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Hydrological modelling of three subcatchements of the Vesdre river
Scenarios on forest, peatland and agricultural land management

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Context : Vesdre 2021

- After the floods of 2021, the strategic master plan proposes four theoretical development programmes for the catchment area
- These plans cover housing and mobility, as well as agriculture, biodiversity and the management of natural areas
- What are the potential effects of these developments on the hydrology of the catchment?

MODREC project - physically based hydrology section

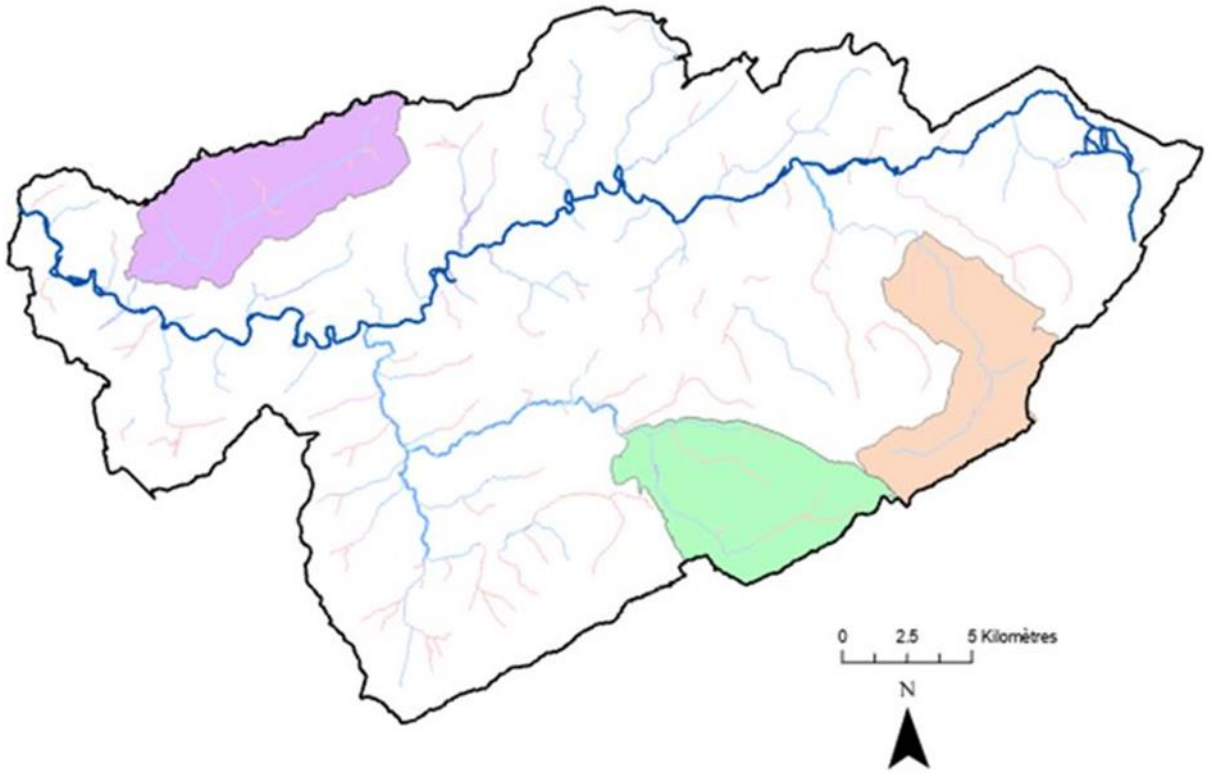
Presentation outlines

- Model parameterisation
- Validation elements
- Some results in different contexts
- Floods and droughts

There are going to be some shortcuts and it's going to be quick, but I love chatting over a coffee :-)

Physically Based Hydrological Modelling

Quantifying the effectiveness of the strategies proposed in the Vesdre scheme

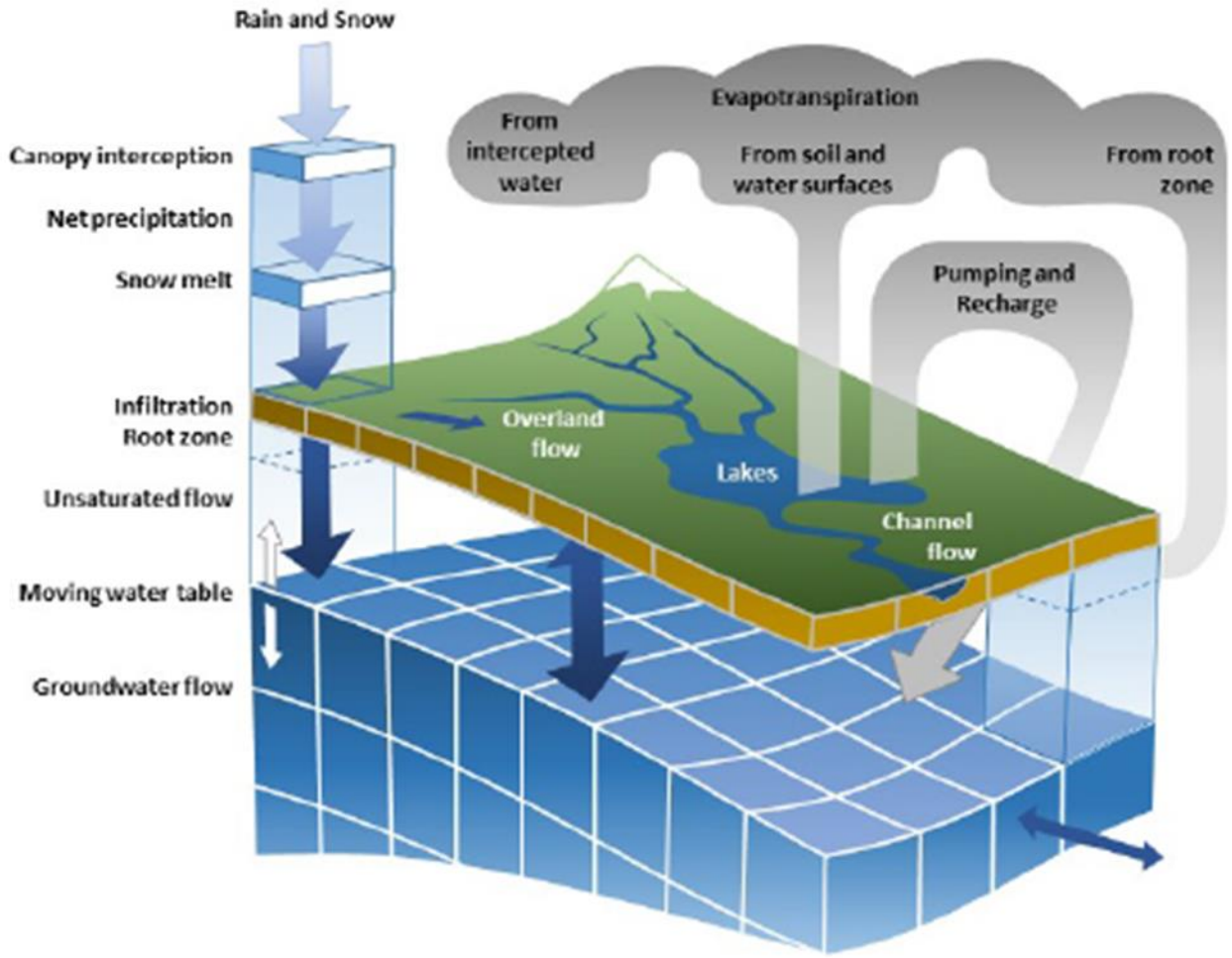


Magne catchment area
- Dominantly agricultural

Hoëgne catchment area
- Forest dominated

Helle catchment area
- Dominantly peat bogs

The tool : MikeSHE



Physical representation of the main processes in the hydrological cycle :

derived from the physical laws governing processes (conservation of mass, energy, etc.)

→ Network drainage

→ Evapotranspiration / Infiltration (vegetation)

→ Surface runoff

→ Vadose discharge

→ Groundwater flow

Spatially distributed - meshed approach

Configuration of the vadose module and saturated zone

- DTM (SPW)
- Landuse (SPW)
- Vegetation cover (Satellite/Sigec)
- Geology (EPICgrid model)
- River network (SPW lidaxes)
- …

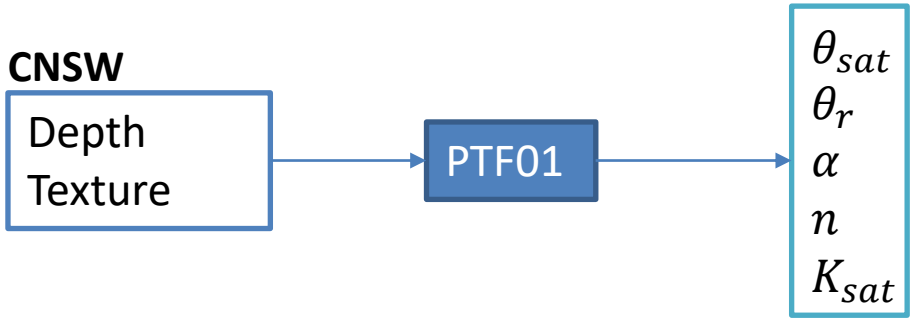
+ weather data from KMI and SPW (1 hour time-step)

Configuration of the vadose module and saturated zone

- Retention and hydraulic conductivity curves
  - Mineral soils :
    - Soil map: Textures and granulometric fractions of Walloon soils (surface, 40-80 cm, 80-120 cm)
    - Soil map: Stony load
    - COT
  - Raised bog and degraded peat
    - Retention measures for the "peat bogs" project (C. Sohier & C. Wastiaux)

Configuration of the vadose module and saturated zone

- Retention and hydraulic conductivity curves
  - Methodology
    - pedotransfer function EU-PTF(v2) *(Szabo et al. 2021)*

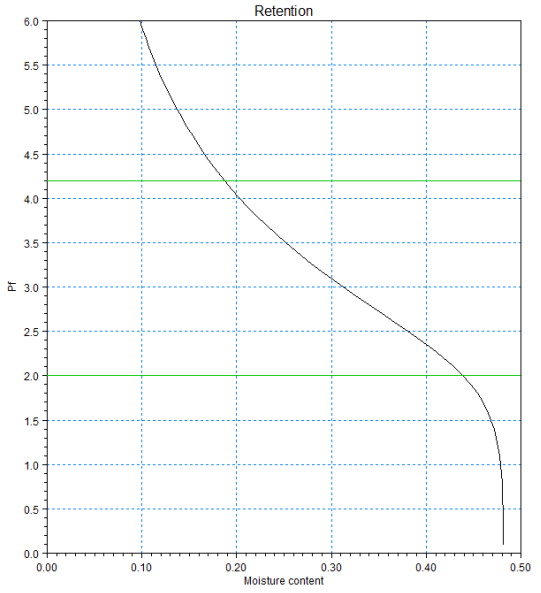


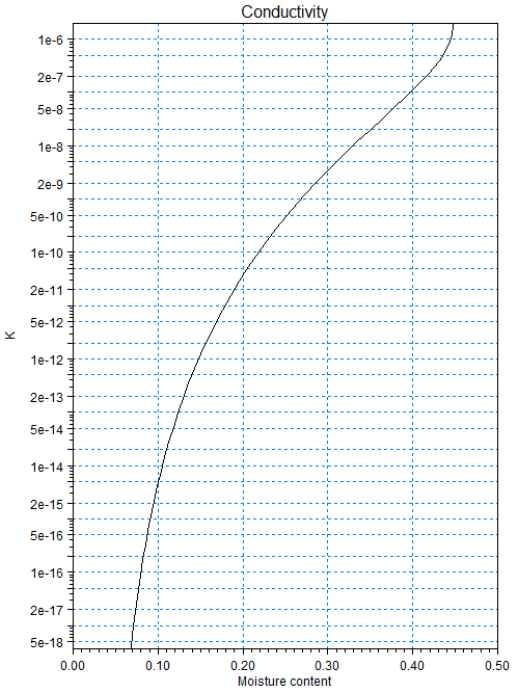
adjusted according to the % volume occupied by the stony load (considered to be non-porous)

Little stony
Topsoil→ 5%
subsoil → 15%

Stony
Topsoil→ 25%
subsoil → 35%

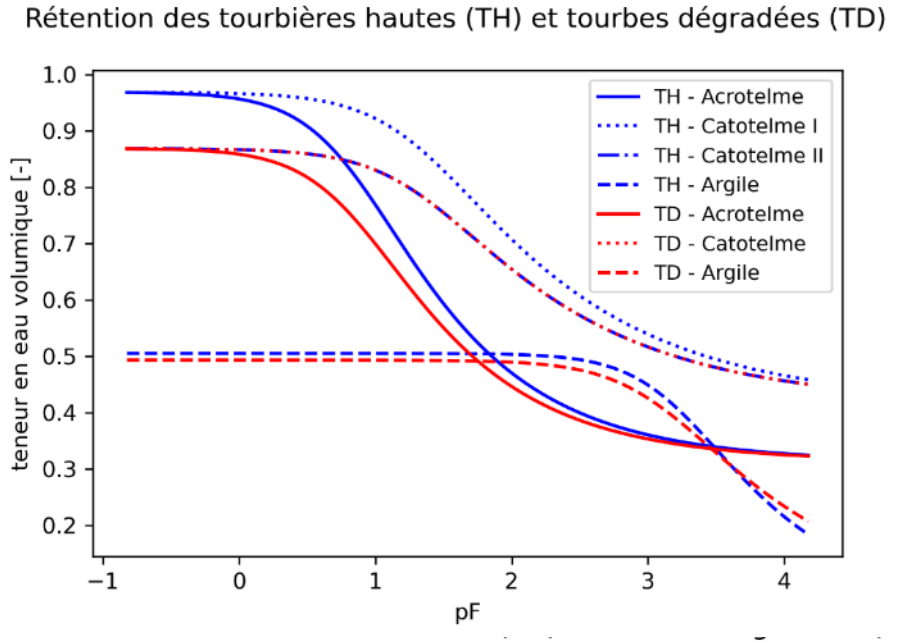
Very stony
Topsoil → 50%
Subsoil → 70%

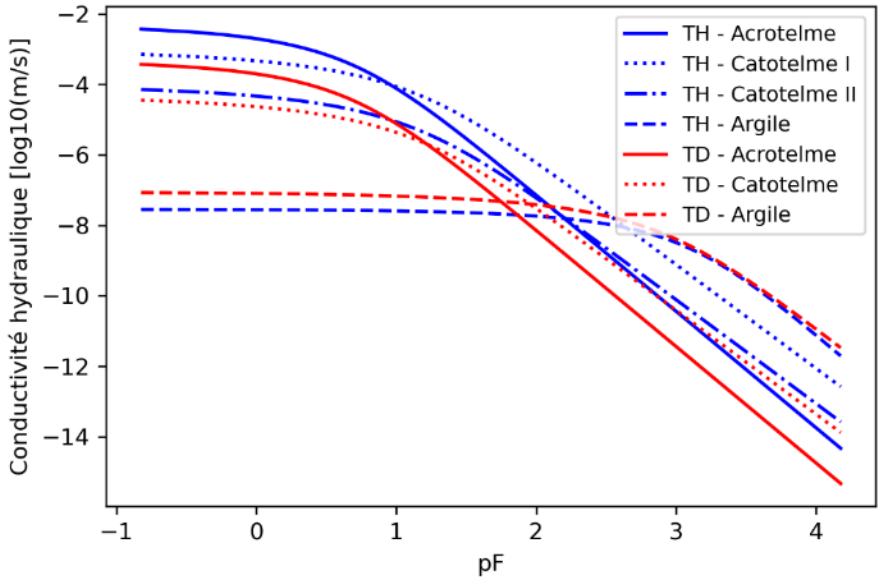




Configuration of the vadose module and saturated zone

- Retention and hydraulic conductivity curves
  - Retention measures for the "peat bogs" project (C. Sohier & C. Wastiaux)
  - Raised bog
    - Acrotèlme = fitting of a Van genuchten function (θsat, θr, α, n) to retention points measured in Sphaignes and Touradons de molinies
    - Catotèlme I = fitting of a Van genuchten function (θsat, θr, α, n) to the retention points measured under Sphaignes and Touradons de molinies.
    - Catothelme II = Catothelme I - 10% pore volume
  - Degraded peat
    - Acrotèlme = Acrotèlme raised bog - 10% pore volume
    - Catoterm = Catoterm I raised bog - 10% pore volume

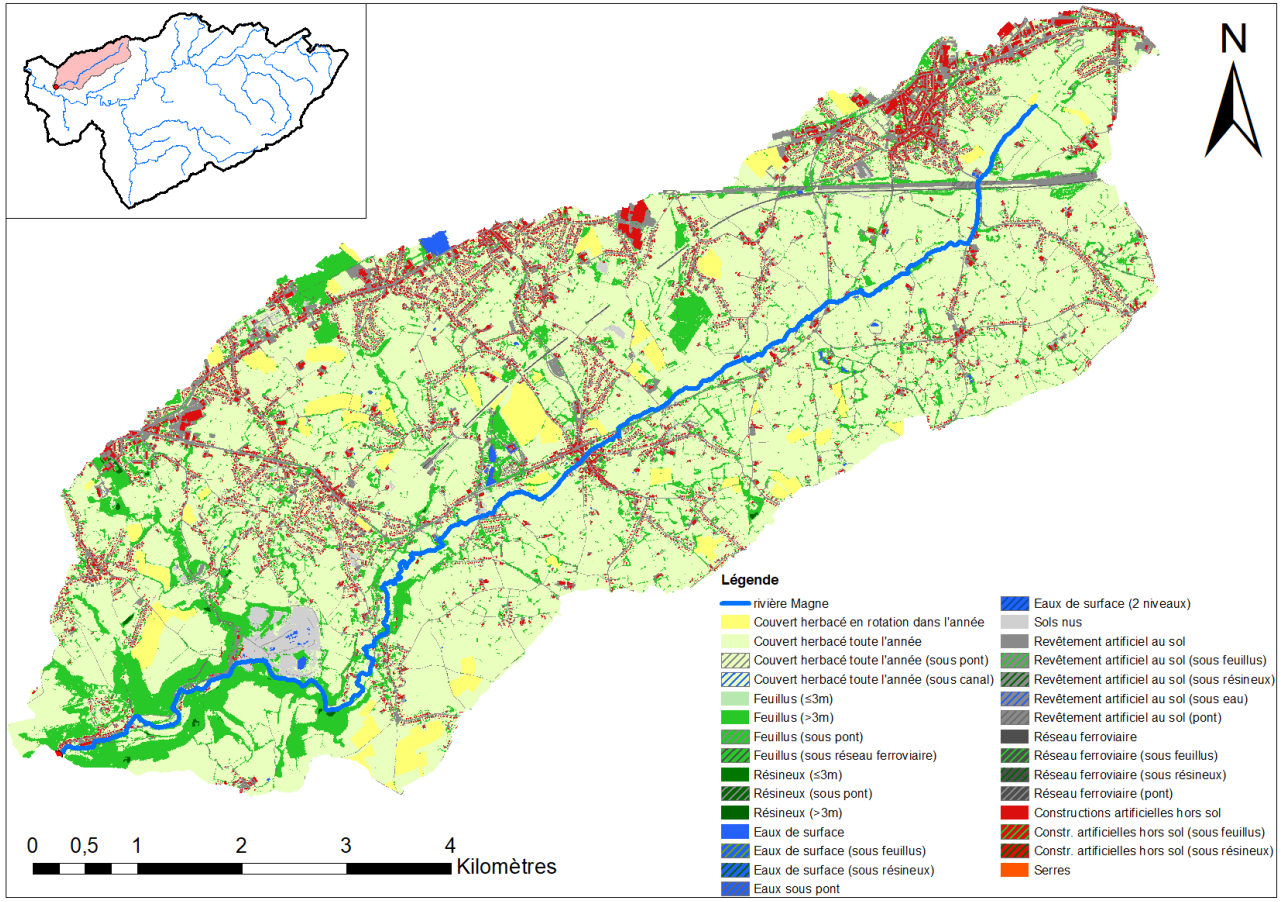




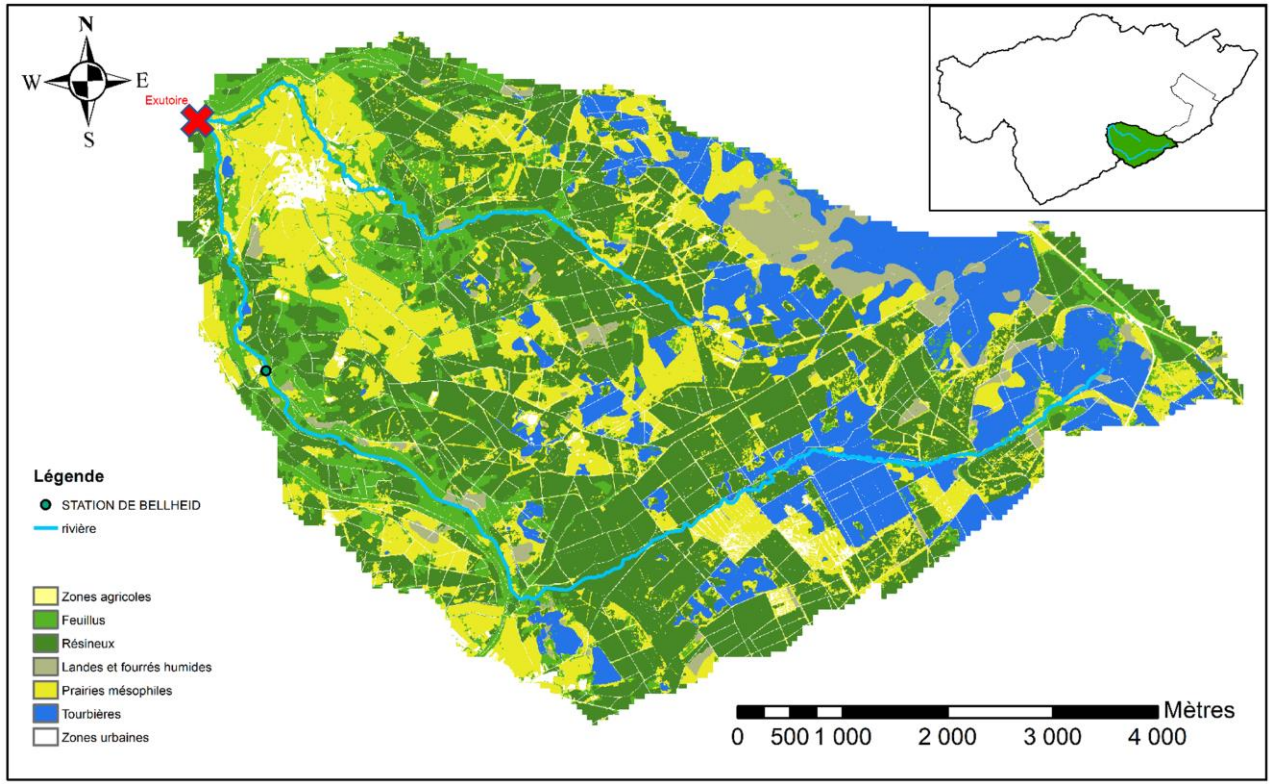
Agricultural catchment

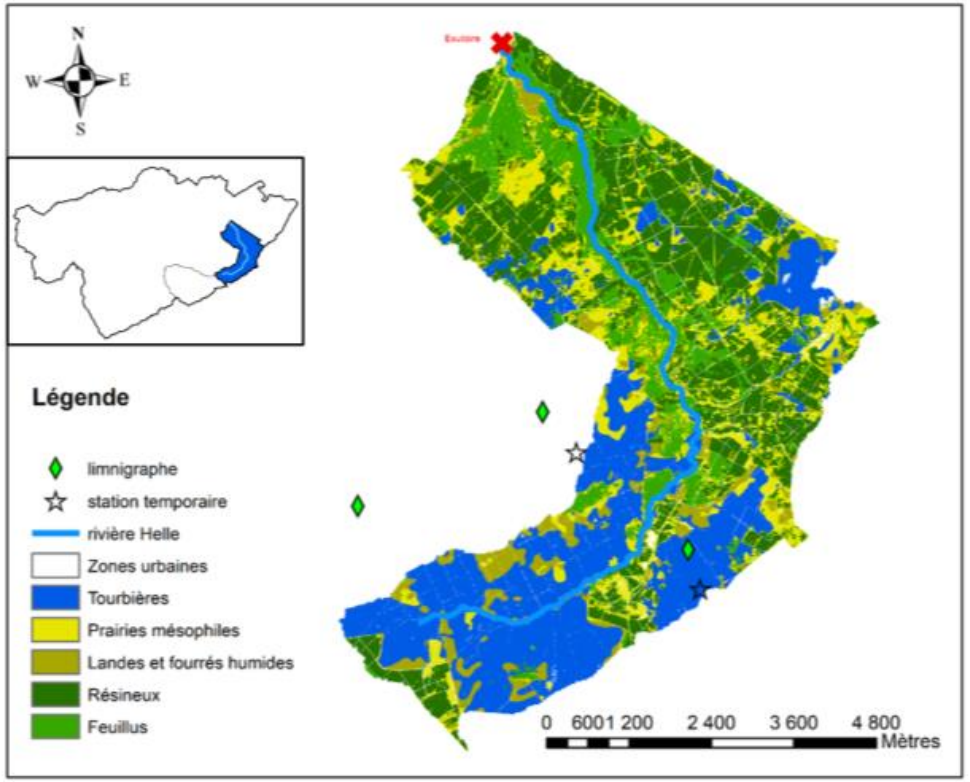
Magne

- Surface area : 40 km²
- Occupation :
  - 69% agricultural areas (of which 65% grassland)
  - 17 % impervious areas
- Discharge station SPW-ARNE of the "ruisseau des fonds des forêts" (L7600).
  - Max gauged: approx. 5 m³/s
  - In place since 11/05/2011

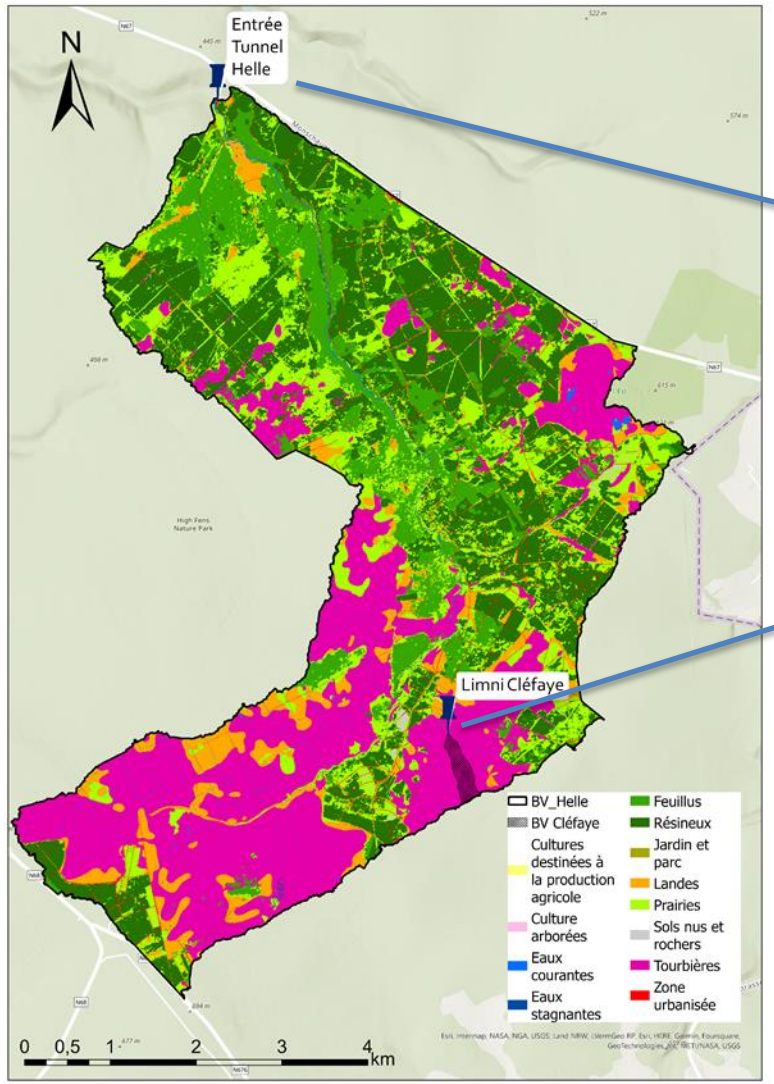


Other subcatchments
La Hoegne (Forest) and la Helle (Peat)

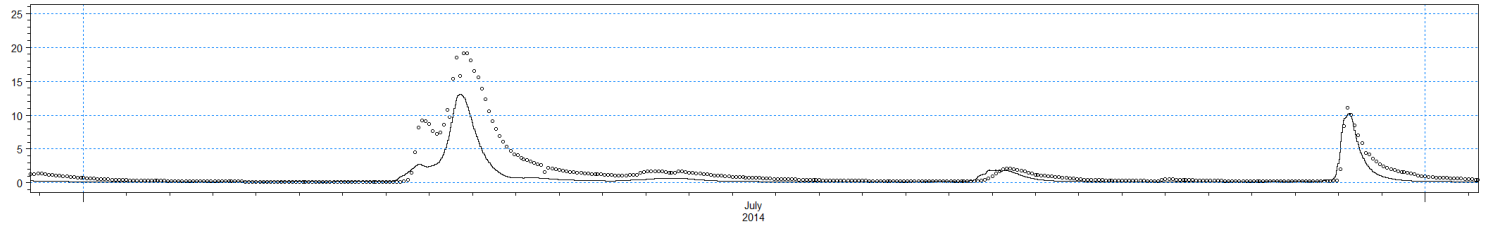




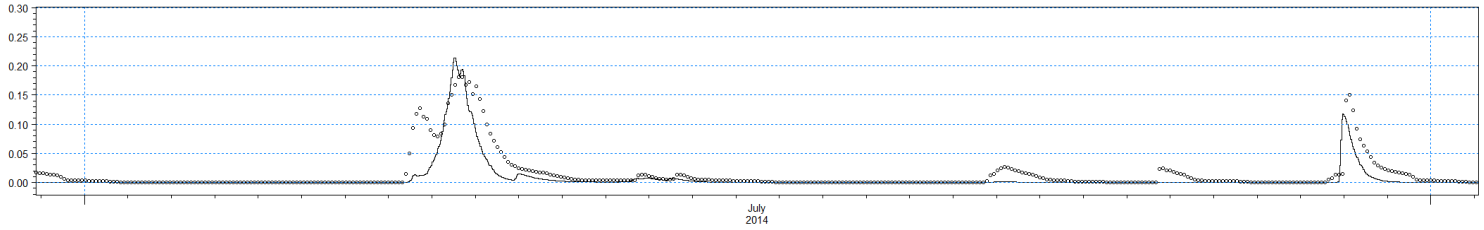
Peaty catchment



Helle outlet (36,9 km²)

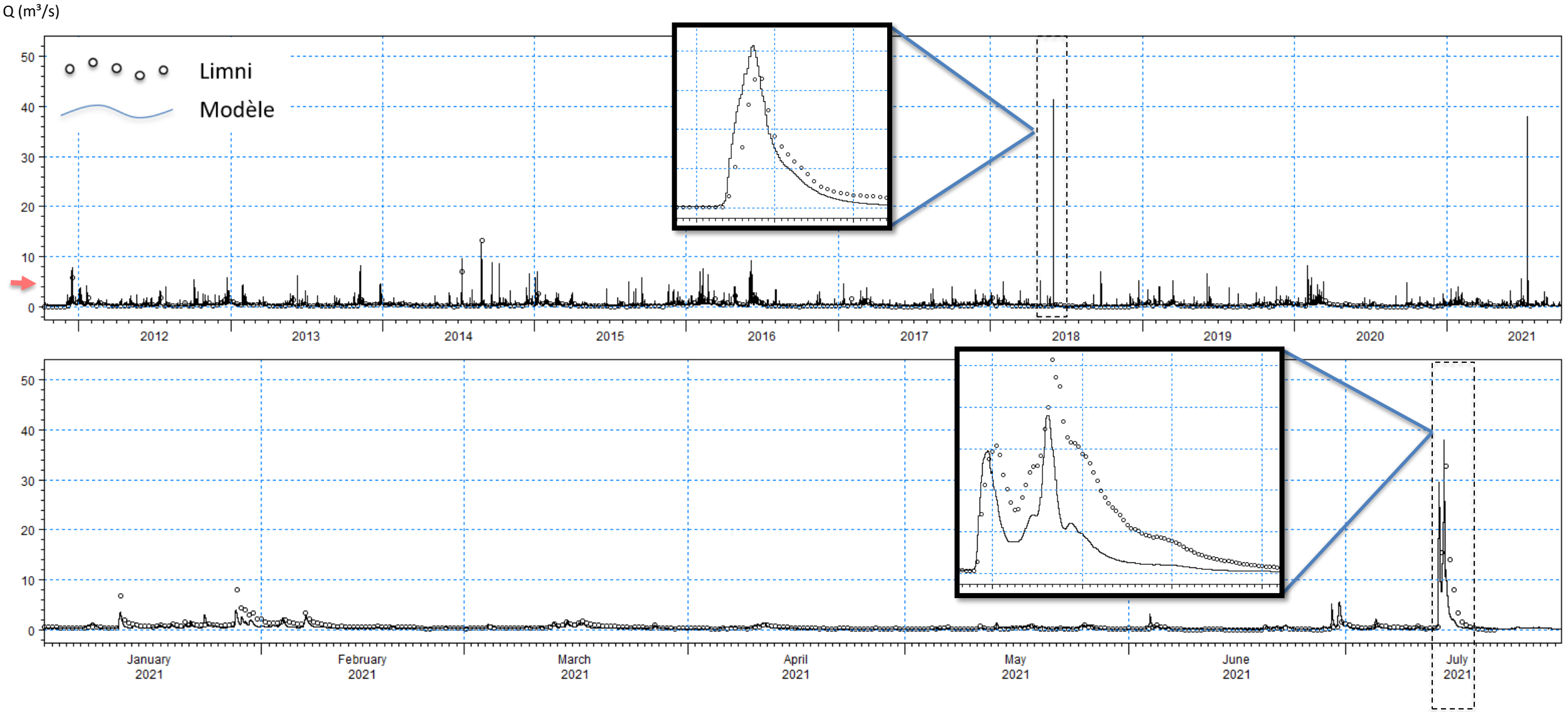


Cléfaye outlet (14ha)



Agricultural catchment

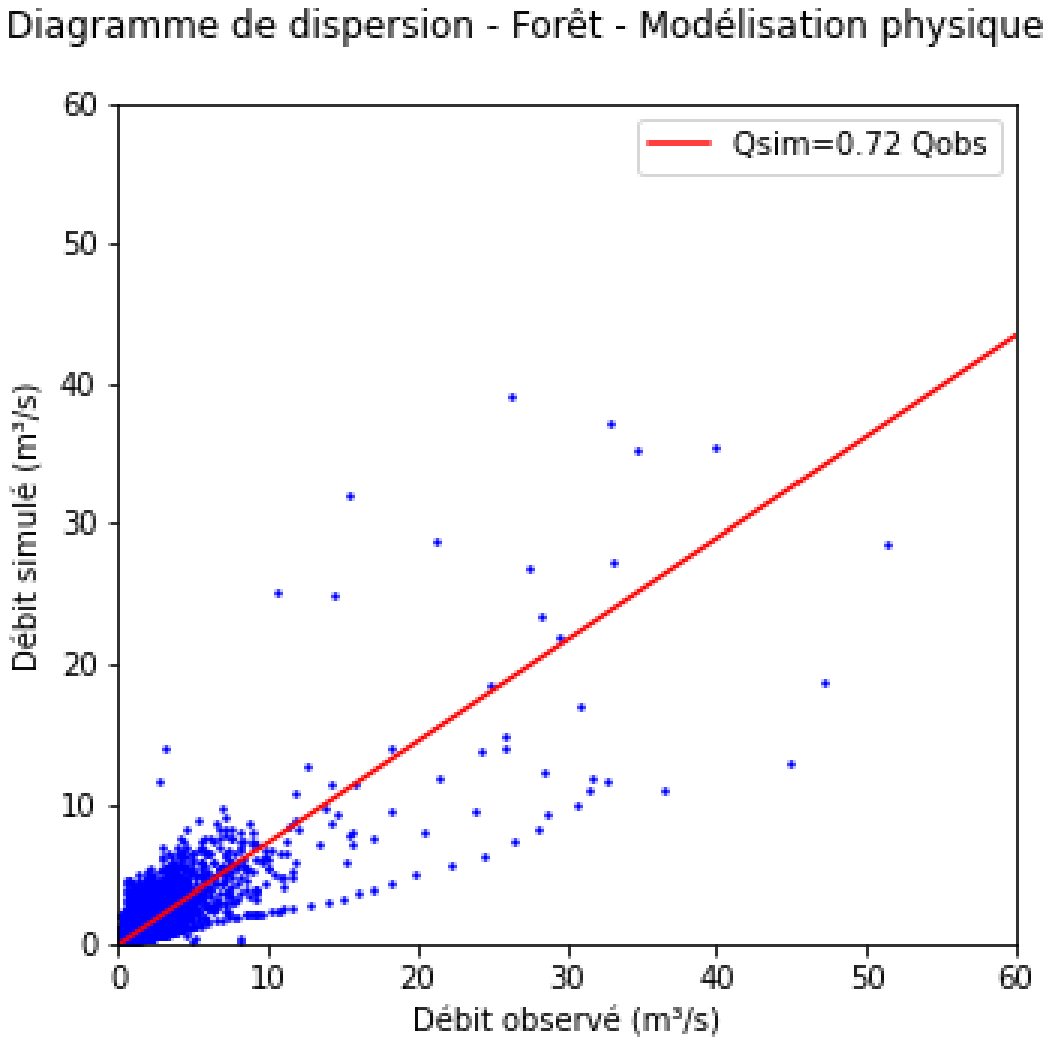
Max discharge measured on the rating curve : 5m³/s /!\



Agricultural catchment

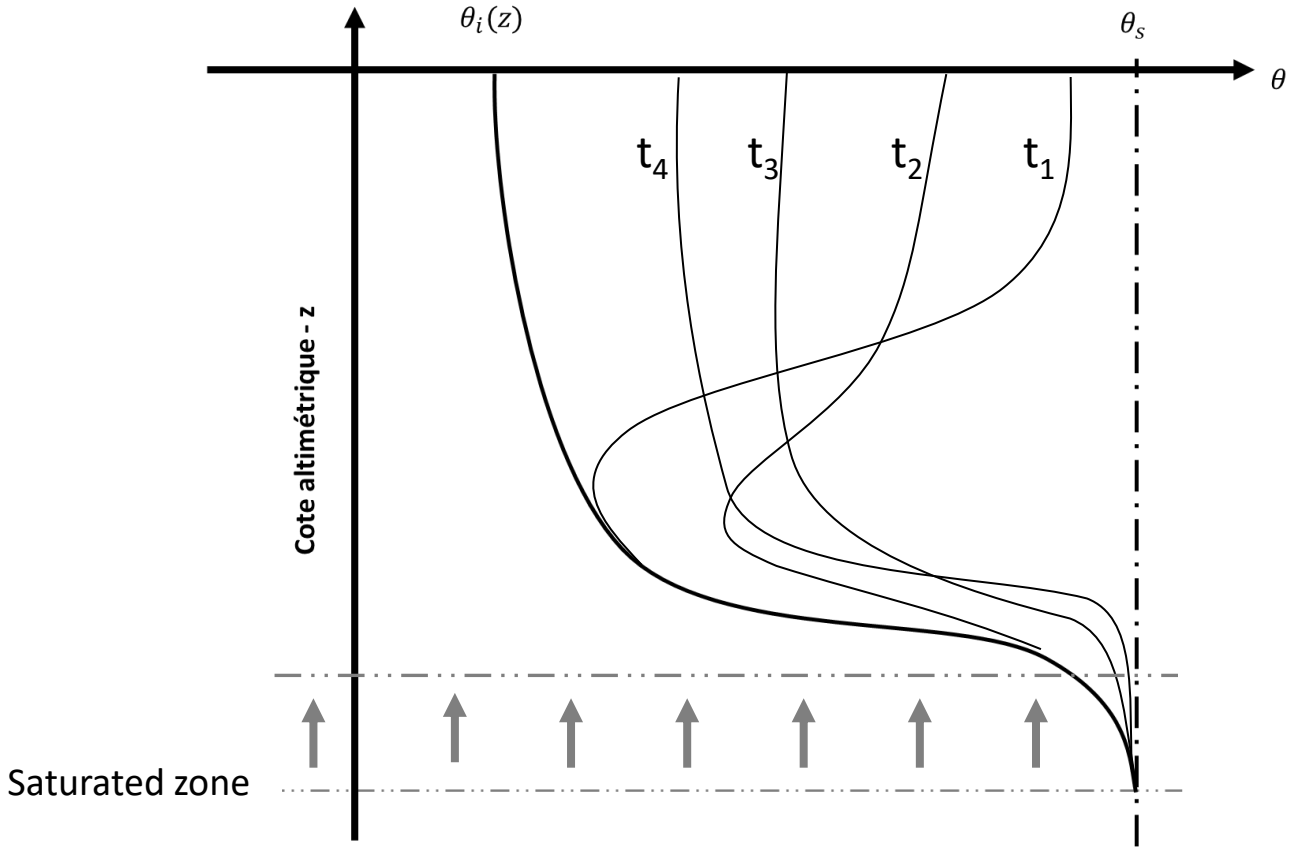
Hydro year	ME	MAE	RMSE	STDres	R	**R^2 - Nash**
2012	-0.0734671	0.197003	0.311776	0.302996	0.814079	0.642428
2013	-0.0252865	0.168152	0.318273	0.317267	0.803208	0.634548
2014	-0.0551104	0.140319	0.307514	0.302535	0.881499	0.759072
2015	-0.0701512	0.165078	0.279127	0.270168	0.853738	0.691858
2016	0.0454241	0.305206	0.524472	0.522501	0.813156	0.652682
2017	-0.185832	0.219136	0.291693	0.224836	0.749942	-0.0337472
2018	-0.0863093	0.16273	0.355884	0.34526	0.927651	0.819321
2019	-0.0929198	0.171308	0.298962	0.284155	0.801971	0.601217
2020	0.0845958	0.229815	0.401215	0.392196	0.849105	0.677217
2021	0.135175	0.332789	1.24801	1.24067	0.872909	0.662086
2012-2021	**-0.0313491**	**0.207839**	**0.507214**	**0.506244**	**0.831835**	**0.681767**

- Acceptable adjustment but based on limited data and only at the outlet
- Need to compare with other observations, even qualitative ones

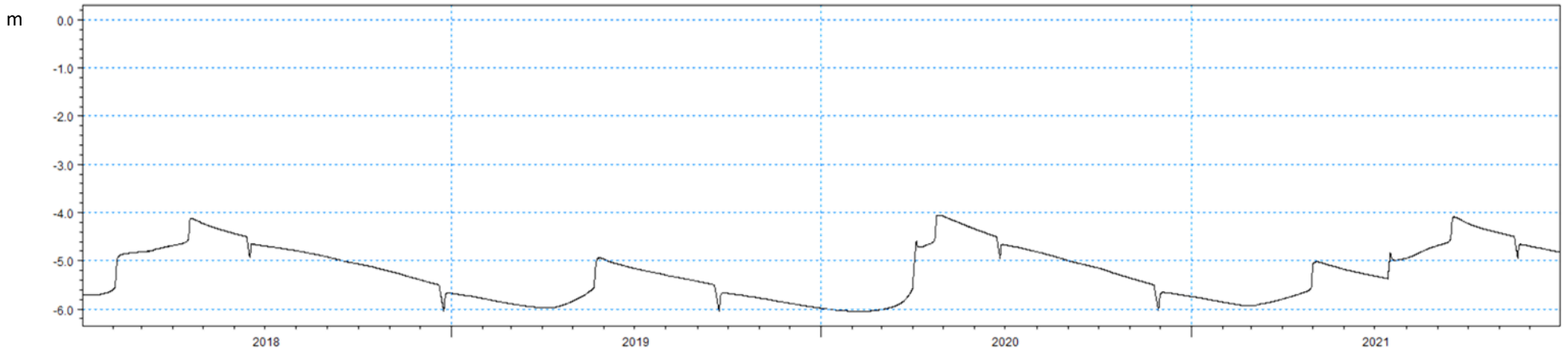


An example from the forested catchment

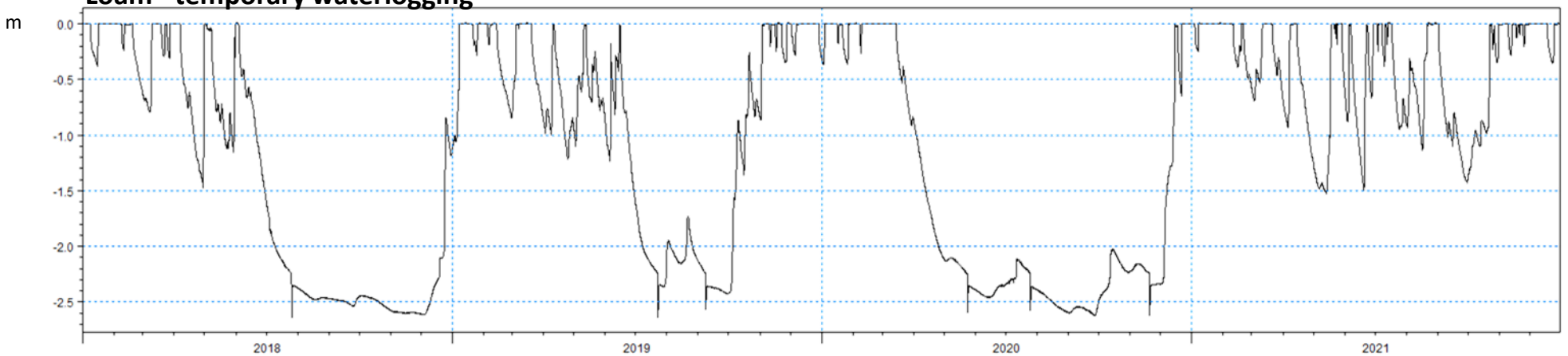
- Analysis of soil hydrodynamics
  - Vertical dynamics of the saturated zone



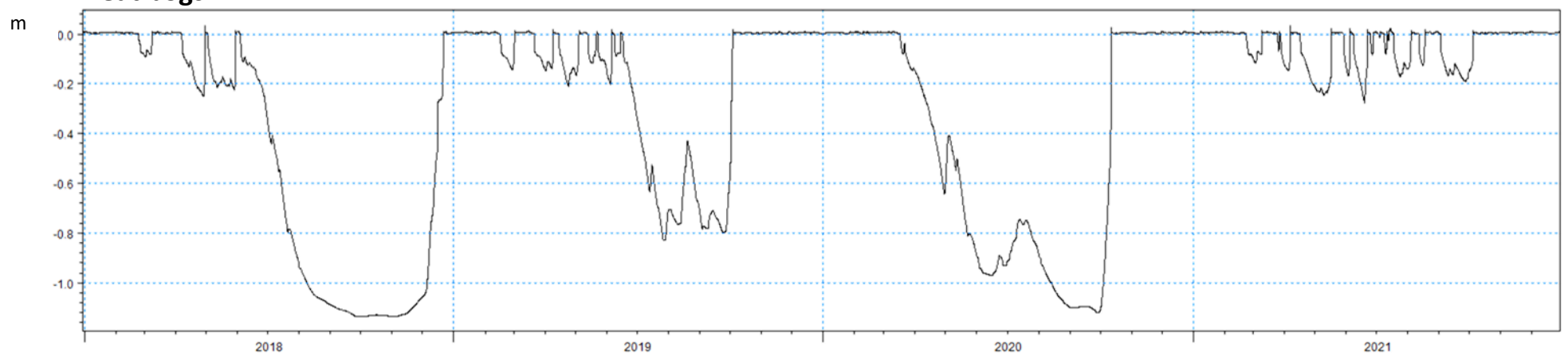
Loam - favourable drainage



Loam - temporary waterlogging

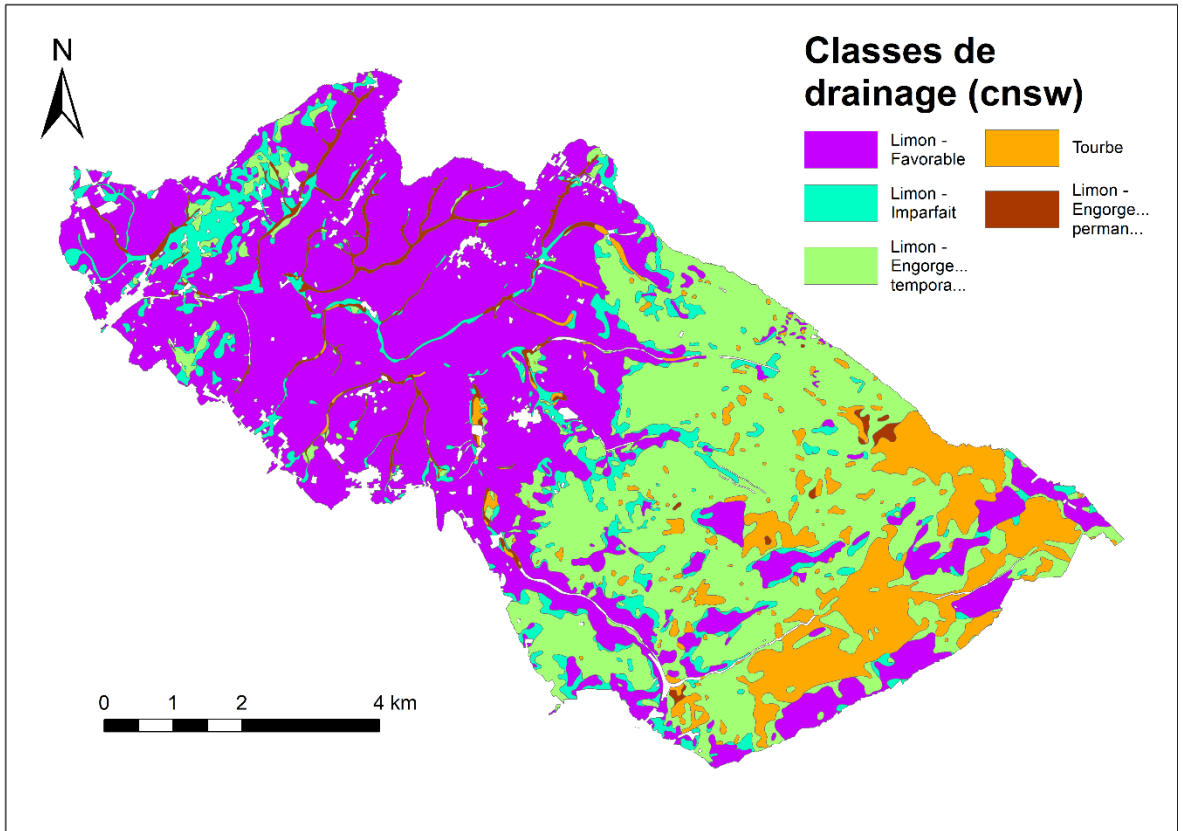


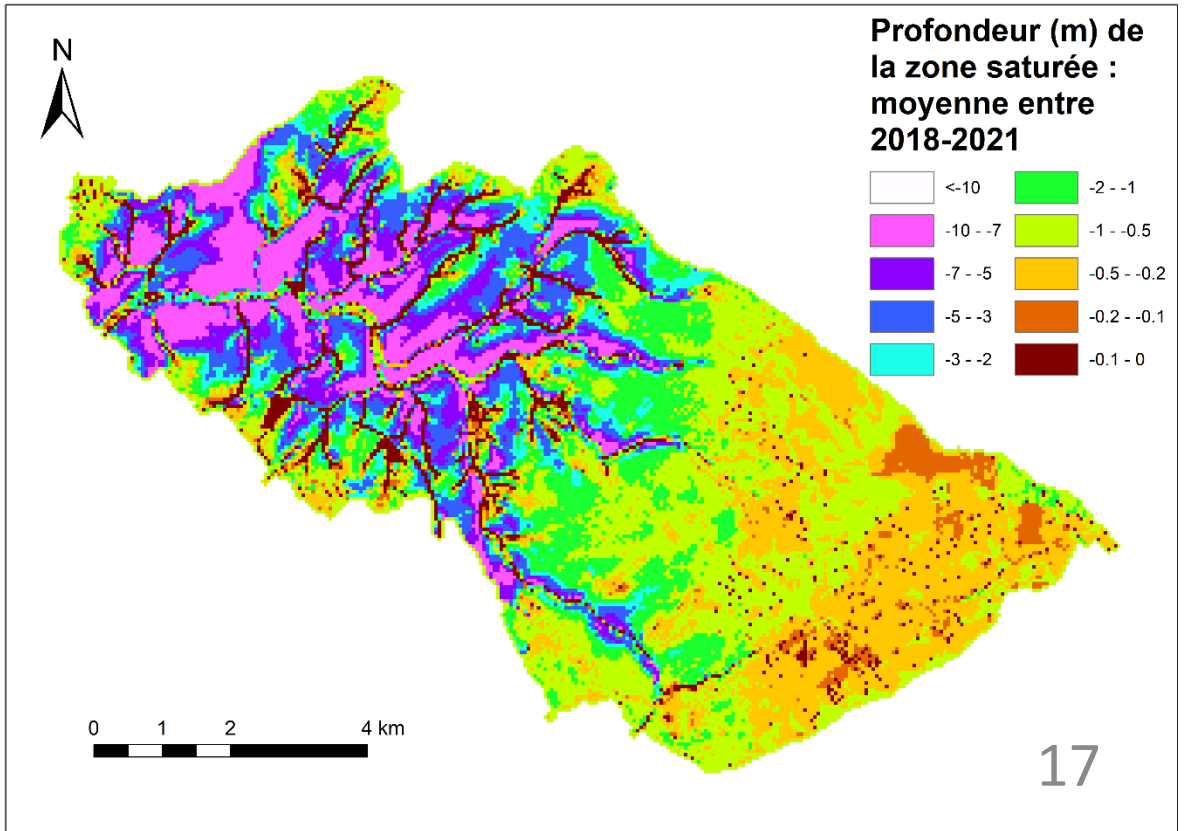
Peat bogs



Forested catchment

- Analysis of soil hydrodynamics
  - Vertical dynamics of the saturated zone





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The scenarios….

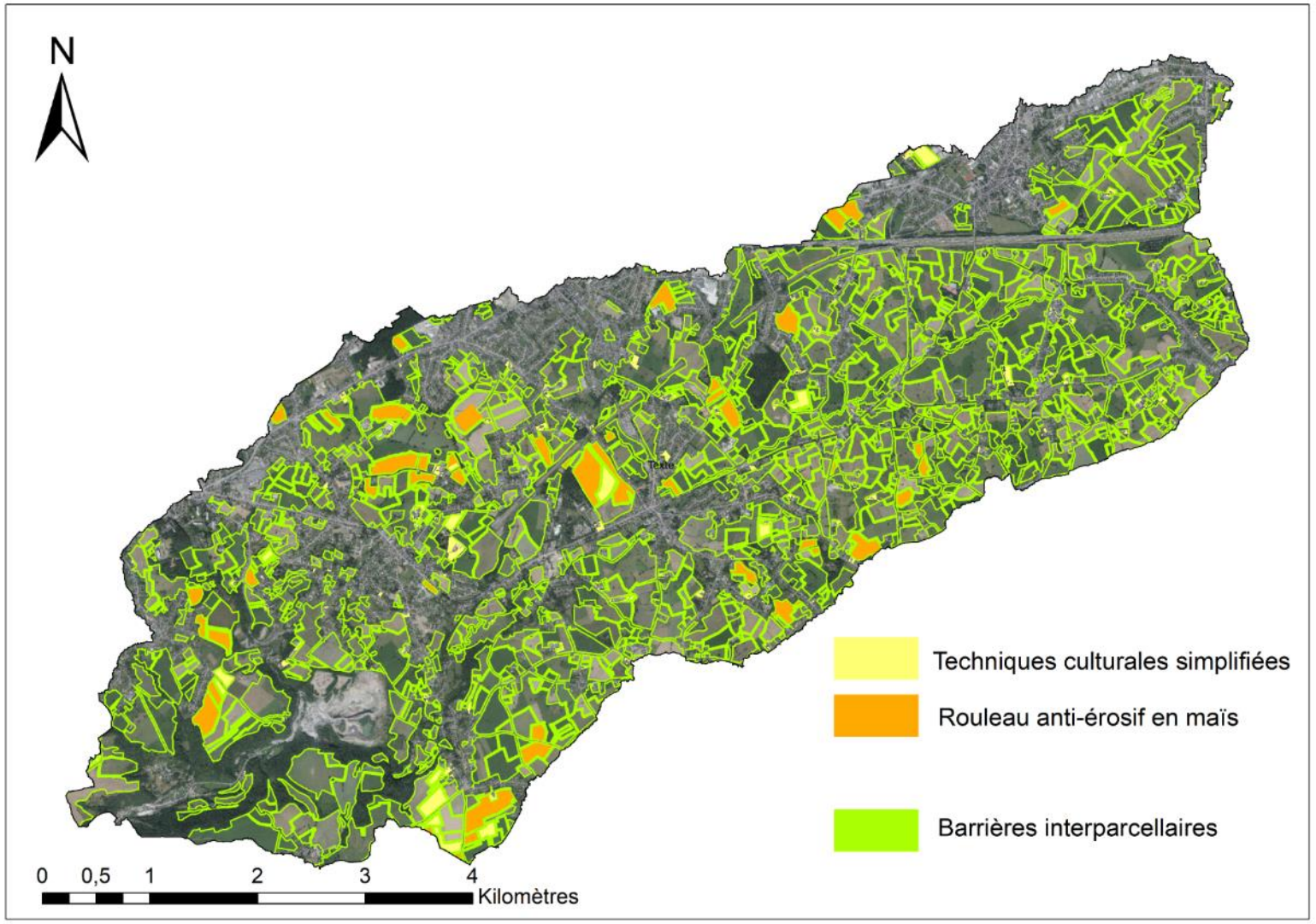
Implementation by basin

MIKESHE- HOEGNE

MIKESHE- MAGNE

	CATEGORY I	CATEGORY II	CATEGORY III
LEVEL A	A1 : Restoration of peaty and paratourbous soils A2 : Diversification of environments on hydromorphic soils	A3: Conservation of grassland in agricultural areas A4: Agricultural practices to conserve water and soil in maize production A5: Forestry practices limiting soil compaction	
LEVEL B	B1: Bocage network in agricultural areas	B2: Alternative drainage management for forest roads and firebreaks B3: Installation of slopes on steeply sloping roads B4: Inter-plot forage production	B5: Development of canals, diversion bays, keyline B6: Torrential correction of incised runoff axes
LEVEL C	C1: Restoration of riparian zones C2: Hydromorphological restoration (re-mandration)	C3: Use of quarries as storage areas for major floods	C4: Creation of reservoirs (with dykes and sluices) along the tributaries of the Vesdre river

Magne (agricultural catchement)

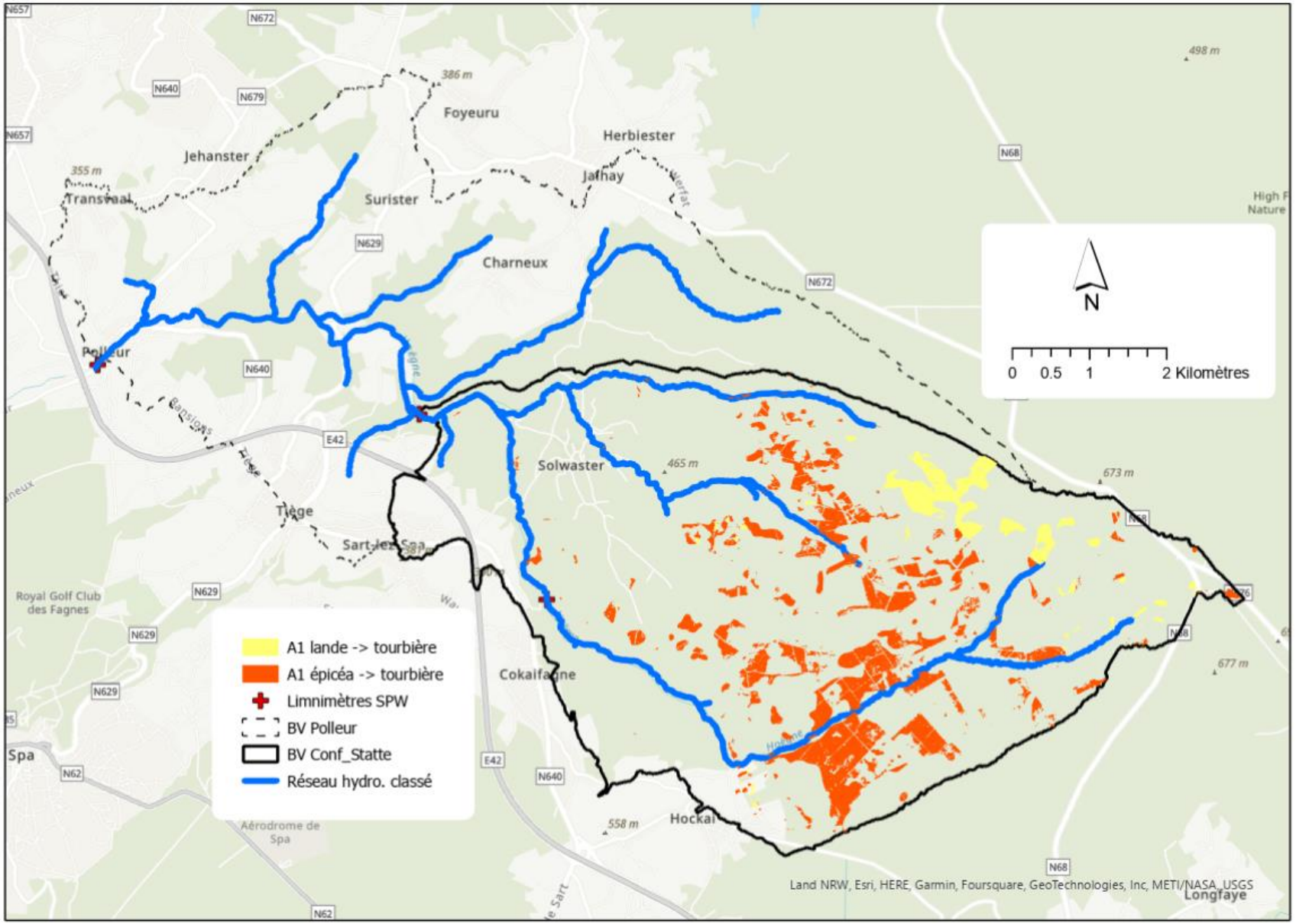


cipf

- ± 42 ha conservation agricultural practices
- ± 86 ha anti-erosion roller for maize

- ± 700 km interparcel hedges

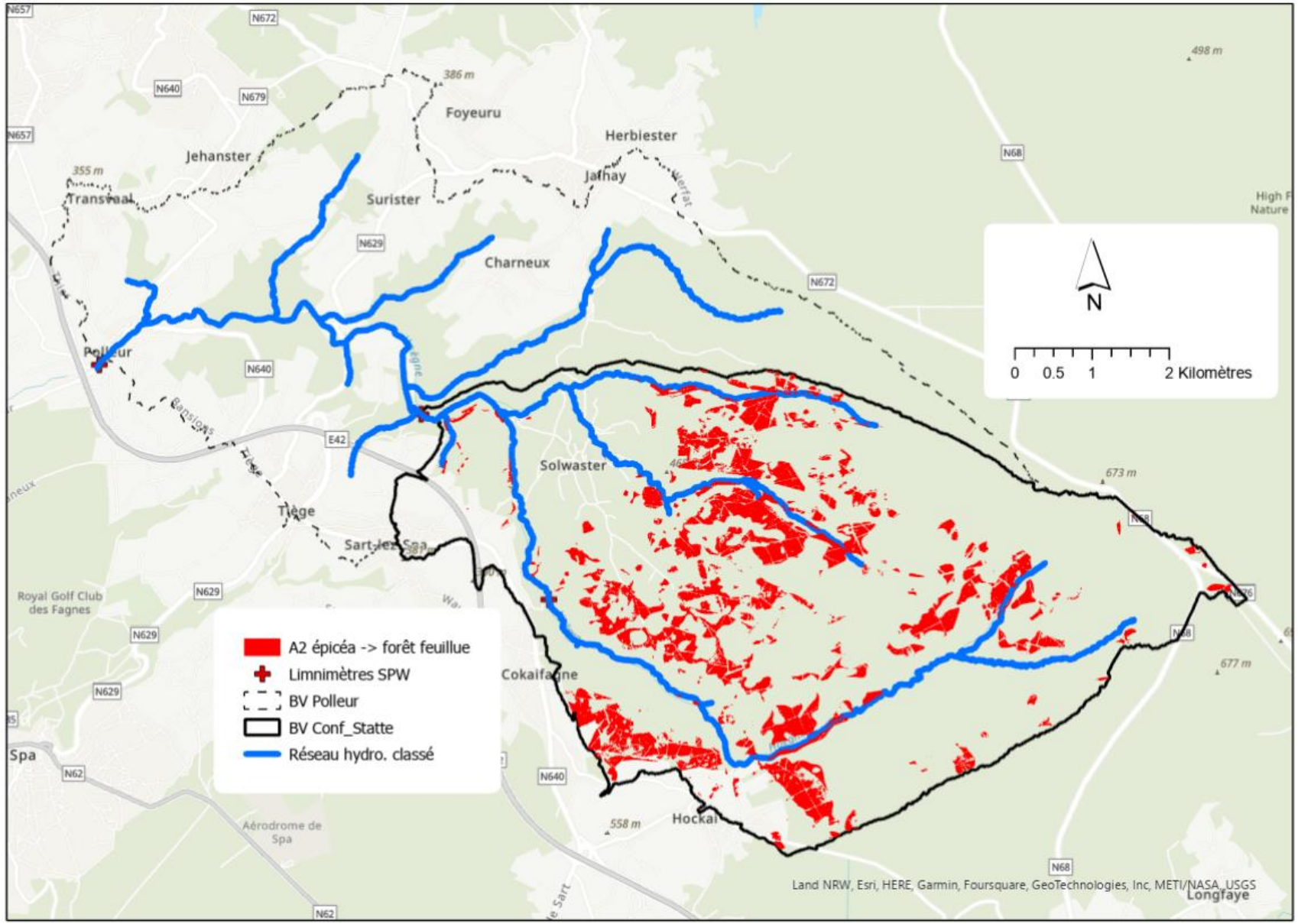
Hoëgne (forested catchment)



Peat and para-peat soils :
Managed area: 460 Ha
(11% of the area)

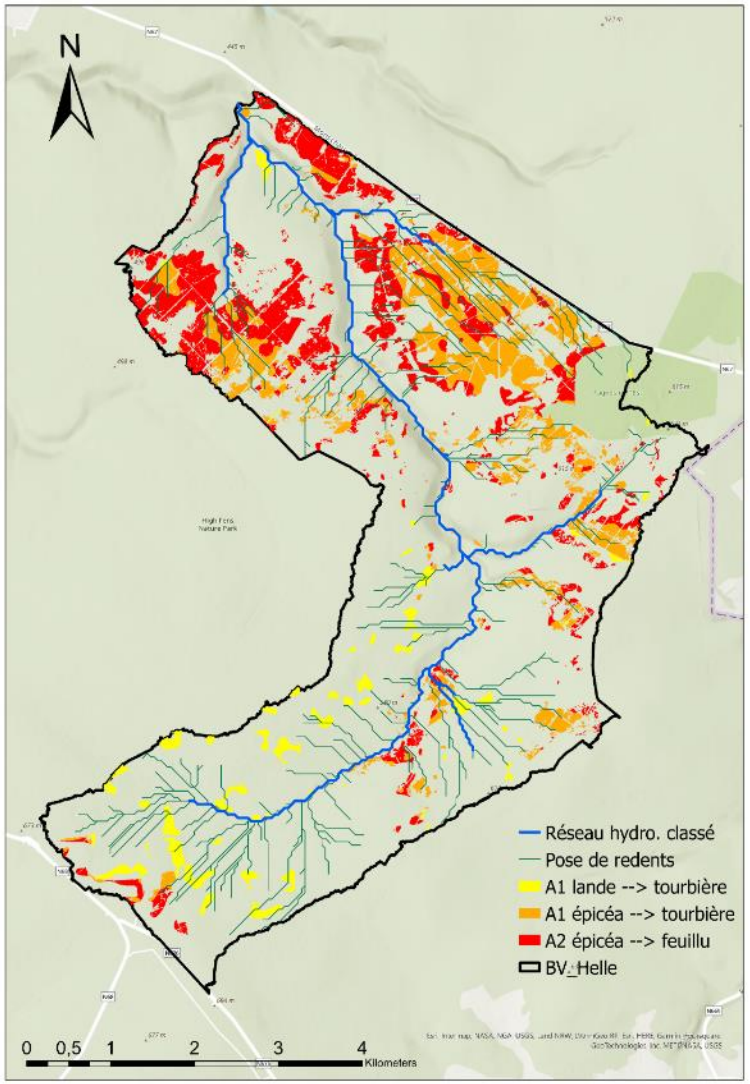
49 ponds
158 redents (± 24 km of managed small rivers axis)

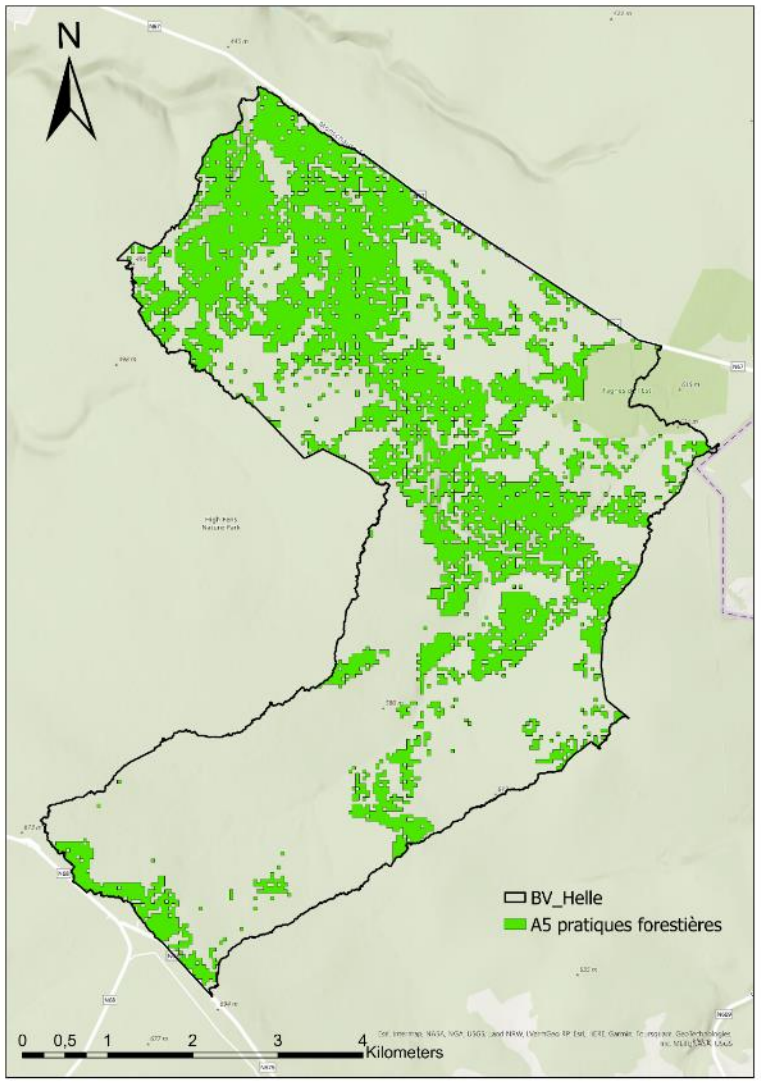
Hoëgne (forested catchment)



Hydromorphic soils
Managed area: 539 Ha
(13% of the area)
165 redents (± 25 km of managed small rivers axes)

Helle (peaty catchment)





- 197 redents in small rivers axis
- 26 ponds
- 83 ha (moor to bog)
- 319 ha (spruce to peatland)
- 349 ha (spruce to deciduous)
- 1234 ha (forestry practices limiting soil compaction)

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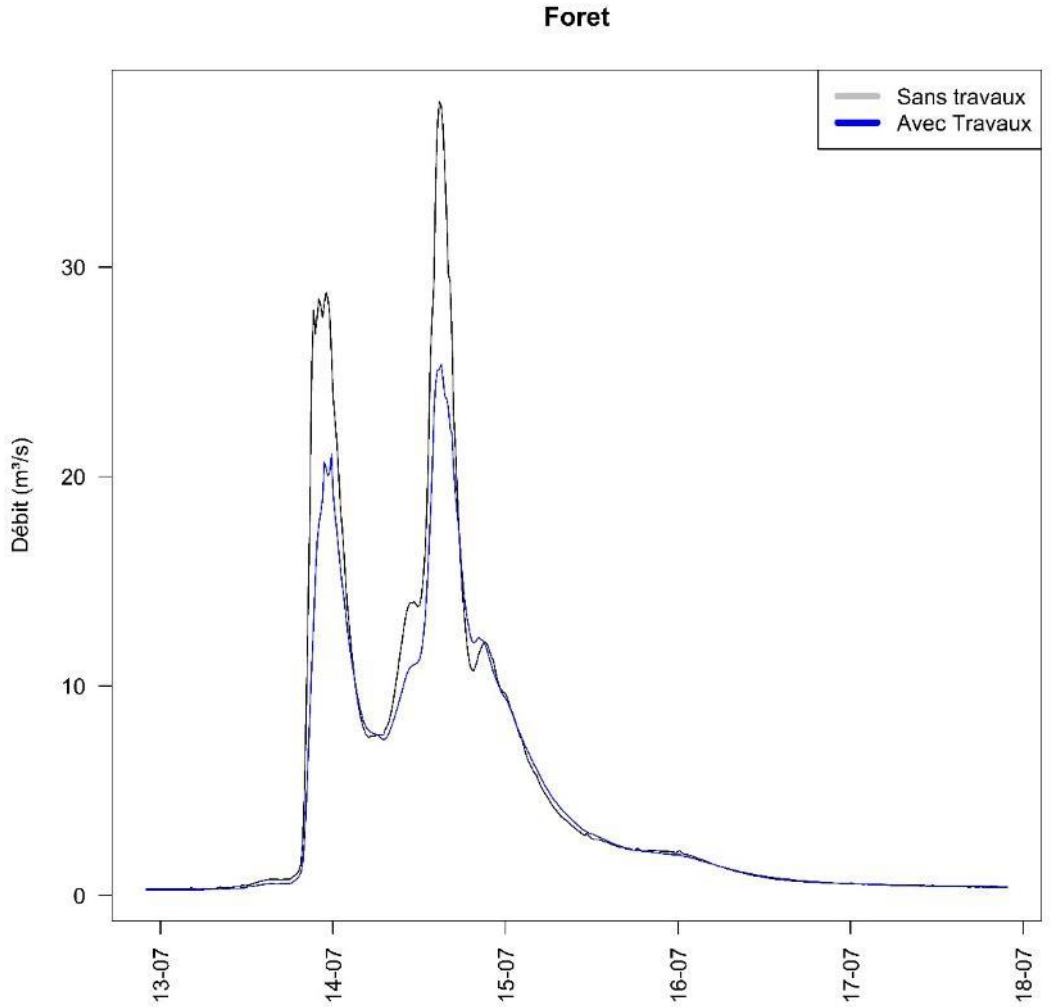
Some results

Results: July 2021 – Hydrographs - Magne



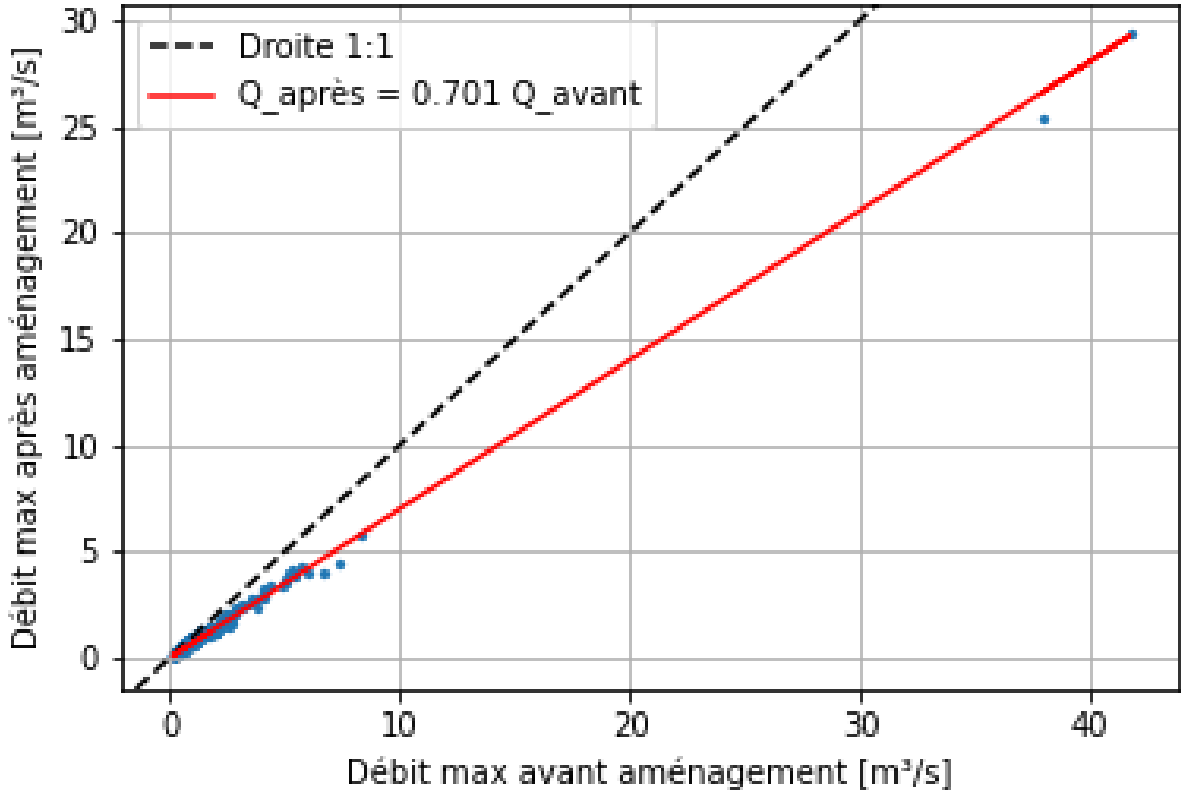
	site_ref	QMax delta (%)	Qmax Time delta (min)	Vol. tot. delta (%)
1	Foret	-33	15	-14

Overall comparison of maximum flows per event

Magne (since 2018)

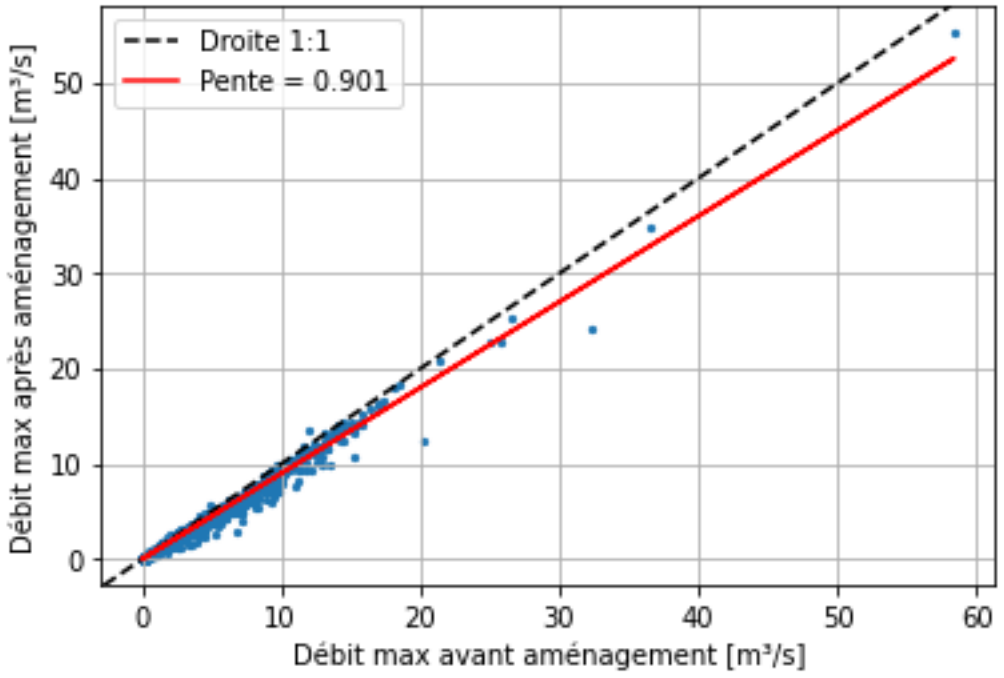
- The points correspond to the maximum flows of isolated events (6h without rain)

- Maximum flow rates reduced by around 30% (including for the highest flow rates) (including for the highest flow rates)

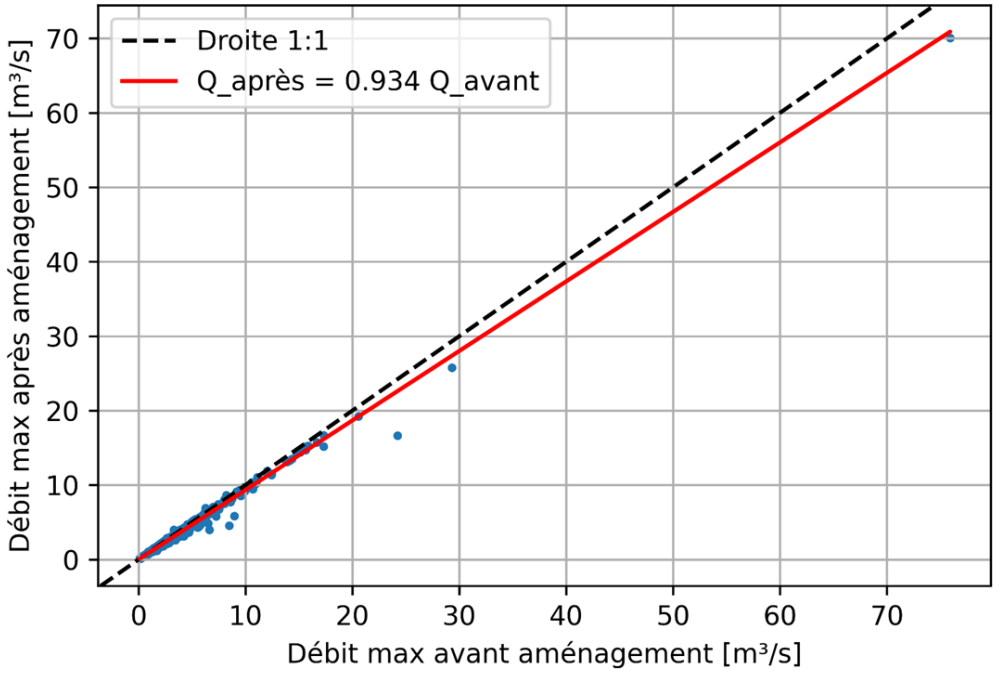


Overall comparison of maximum flows per event

Forested catchment
Belleheid (since 2002)

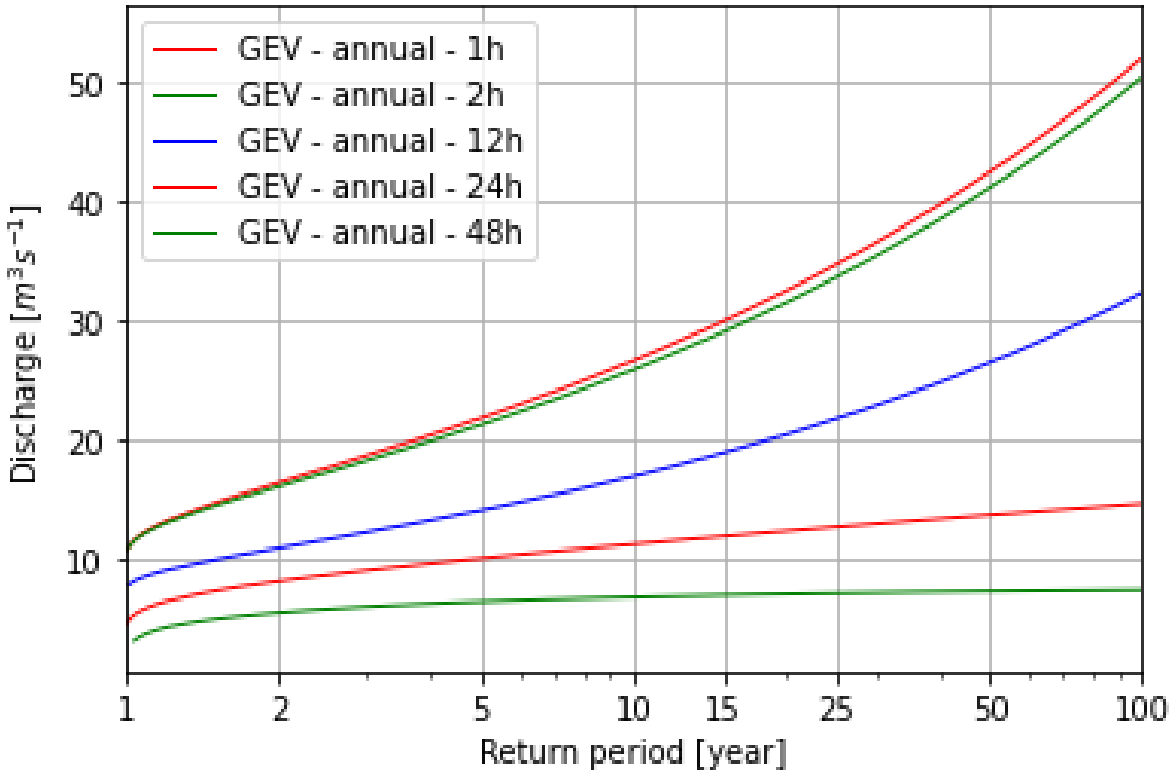


Peat catchment

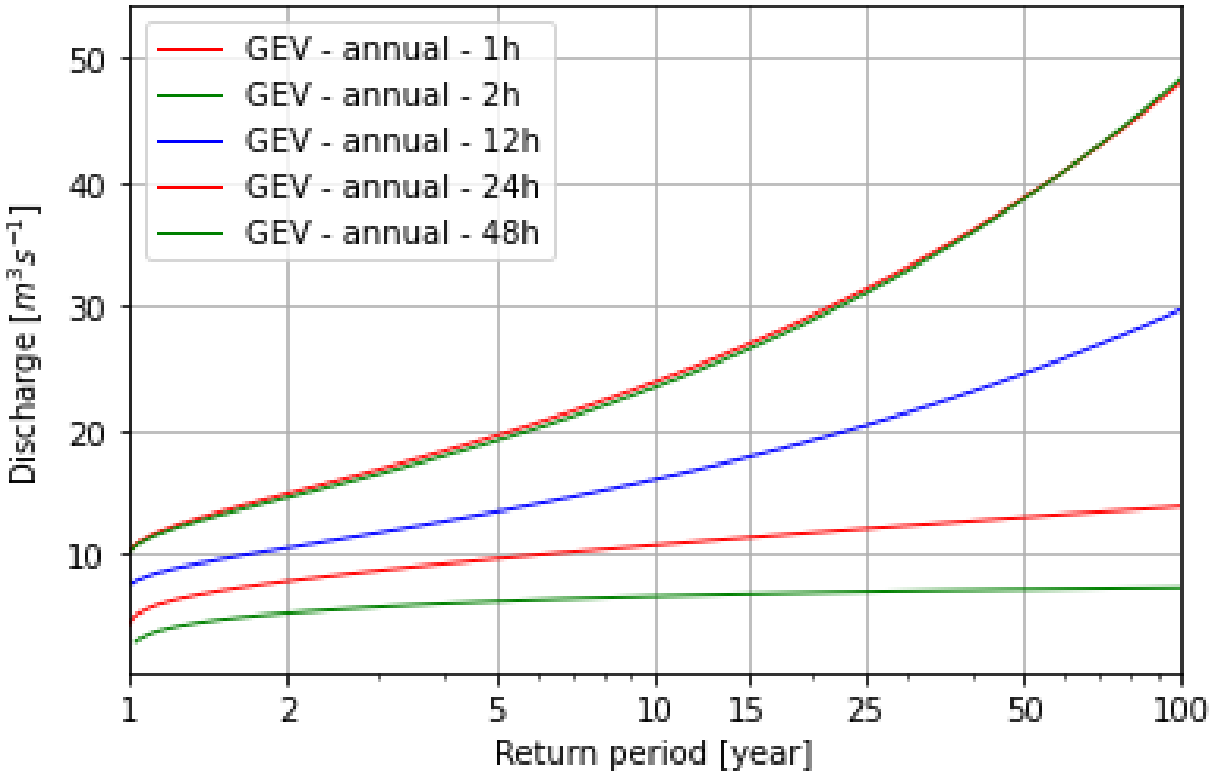


Time series analysis : forested catchment

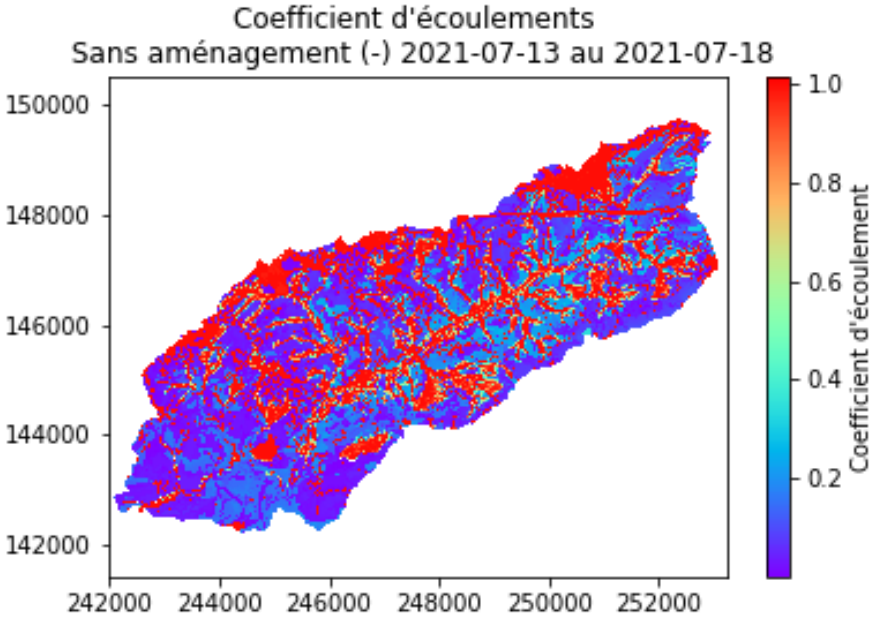
prior to management (2003 - 2020)

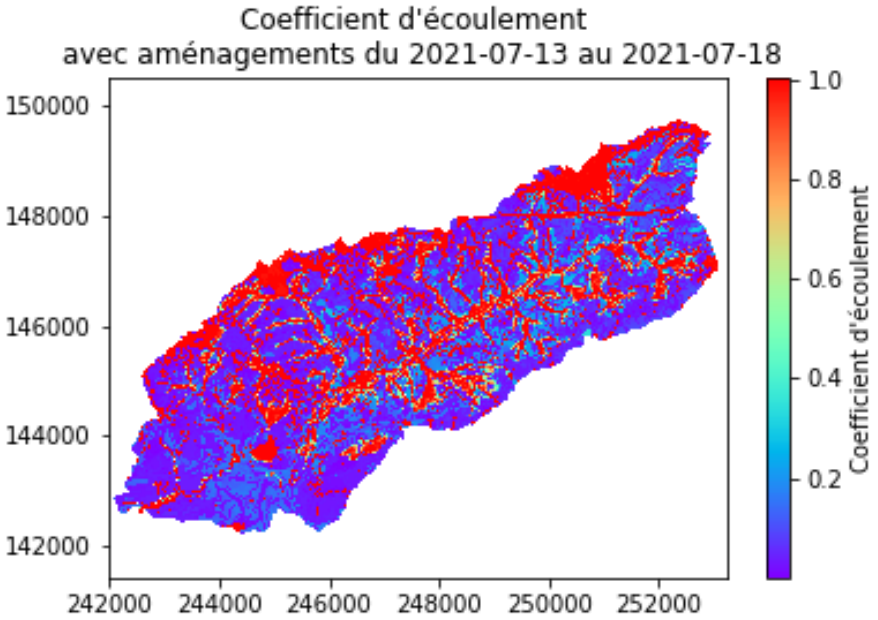


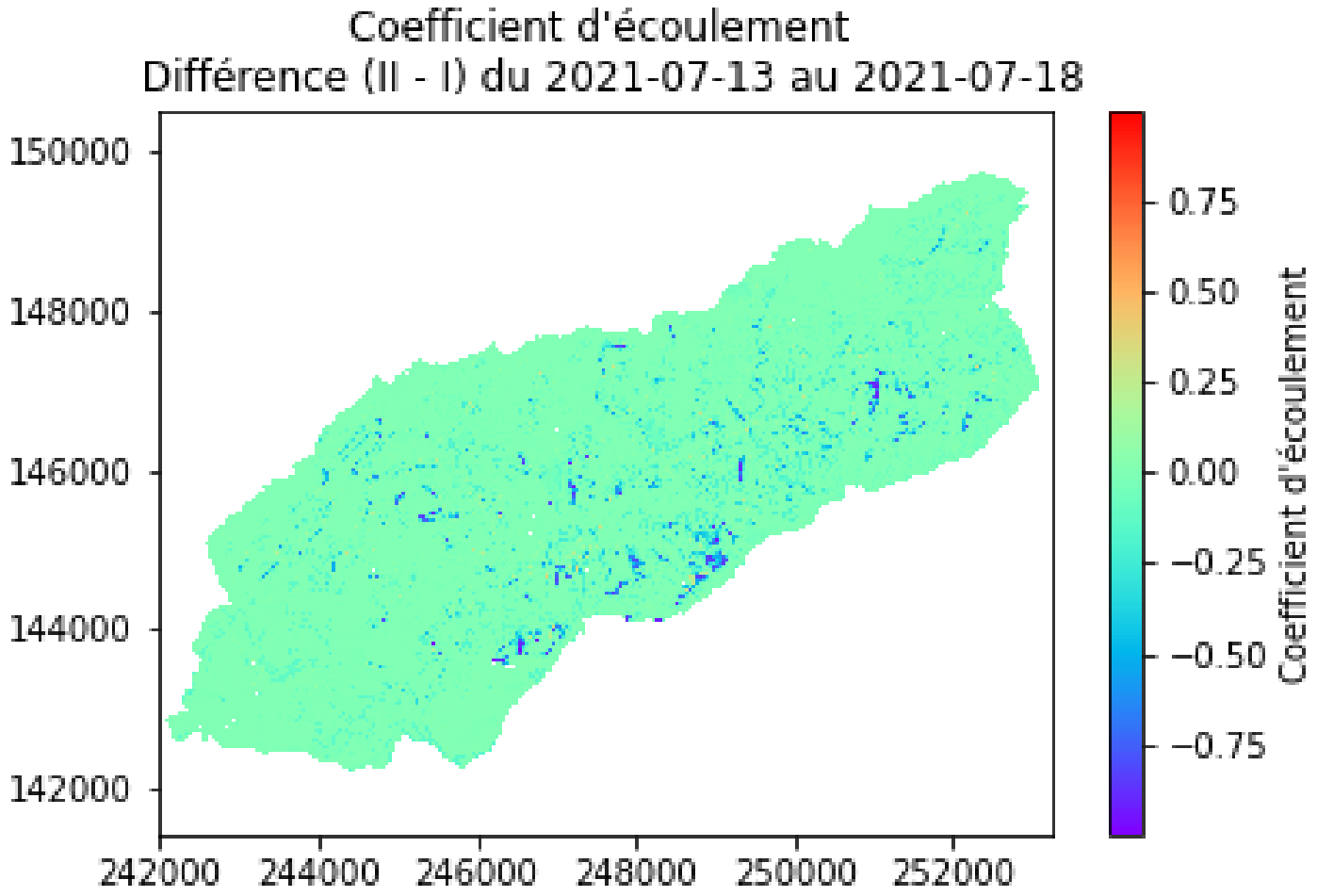
post-management (2003 - 2020)



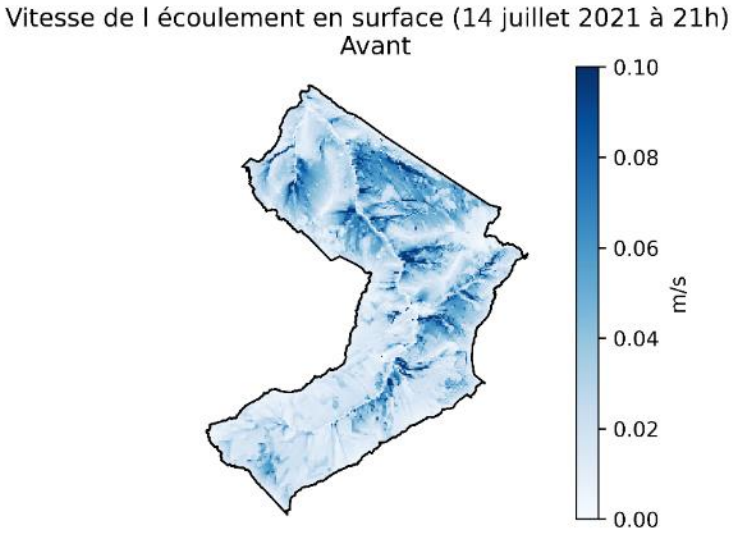
Flow coefficients – agricultural catchment

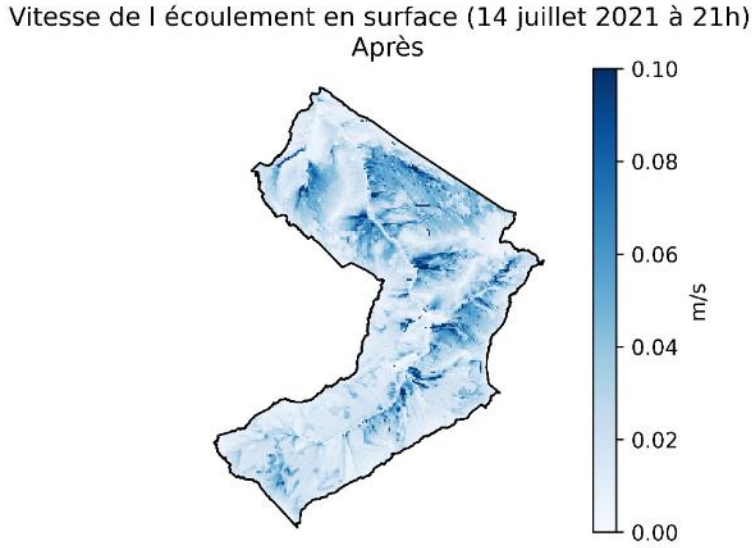


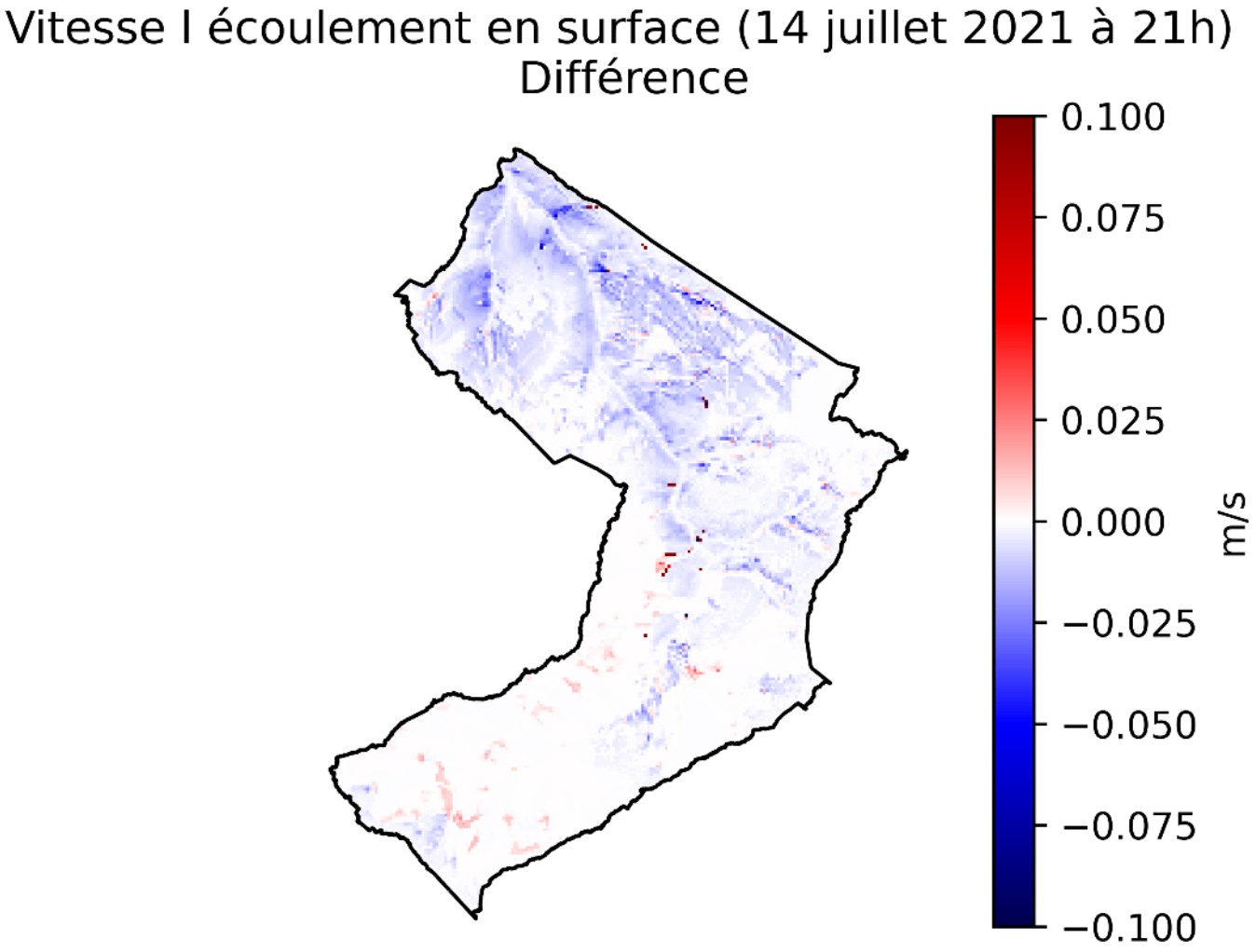




Runoff instant speeds – peaty catchment







Summary for policy makers
« Identity card » of the management actions

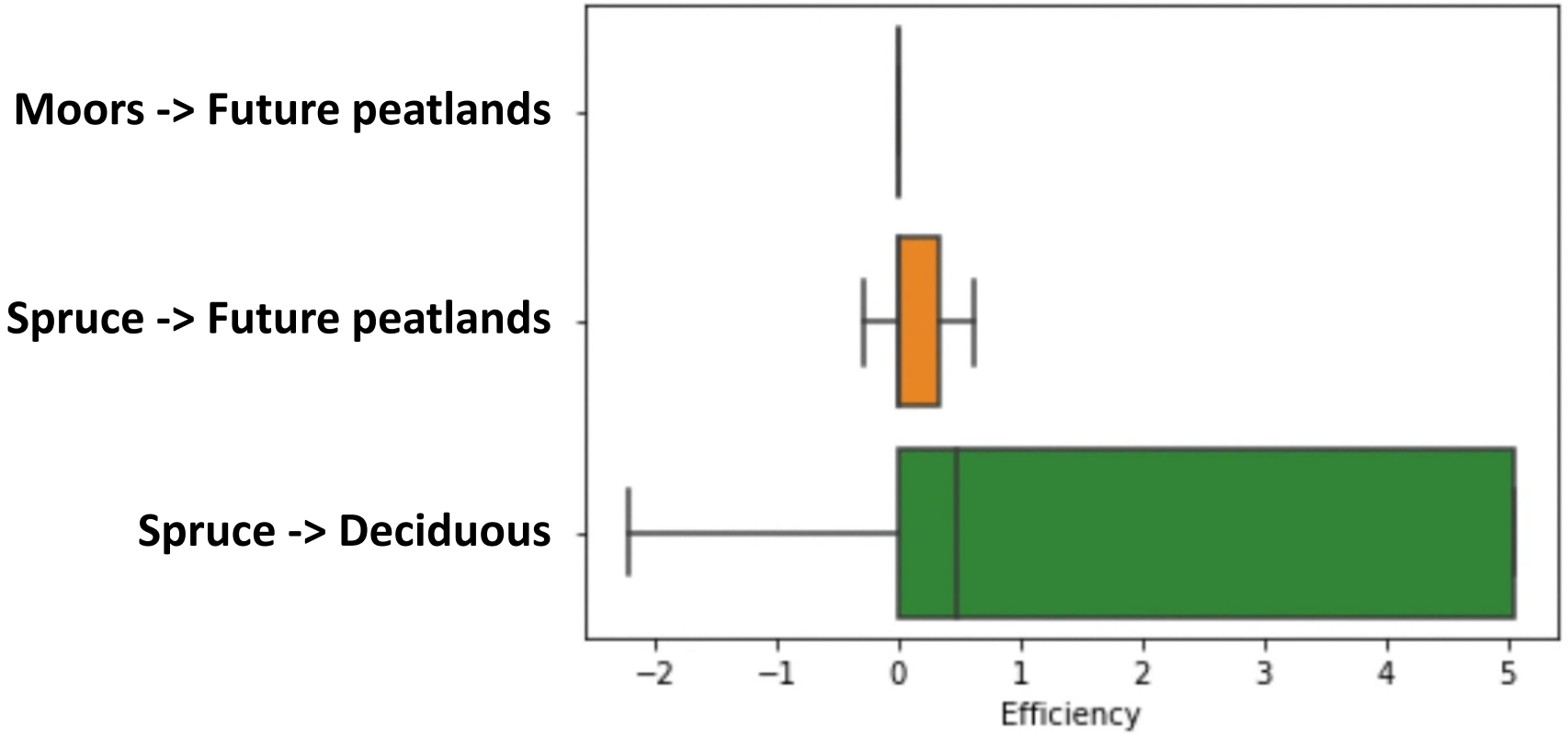
- Objectives
  - Quantifying the hydrological efficiency of the various actions
- Method
  - Analysis of runoff production before and after development
    - Estimated efficiency

$$Efficiency\ (\%) = 100.\frac{(runoff_{before} - runoff_{\ after})}{runoff_{before}}$$

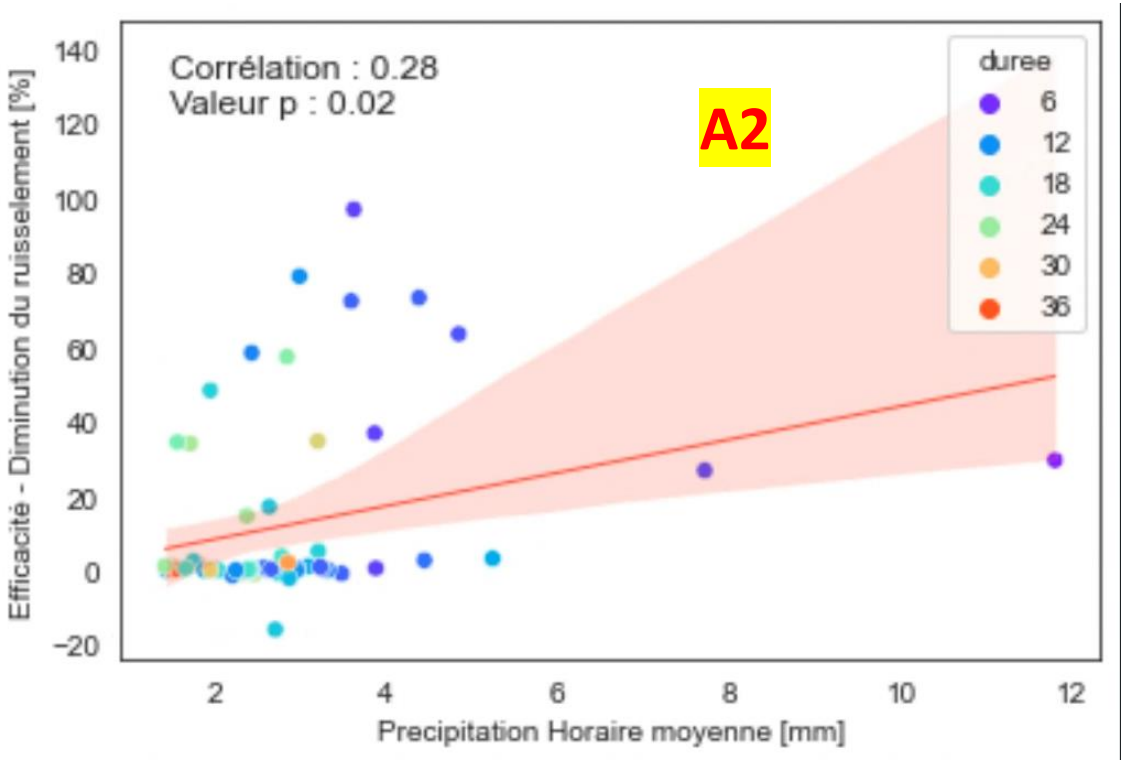
  - Carried out for each managed area and for each rainfall event
    - 6 hours without rain between two events
    - First test: 2002-2011 period

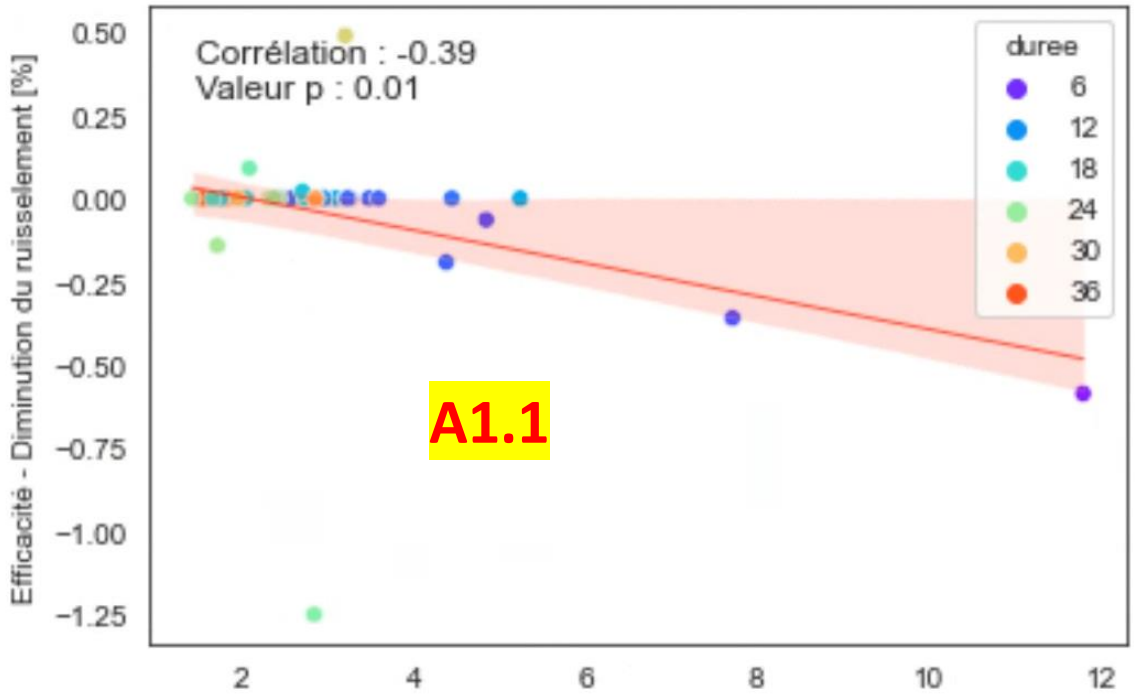
« Identity card » of the management actions

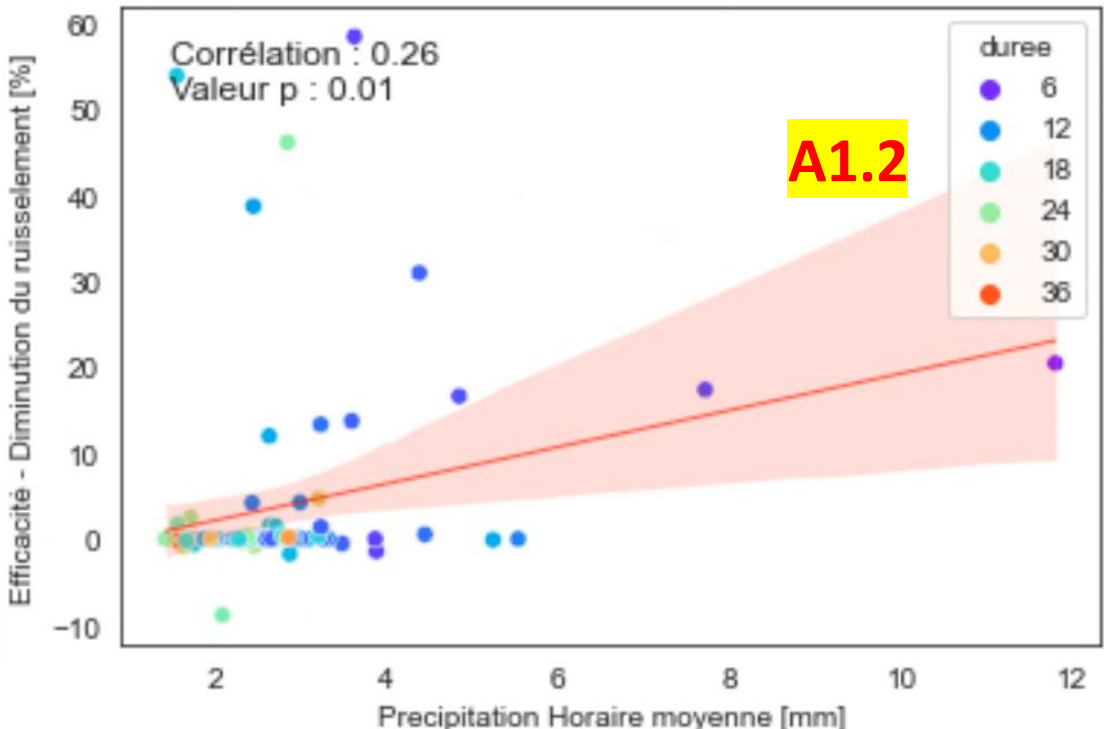
- Efficiency in runoff volume reduction
  - 1089 rainfall events -> 88 with runoff > 5 mm (before management)



Results forested catchment



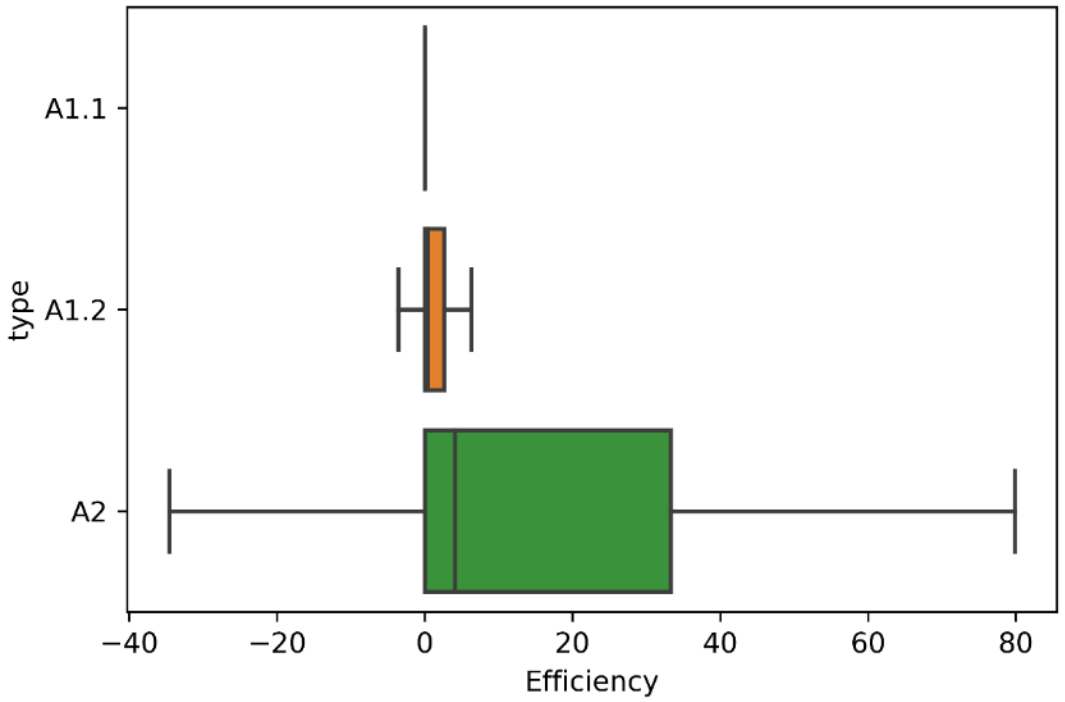


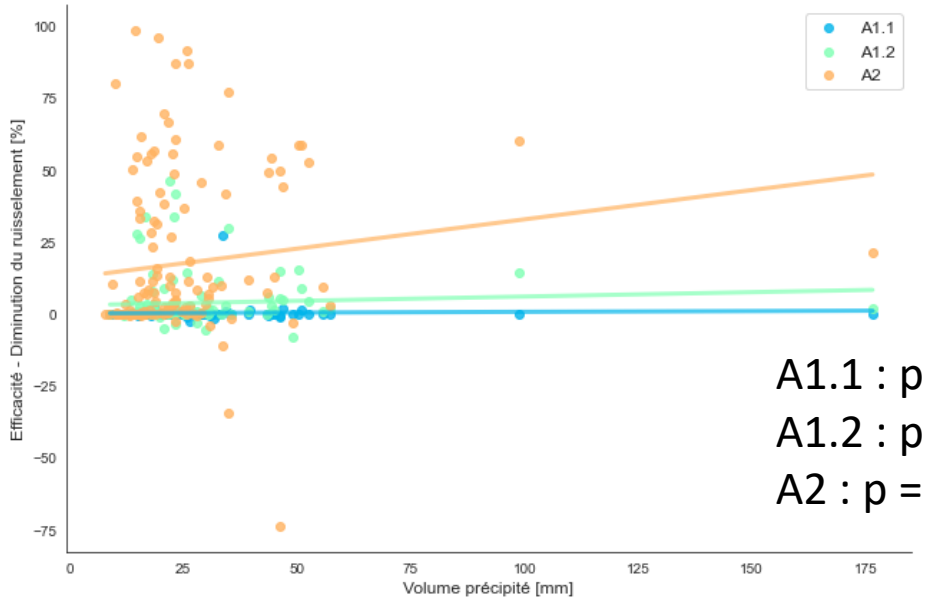


A1.1	**: Moors -> Future peat bogs**
A1.2	**: Spruce -> Future peat bogs**
A2	**: Spruce -> Deciduous**

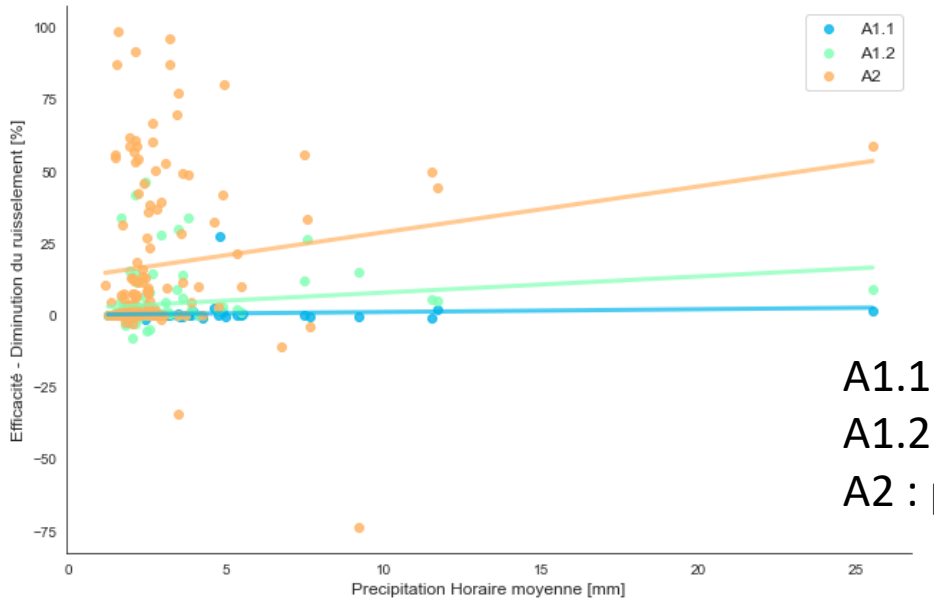
Results BV Peaty catchment

A1.1	**: Moors -> Future peatlands**
A1.2	**: Spruce -> Future peatlands**
A2	**: Spruce -> Deciduous + limit compaction**





A1.1 : p =0.68
A1.2 : p =0.49
A2 : p = 0.12

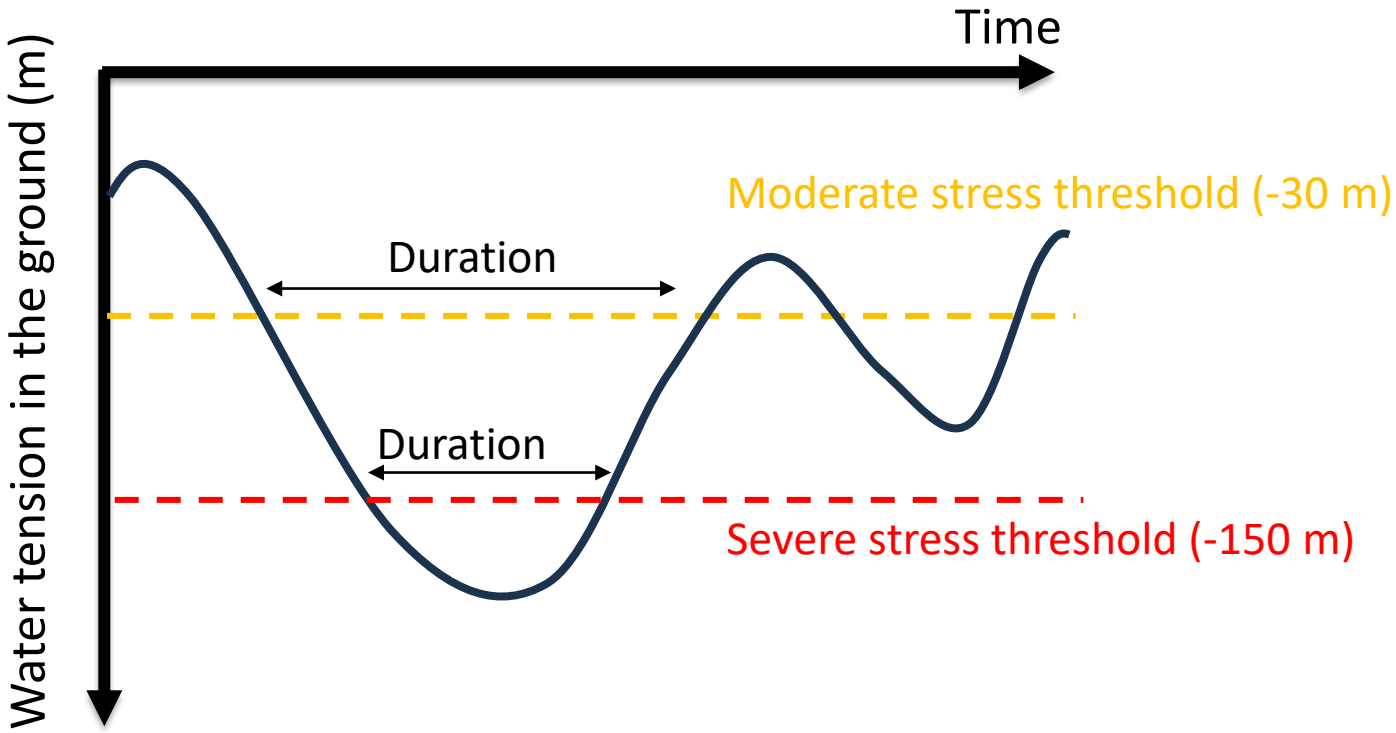


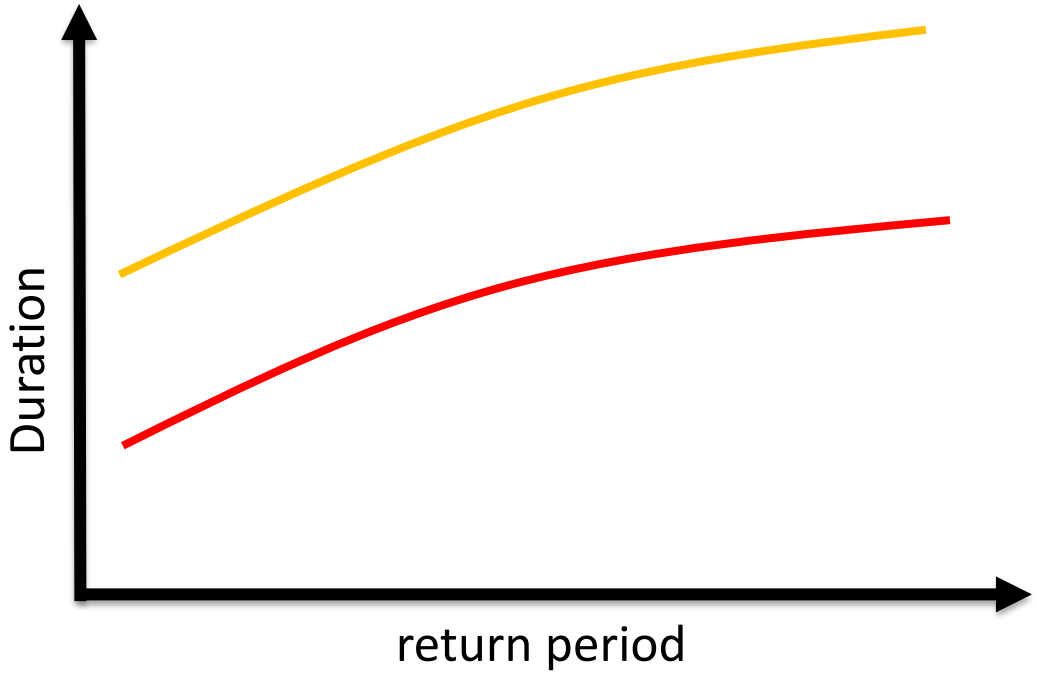
A1.1 : p = 0.27
A1.2 : p = 0.07
A2 : p = 0.08

Focus on drought: Construction of an edaphic stress indicator

For each model cell and each year (2003-2021), extraction of the maximum duration when the water pressure in the soil profile explored by the roots is below the stress threshold.

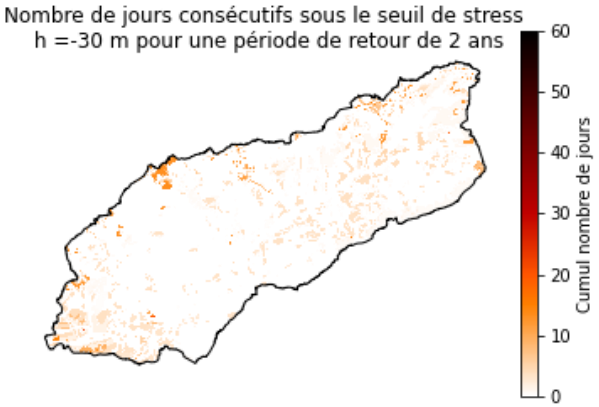
For each cell, adjustment of a Gumbel law to establish the link between the duration, intensity (threshold) and probability of occurrence (return period) of the stress. → **Drought – Duration – Frequency (DDF)**

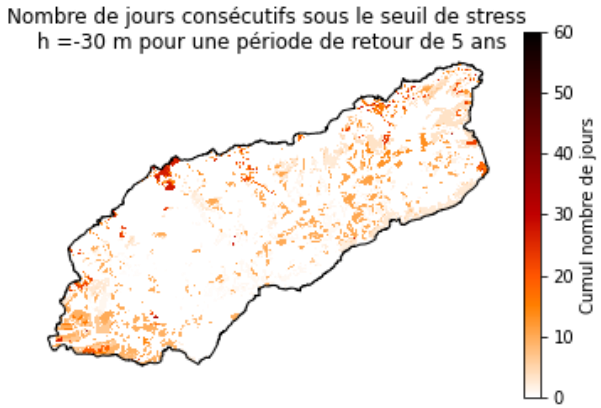


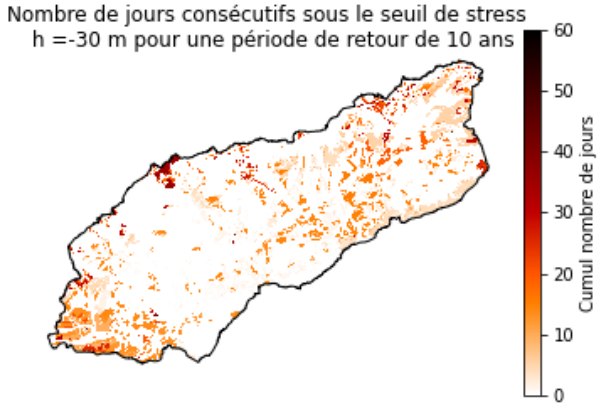


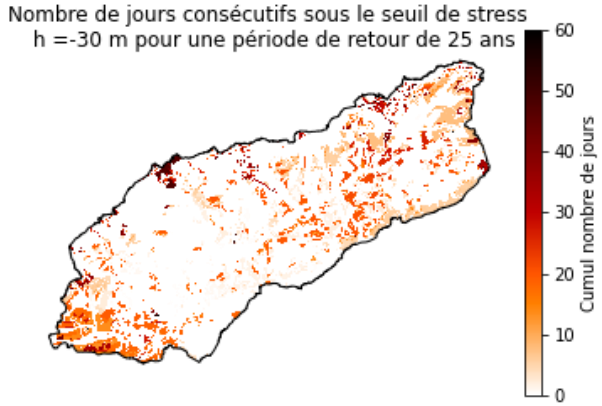
Focus on drought: Results (before management)

Moderate stress(-30 m)

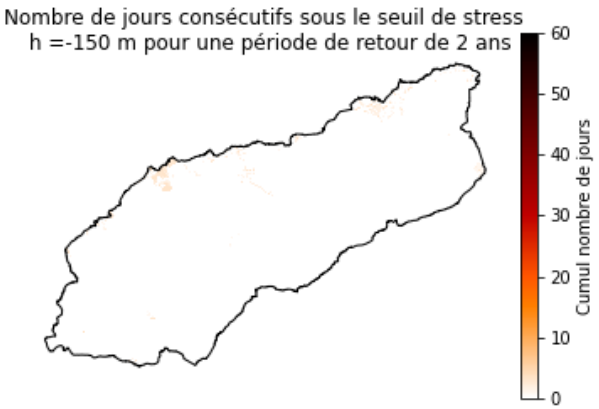


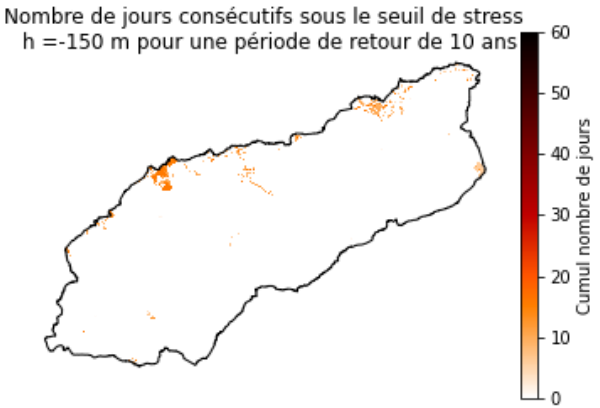


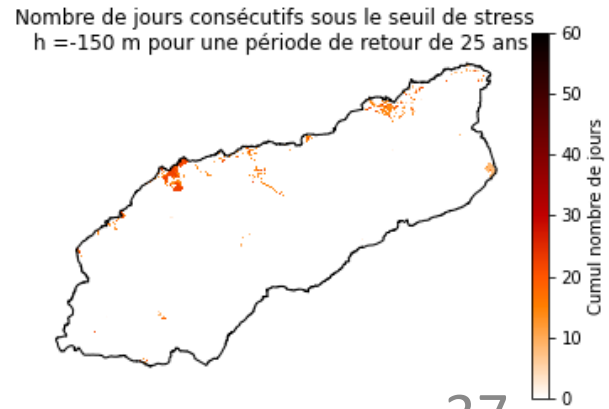




Severe stress(-150 m)

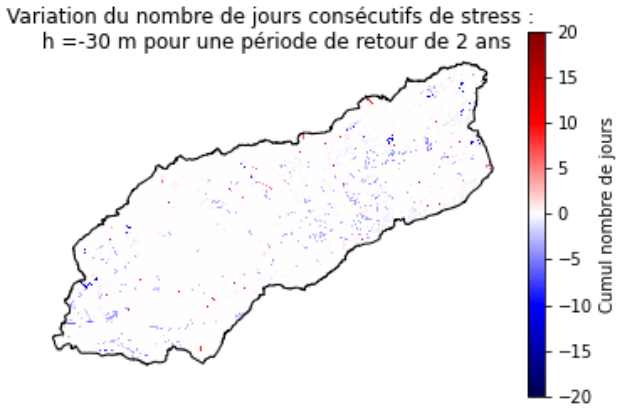


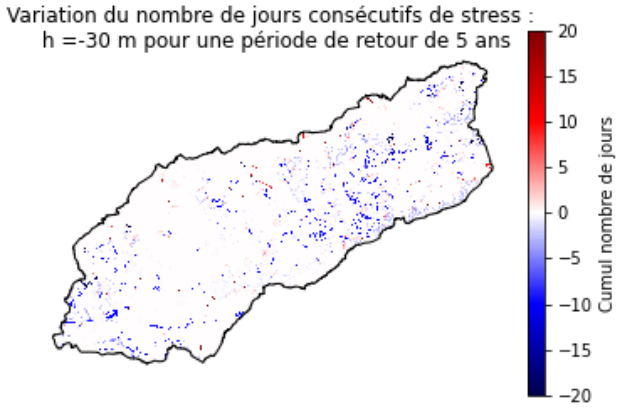


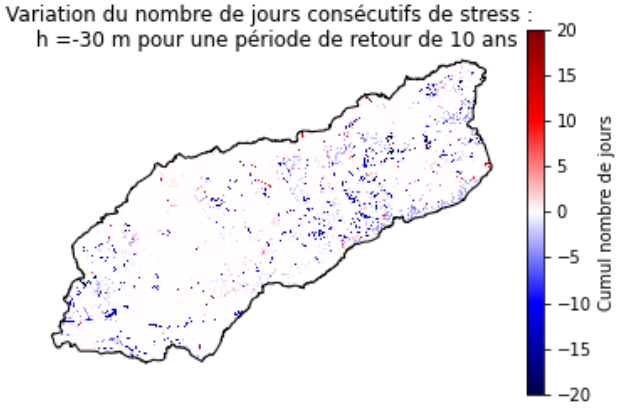


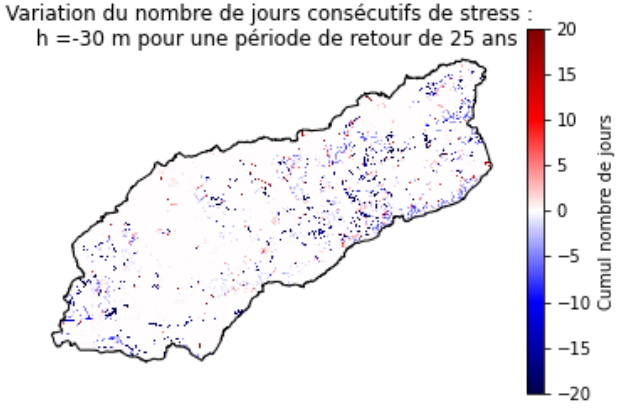
Focus on drought: Results (difference)

Moderate stress(-30 m)

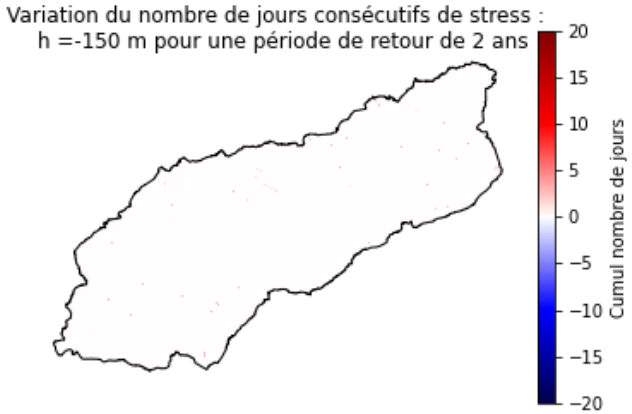


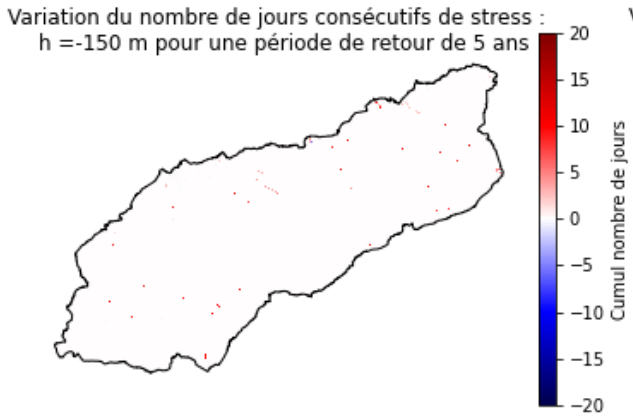


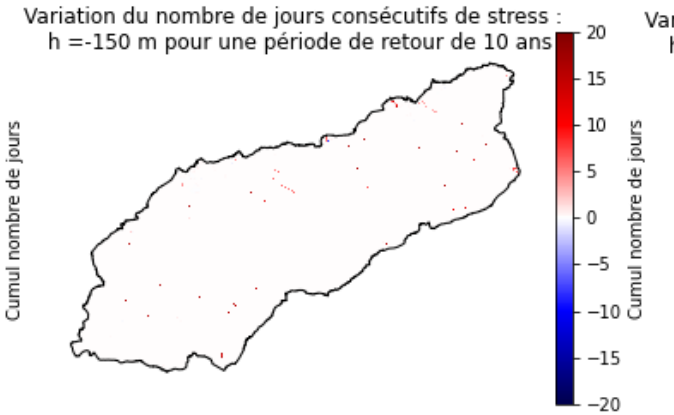


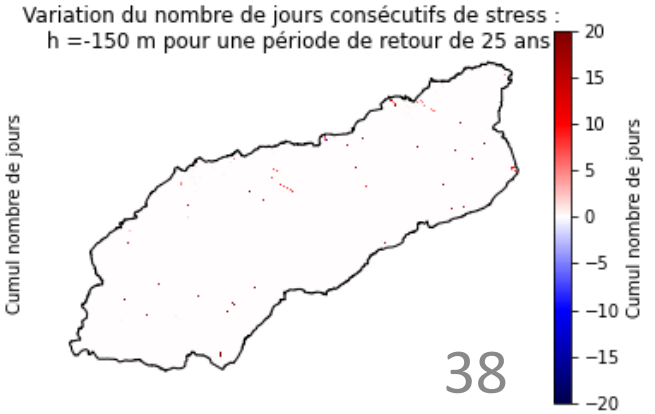


Severe stress(-150 m)



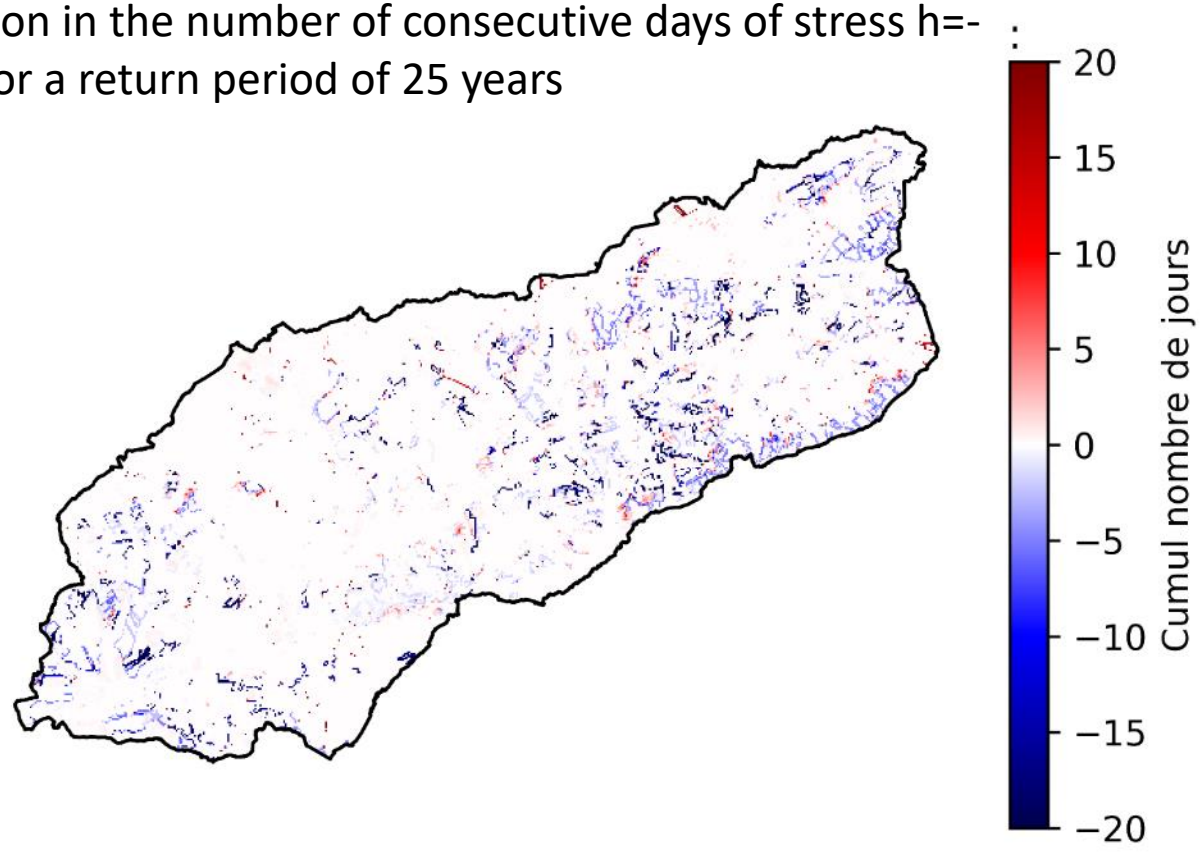


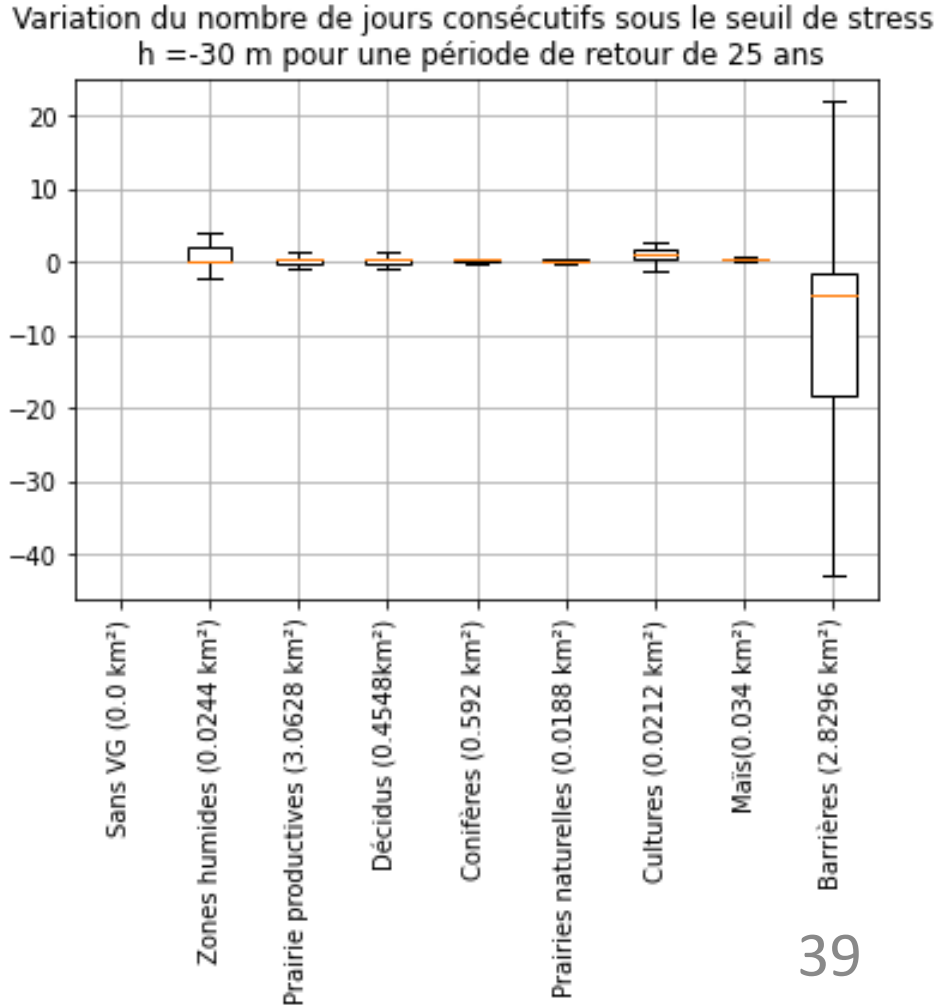




Focus on drought: Results (difference)

variation in the number of consecutive days of stress h=-30m for a return period of 25 years





Conclusions so far….

- Although its full validation remains a challenge….
- This type of model offers the possibility of explicitly testing a wide range of catchment management actions,
  - both in terms of floods and droughts.
- It is possible to
  - run different types of management actions,
  - extract key intermediate variables and
  - subject the models to climate change scenarios, etc.
- We are only at the beginning of exploiting the results,
- We remain aware of the limitations and value the comparative approach before and after development more than the absolute results

Thank you!

Still a lot to show, a lot to discuss…
do not hesitate to contact us
aurore.degre@uliege.be