HOW TO PREDICT OF WATER QUALITY AND QUANTITY TRAJECTORIES UNDER CLIMATE AND AGRICULTURAL CHANGES ?

Application to the Souffel catchment (Bas-Rhin) under SWAT+

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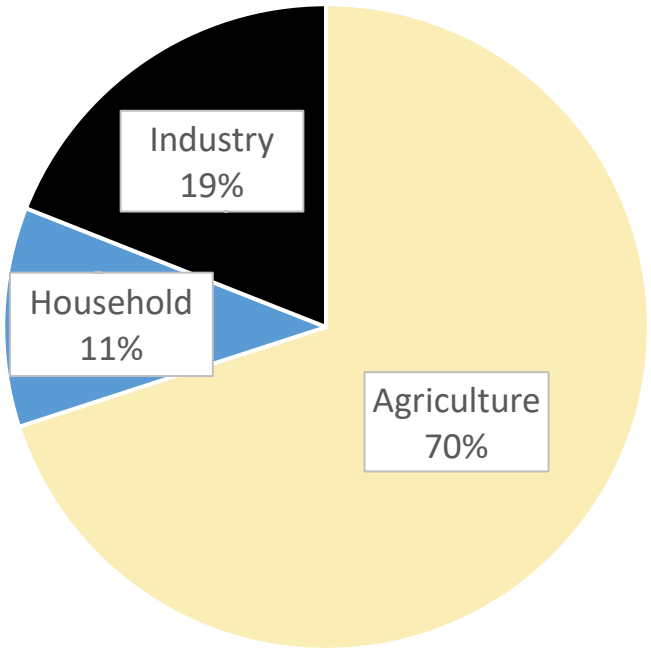
AGRICULTURE

CONTEXT - (Un)sustainability of farming systems worldwide

AGRICULTURE

World water use [1]



[1] https://cleanwaterforthefuture.weebly.com/global-water-use.html
[2] https://www.fao.org/home/fr

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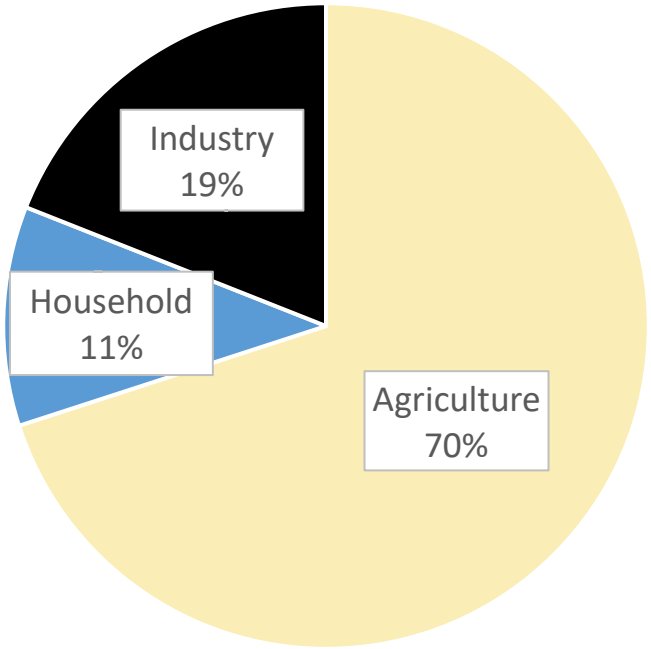
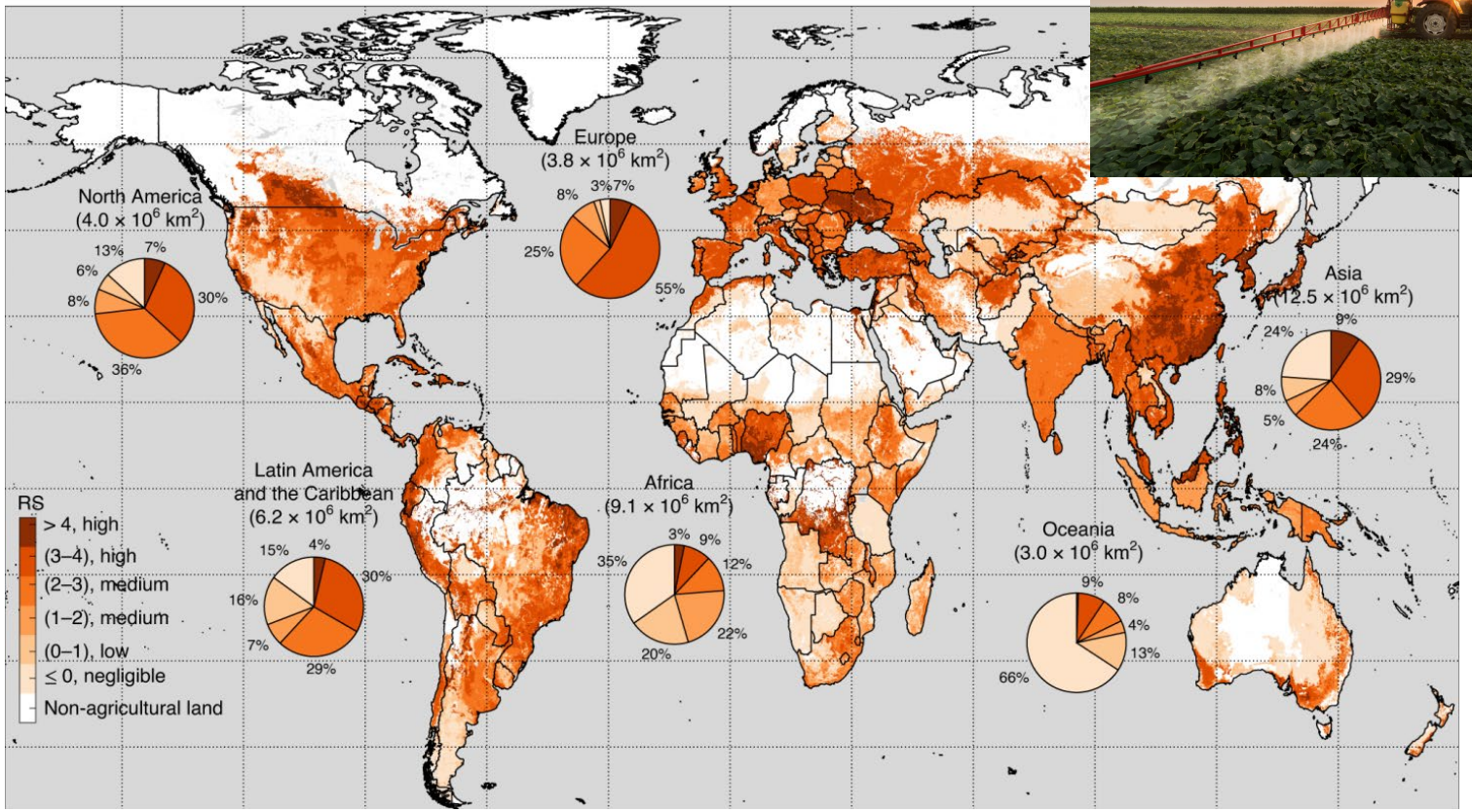


Use of pesticides worldwide - 2020



Source : https://www.infomedocpesticides.fr/lusage-des-pesticides-dans-le-monde/

[1] https://cleanwaterforthefuture.weebly.com/global-water-use.html
[2] https://www.fao.org/home/fr

RESEARCH QUESTIONS

How can we help farmers move towards a more sustainable system?

RESILIENT

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How can we help farmers move towards a more sustainable system?

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LESS IMPACTFUL

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DESIRABLE FOR FARMERS

TRAJECTORIES Project

2021-2025

RESEARCH QUESTIONS AND MAIN OBJECTIVES

How can we help farmers move towards a more sustainable system?

RESILIENT

LESS IMPACTFUL

ECONOMICALLY WORKABLE

DESIRABLE FOR FARMERS

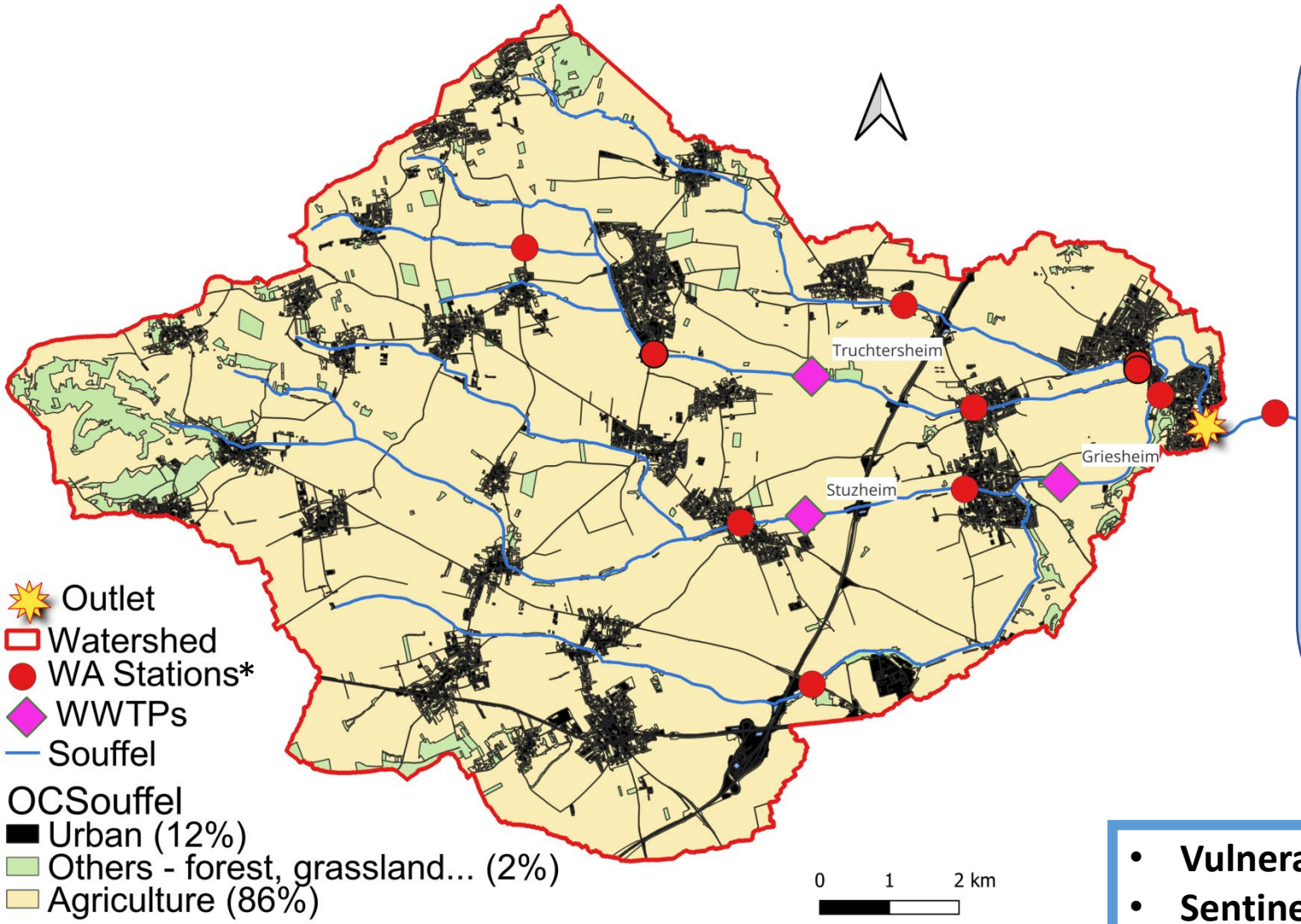
TRAJECTORIES Project
2021-2025

- Initiate a change in farming practices **by 2070**
- Use **modelling (SWAT+[3])** to provide quantitative assessment
- Involving stakeholders in foresight work through a **bottom-up approach**
- Provide a **frugal** and **parsimonious** method, that can be **transposed** to other catchments (10 to 100 km²)

SWAT Soil & Water Assessment Tool

[3] *Bieger et al. 2017*

STUDY SITE - The Souffel catchment (Northeast of France), an impacted area



The Souffel catchment
Bas-Rhin (67), France

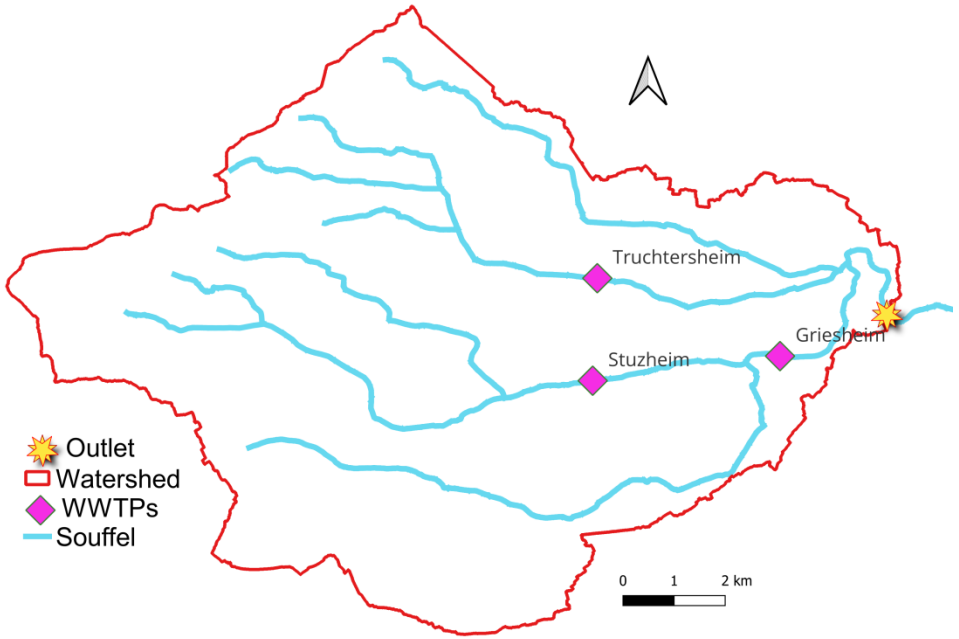
- 115 km²
- 712 mm/y
- ET = 515 mm/y
- < 3%
- Agriculture (86%)
- Corn (72%), winter wheat (8%)
- 3 WWTPs
- Loessic soils

- **Vulnerable** territory : the most contaminated area
- **Sentinel river** : low specific discharge

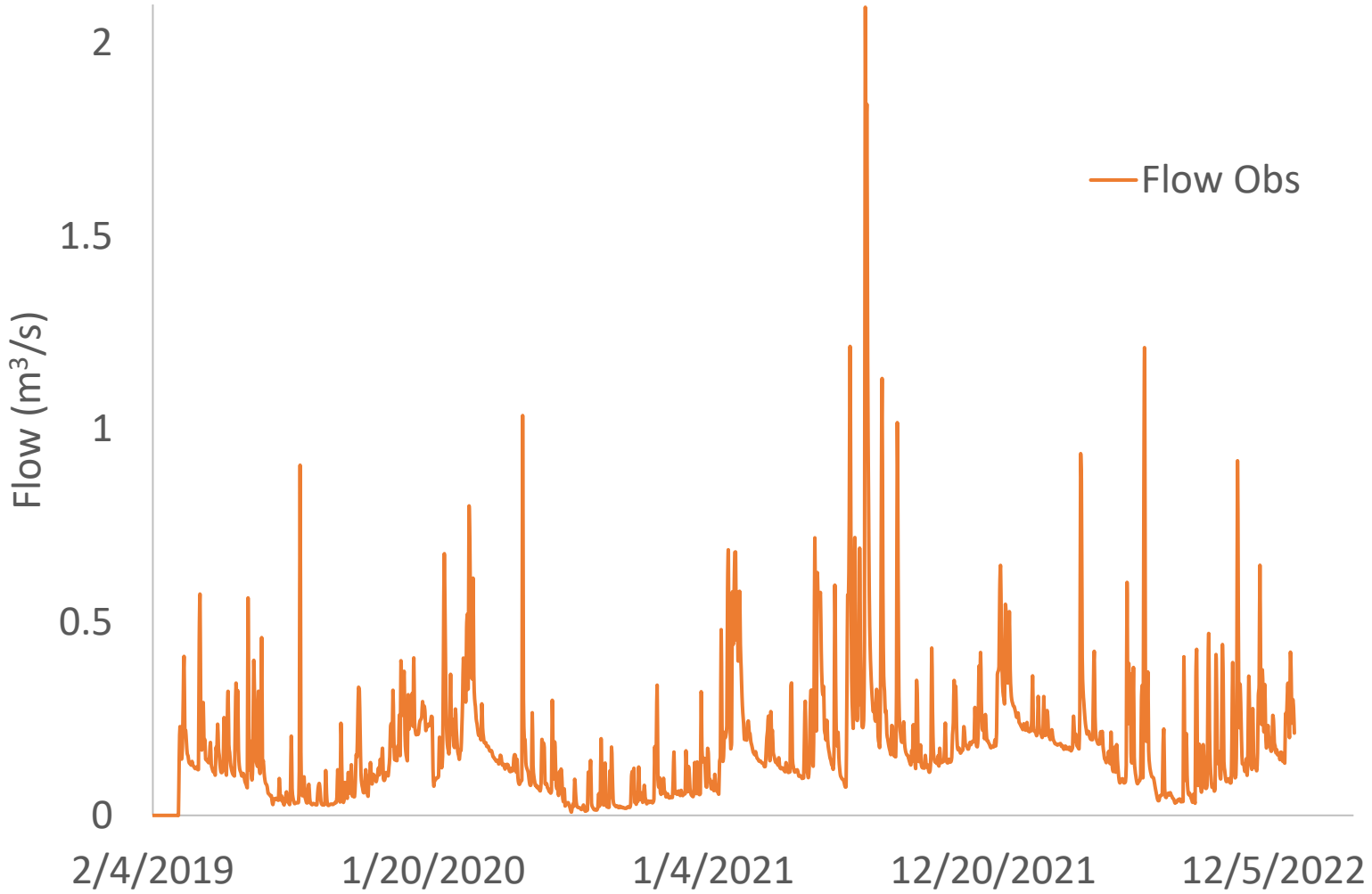
*WA=Water Agency

STUDY SITE - The Souffel catchment, an impacted area

Average Flow : 180 L/s
Specific flow : 1.56 L/s/km²



data **Flow** : EMS* (2019-2023)

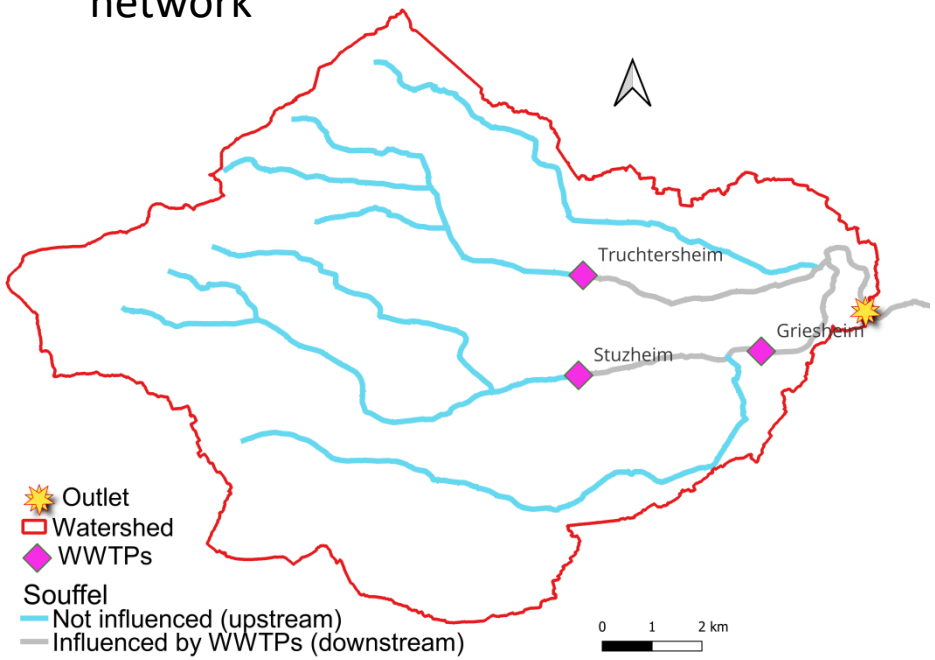


- Average specific flow about **10 times lower** than the surrounding rivers

EMS = Eurométropole de Strasbourg

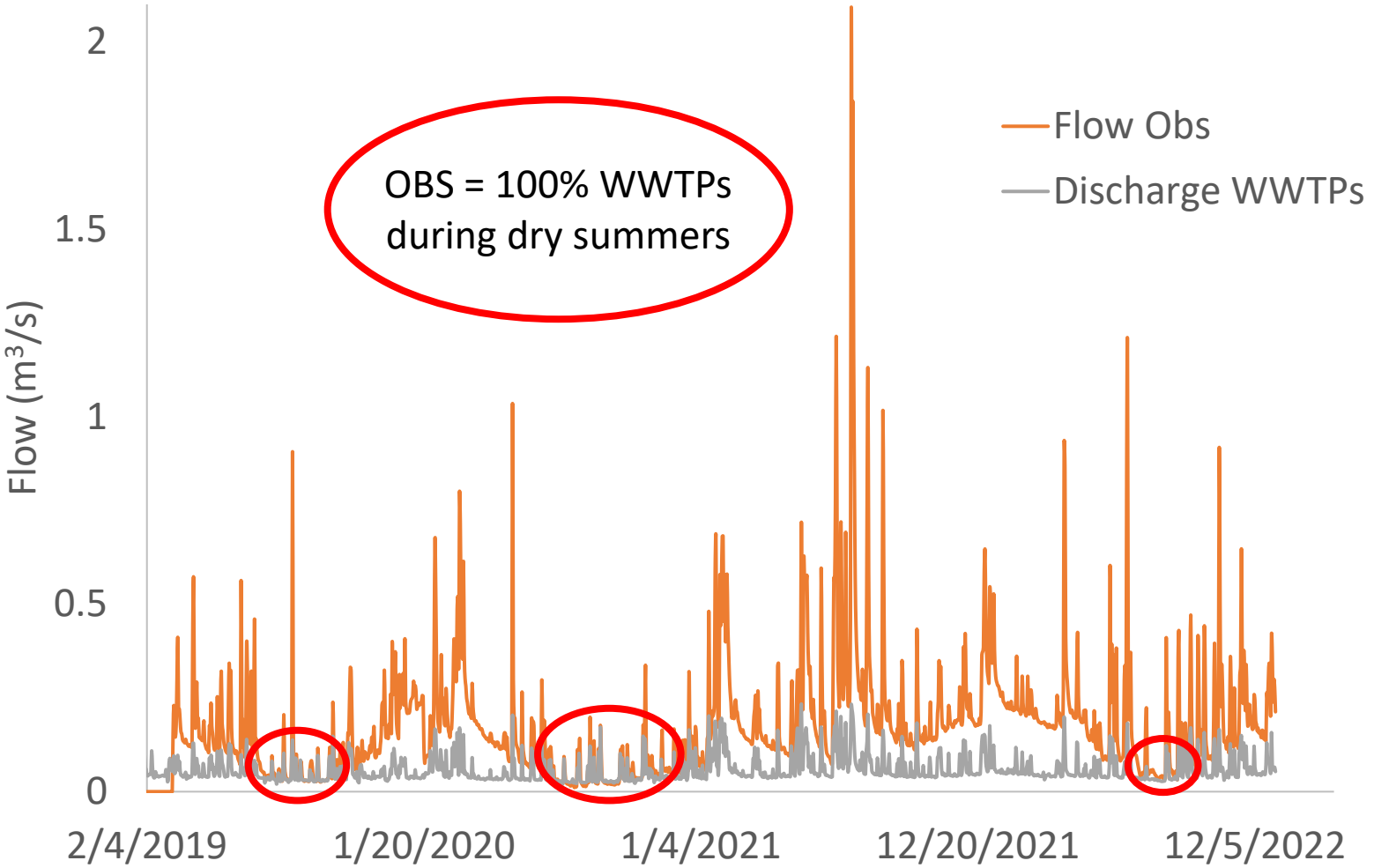
STUDY SITE - The Souffel catchment, an impacted area

Average Flow : 180 L/s
Specific flow : 1.56 L/s/km²
Upstream of WWTPs : 76% of channel network



data

Flow : EMS* (2019-2023)
WWTPs discharge : SDEA* (2015-2023)



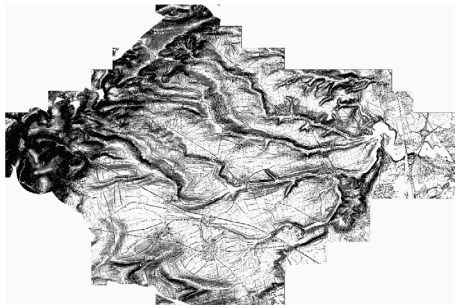
- Average specific flow about **10 times lower** than the surrounding rivers
- High contribution of WWTPs* discharge

EMS = Eurométropole de Strasbourg
WWTPs = Waste Water Treatment Plants
SDEA = Syndicat des eaux et assainissement

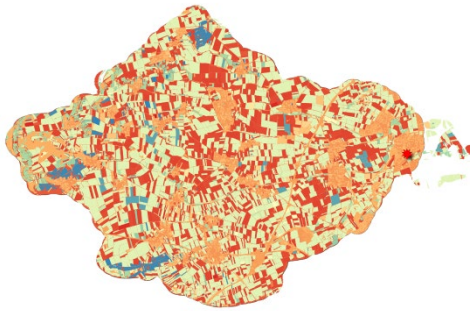
METHOD AND RESULTS – Model building under QSWAT+

1. SWAT+ model construction

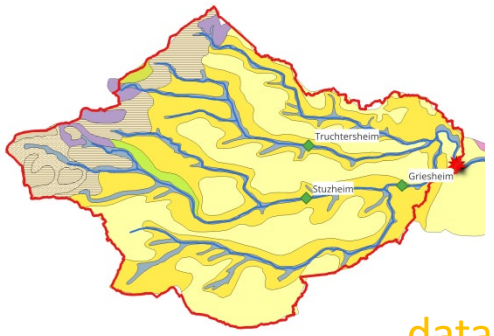
Slope



Landuse



Soils



data

DEM (5mx5m) : IGN*
Land Uses : IGN* 2021
Soils (1/100,000e): GIS Sol* 2019

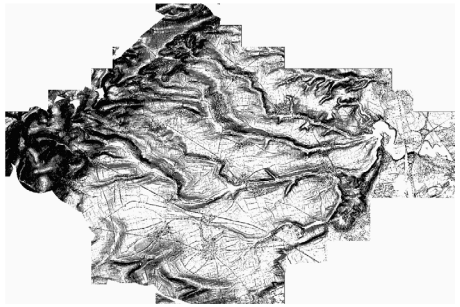
GIS Sol = program composed by BRGM, IGN, INRAE, IRD, OFB

IGN = Institut national de l'information géographique et forestière

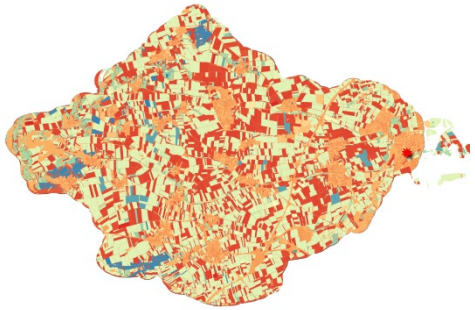
METHOD AND RESULTS – Model building under QSWAT+

1. SWAT+ model construction

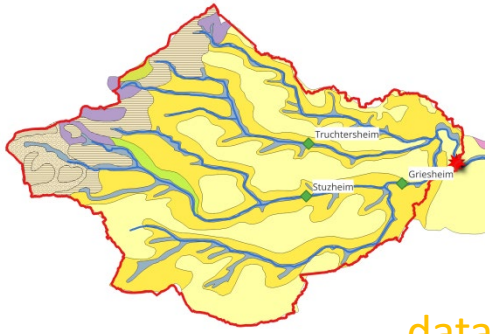
Slope



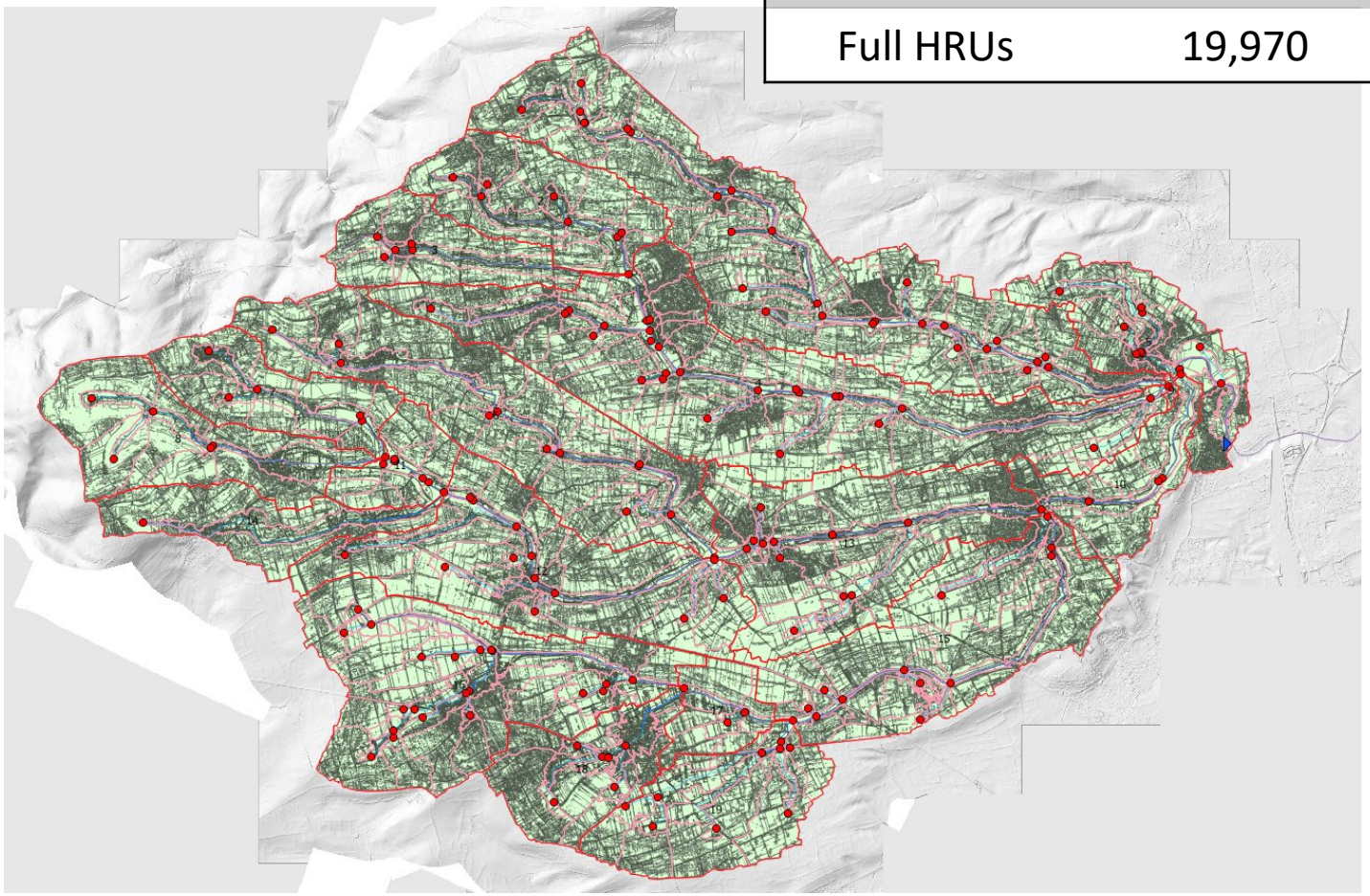
Landuse



Soils



	Entities
Subbasins	19
Full HRUs	19,970



data

DEM (5mx5m) : IGN*
Land Use : IGN* 2021
Soils (1/100000e): GIS Sol* 2019

- Dominant HRUs are targeted, to run the calculations with only **376 HRUs**

GIS Sol = program composed by BRGM, IGN, INRAE, IRD, OFB

IGN = Institut national de l'information géographique et forestière

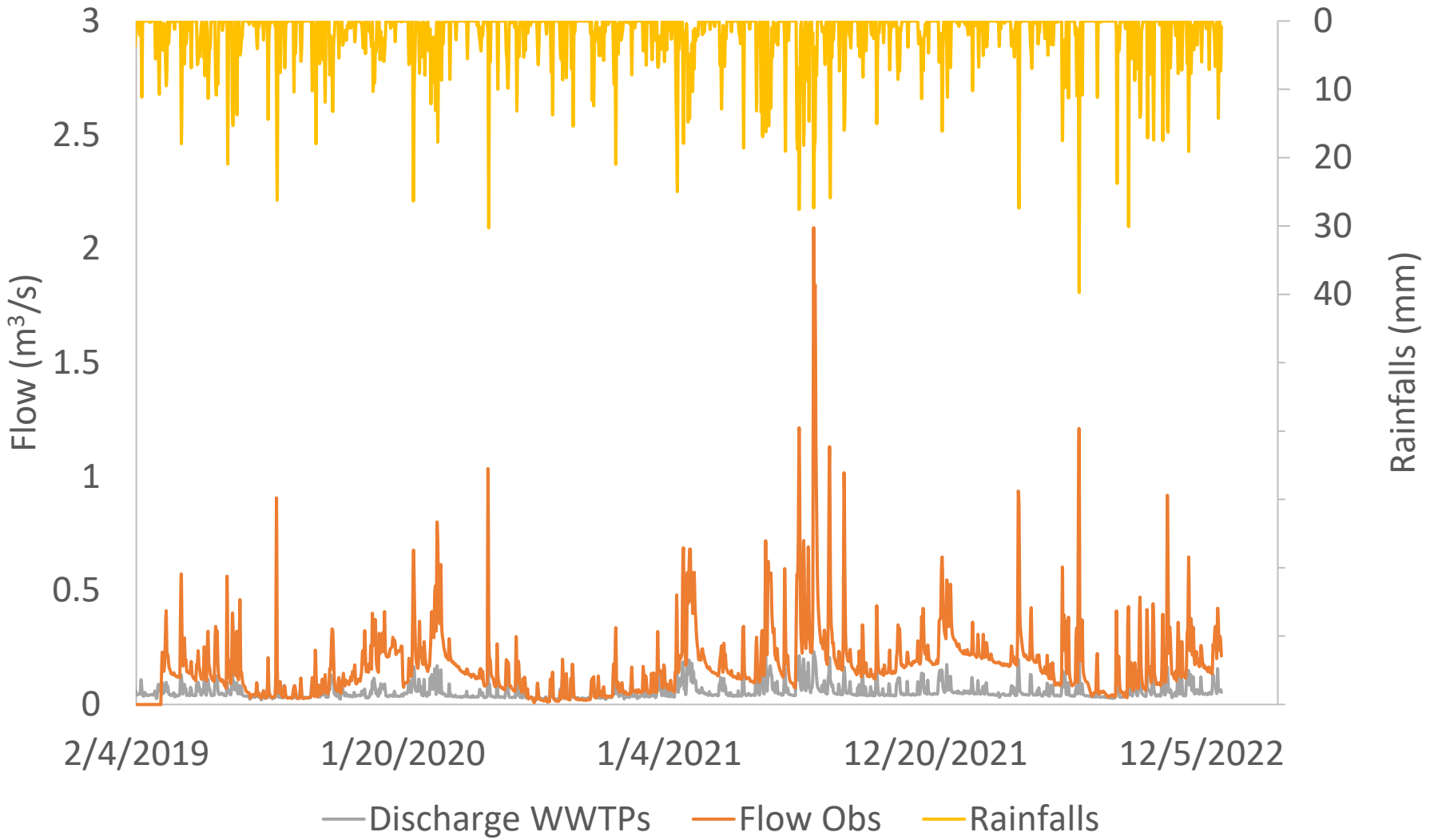
METHOD AND RESULTS – Manual calibration on flows (2019-2022)

1. SWAT+ model construction

2. SWAT+ model calibration

data

Climate (ET, PET, Runoff) : Météo France (2015-2023)
Rainfalls : Météo France (2015-2023)



METHOD AND RESULTS – Manual calibration on flows (2019-2022)

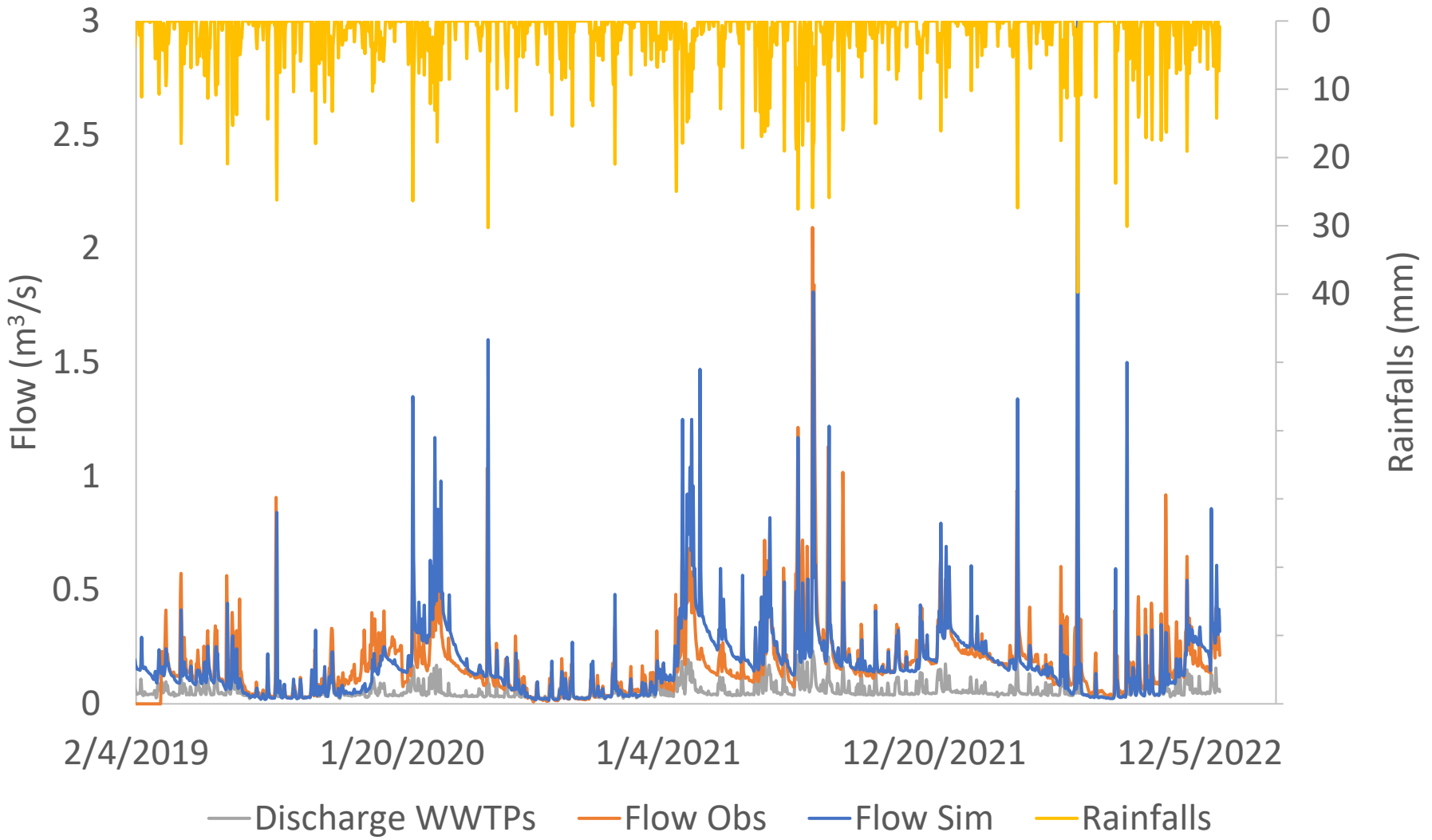
1. SWAT+ model construction

2. SWAT+ model calibration

	DAILY	WEEKLY
NSE	0.24	0.97
LOGNSE	0.66	0.80
PBIAS	-3.57	-9.83
R^2	0.64	0.99

data

Climate (ET, PET, Runoff) : Météo France (2015-2023)
Rainfalls : Météo France (2015-2023)



- Some **high peaks** disturb the accuracy of my model
- Calibration could be **enhanced** but the global hydrology is **well represented**

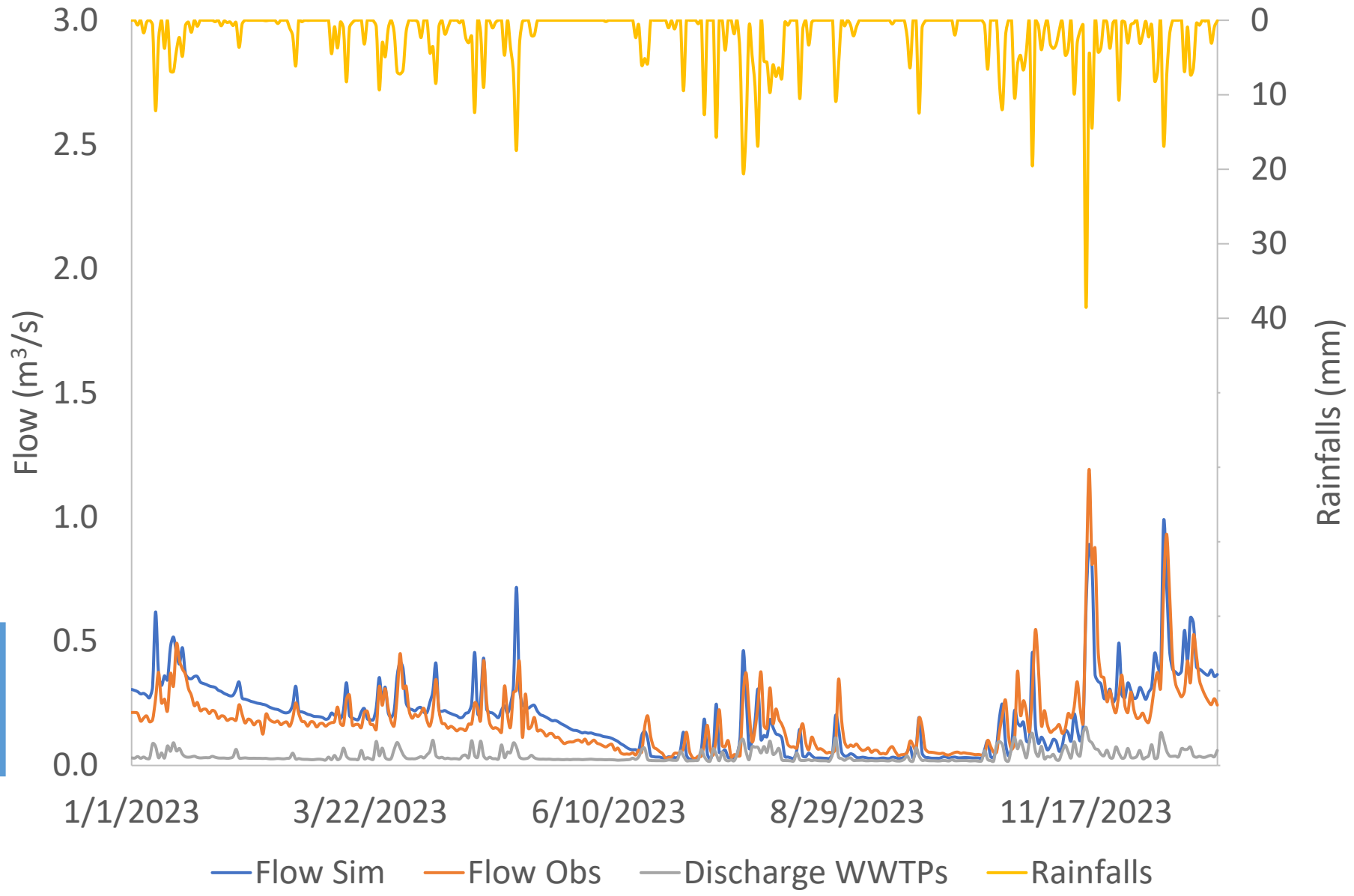
METHOD AND RESULTS – Model validation on flows (2023)

1. SWAT+ model construction

2. SWAT+ model validation

	DAILY
NSE	0.58
LOGNSE	0.65
PBIAS	-7.85
R^2	0.81

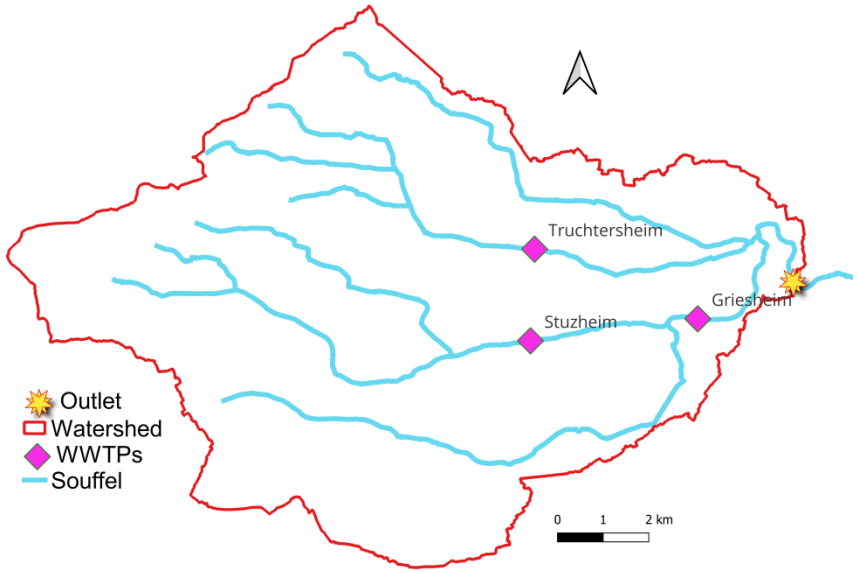
- **Short period** for validation (one year) due to the small set of data



METHOD AND RESULTS – First attempt on nitrates without calibration (2019)

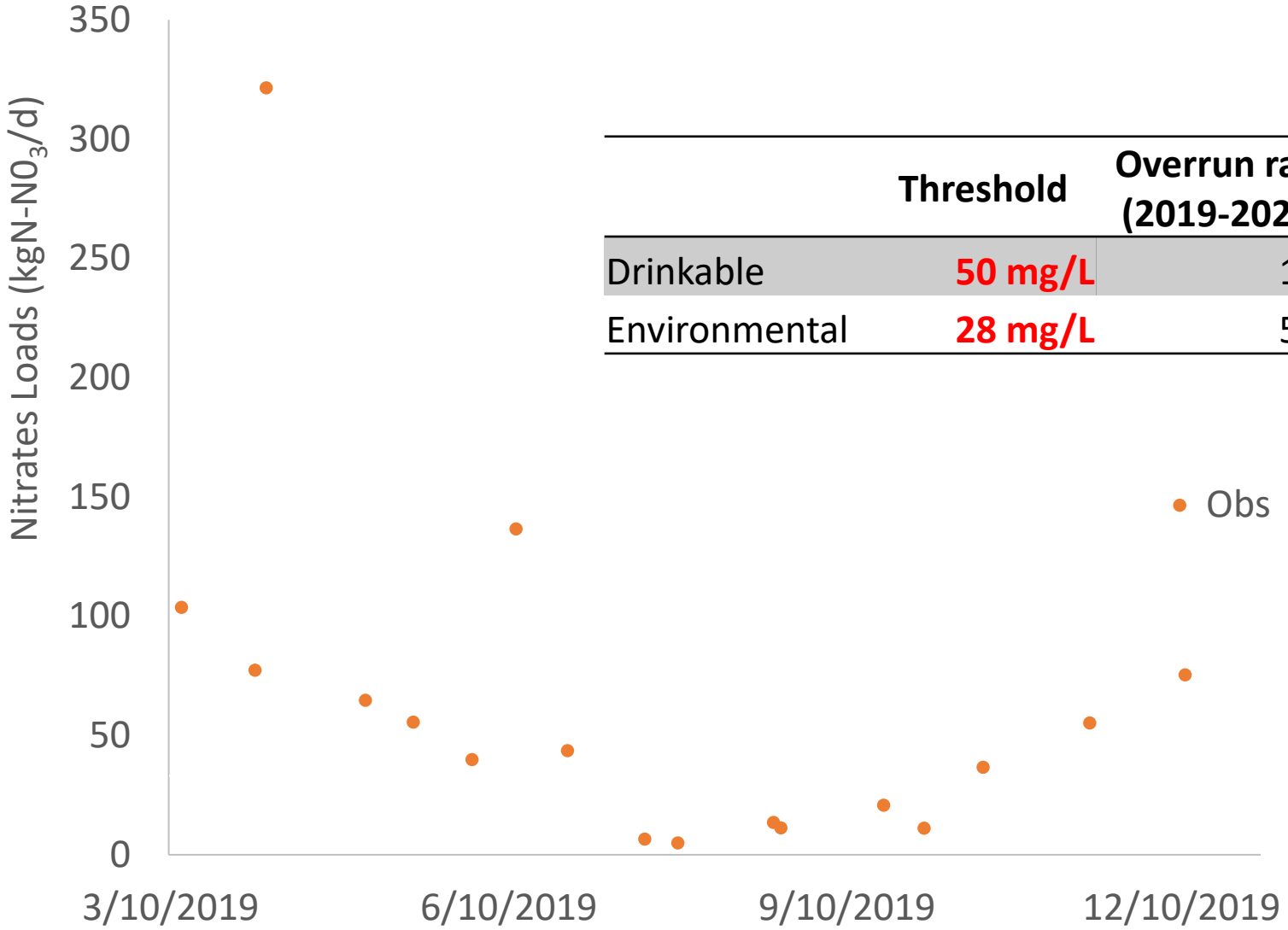
1. SWAT+ model construction

2. SWAT+ model calibration



data

Nitrates : Mundolsheim (outlet point) Station (Monthly, 2019-2023) + ITES* campaign (2019)



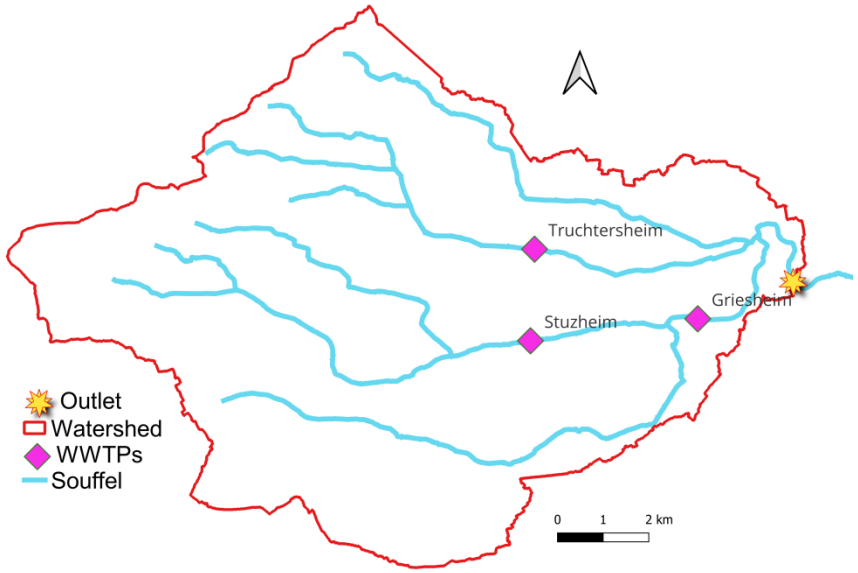
	Threshold	Overrun rate (2019-2023)
Drinkable	**50 mg/L**	11%
Environmental	**28 mg/L**	55%

ITES = Institut Terre et Environnement de Strasbourg

METHOD AND RESULTS – First attempt on nitrates without calibration (2019)

1. SWAT+ model construction

2. SWAT+ model calibration



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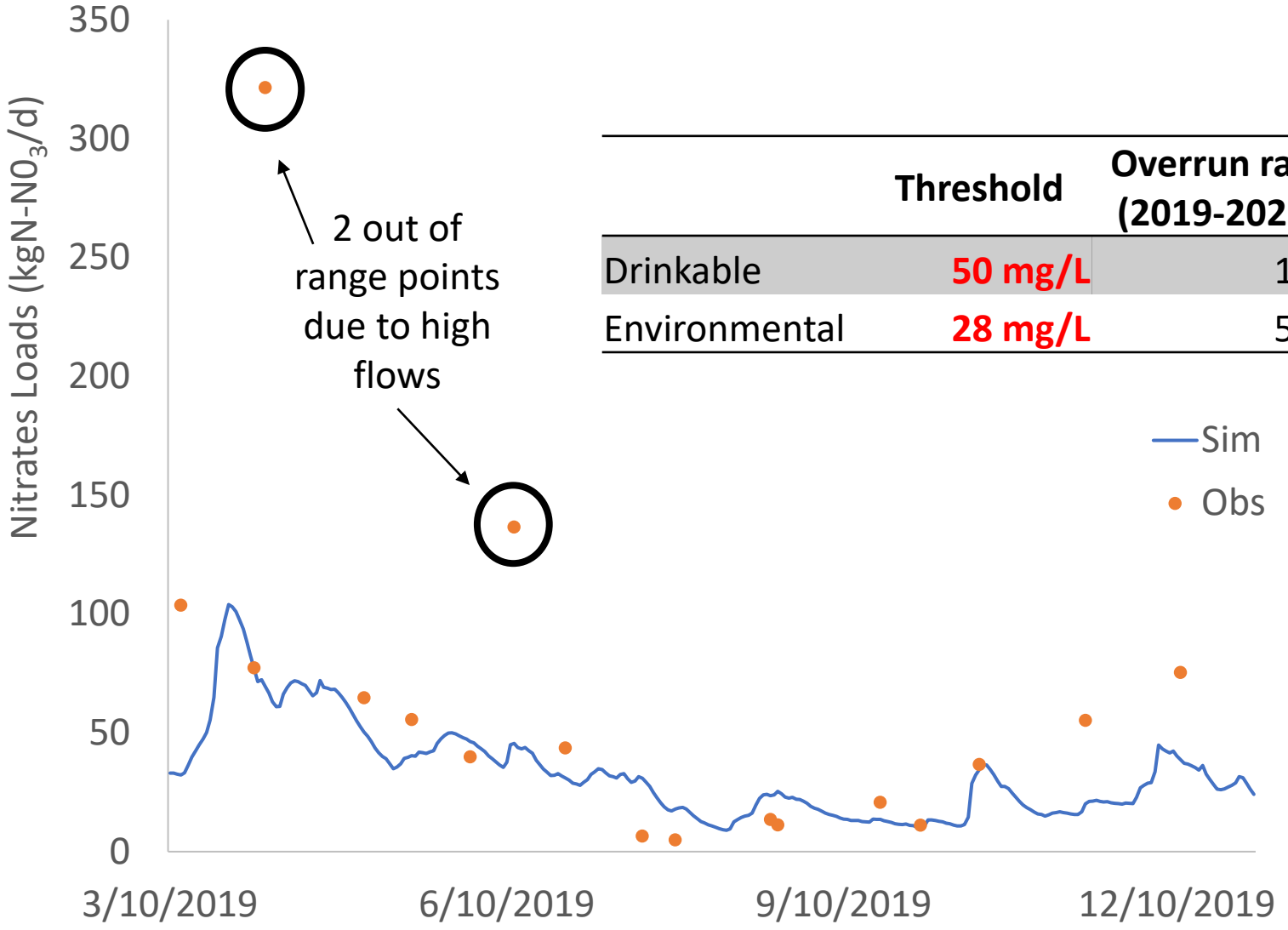


	Threshold	Overrun rate (2019-2023)
Drinkable	**50 mg/L**	11%
Environmental	**28 mg/L**	55%

- **Seasonality** of nitrates release well represented
- Values **out of range** : observed values influence by floods

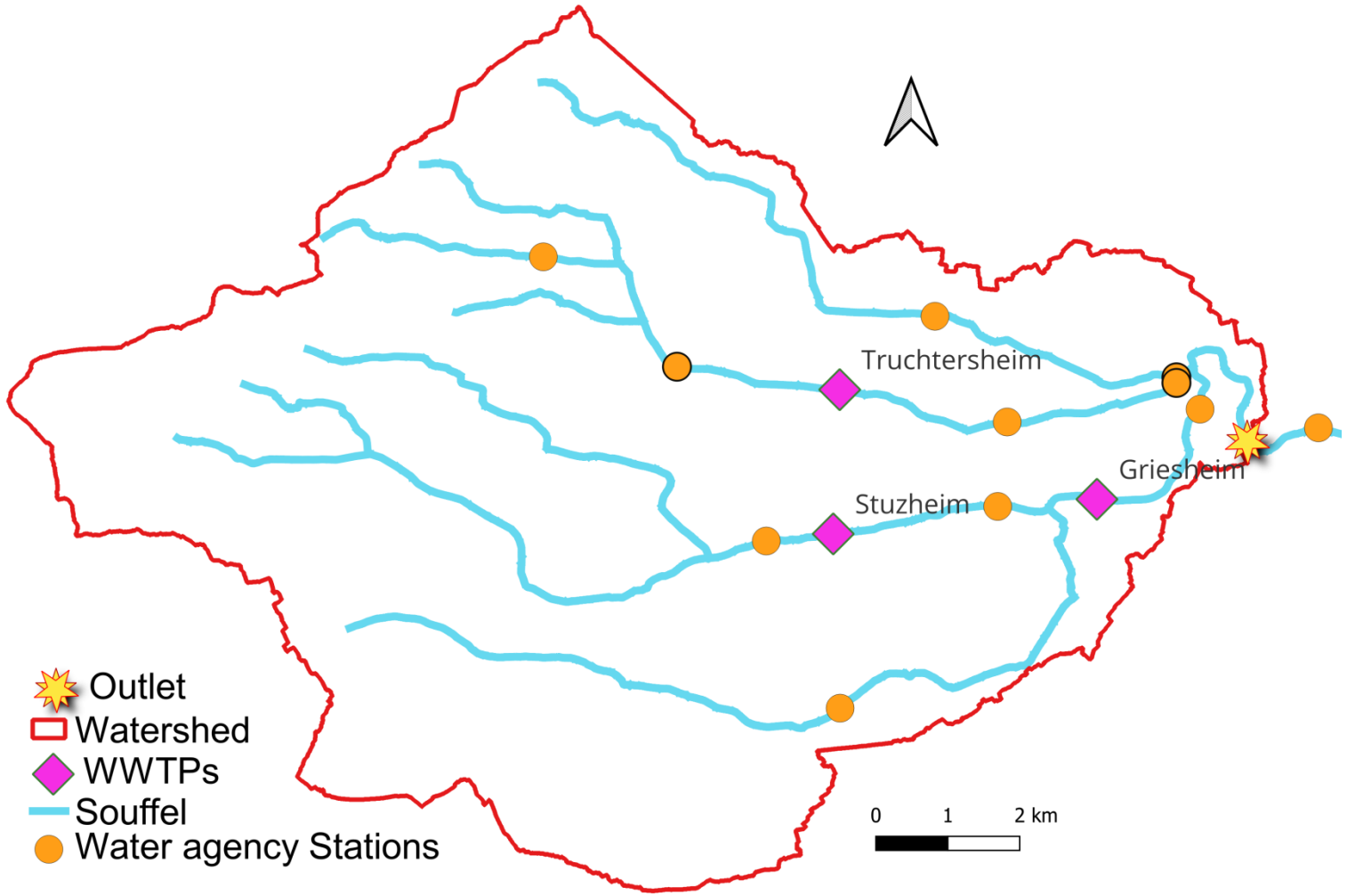
ITES = Institut Terre et Environnement de Strasbourg

METHOD AND RESULTS – Model calibration on nitrates (2019)

1. SWAT+ model construction

2. SWAT+ model calibration

WORK IN PROGRESS…



data

Nitrates : 10 Water Agency Stations (Monthly, 2019-2023)

- **Underestimated** values of nitrates on the others stations of the catchment

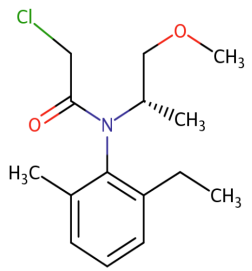
ITES = Institut Terre et Environnement de Strasbourg

METHOD AND RESULTS – First attempt on pesticides without calibration (2019)

1. SWAT+ model construction

2. SWAT+ model calibration

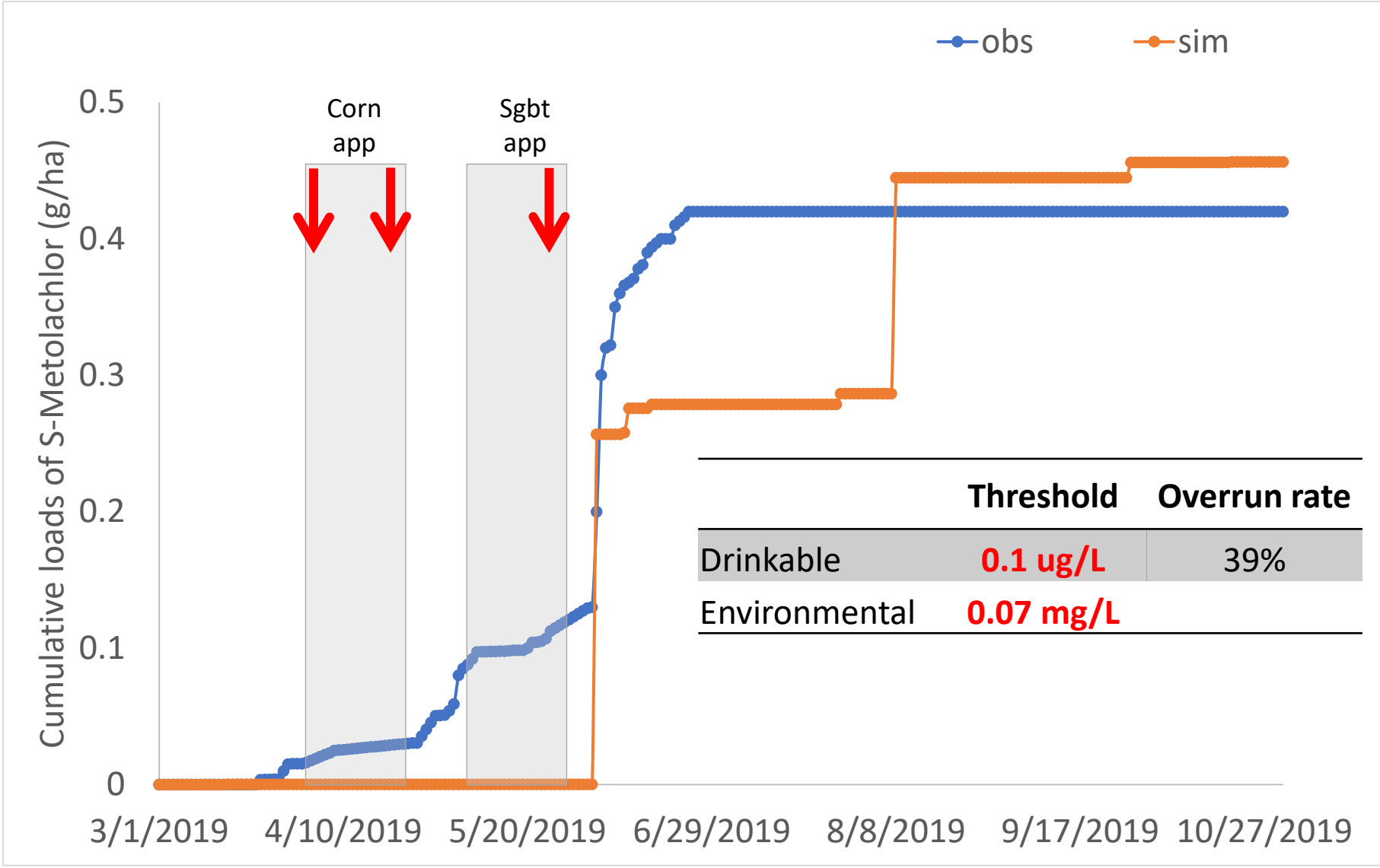
S metolachlor = selected reference molecule used on corn and sugar beet



Banned last december (last application on 2024)

data

S-Metolachlor : Water Agency (Monthly, 2019-2023) + ITES* campaign (2019)



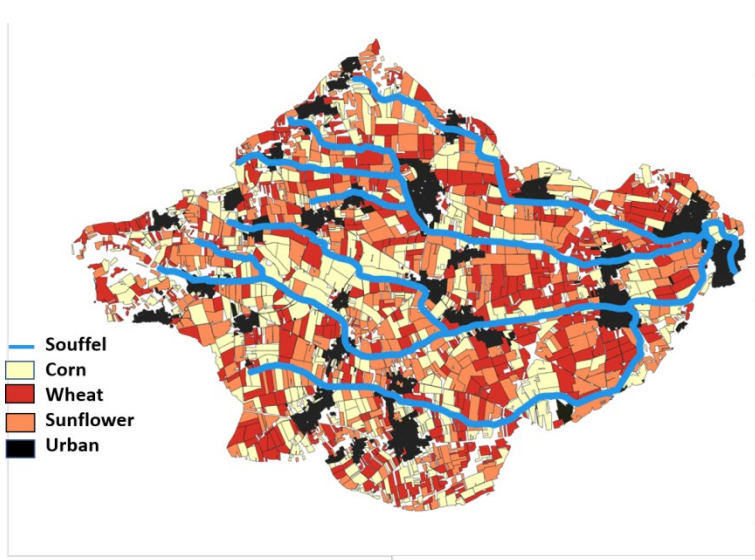
	Threshold	Overrun rate
Drinkable	0.1 ug/L	39%
Environmental	0.07 mg/L	

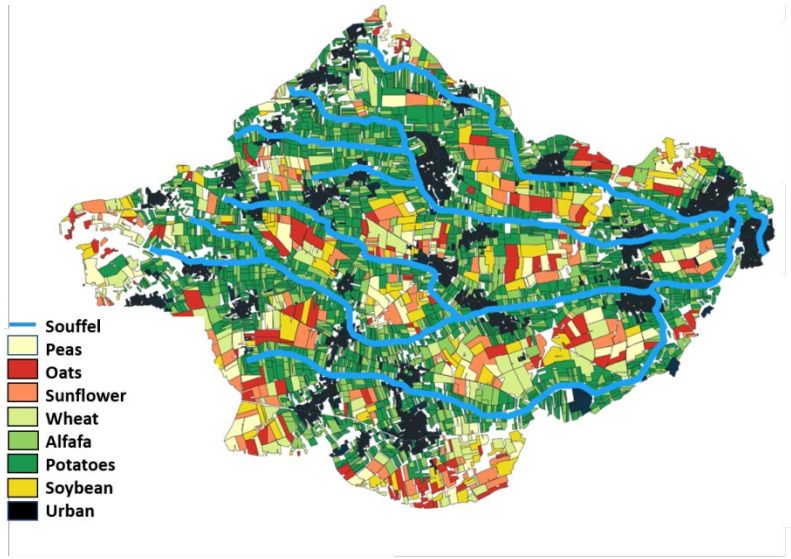
METHOD AND RESULTS – 3 farming systems scenarios by 2070

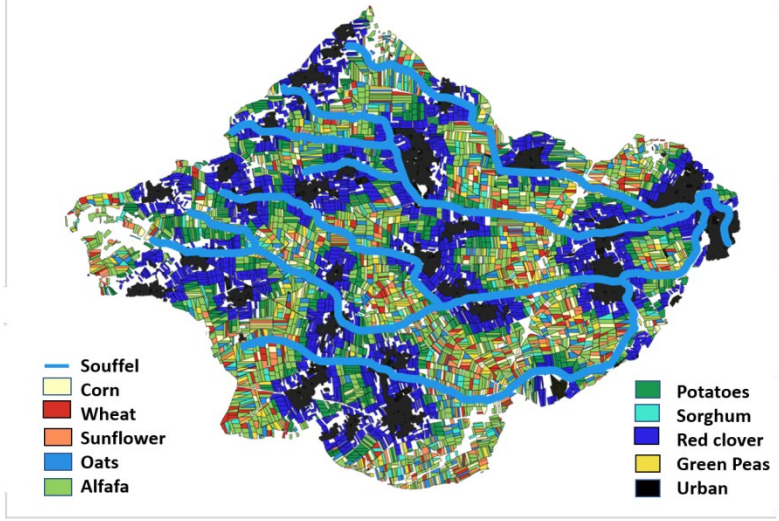
1. SWAT+ model construction

2. SWAT+ model calibration

3. Farming system scenarios







Farmers ideas **turned into modelling** processes
by Lou W., PhD student (2021-2024)

METHOD AND RESULTS – Farming systems scenarios by 2070

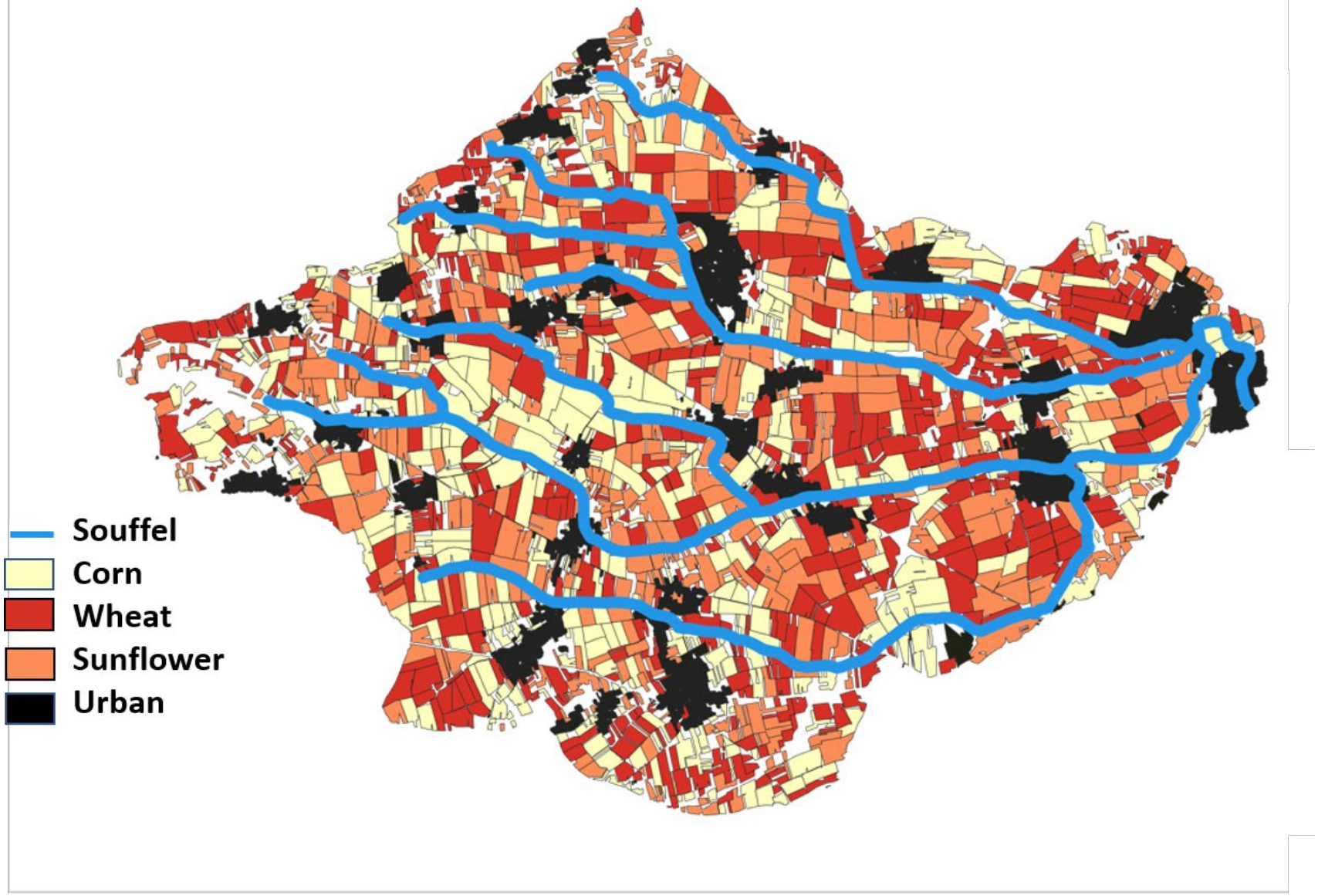
1. SWAT+ model construction

2. SWAT+ model calibration

3. Farming system scenarios

- Larger parcels and **few farmers**
- Still **corn** and **wheat** as main crops

LU1. Standardised corporate farming



METHOD AND RESULTS – Farming systems scenarios by 2070

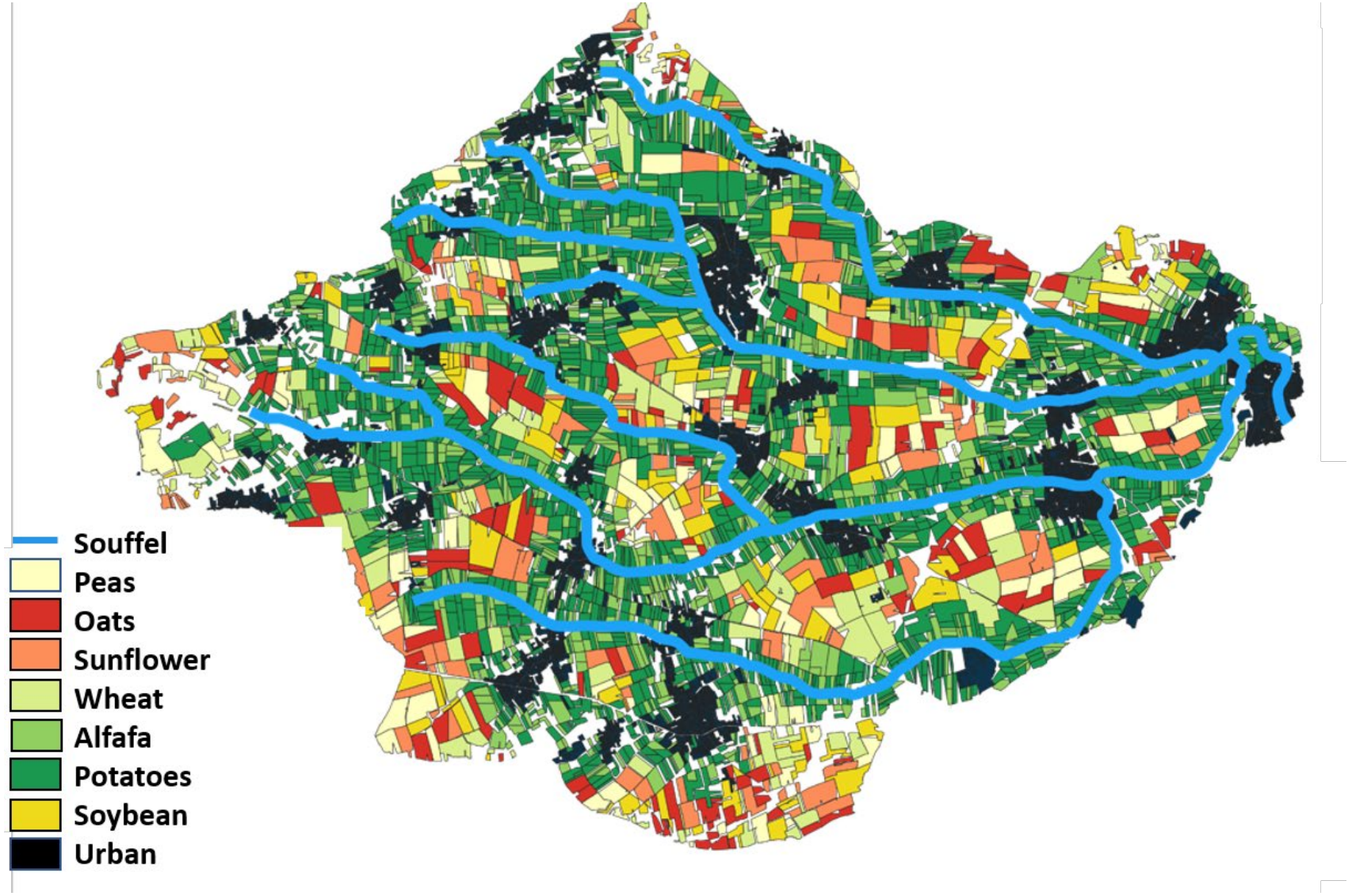
1. SWAT+ model construction

2. SWAT+ model calibration

3. Farming system scenarios

- Association of both **large** parcels and **small** ones
- Mix **local consumption** and exportation

LU2. Dual agriculture of spatialised agricultural models



METHOD AND RESULTS – Farming systems scenarios by 2070

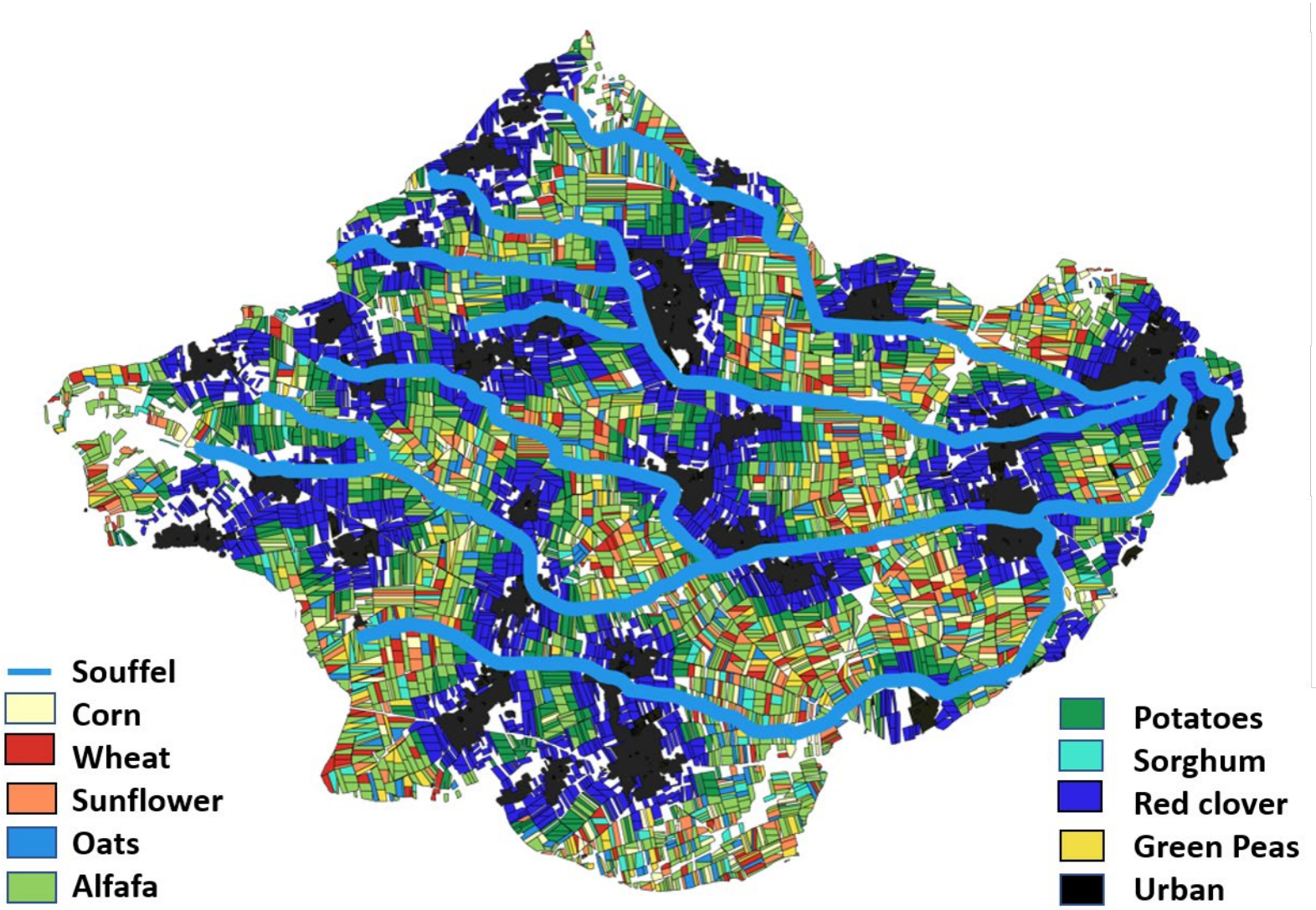
1. SWAT+ model construction

2. SWAT+ model calibration

3. Farming system scenarios

- **Buffer area** around cities and rivers and no pesticides
- **Local** production and consumption

LU3. Agro-ecological farming for local autonomy



METHOD AND RESULTS – Climate change scenario

1. SWAT+ model construction

2. SWAT+ model calibration

3. Farming

4. Climate

C0. Current climate

712 mm/year

12.4 °C

- **« Storyline » approach** = plausible sequence of climate events
- Contrasted climate trajectories selected among the **DRIAS simulations**

[2] *https://webgr.inrae.fr/recherches/projets/explore2*

METHOD AND RESULTS – Climate change scenario

1. SWAT+ model construction

2. SWAT+ model calibration

3. Farming

4. Climate

C0. Current climate

712 mm/year

12.4 °C

C1. DAHLIA

14.6 °C

707 mm/y

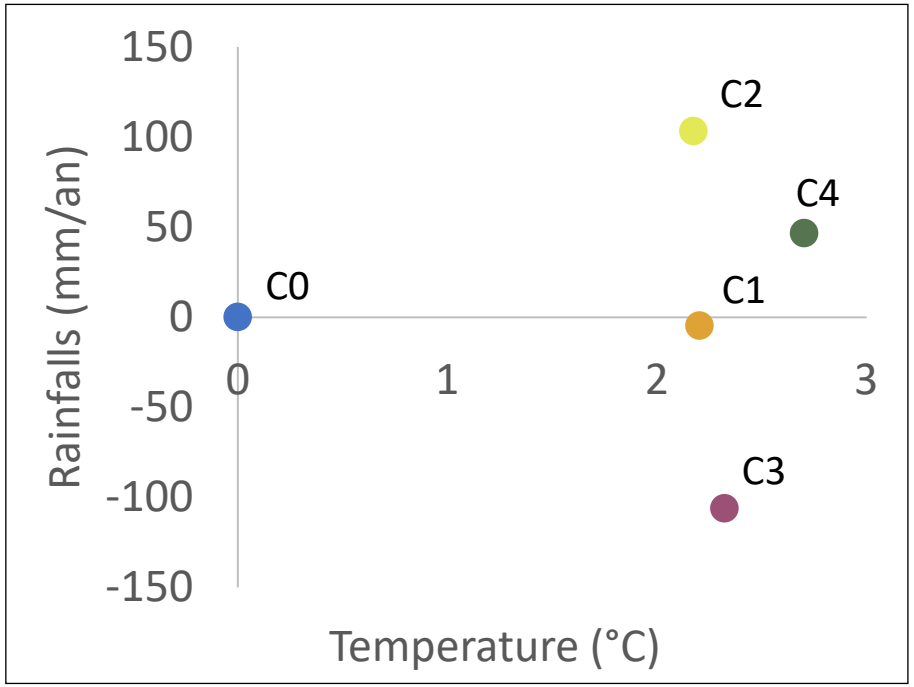
Dry summer

C2. NARCISSE

14.5 °C

815 mm/y

Rainy summer



C3. ASTER

14.7 °C

606 mm/y

Very dry summer

C4. EUPHORBE

15.1°C

759 mm/y

Very rainy summer

- **« Storyline » approach** = plausible sequence of climate events
- Contrasted climate trajectories selected among the **DRIAS simulations**

[2] *https://webgr.inrae.fr/recherches/projets/explore2*

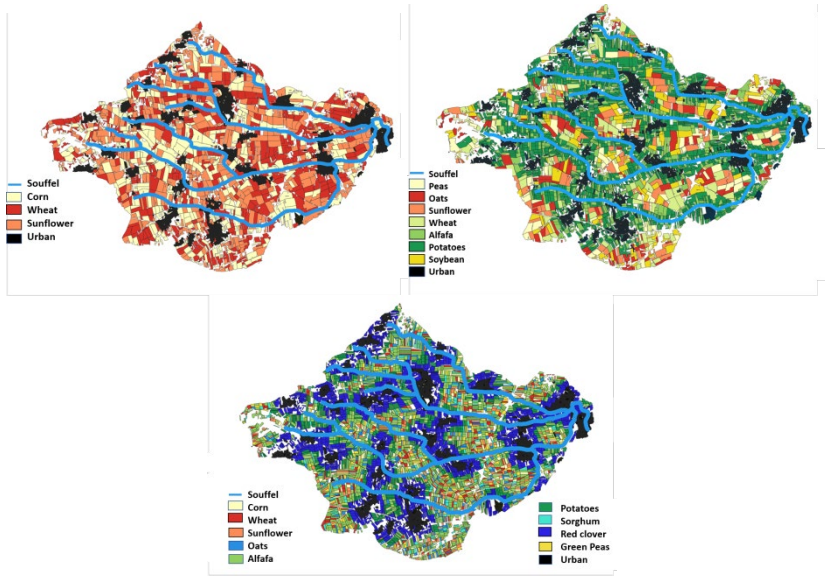
METHOD AND RESULTS – Simulations : 4 farming systems under 4 climate scenarios

1. SWAT+ model construction

2. SWAT+ model calibration

3. Farming ✖ 4. Climate

5. SWAT+ simulations



METHOD AND RESULTS – Simulations : 4 farming systems under 4 climate scenarios

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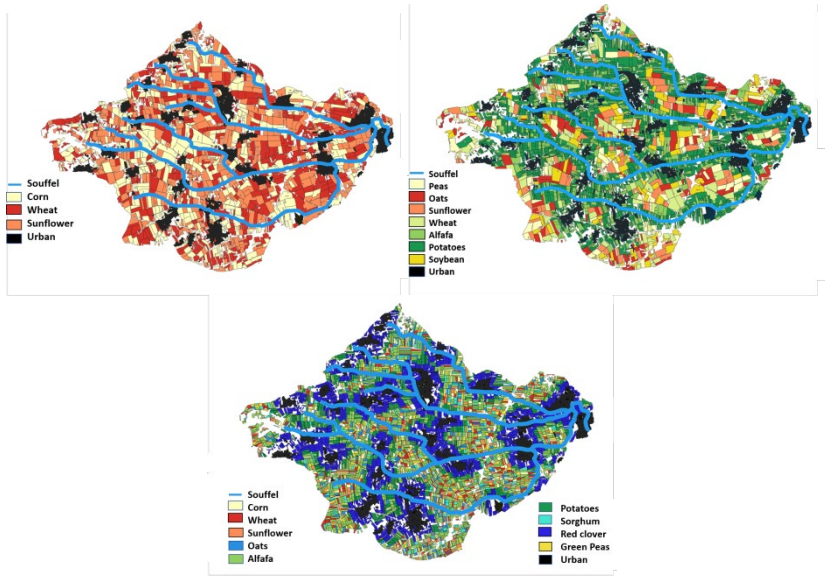
2. SWAT+ model calibration

3. Farming ✖ 4. Climate

5. SWAT+ simulations



✖

C1 C2 C3 C4

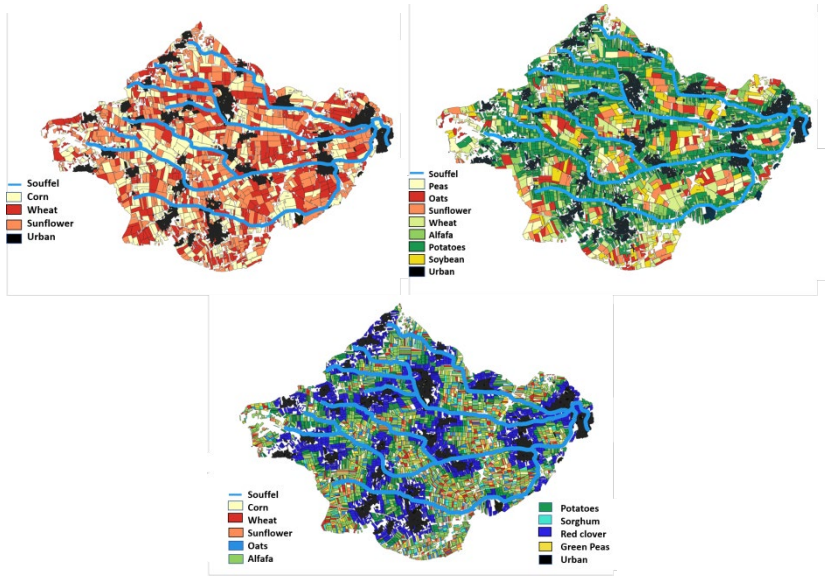
METHOD AND RESULTS – Simulations : 4 farming systems under 4 climate scenarios

1. SWAT+ model construction

2. SWAT+ model calibration

3. Farming ✖ 4. Climate

5. SWAT+ simulations

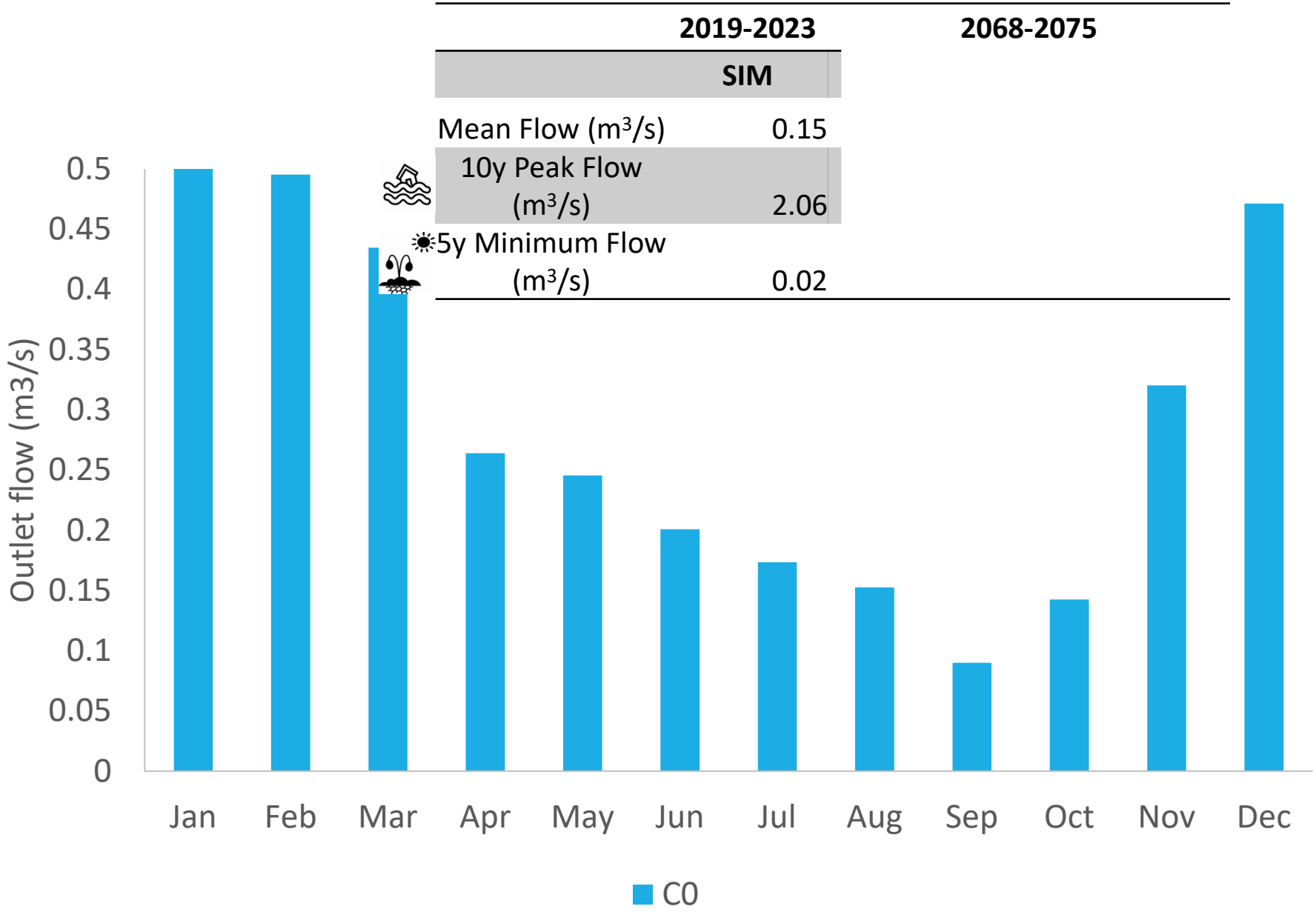


C1 C2 C3 C4

12 Futur LU Simulations + 4 Current LU Sim

METHOD AND RESULTS – Flow results for the current land use

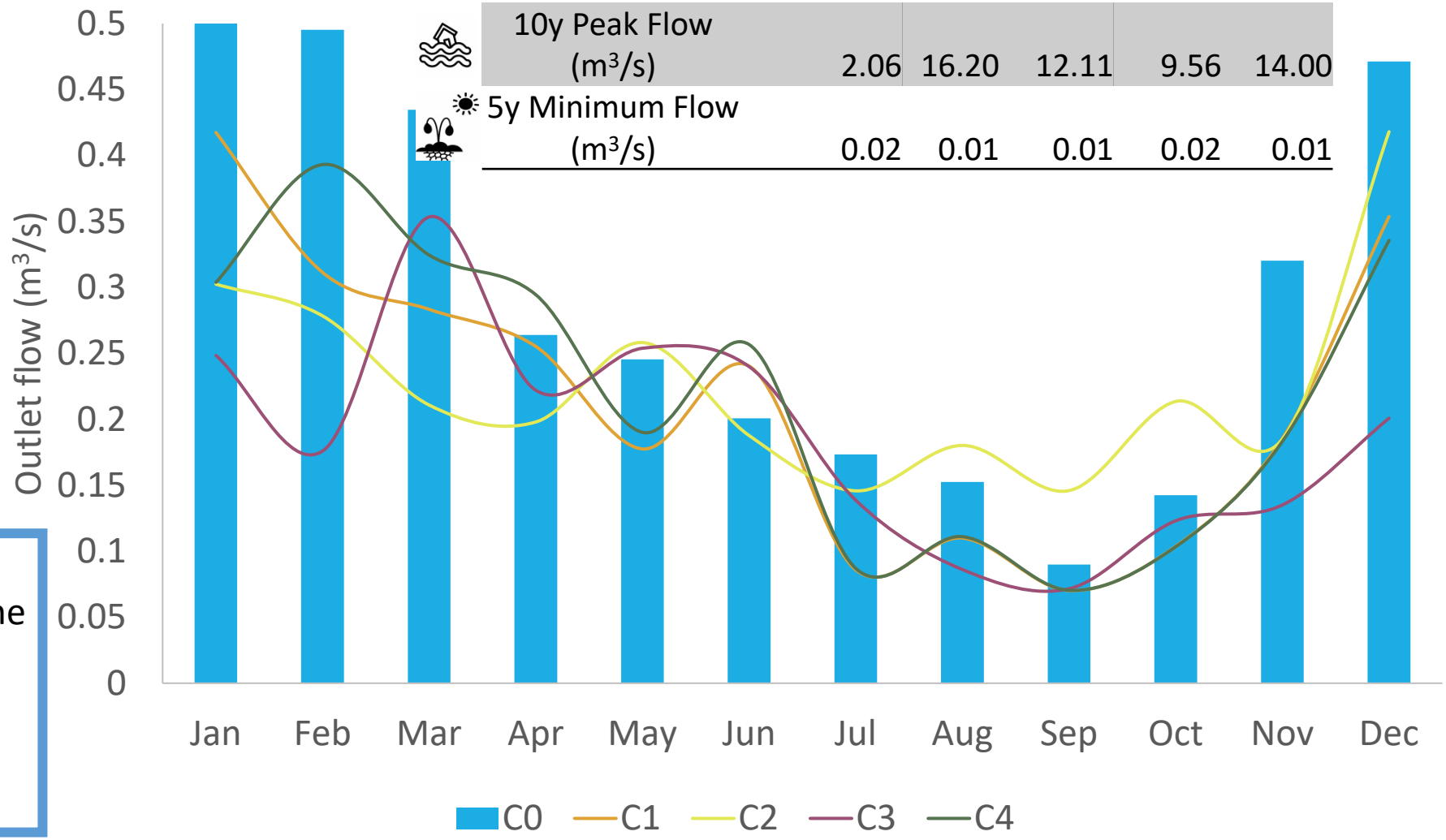
1. SWAT+ model construction
2. SWAT+ model calibration
3. Farming × 4. Climate
5. SWAT+ simulations
6. Quantity results



METHOD AND RESULTS – Flow results for the current land use

1. SWAT+ model construction
2. SWAT+ model calibration
3. Farming × 4. Climate
5. SWAT+ simulations
6. Quantity results

	2019-2023	2068-2075			
	SIM	SC1	SC2	SC3	SC4
Mean Flow (m^3/s)	0.15	0.22	0.23	0.19	0.22
10y Peak Flow (m^3/s)	2.06	16.20	12.11	9.56	14.00
5y Minimum Flow (m^3/s)	0.02	0.01	0.01	0.02	0.01

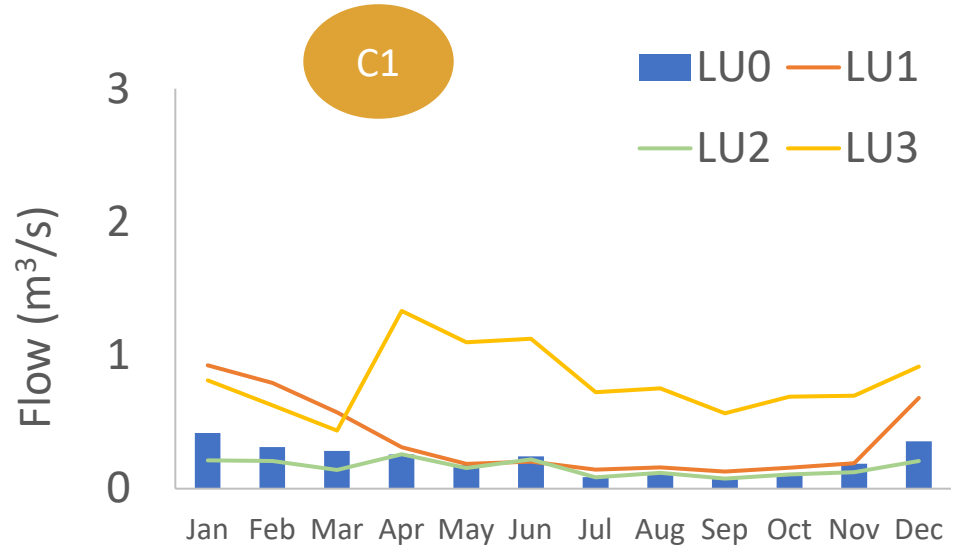


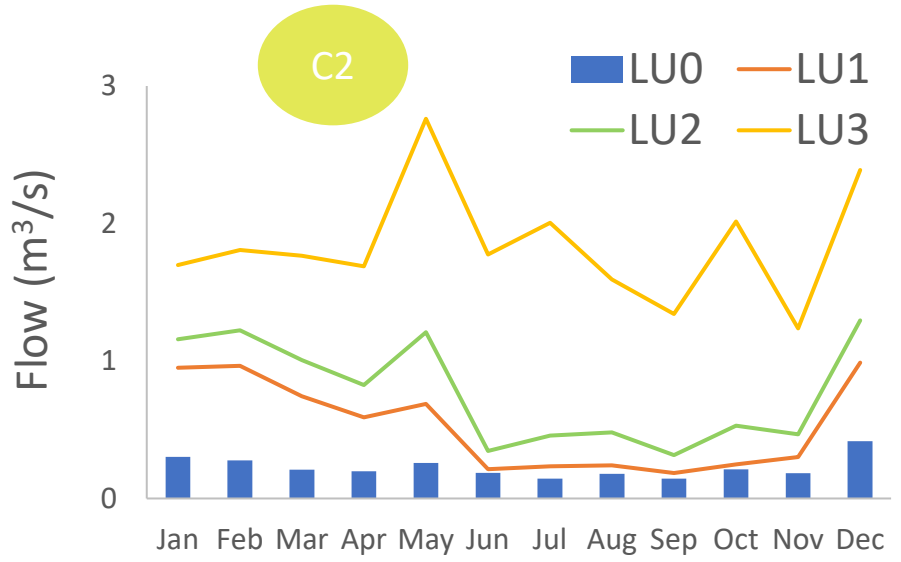
- **Less water** during winter and summer resource depends on the scenario
- Maximum flow increases dramatically : **huge floods**

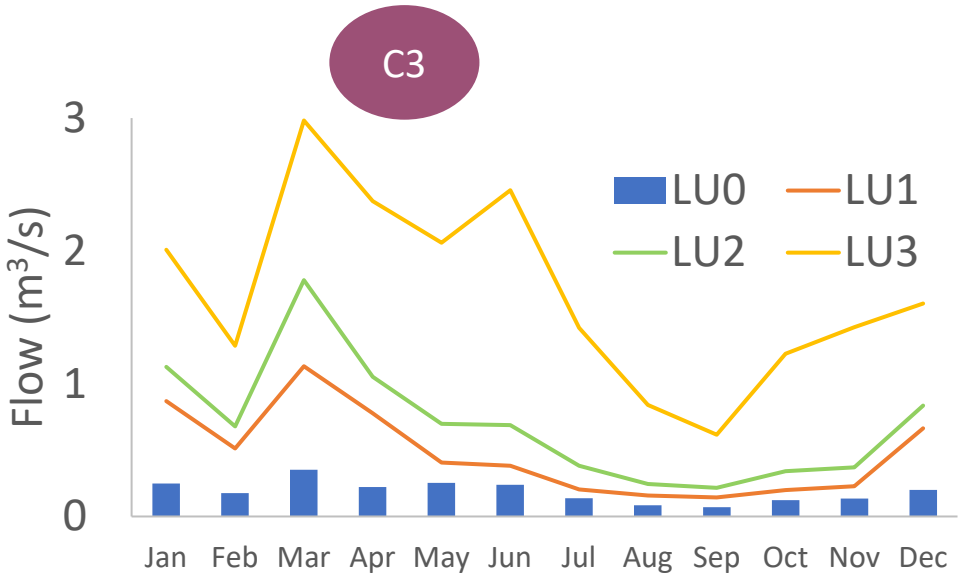
METHOD AND RESULTS – Flow results for the future land use

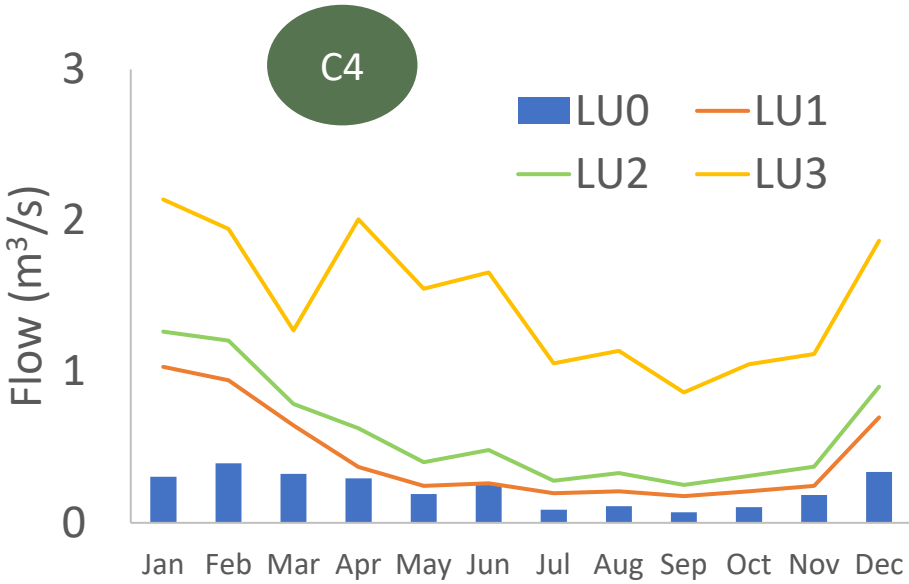
1. SWAT+ model construction
2. SWAT+ model calibration
3. Farming ✖ 4. Climate
5. SWAT+ simulations
6. Quantity results

- Globally **more water** for any land use but LU3 provides the biggest amount
- Climate scenario does not change this order





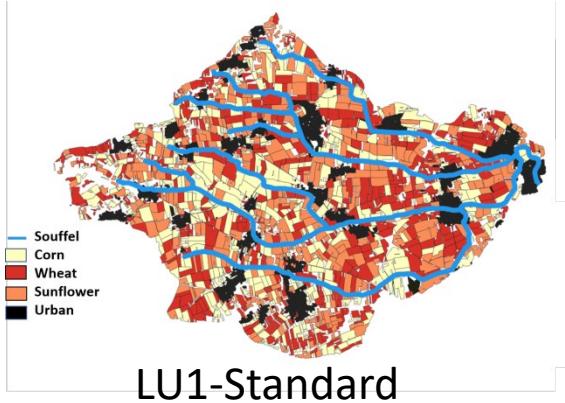




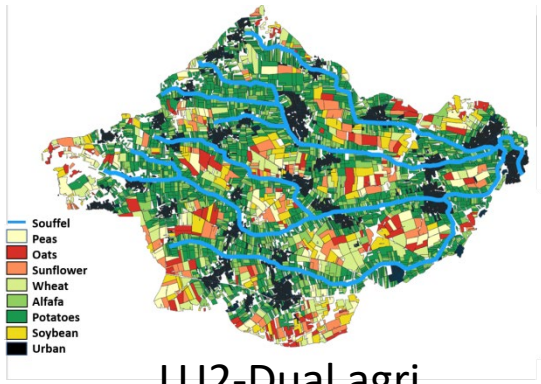
METHOD AND RESULTS – Average annual loads of nitrates according to LU scenarios

1. SWAT+ model construction
2. SWAT+ model calibration
3. Farming × 4. Climate
5. SWAT+ simulations
6. Quantity results
7. Quality results

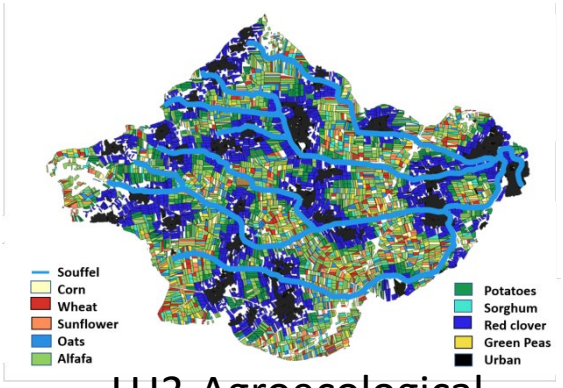
	LU0 (kgN-NO_3/d)	LU1	LU2	LU3
C1-6875	63	+7%	-15%	**In progress…**
C2-6875	67	+0%	-16%	
C3-6875	58	+3%	-21%	
C4-6875	63	+10%	-19%	



LU1-Standard



LU2-Dual agri.



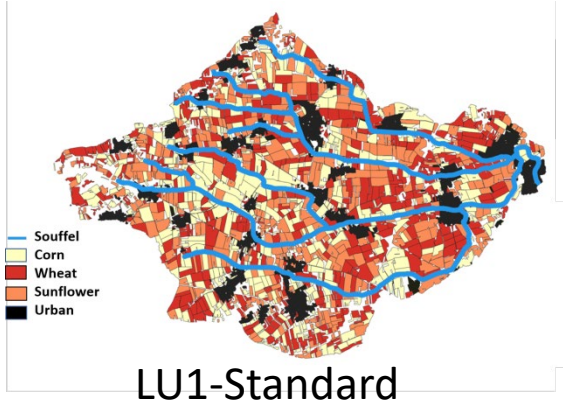
LU3-Agroecological

- LU1 stays close to the current scenario whereas LU2 seems to help **reduce nitrates levels**
- Climate scenario does not influence so much on nitrates rate

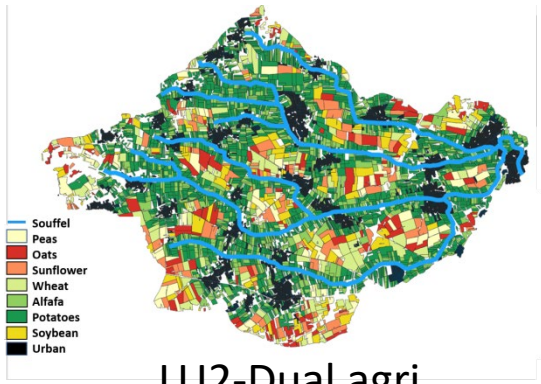
METHOD AND RESULTS – Average annual export rate according to LU scenarios

1. SWAT+ model construction
2. SWAT+ model calibration
3. Farming ✖ 4. Climate
5. SWAT+ simulations
6. Quantity results
7. Quality results

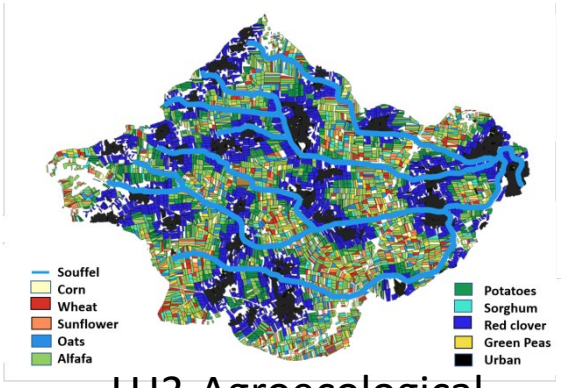
	LU0	LU1	LU2
C1-6875	0.8%	0.3%	0.15%
C2-6875	0.6%	0.3%	0.09%
C3-6875	0.7%	0.8%	0.02%
C4-6875	1.6%	0.4%	0.13%



LU1-Standard



LU2-Dual agri.



LU3-Agroecological

- **Export rate** = Output Loads / Input Loads
- LU3 do not require anymore chemicals

METHOD AND RESULTS – Is current system resilient to future climate ?

1. SWAT+ model construction
2. SWAT+ model calibration
3. Farming ✖ 4. Climate
5. SWAT+ simulations
6. Quantity results
7. Quality results

- Corn and wheat seems to be **resilient**
- What about **heat stress** ? (limits of SWAT+)

TAKE HOME MESSAGES

How can we help farmers move towards a more sustainable system?

Is the current farming system resilient under futur CC ?

- Resilient in terms of harvest but **heat stress** ? ✔
- Water quality similar or worst (export rate of nitrates and pesticides) ✖

TAKE HOME MESSAGES

How can we help farmers move towards a more sustainable system?

Is the current farming system resilient under futur CC ?

- Resilient in terms of harvest but **heat stress** ? ✔
- Water quality similar or worst (export rate of nitrates and pesticides) ✖

How farmers involved in farming systems evolution ?

- Results under **another model** (Maelia by Lou W.) presented to farmers during the last **workshop** (20/06/2024 – Truchtersheim)
- Well perceived by farmers and able to mix system
- **Transposable method** to other degradated catchments

CTEC = Contrat de Territoire Eau et Climat

HOW TO PREDICT OF WATER QUALITY AND QUANTITY TRAJECTORIES UNDER CLIMATE AND AGRICULTURAL CHANGES ?

Application to the Souffel catchment (Bas-Rhin) under SWAT+

Manon Picot, Lou Weidenfeld, Sylvain Payraudeau, Sara Fernandez, Rémi Barbier

Thank you for your attention

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