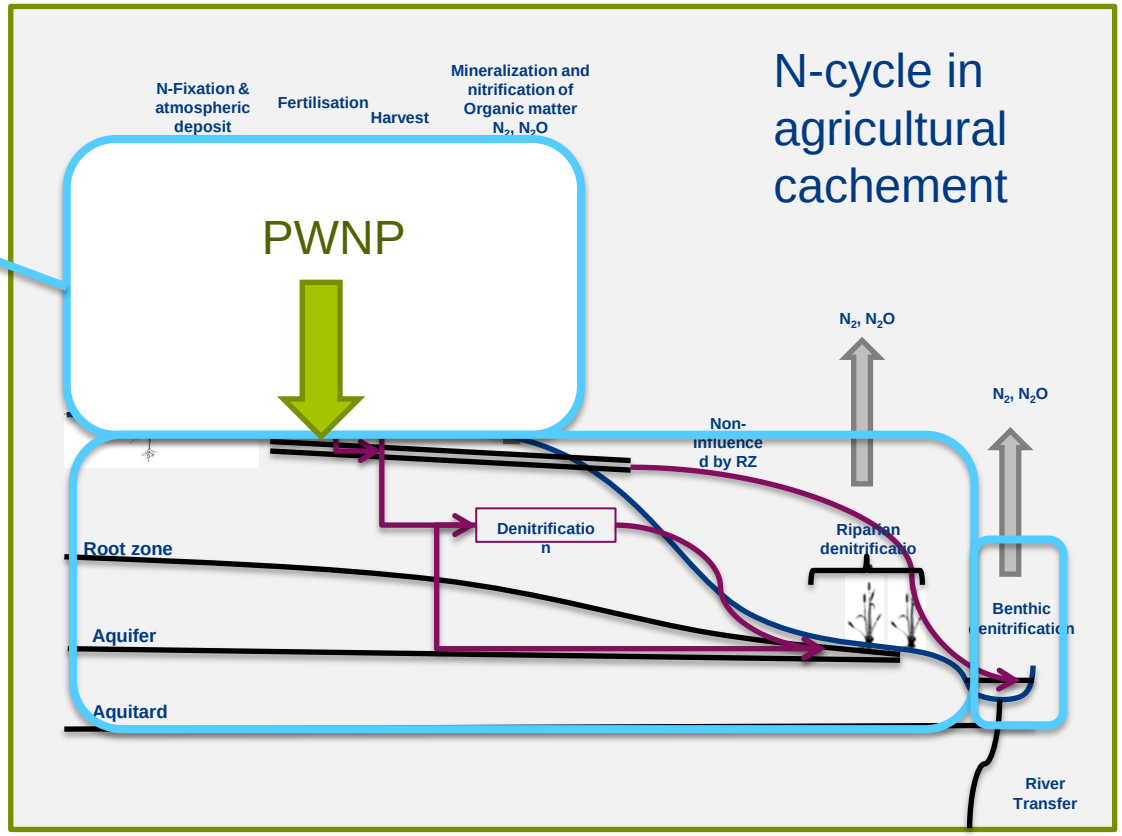
River transfer model

- Numerical model : (Saint-Venant + transport model)
- Conceptual model (Muskingum model, …)

Nitrogen transfer modeling : N-cycle at the catchment scale

PWNP (Pre-winter Nitrogen Pool)

- Crops model
- Measurement : Porous ceramic cups, soil sampling
- Nitrogen balance : The difference between input (fertilization, …) and output (harvest) Mode

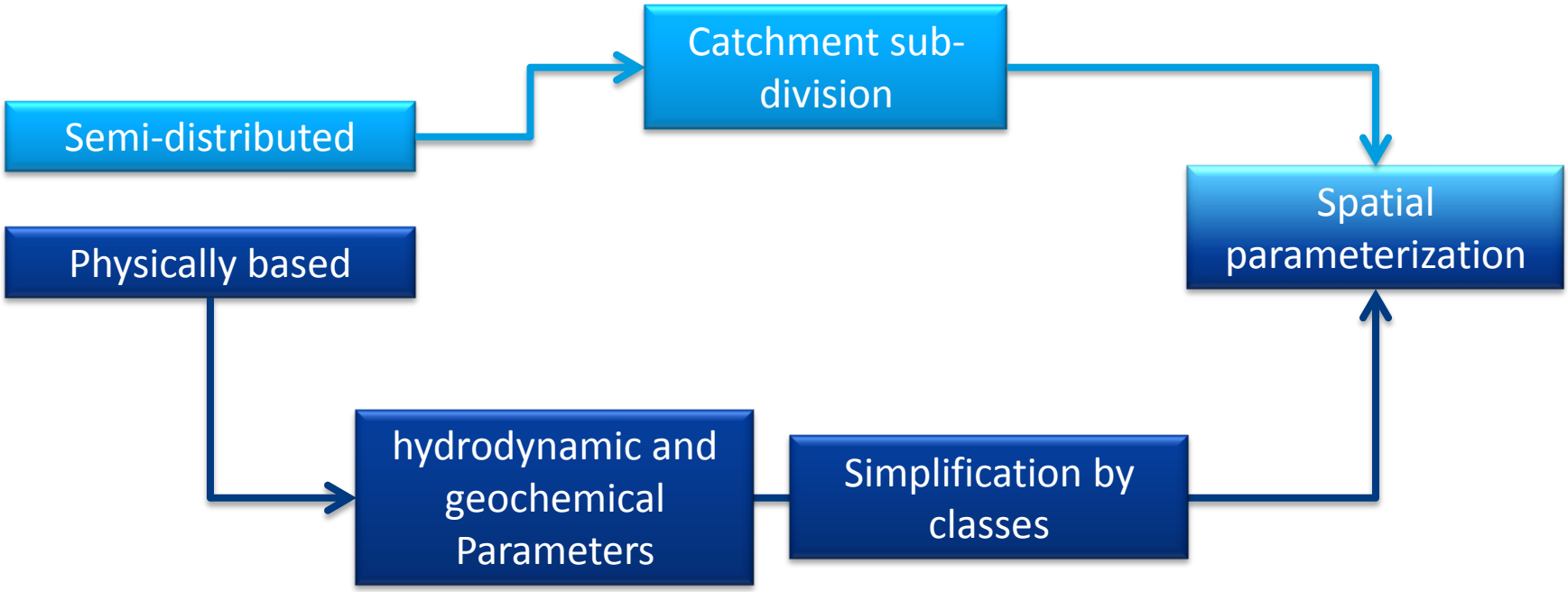


Assumpotion: 90 % of the annual nitrate flux is controlled by leachate PWNP (Arlot, 1999; Magasan, 1991, Tournebize 2008)

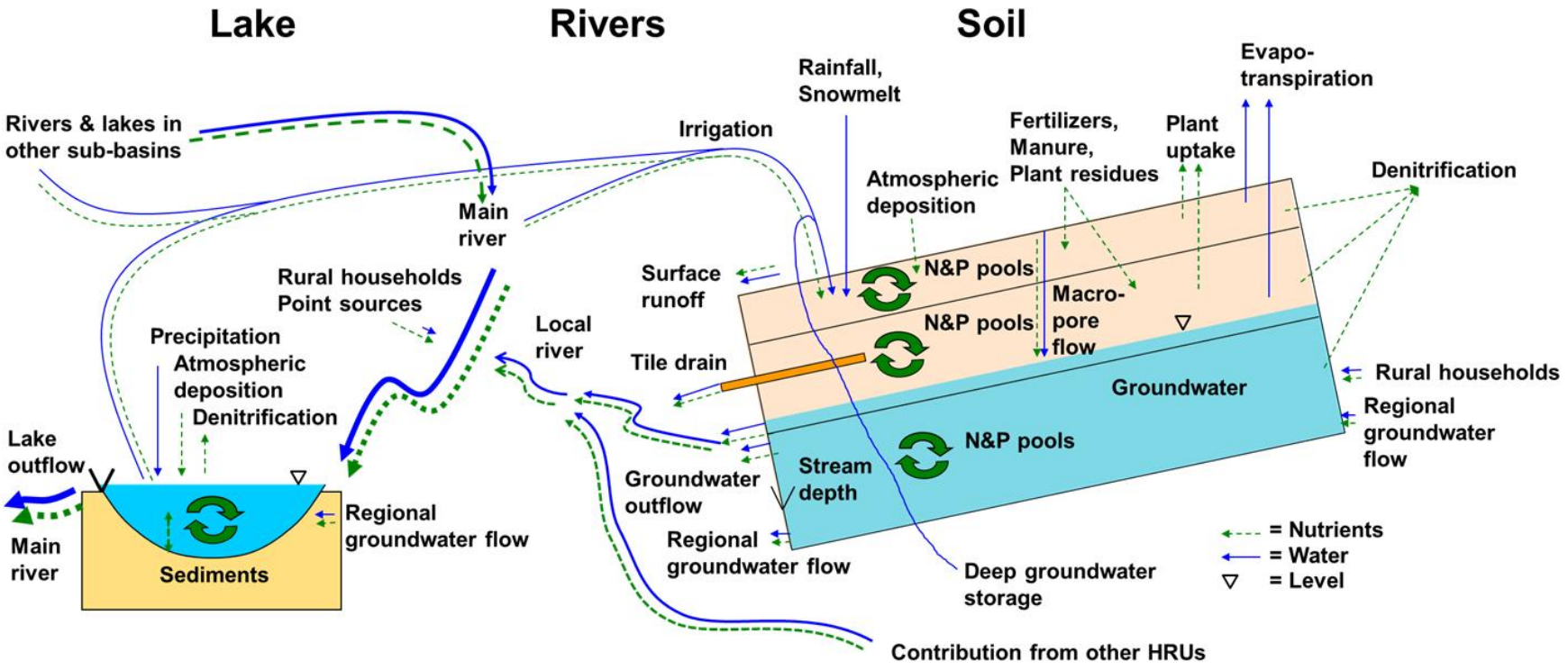
Nitrogen transfer modeling : Hydrological semi-distributed model

C) Hydrological and nitrogen transfer simulations

Spatial distributed model: Hype model (Arheimer et al., 2008)



HYPE model



Blue lines : flow pathways

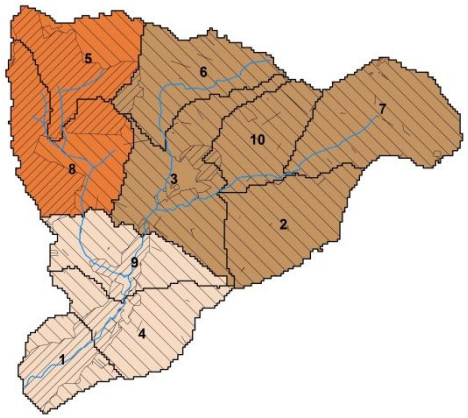
Green lines : nitrogen transfer

➔ **Nitrogen transfer requires a good calibration of hydrological model**

Hype model: Fortran executable, Excel interface

HYPE model: input data (Arheimer et al., 2008)

Soil Landuse Classes (SLC)



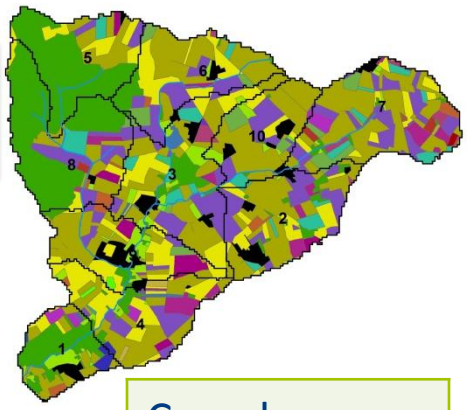
6 soil type

54 classes

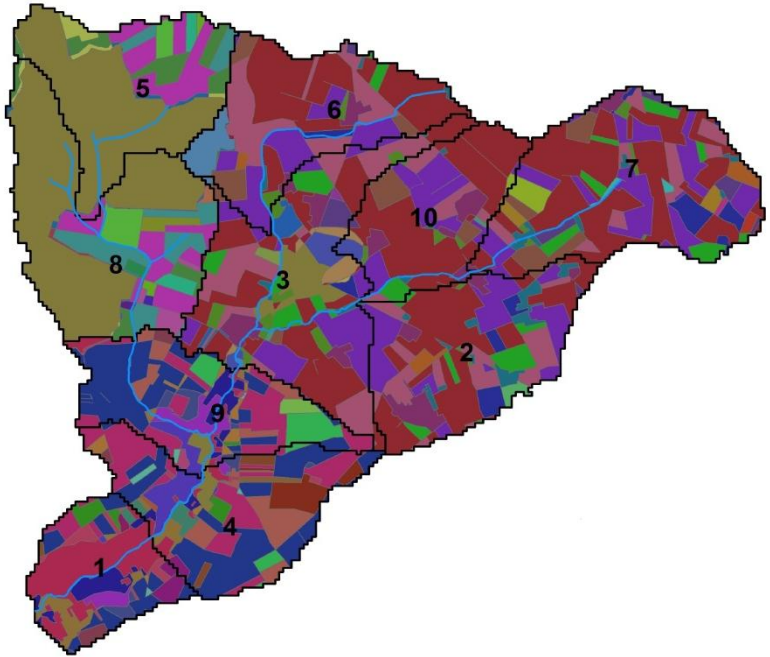
9 landuse type

Simplification

30 SLC



Drained	Non drained
N-E	N-E
N-O	N-O
S	S



- Cereals
- Forest
- Rape
- Lin
- Alfalfa
- Corn
- Pastures
- Urban
- Others

HYPE model: Input data

Hydrology

- Rainfall and PET
- Discharge at the outlet aux exutoires de sous-bassins versants jaugés

Pour la géochimie:

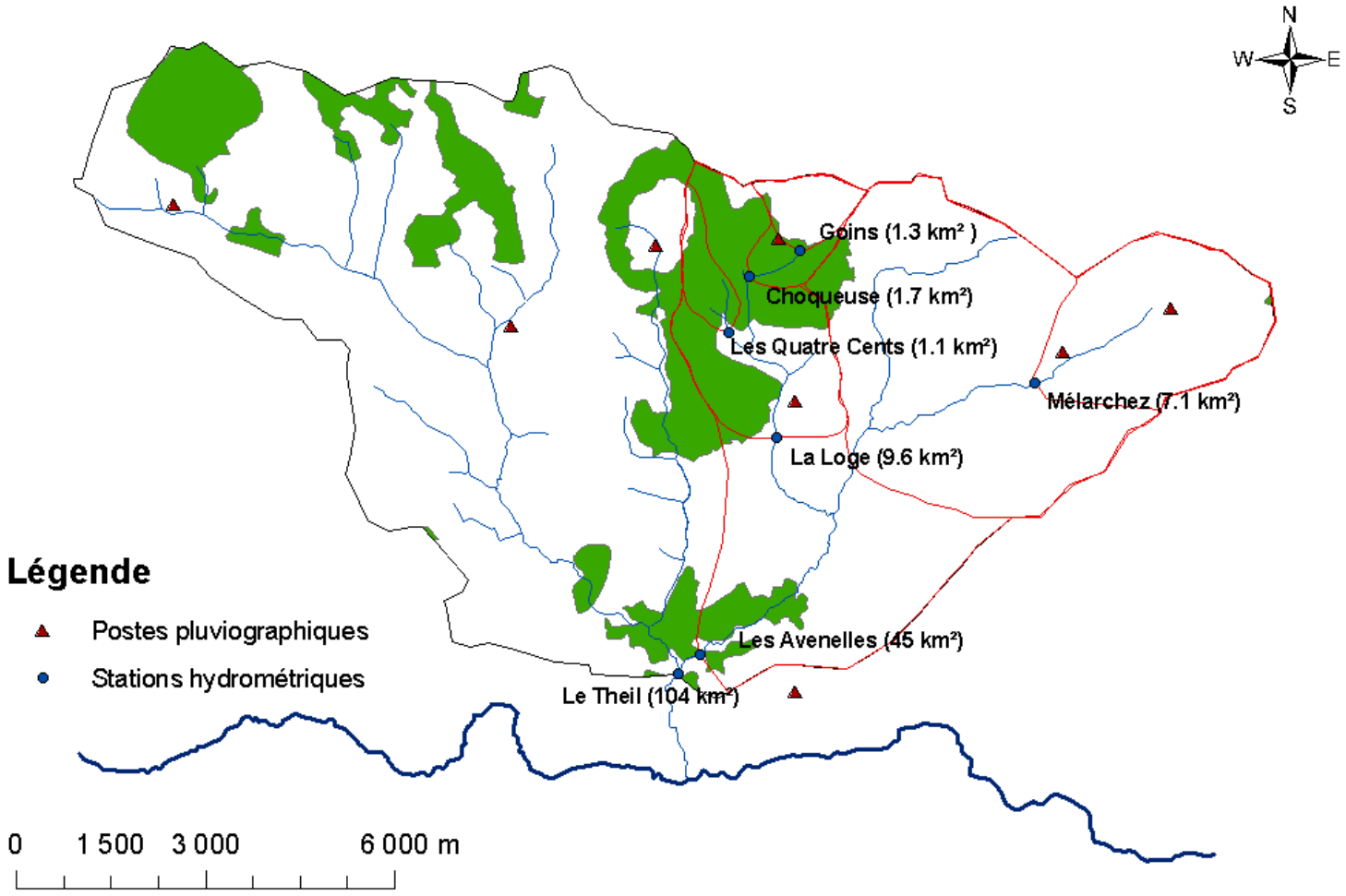
- Le Reliquat Entrée-Hiver (REH) : Quantité d'azote minéral présente dans le sol après récoltes (avant l'hiver)

  ➔ Relativement facile à acquérir (AquiBrie)

  (par rapport à une simulation agronomique complète)

- Les taux de dénitrification dans le sol et en rivière

C.1) Hydrological simulations

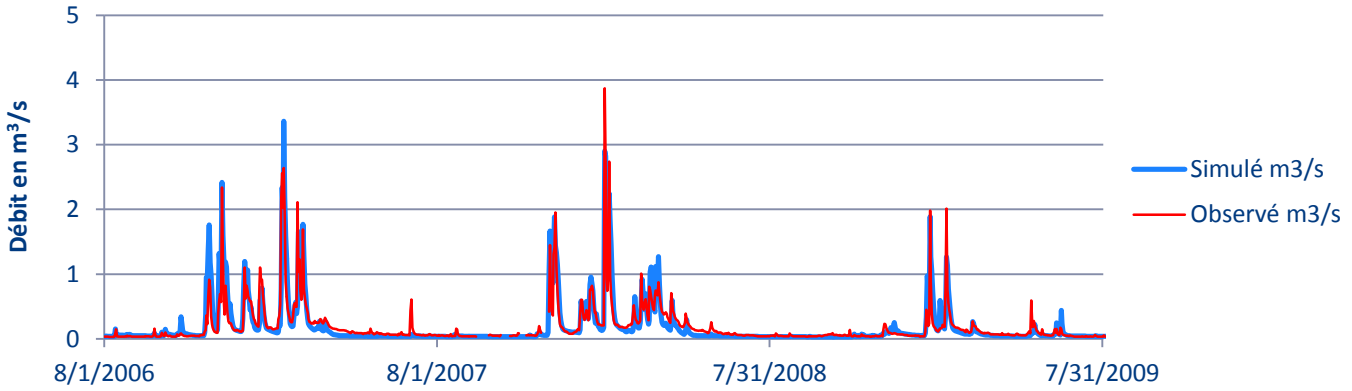


C.1) Hydrological simulations : calibration

Les Avenelles

Nash : 0.742

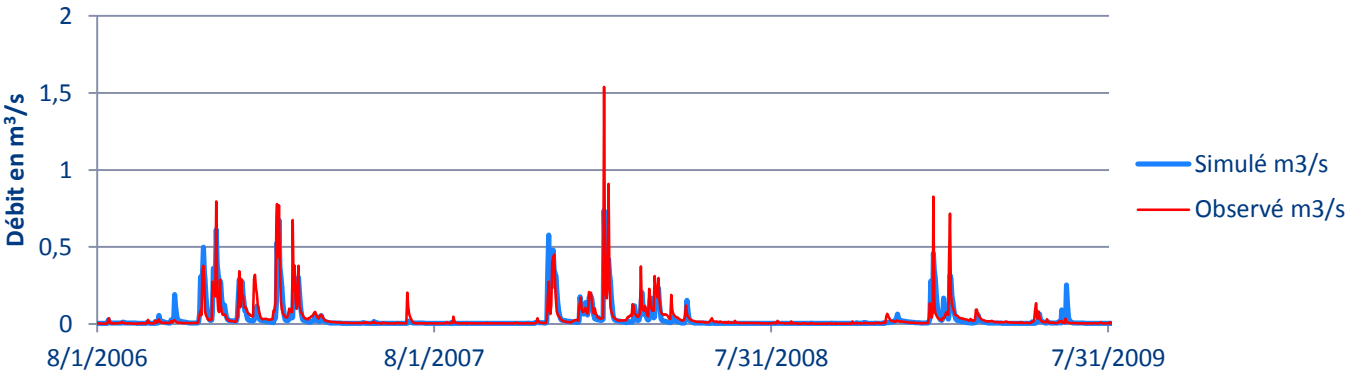
Moyenne : +4%



Mélarchez

Nash : 0.622

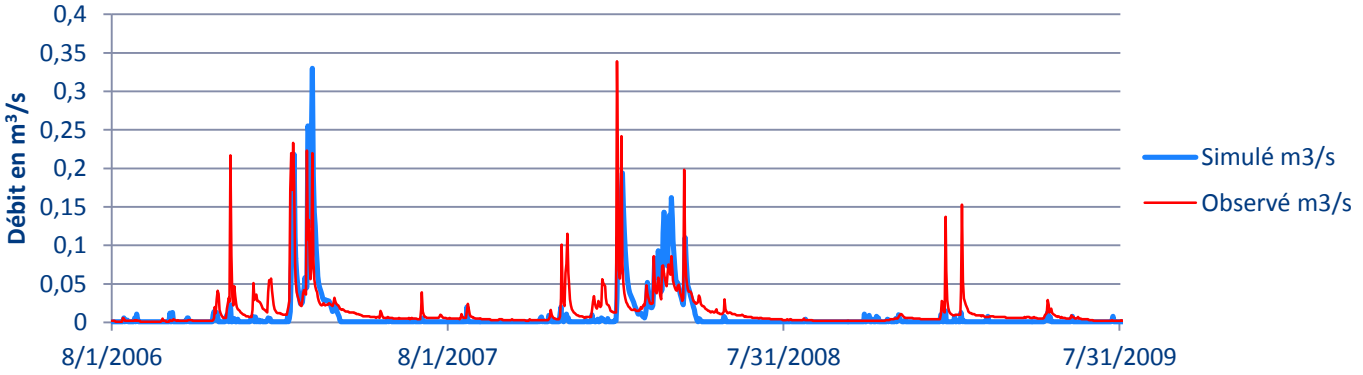
Moyenne : -11%



La Loge

Nash : 0.210

Moyenne : -35%

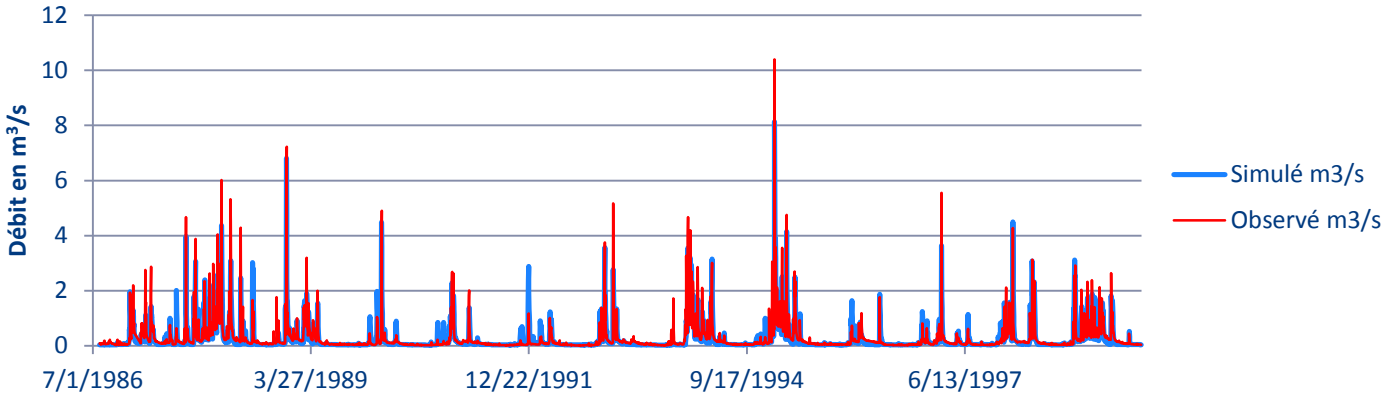


C.1) Hydrological simulations : validation

Les Avenelles

Nash : 0.740

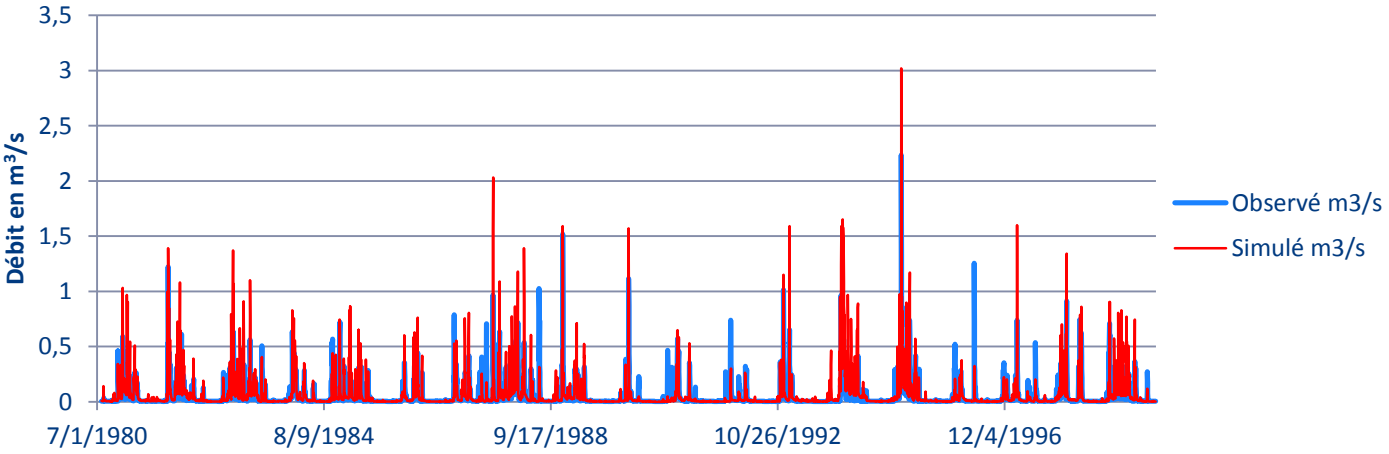
Moyenne : +5%



Mélarchez

Nash : 0.592

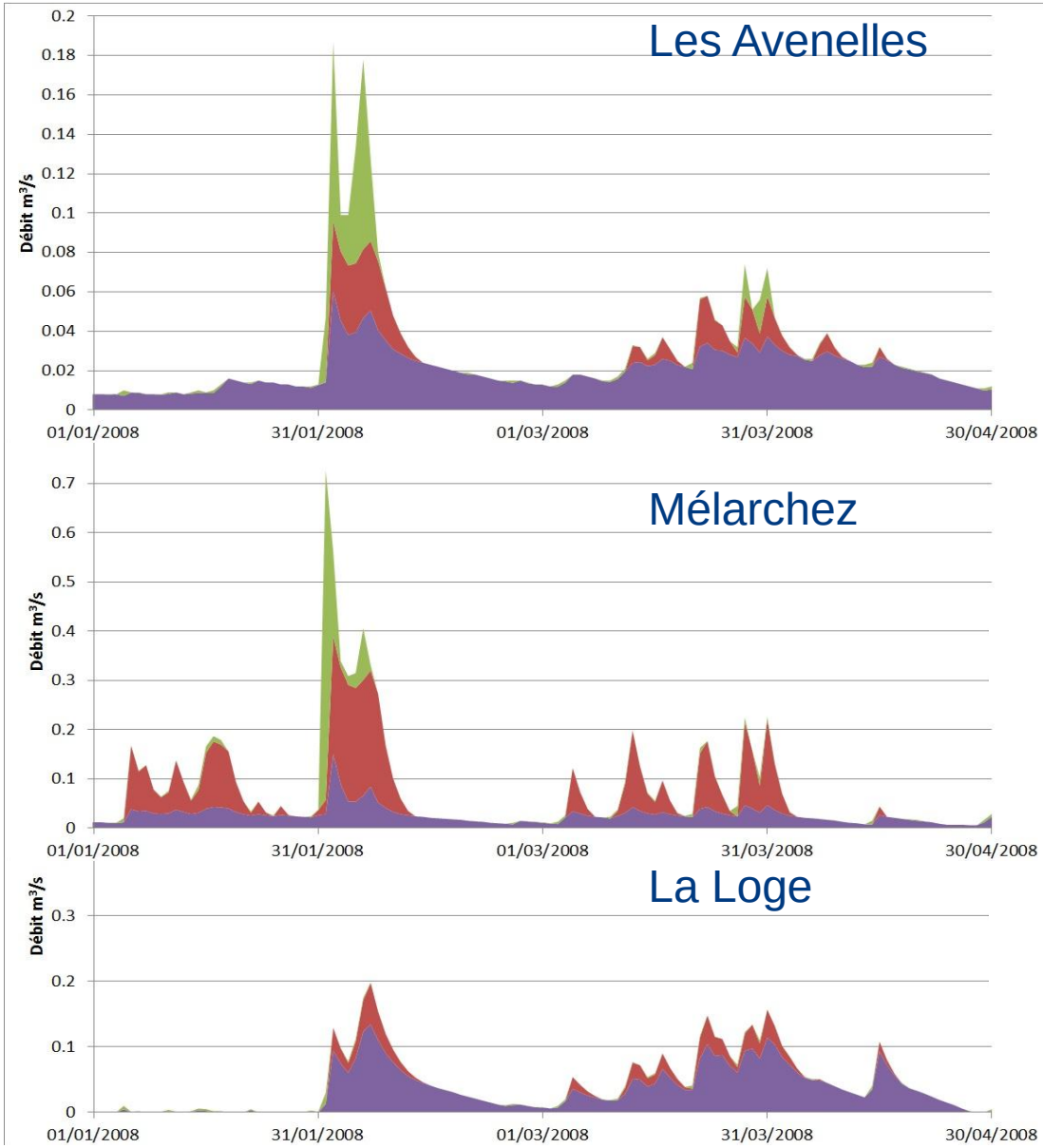
Moyenne : +5%



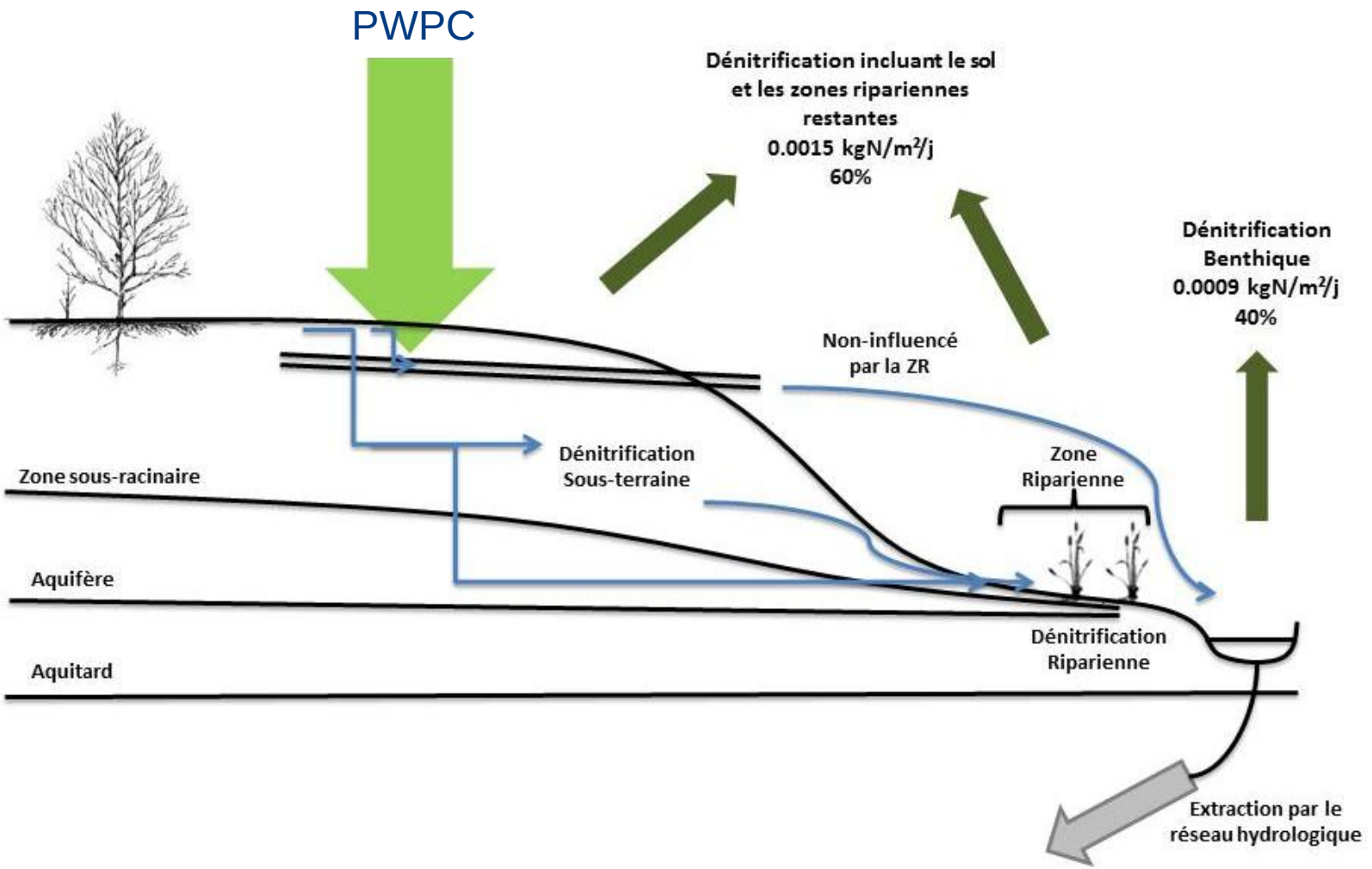
C.1) Hydrological simulations : Hydrograph separation

surface runoff
Drainage
groundwater discharge

- The drainage is dominant in Mélarchez sub-catchment
- Surface runoff only during high rainfall events
- Groundwater discharge during the dry periods



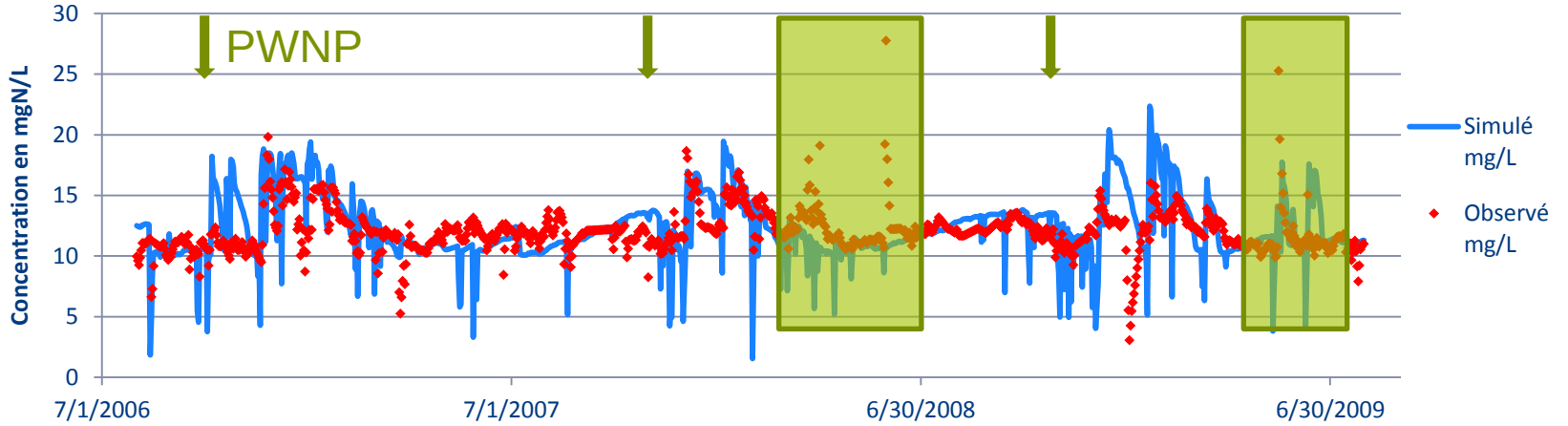
C.2) Nitrogen transfer simulation



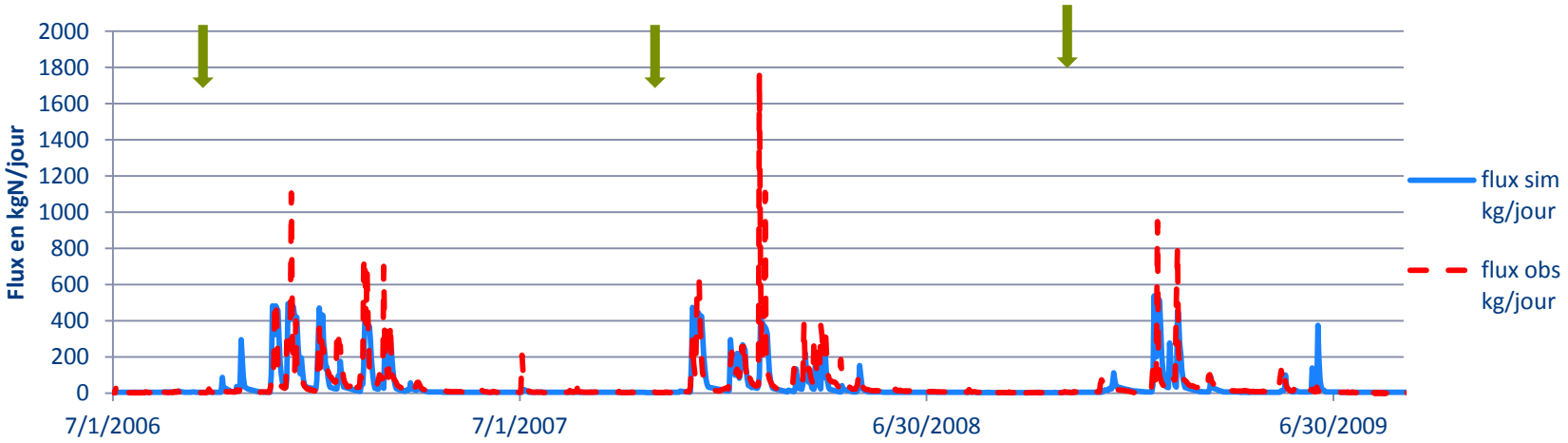
PWPC : same value for every crops

C.2) Nitrogen transfer simulation

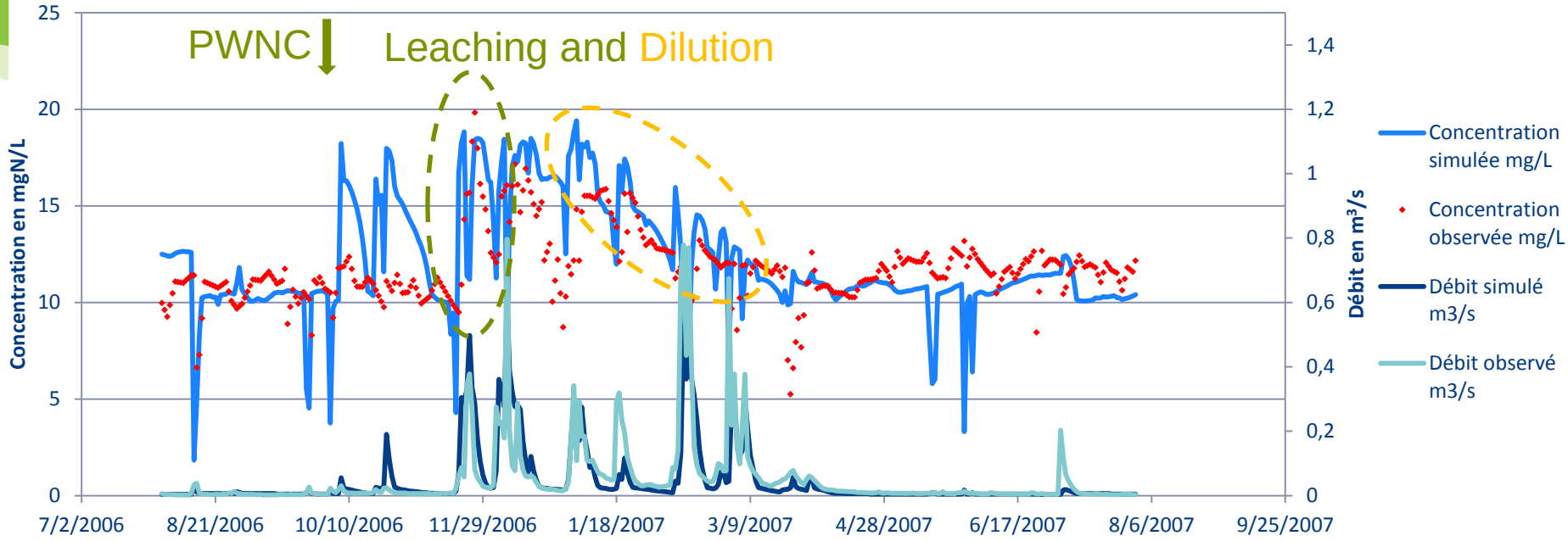
- Daily concentration at Mélarchez (mg N /L)



- Daily flux– Nash : 0.588



C.2) Nitrogen transfer simulation



- The basic concentration is accurately simulated
- The dynamic of nitrogen transfer at the catchment scale is well reproduced
  - Leaching during the beginning of the winter season
  - Dilution after

- Le PWNC is a good indicator for nitrogen transfer

Conclusion

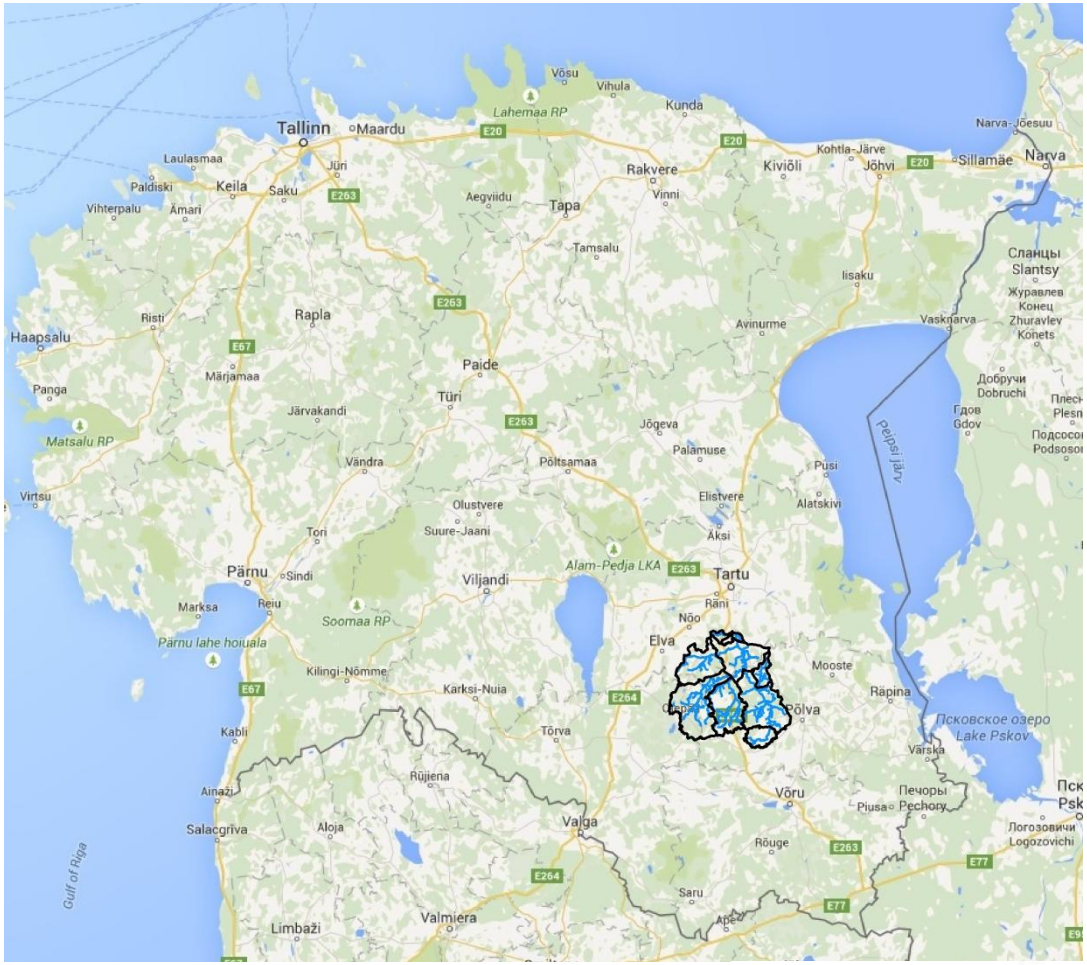
- The Hype model is well for hydrological and nitrate transfer (understand the catchment behaviour)
- Importance of hydrological simulation before nutrient transfer
- The use of PWNC, as function of crops production, allow the simulate currently the dynamic transfer of nitrate

Nitrogen transfer modeling : Hydrological semi-distributed model

II) Study sites : Porijõgi catchment (Estonia)

Study sites : Porijõgi catchment (Estonia)

Surface : 243 km²

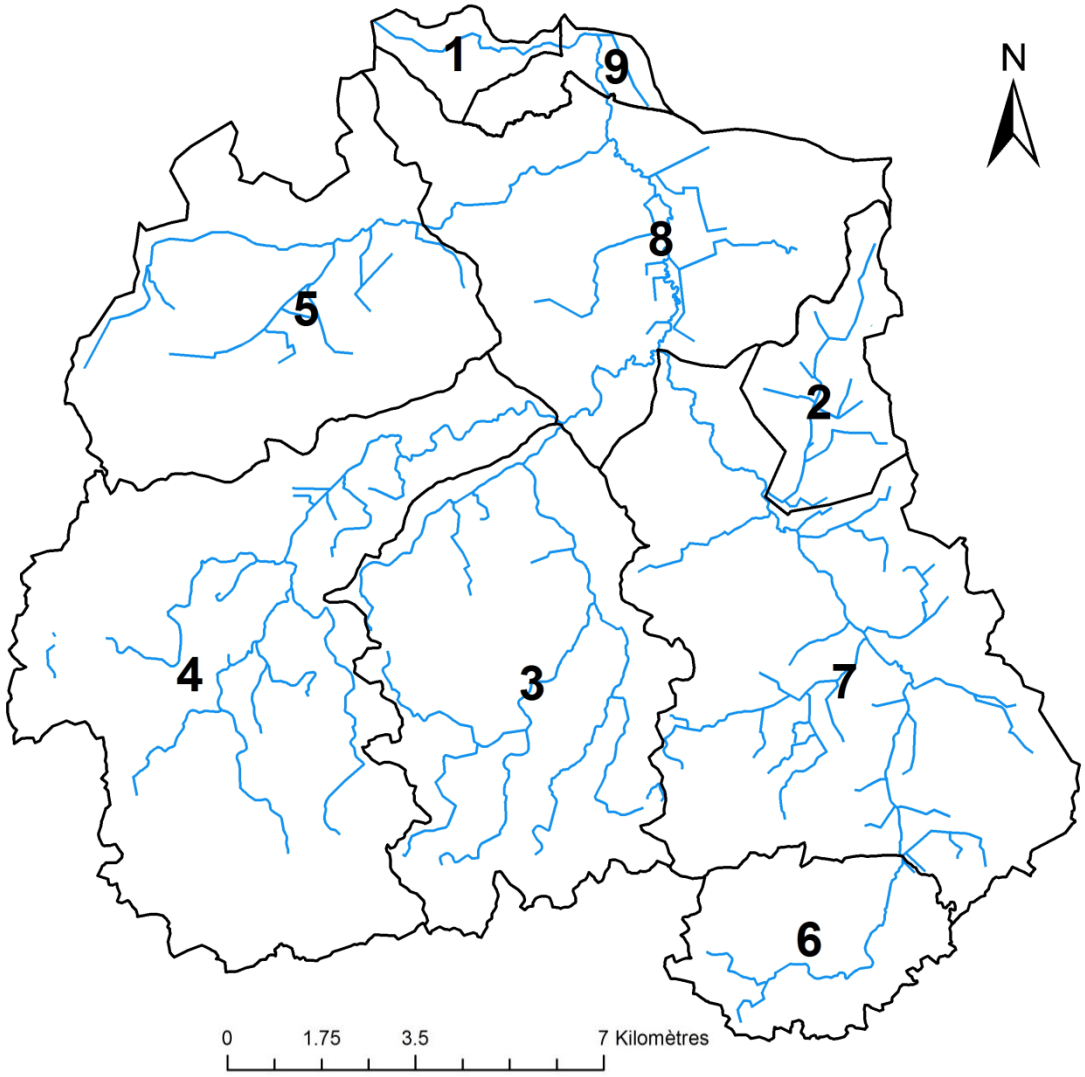


Study sites : PorijõgiCatchment (Estonia)

Surface : 243 km²

Before 1990 :
50% agricole

After 1990 :
24% agricole



Soil type

1 à 5%

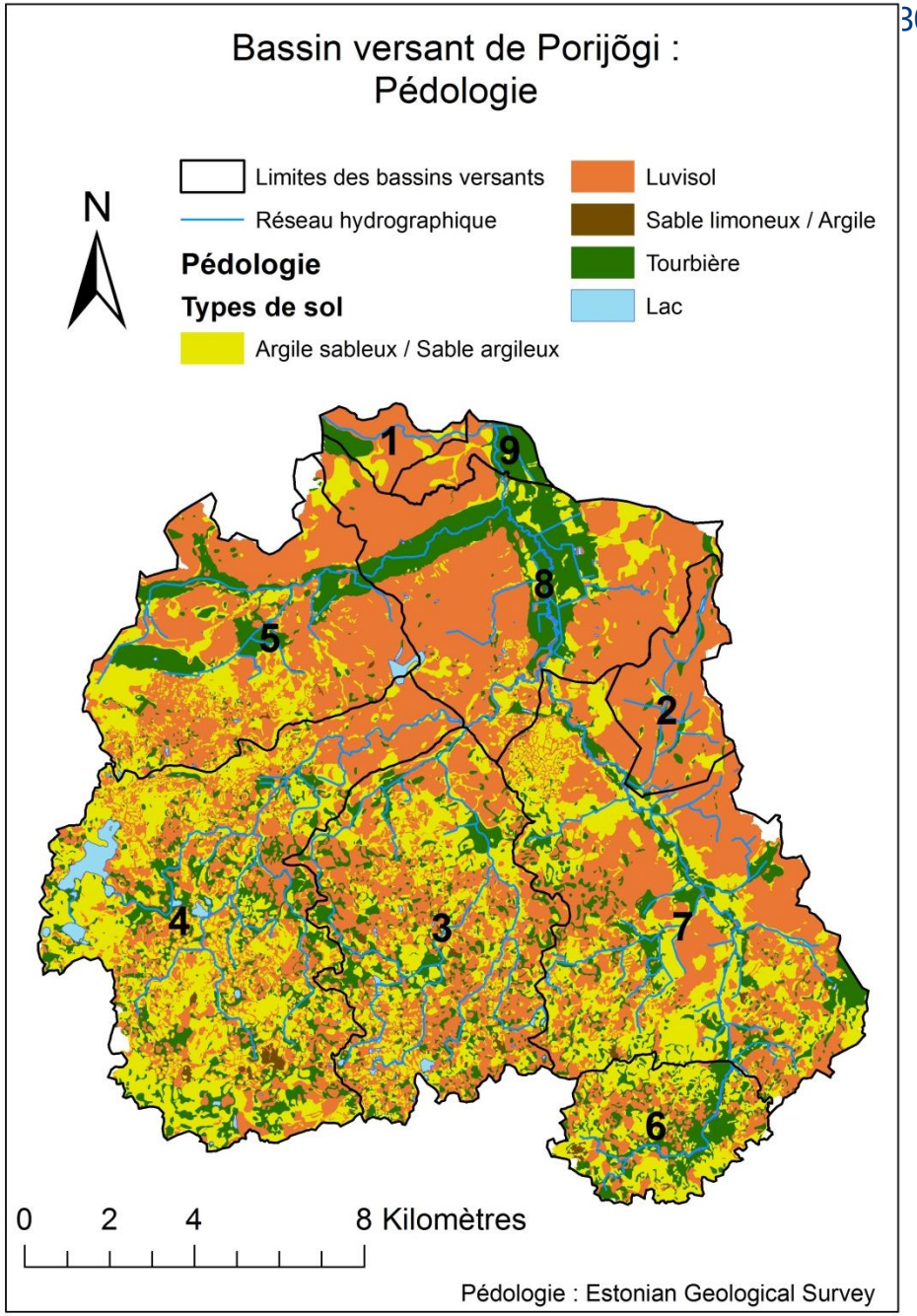
10 à 15%
Pente

- North :

Luvisol et peat

- South:

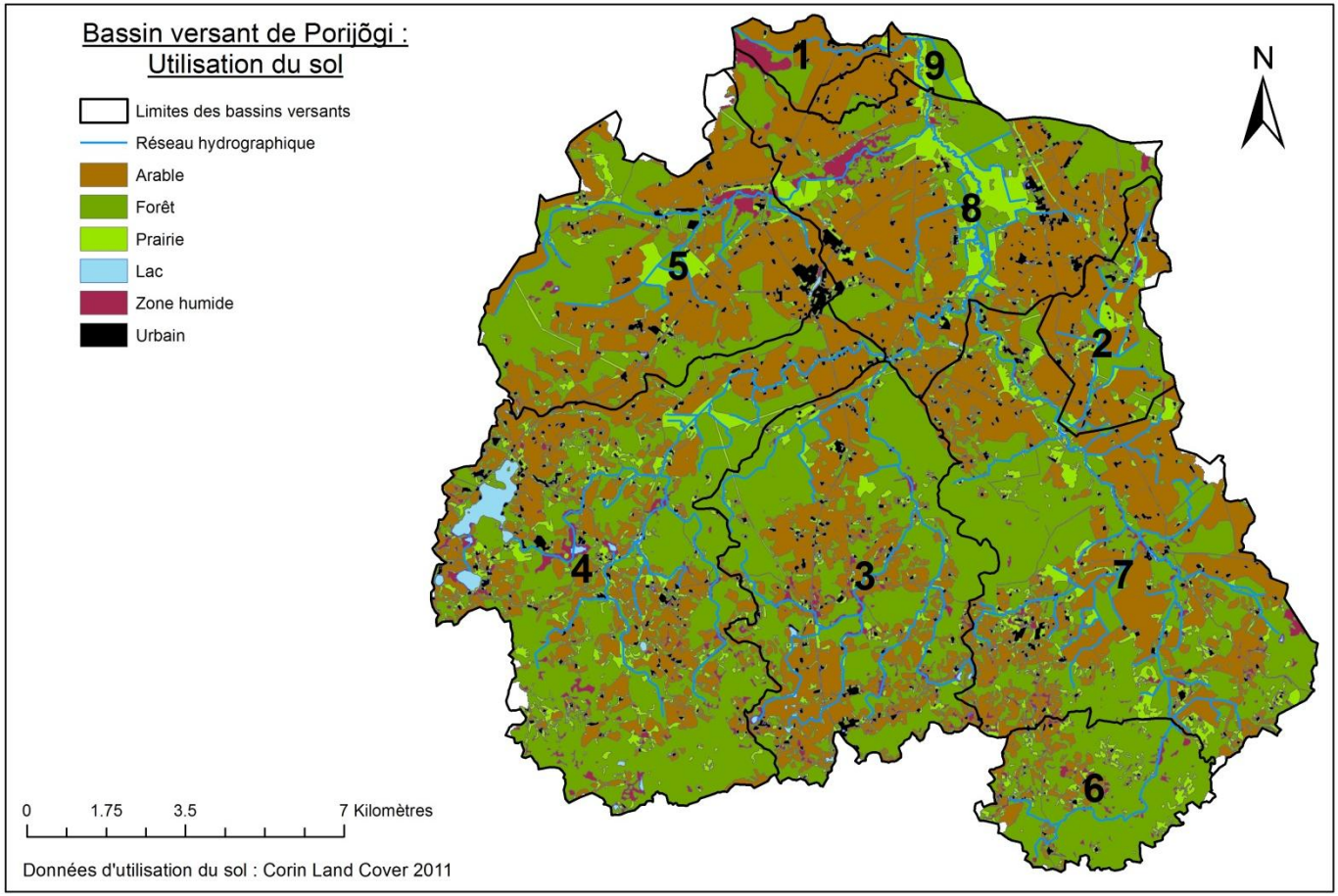
Sandy/Loamy soil



Landuse type

Before 1990 :
50% agricole

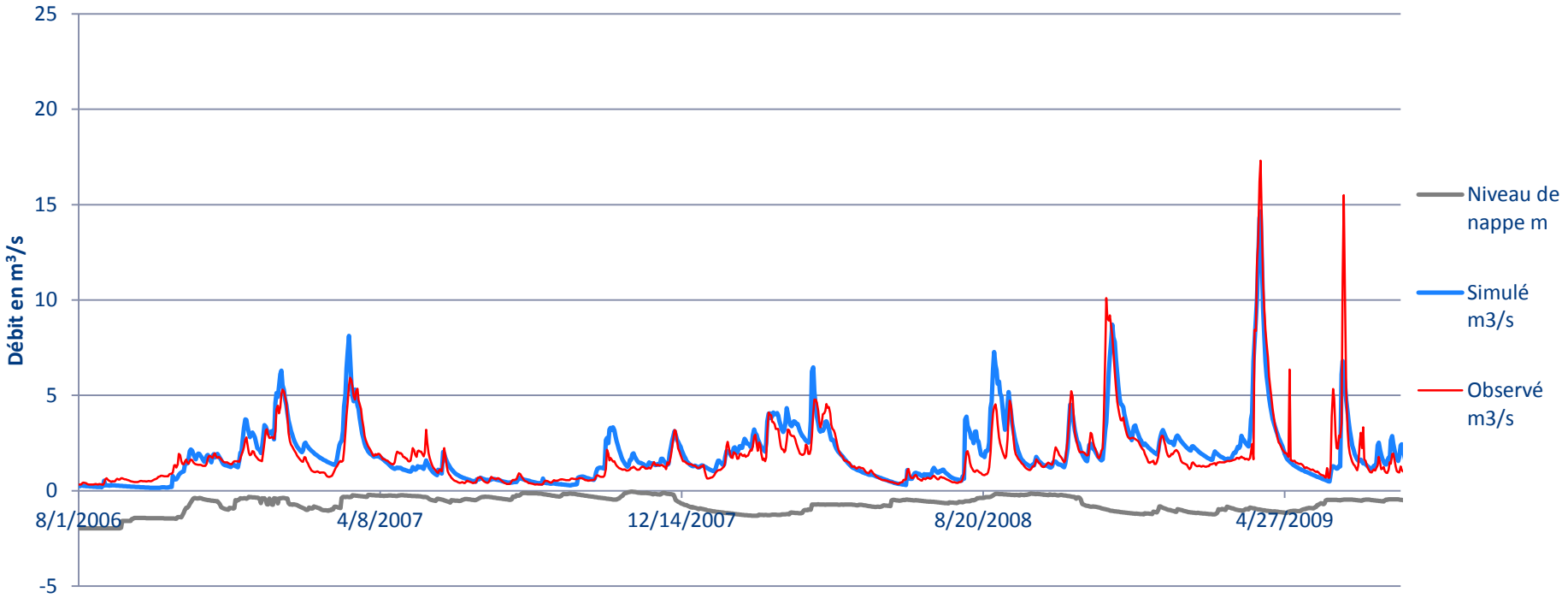
After 1990 :
24% agricole



Landuse type		1987 Soviet period	1990 Reforms	1993	1997
Porijõgi 258 km²	Arable	41.8	34.4	25.7	23.9
	Pastures	14.8	20.5	26.9	27.6
	Forest and wetlands	43.4	45.1	47.4	48.5

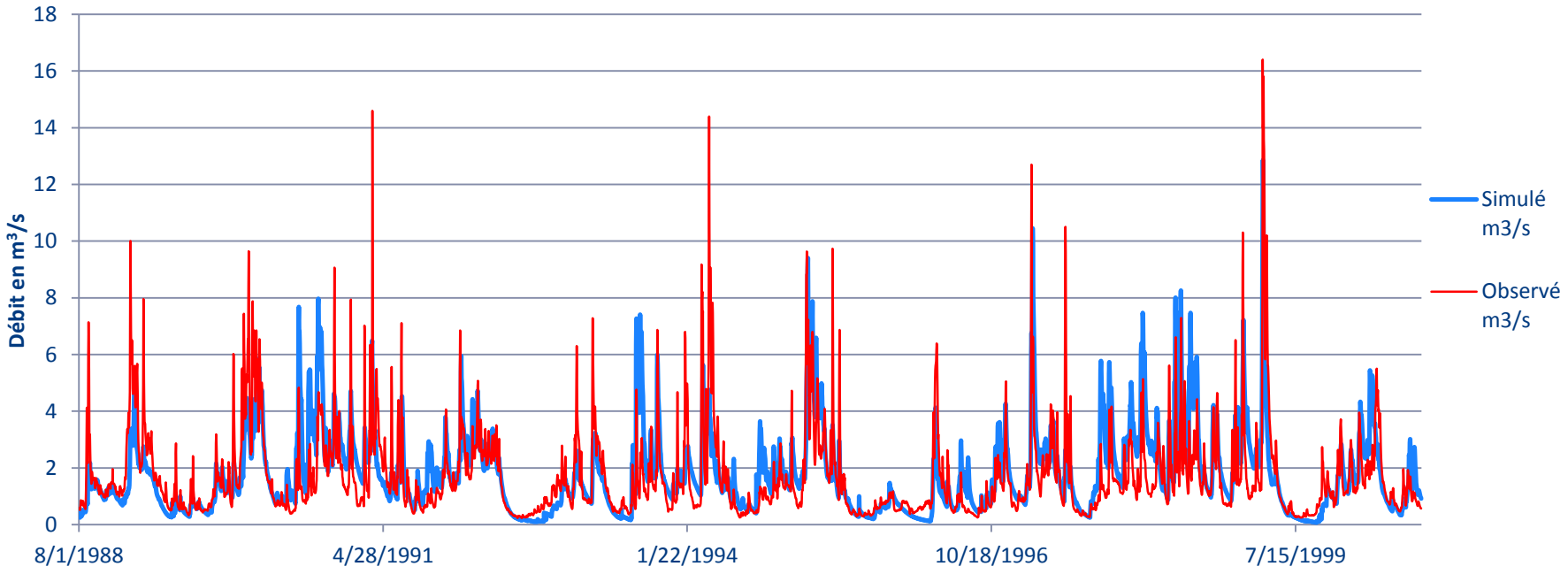
Hydrologic simulation: calibration

Nash : 0.802 Moyenne : +1%



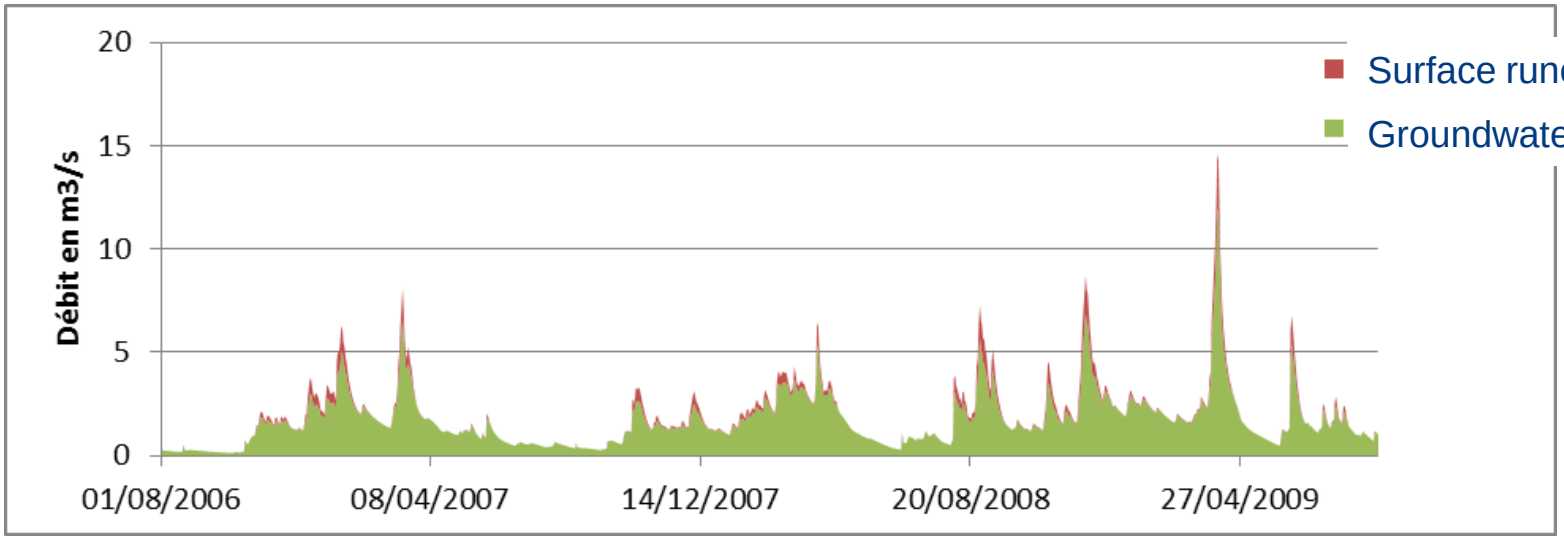
Hydrologic simulation: validation

Nash : 0.447 Mean: +7%



- High impact of landuse modification, since 1990, on peaks flow

Hydrologic simulation: hydrograph separation



Thanks !

Hydrogeology

Perched groundwater table

North-West Zone

Permeable soil (Forest)

Water losses

North-East Zone

Permeable soil

South Zone

Permeable

Non-drained

Drained

silt

Brie limestone

clay