



Sensitivity of water quality of three constricted north-eastern French watersheds to climate change (2006-2100) using SWAT model

Karstic spring of Ru d'Anteuil, (Brulebois, 2013)

Etienne BRULEBOIS, Marjorie UBERTOSI, Jérémy BACHMANN, Aurélien ROSSI, Thierry CASTEL, Yves RICHARD, Sabine SAUVAGE, José-Miguel SANCHEZ-PEREZ, Philippe AMIOTTE-SUCHET

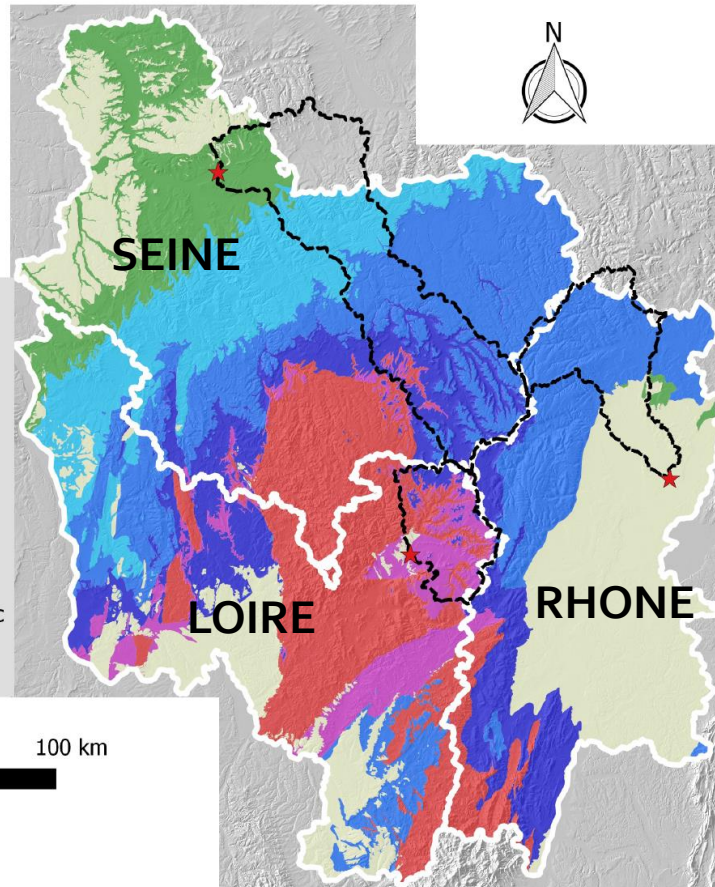


Ignon spring, (Brulebois, 2014)

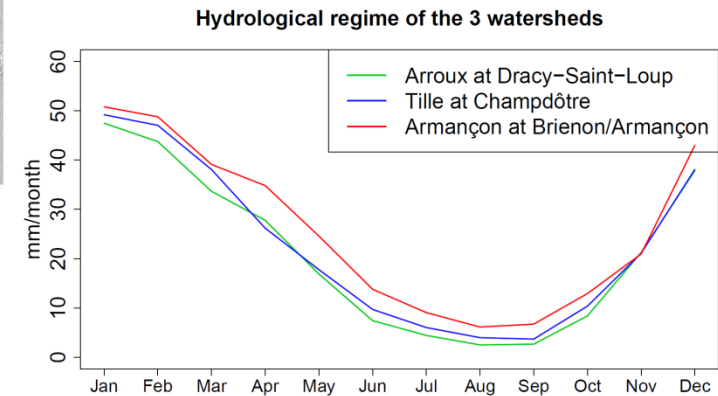
In collaboration with:

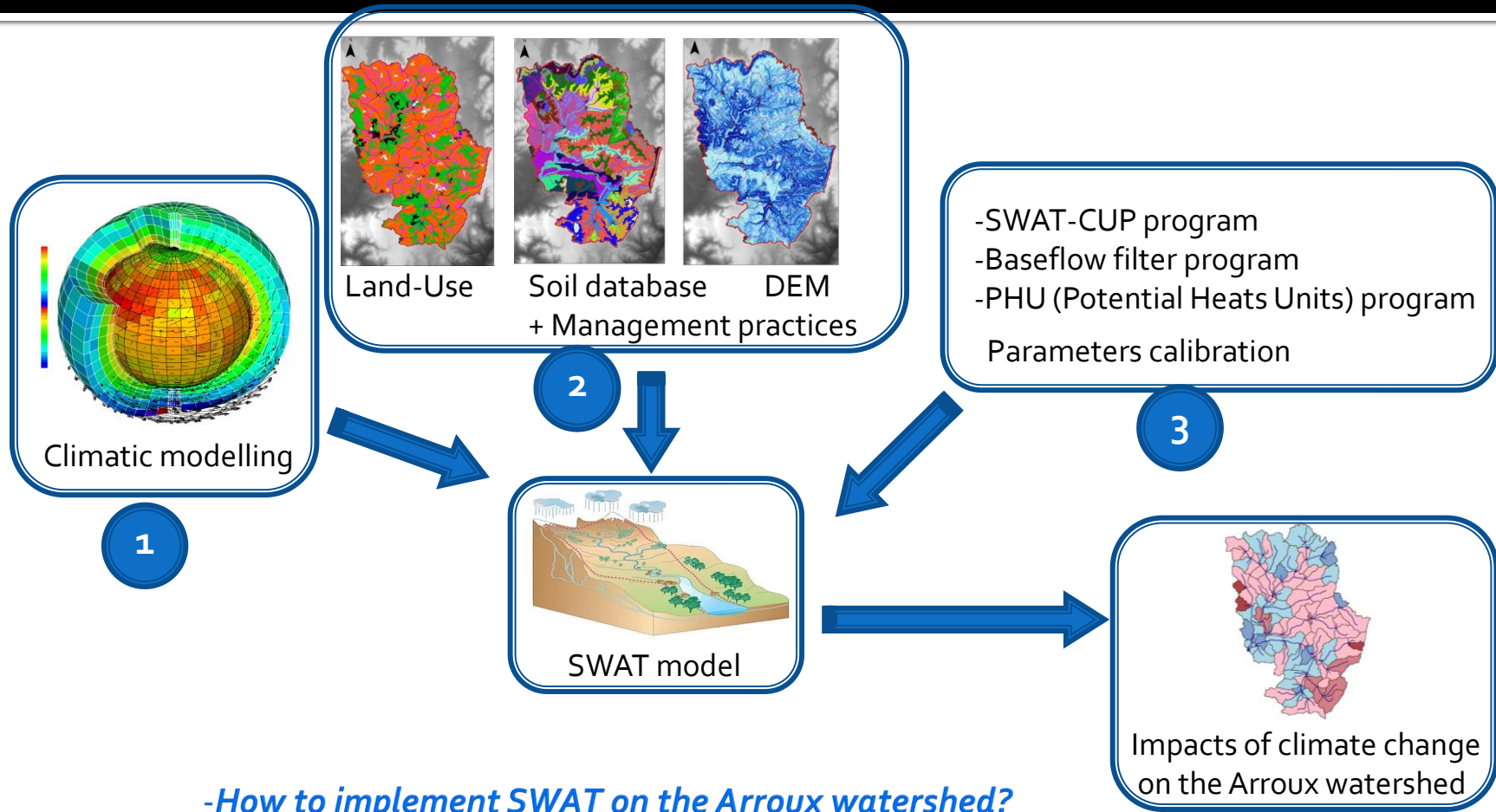
Financed by:

How to assess the impacts of climate change on water quantity and water quality at local scale ?



Watershed	Area (km ²)	Basin
Arroux	773	Loire
Tille	1260	Rhône
Armançon	2982	Seine





*-How to implement SWAT on the Arroux watershed?
- Is a high-resolution soil database useful to improve SWAT simulations ?*

Material and Methods

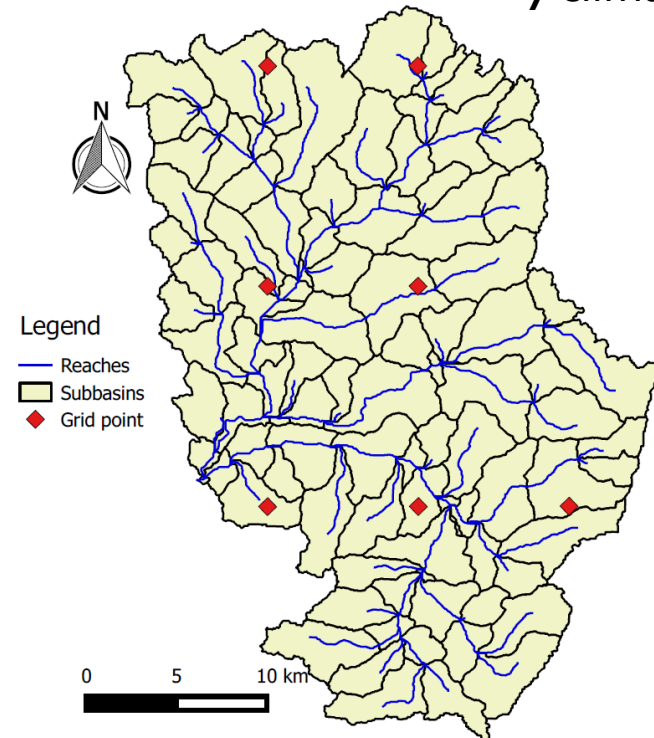
1. Climate data

Using	Period	Type of data	Resolution
SWAT Calibration	1980-2011	Interpolated observations	12km

Arroux watershed

98 Subbasins

7 climate stations



Material and Methods

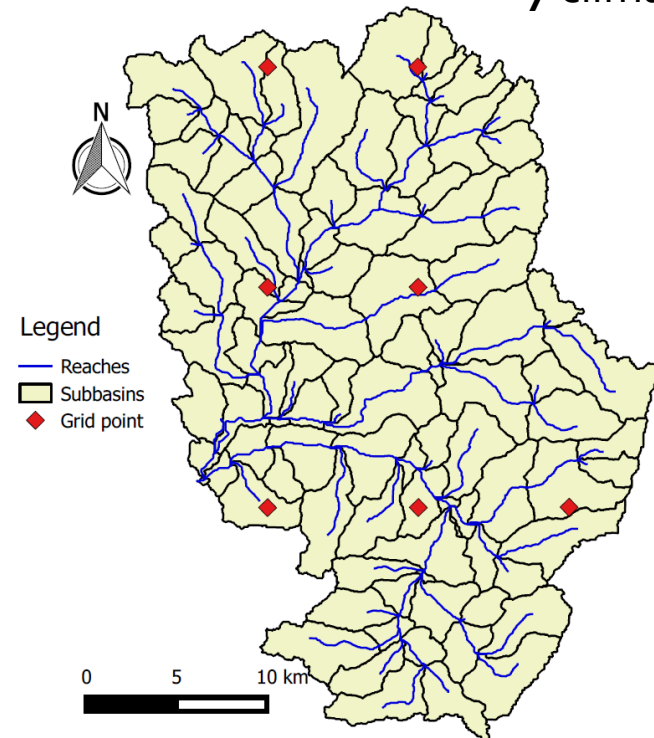
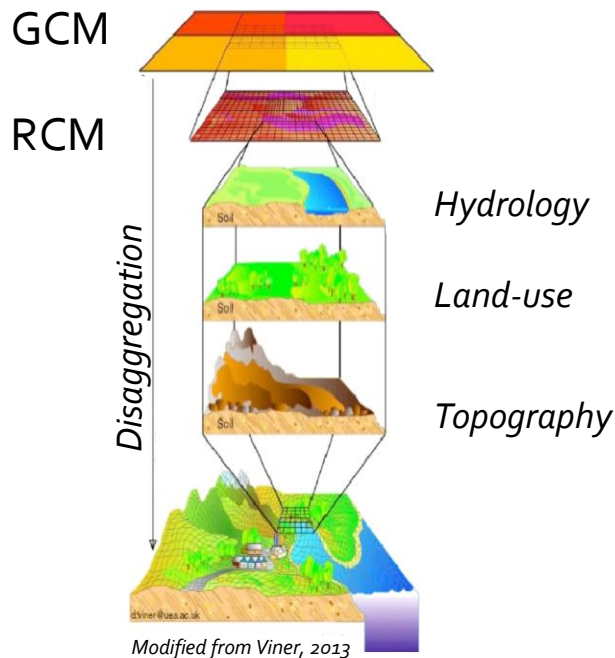
1. Climate data

Using	Period	Type of data	Resolution
SWAT Calibration	1980-2011	Interpolated observations	12km
SWAT Simulation	2006-2100	Dynamical disaggregation of GCM by a RCM	12km

Arroux watershed

98 Subbasins

7 climate stations

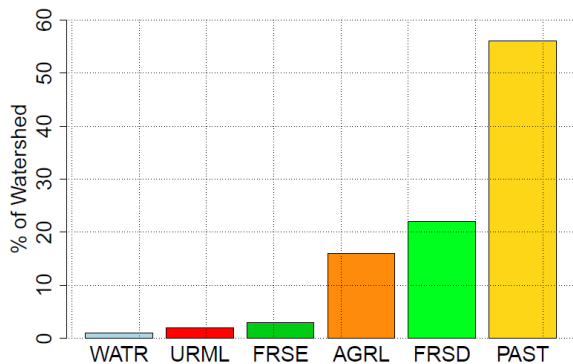


Material and Methods

2. Land-Use/Soil database/Slope

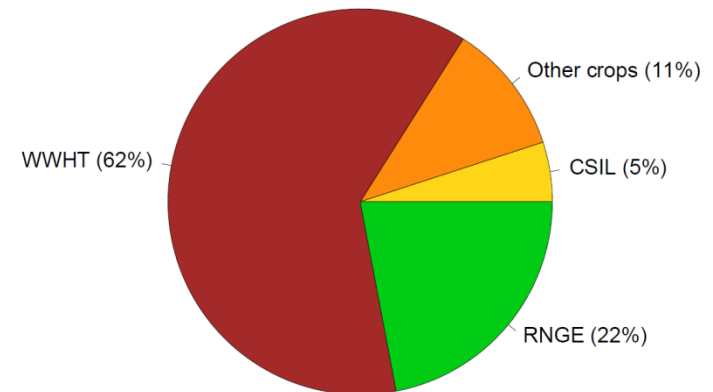
■ Land-use

Watershed land-use (Corine Land Cover 2006)



- Permanent grassland (PAST)
- Deciduous forest (FRSD)
- Agricultural area (AGRL)

Land-Use refinement



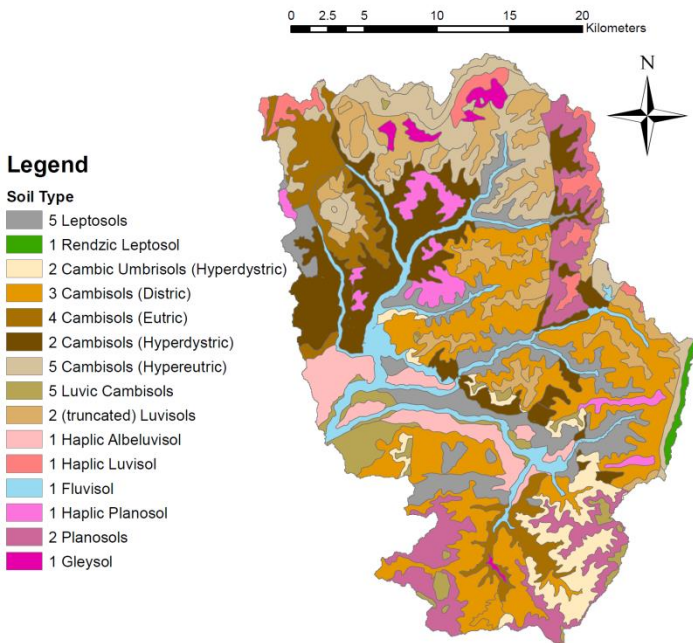
Field referential of french Agricultural ministry

- Rapeseed/Wheat/Barley → similar crops, represented by Winter Wheat (62%)
- Temporary grassland (22%)
- Others crops (11%)
- Corn silage (5%)

Material and Methods

2. Land-Use/Soil database/Slope

■ 36 soils database

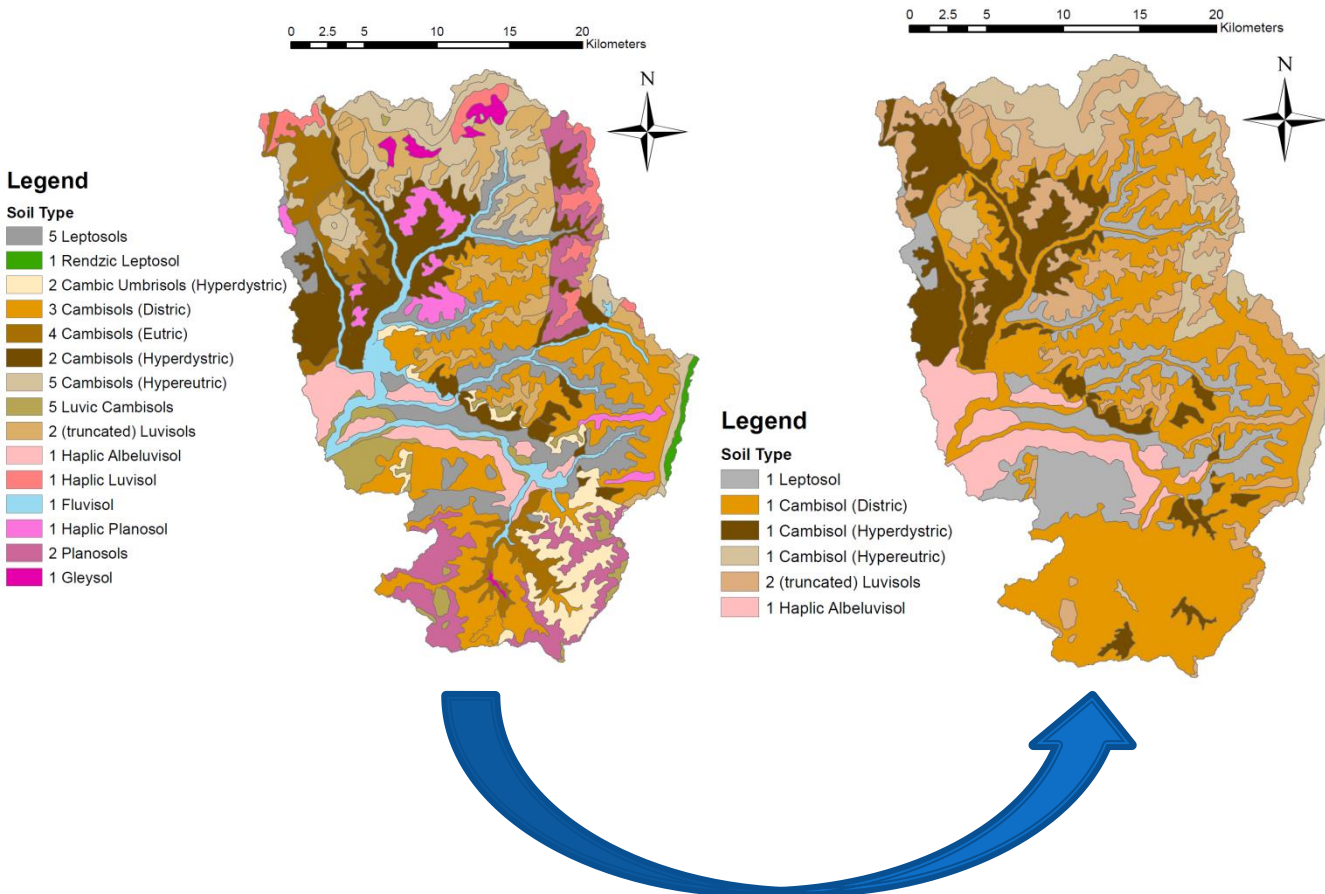


Material and Methods

2. Land-Use/Soil database/Slope

36 soils database

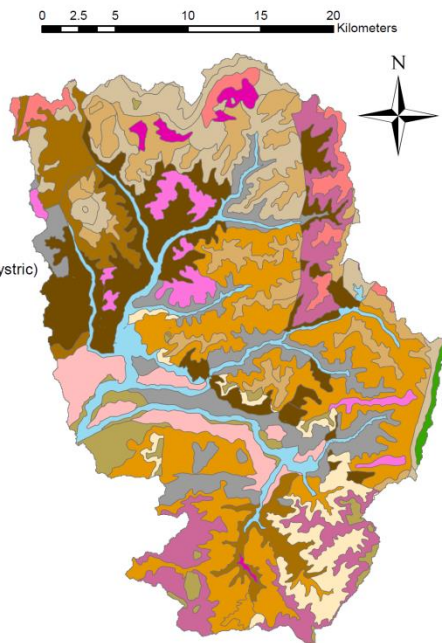
7 soils database



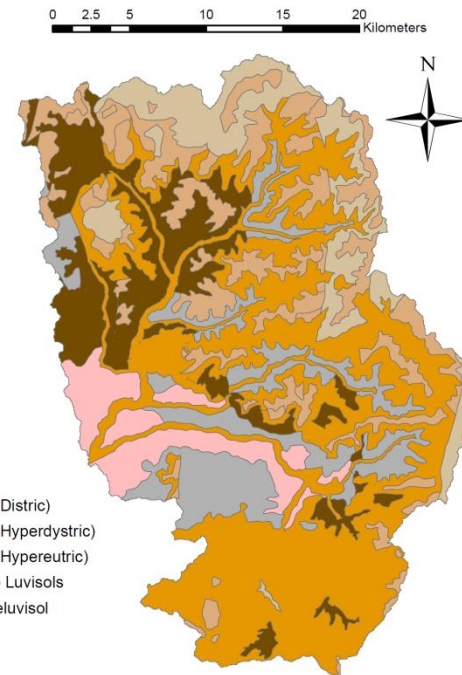
Material and Methods

2. Land-Use/Soil database/Slope

36 soils database



7 soils database



Soil Aggregation:

-PCA analysis

Texture, Gravel (%), Soil depth (mm), Albedo)

-Clustering (HCPC analysis)

7 clusters highlighted

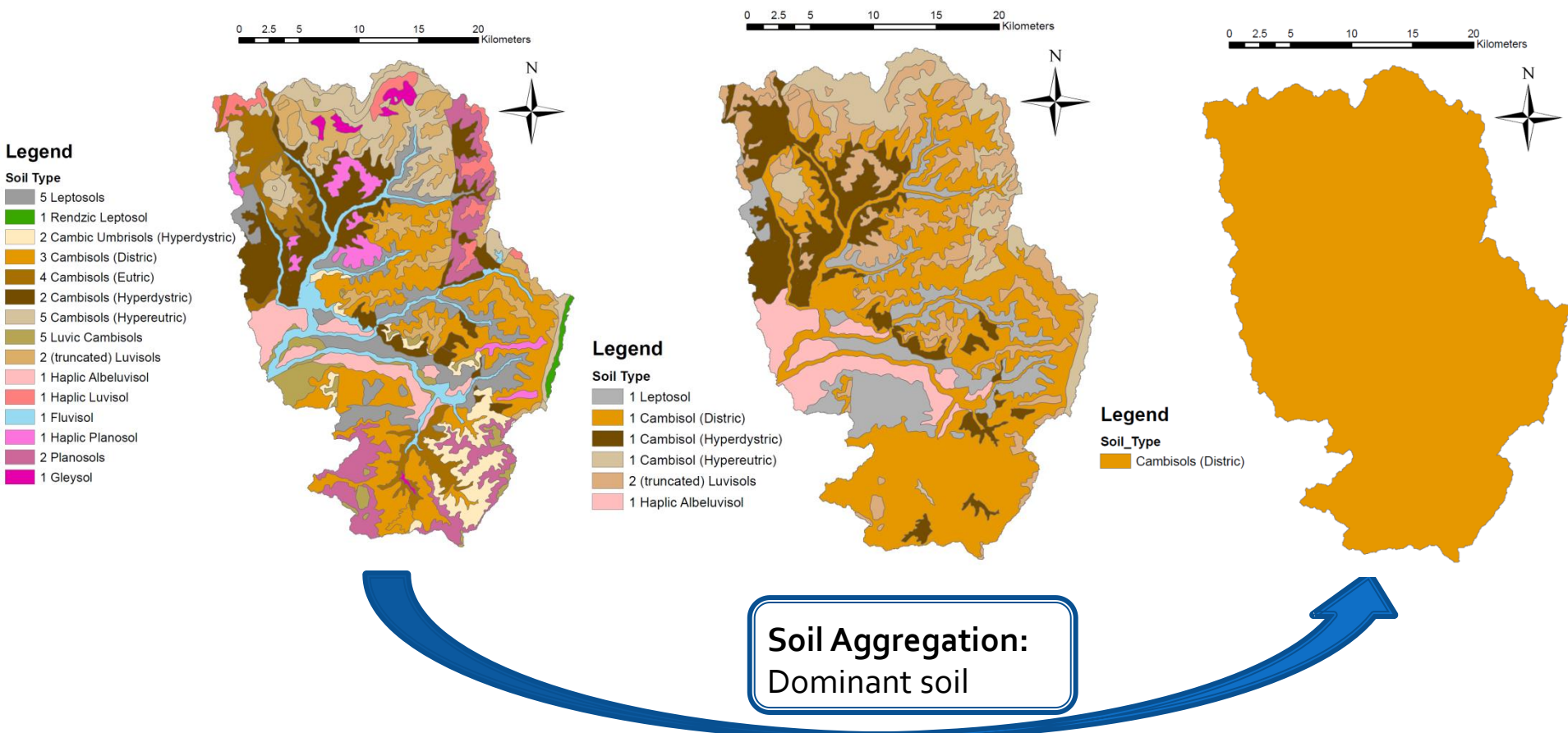
Material and Methods

2. Land-Use/Soil database/Slope

■ 36 soils database

7 soils database

1 soil database



Material and Methods

2. Land-Use/Soil database/Slope

- DEM: 25m-resolution, single slope class

Material and Methods

2. Land-Use/Soil database/Slope

- DEM: 25m-resolution, single slope class

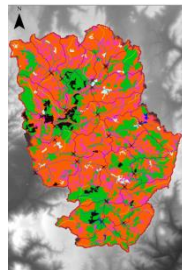
HRU delineation

98 subbasins



X

Land-Use



X

Soils

36-soils database
7-soils database
1-soil database

X

Slope



→ 2857 HRU
→ 1875 HRU
→ 632 HRU

Material and Methods

2. Land-Use/Soil database/Slope

- DEM: 25m-resolution, single slope class

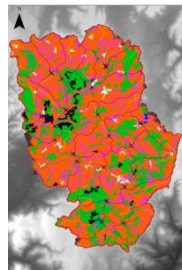
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X

Land-Use



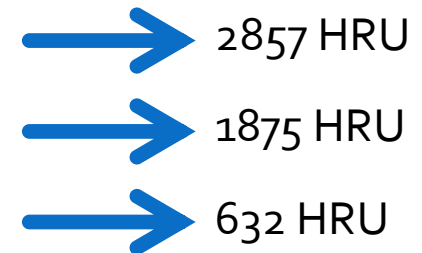
X

Soils

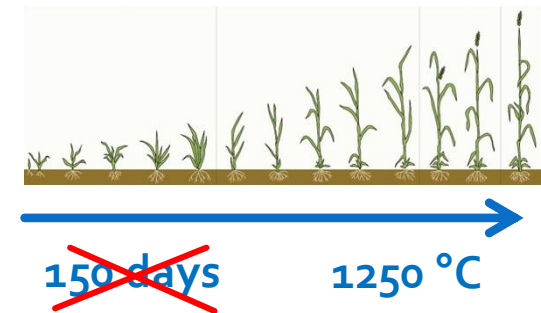
36-soils database
7-soils database
1-soil database

X

Slope



- + Management practices and crop data
 - Management operations scheduled by Heat Units
 - Crop data modified among the PHU (Potential Heat Unit) program
 - Auto-fertilisation to meet nutrient plant uptake



Material and Methods

3. Parameters calibration

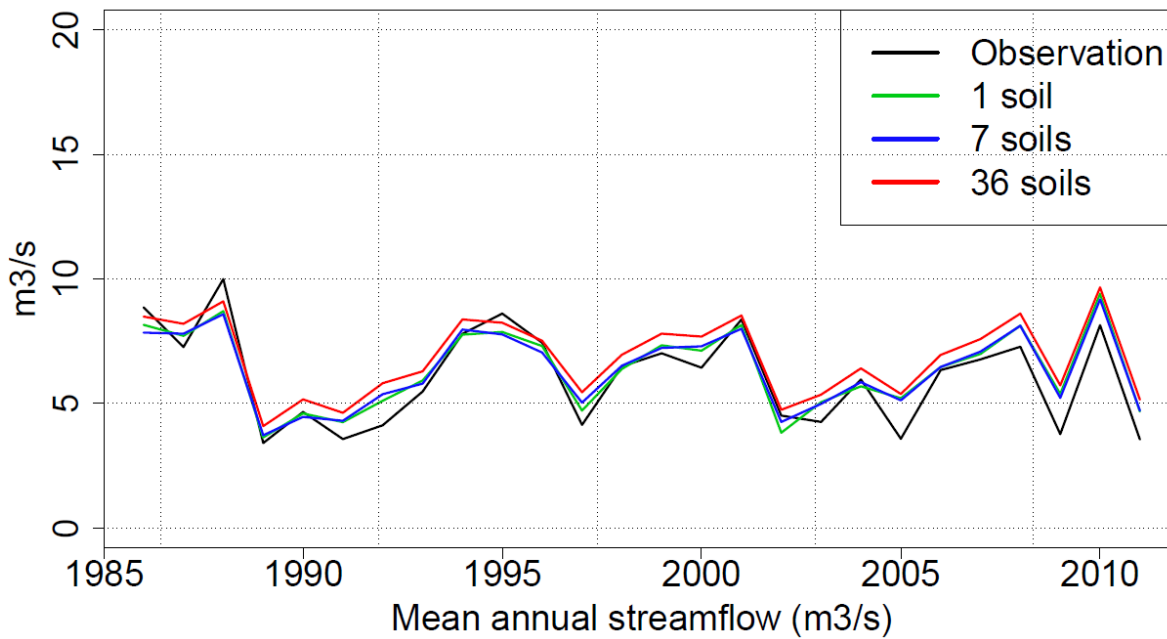
Hydrological cycle phase	Parameter	Default value	Calibrated value	
GROUNDWATER	ALPHA_BF	0.048	0.08 – 0.11	} Baseflow filter program
	GW_DELAY	31	21.5 – 28.5	
	GW_REVAP	0.02	0.12	} Swat-CUP
	RCHRG_DP	0.05	0.3	
SURFACE RUNOFF	SURLAG	4	0.2	

Results

1. Model performance : Streamflow simulation

- Simulation with each soil database

- Slight overestimation of annual streamflow with the 36-soils database

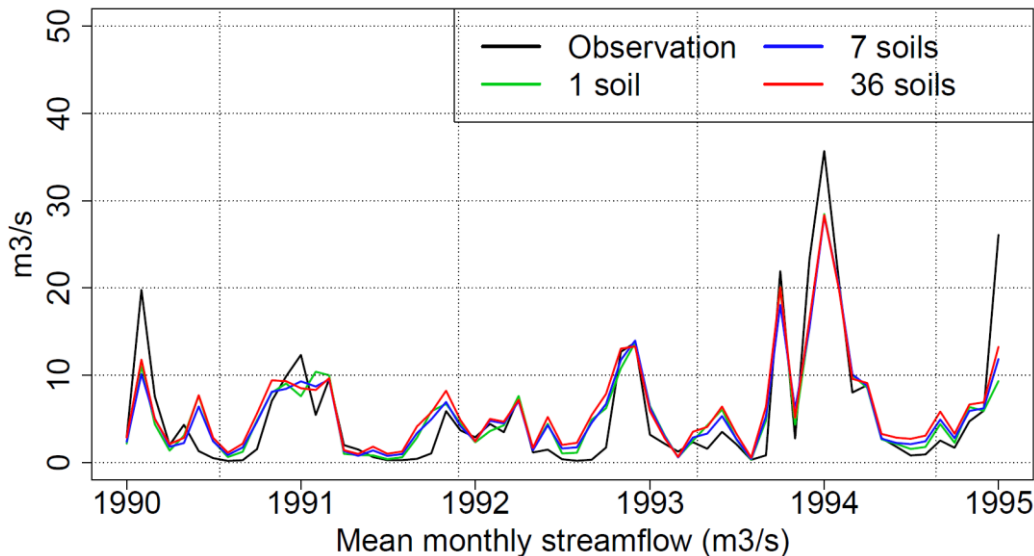


Nash Efficiency (1980-2011)	Annual
1 soil	0.892
7 soils	0.888
36 soils	0.821

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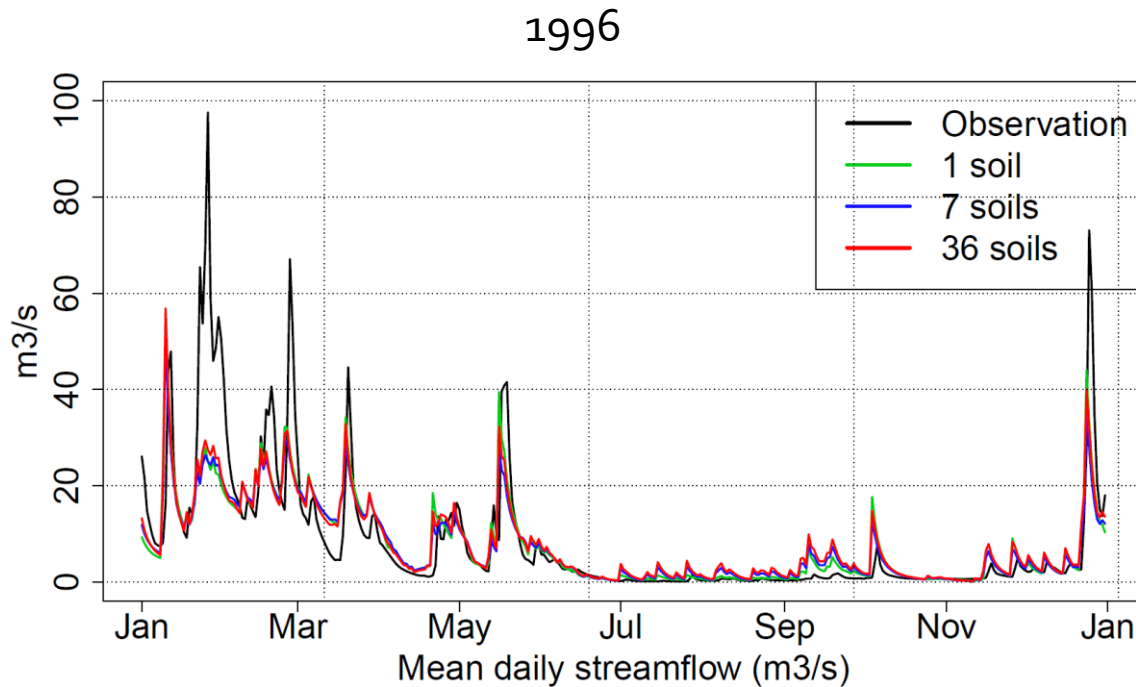
- Very low effect at monthly scale

Nash Efficiency (1980-2011)	Annual	Monthly
1 soil	0.892	0.804
7 soils	0.888	0.809
36 soils	0.821	0.821

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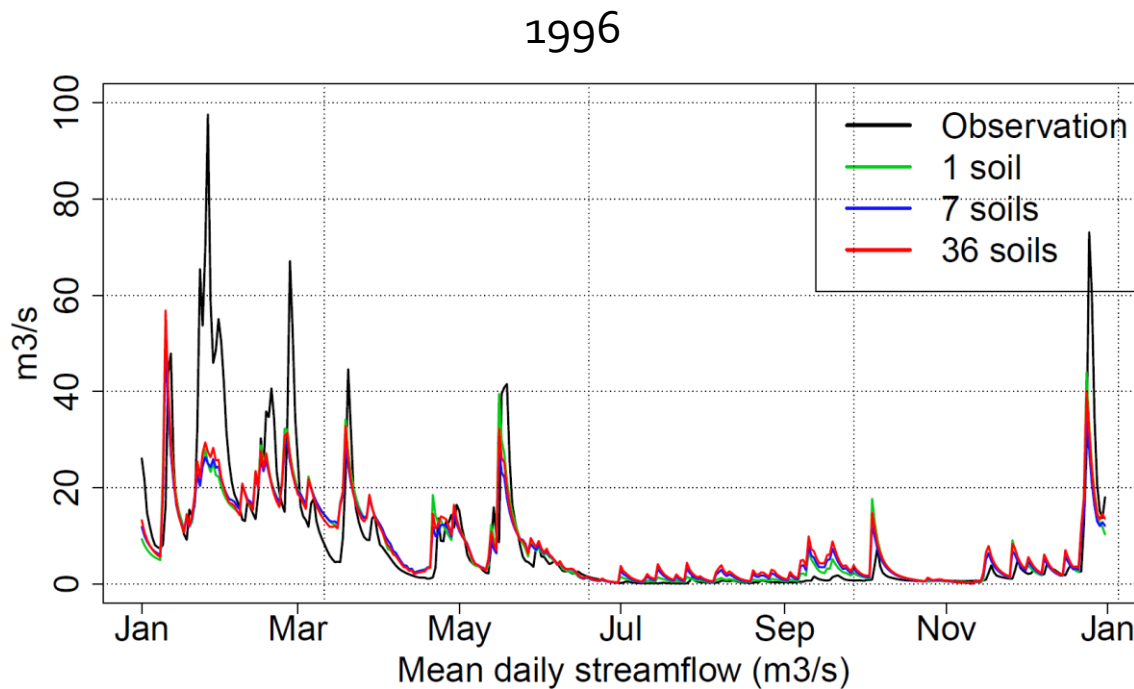
- Very low effect at daily scale

Nash Efficiency (1980-2011)	Annual	Monthly	Daily
1 soil	0.892	0.804	0.498
7 soils	0.888	0.809	0.537
36 soils	0.821	0.821	0.529

Results

1. Model performance : Streamflow simulation

- Simulation with each soil database



- Slight overestimation of annual streamflow with the 36-soils database

- Very low effect at monthly scale

- Very low effect at daily scale

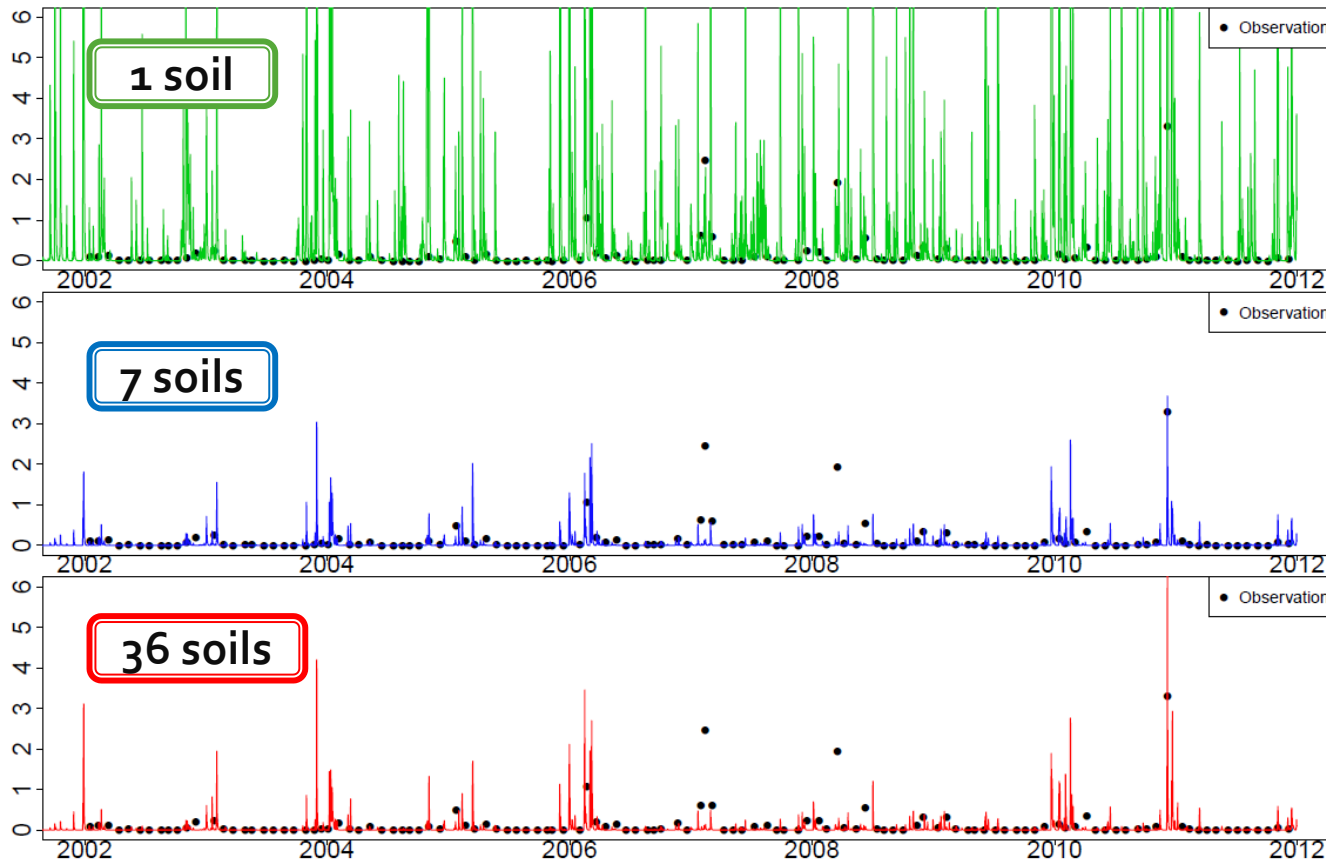
Nash Efficiency (1980-2011)	Annual	Monthly	Daily
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7 soils	0.888	0.809	0.537
36 soils	0.821	0.821	0.529

*Is one soil sufficient for SWAT simulation?
But what about water quality parameters?*

Results

1. Model performance : Water quality parameters

- Total suspended sediment (kg/ha/day)

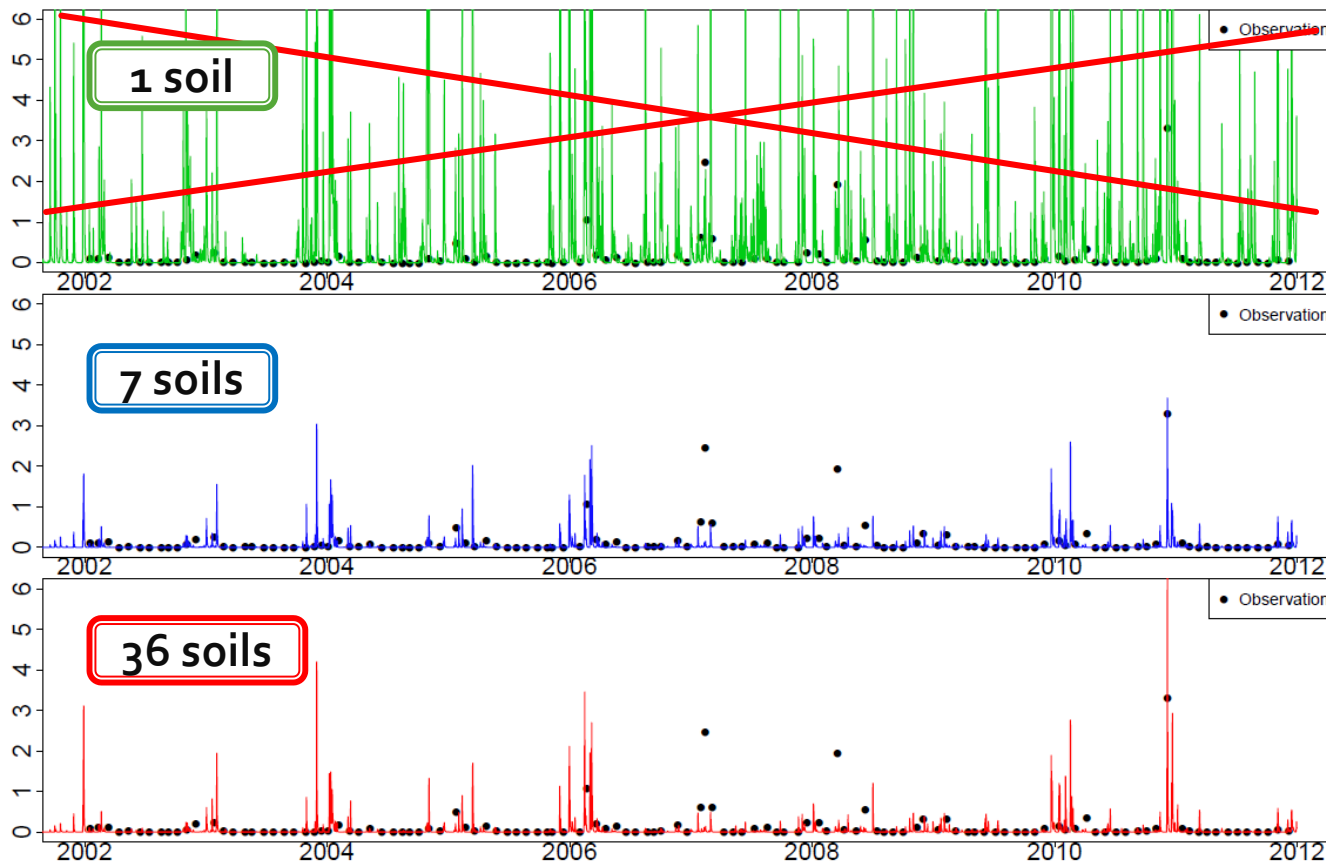


-High influence of the dominant soil choice on daily sediment transport

Results

1. Model performance : Water quality parameters

- Total suspended sediment (kg/ha/day)



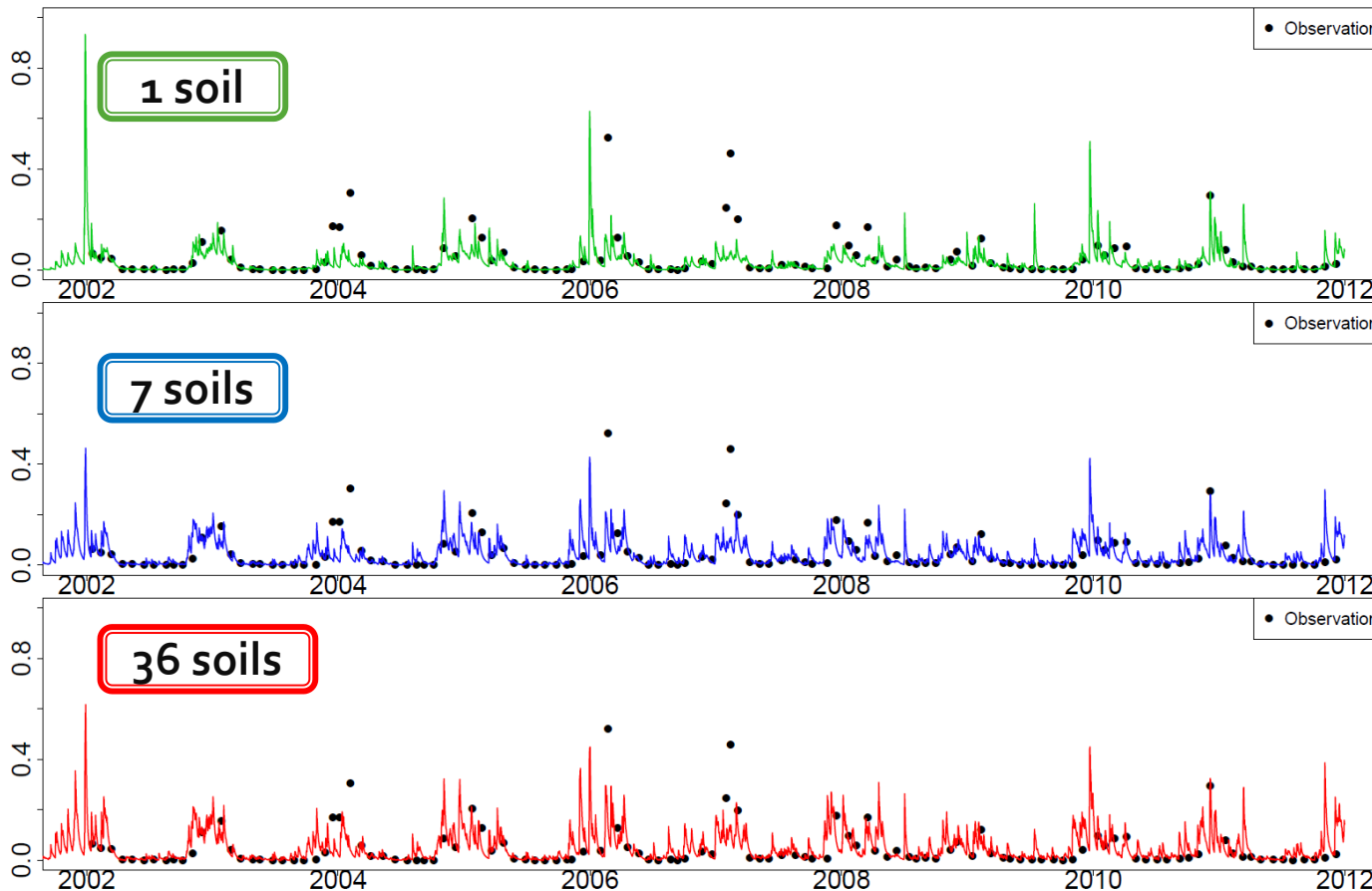
-High influence of the dominant soil choice on daily sediment transport

Results

1. Model performance : water quality parameters

- NO_3^- exports (kg NO_3^- /ha/day)

mainly between 0 and 10mg/l



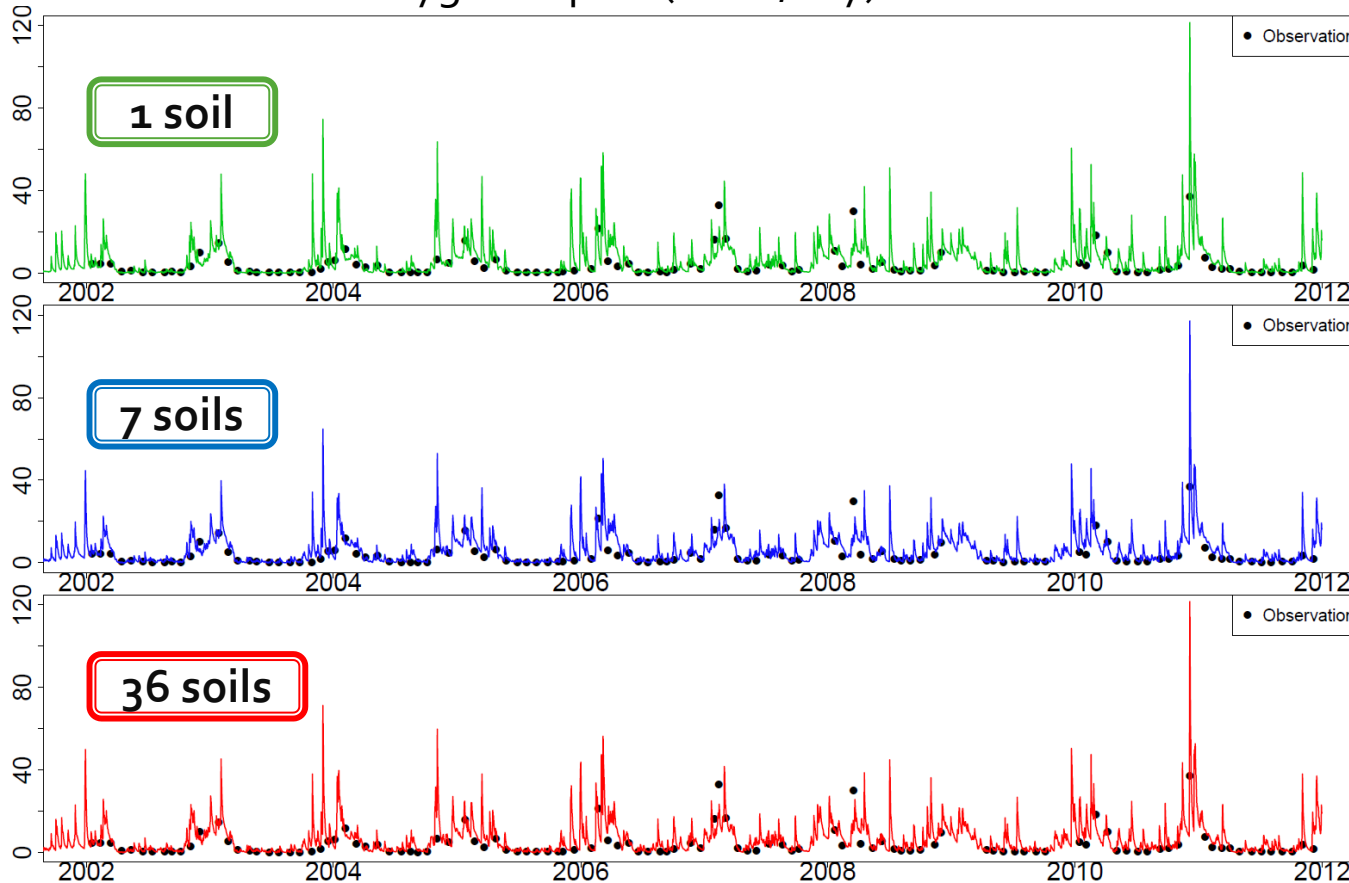
-High influence of the dominant soil choice on daily sediment transport

- Low influence on daily nitrate export.

Results

1. Model performance : water quality parameters

■ Dissolved oxygen export (t DO/day)



-High influence of the dominant soil choice on daily sediment transport

- Low influence on daily nitrate export.

- Low influence on daily dissolved oxygen export.

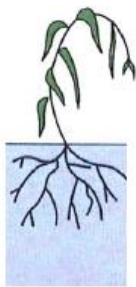
Results

1. Model performance : Available Water Content (AWC)

Soil water content (% AWC) for the present time (1980-2011)

Legend:

- Available water capacity is quite empty
- Readily available water capacity is empty
- Available water capacity is full



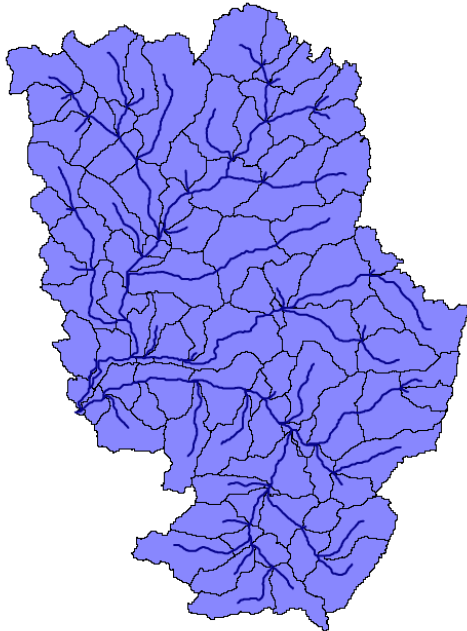
Results

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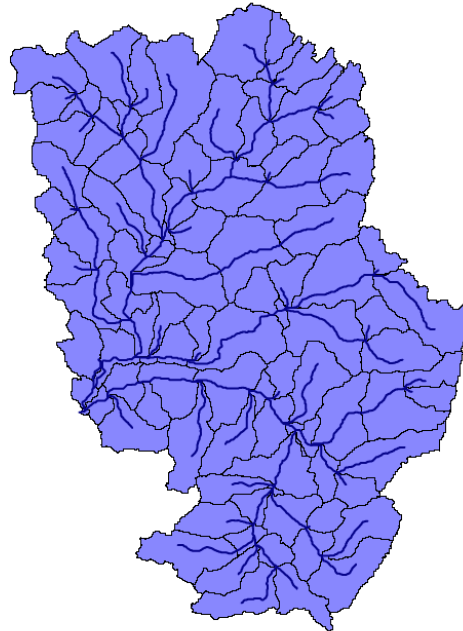
Soil water content (% AWC) for the present time (1980-2011)

January

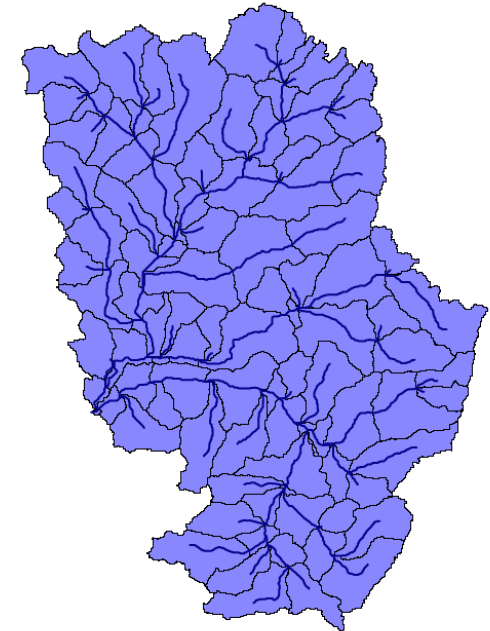
1 soil



7 soils



36 soils



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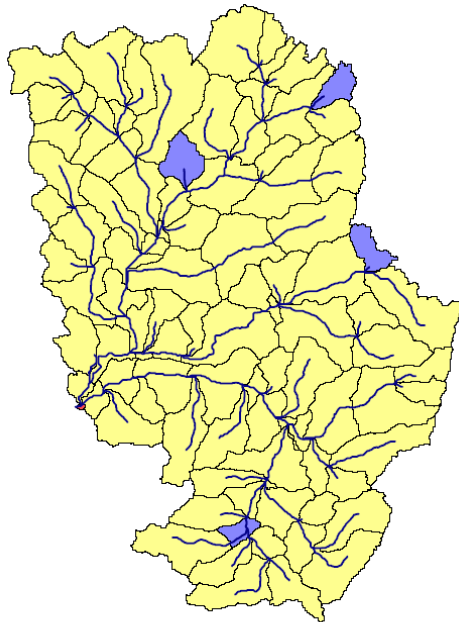
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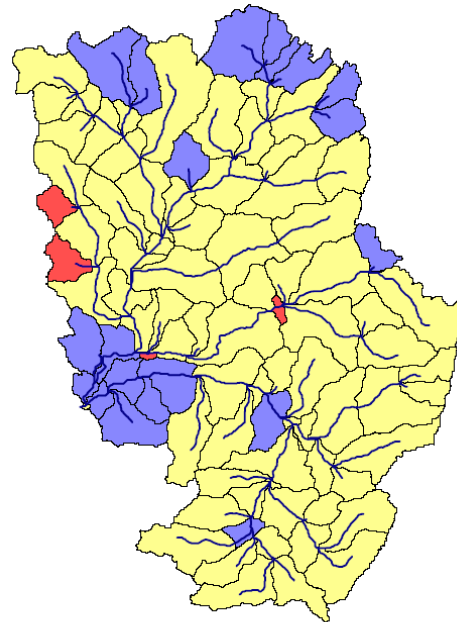
Soil water content (% AWC) for the present time (1980-2011)

June

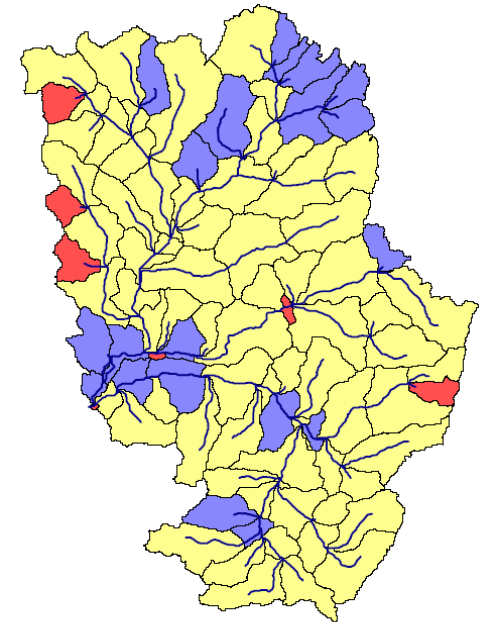
1 soil



7 soils



36 soils



Legend:

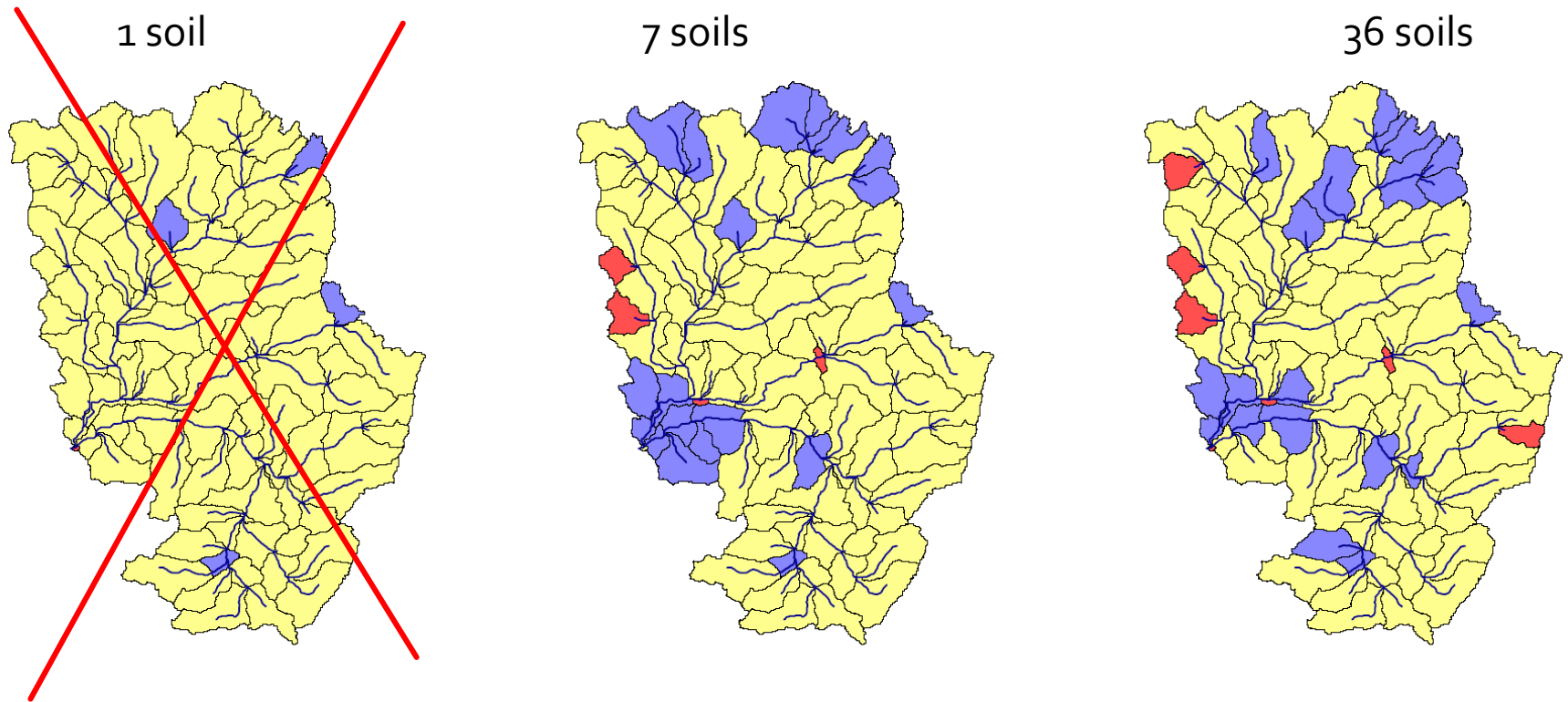
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1. Model performance : Available Water Content (AWC)

Soil water content (% AWC) for the present time (1980-2011)

June



Legend:

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Results

1. Model performance : first conclusions

Validation of SWAT model on Arroux watershed

- Runoff and main water quality parameters are correctly reproduced by the model

Influence of soil database resolution

- 1-soil database: large influence on some parameters (total suspended sediments, soil water content)
- Simulation based on 7 and 36-soils databases have shown very slight differences.



7-soils database is sufficient

However

- The Arroux watershed is too weakly anthropized to see eventual impacts on nutrient loadings

What about climate change?

Results

2. Impact of climate change

- 7-soils database in input
- Precipitation simulations in progress (post-correction needed)
- Temperature data available
 - +3/+4°C in Burgundy (reference period 1980-2011)
- Other climate data inputs (PCP, SLR, WND, RH)
 - Constant for this simulation

Results

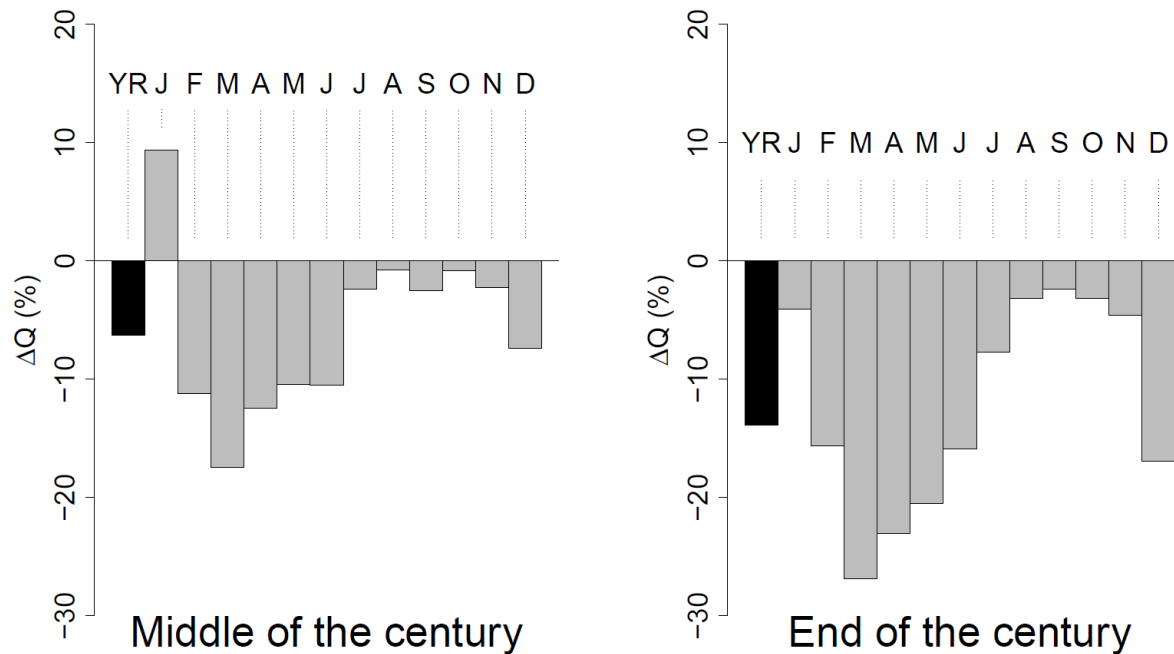
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 - +3/+4°C in Burgundy (reference period 1980-2011)
- Other climate data inputs (PCP, SLR, WND, RH)
 - Constant in this simulation
- 3 periods of 18 years compared :
 - Reference period: 1980-1998
 - Mid-century : 2030-2048
 - End of the century : 2070-2088
 - 2 years of warm-up for each period

Results

2. Impact of climate change: streamflow anomalies

Mean annual and monthly streamflow (compare to the reference period)



Without precipitation change (same data), a global decrease in streamflow...

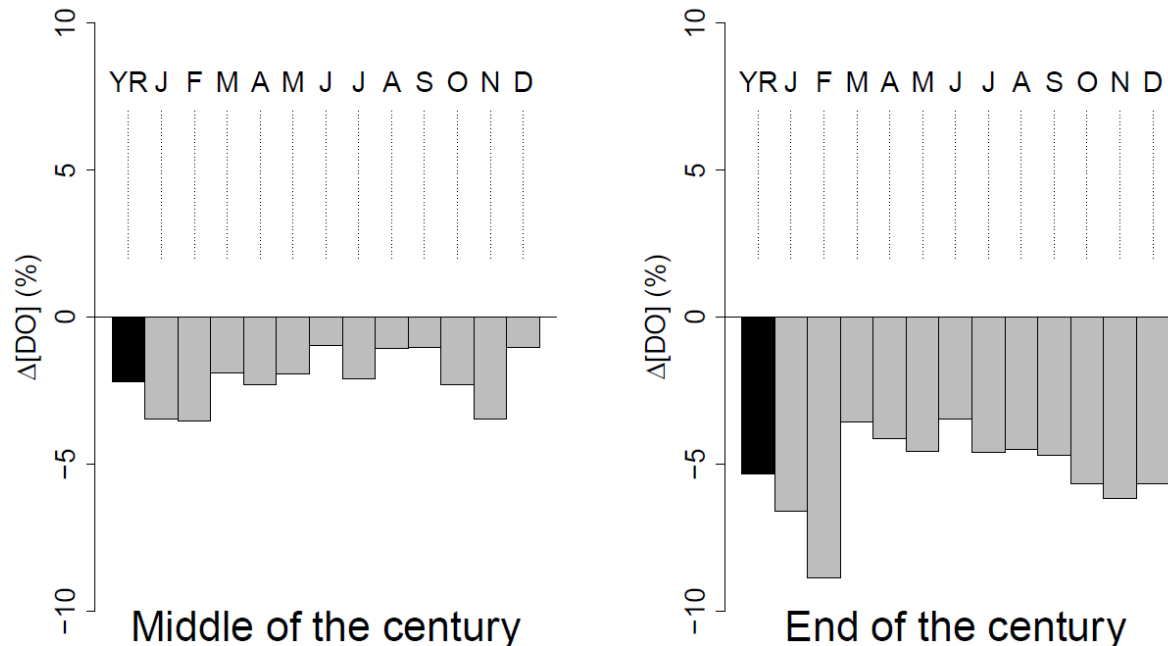
For both middle and end of the century

- At annual and monthly scale
- With a seasonality: strong decrease from December to June

Results

2. Impact of climate change: water quality parameters

Mean annual and monthly dissolved oxygen concentration (compare to the reference period)



- Decrease in dissolved oxygen concentrations : impacts of temperature on dissolved oxygen saturation.

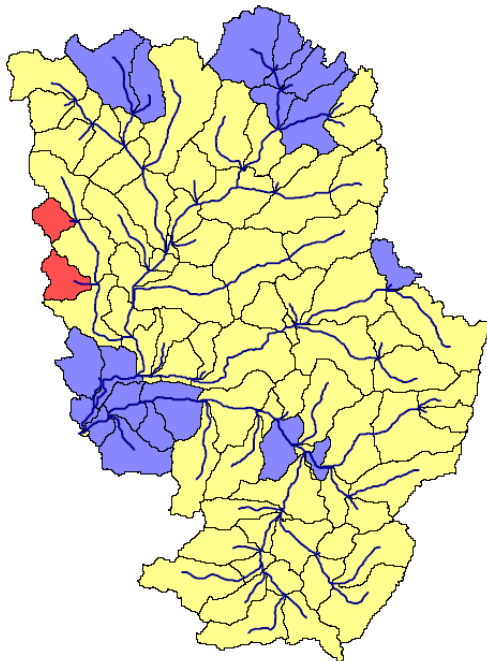
Results

2. Impact of climate change: Available Water Content

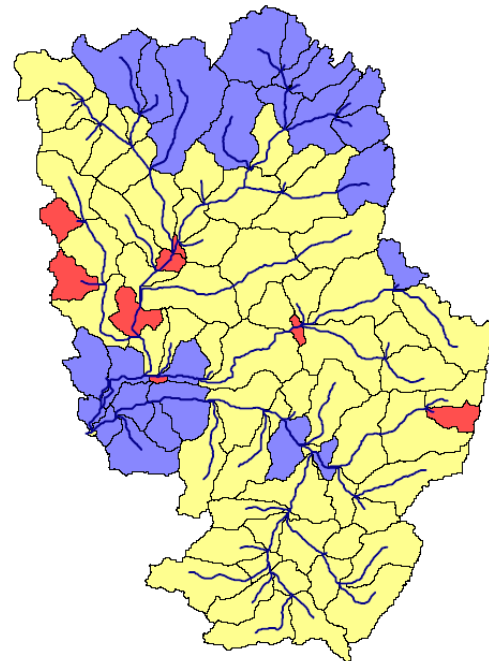
Soil water content (% AWC)

June

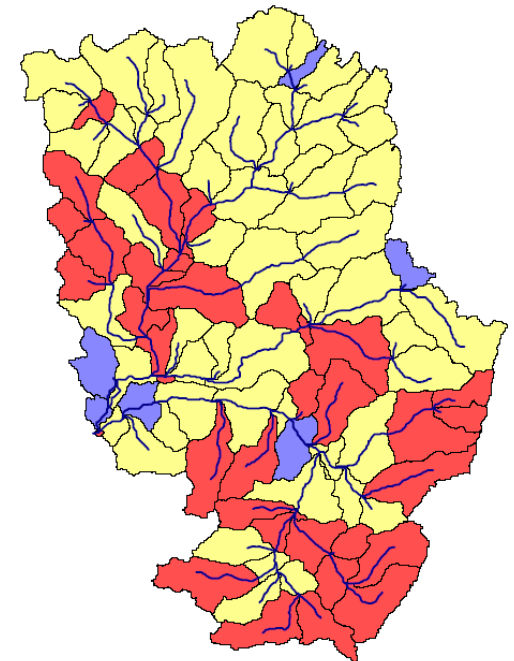
Reference period
(1982-1998)



Mid-period
(2032-2048)



End of century
(2072-2088)



Legend:

- Available water capacity is quite empty
- Readily available water capacity is empty
- Available water capacity is full

Arroux watershed

- Correct reproduction of runoff and main water quality parameters (TSS, NO₃⁻, DO)

Other watersheds

- Implementation in progress
- Analysis of soil database influence will be necessary for the 2 other watersheds, more anthropized.

Impact of climate change

- Impacts on streamflow are observed, with only temperature change.
- Decrease in available soil water capacity filling

Next simulations

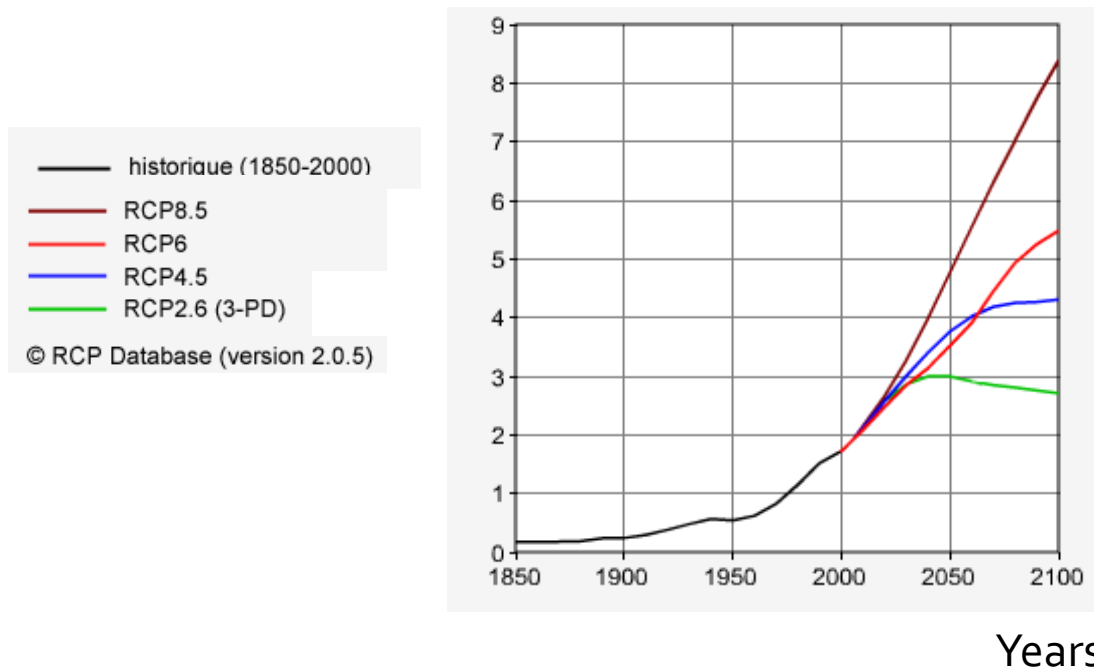
- Continuous simulations, at a daily scale from 1980 to 2100
- For 2 RCP scenarios (2.6 and 8.5)
- With all climate data inputs

Thanks for your attention

***Etienne BRULEBOIS, PhD student
University of Burgundy, Dijon, France
etienne.brulebois@gmail.com***

- RCP scenarios
- Spatial disaggregation interest
- Soil aggregation (PCA and HCPC analysis)
- Modification of plant database
- Parameters calibration
- References

Radiative forcing (w/m²)

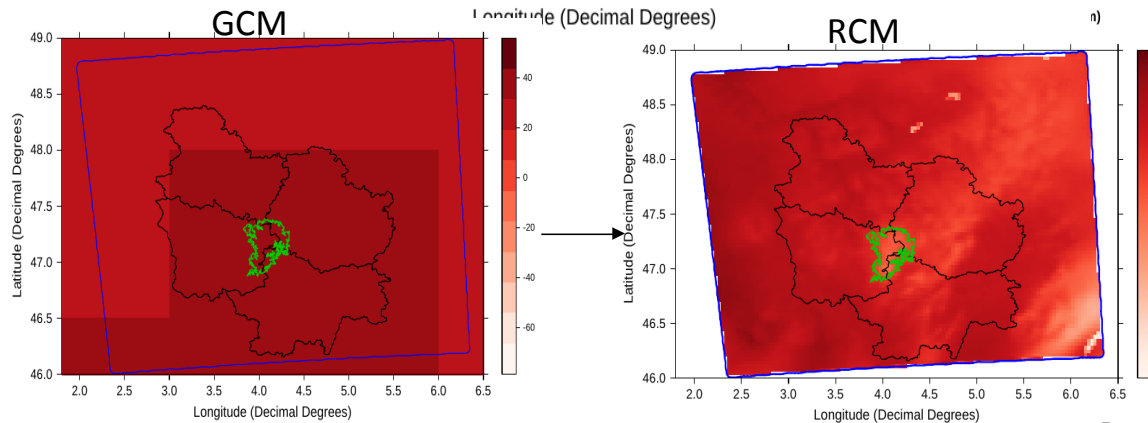
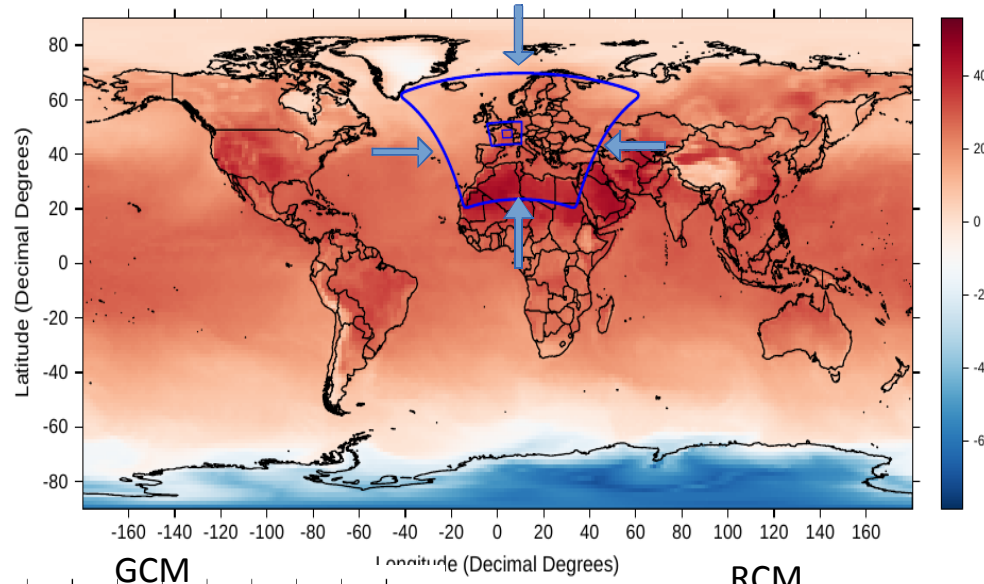
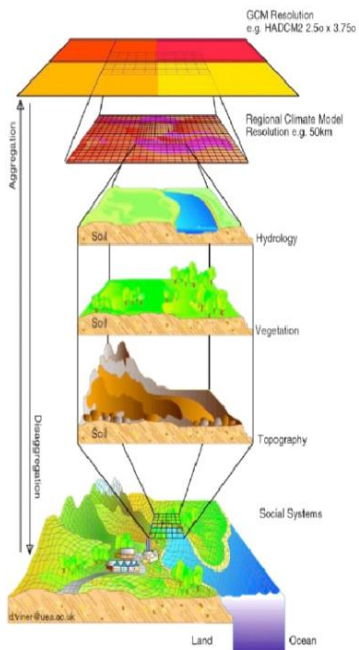


RCPs scenarios and radiative forcing between 1850 and 2000

Material and Methods

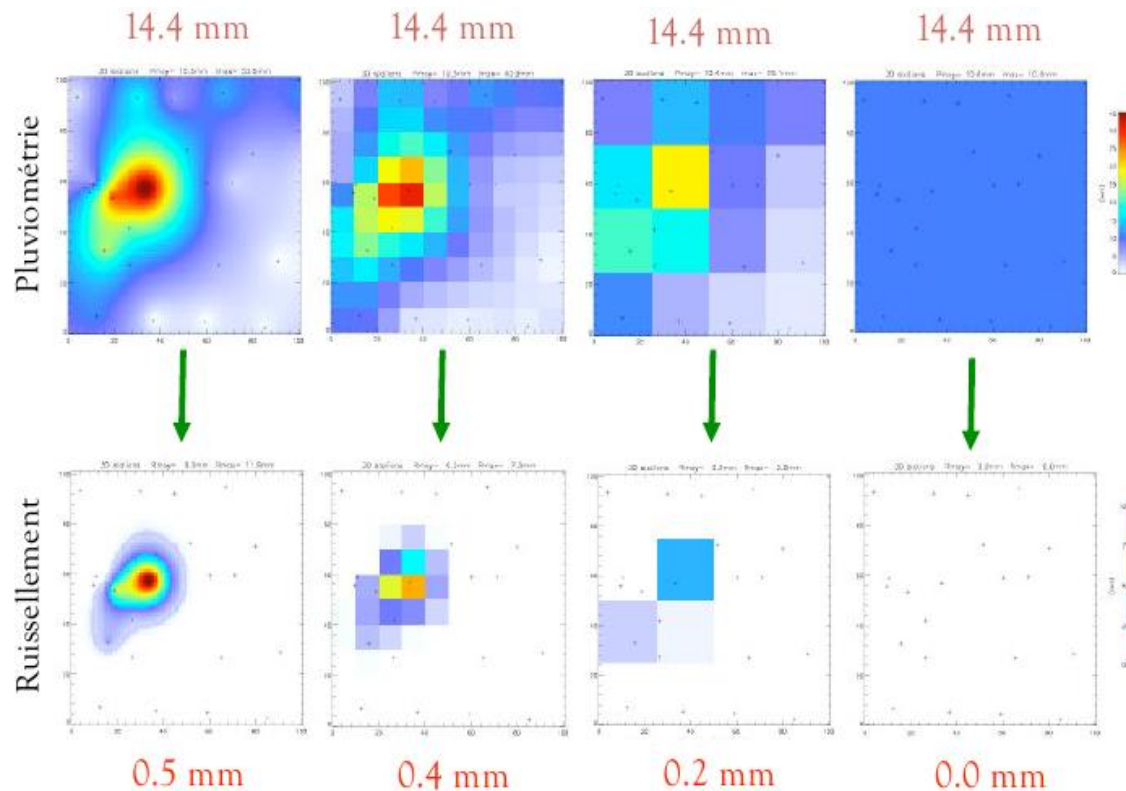
1. Climate modelling

Temperature at global scale (resolution ~130km)



Rossi et al, 2014

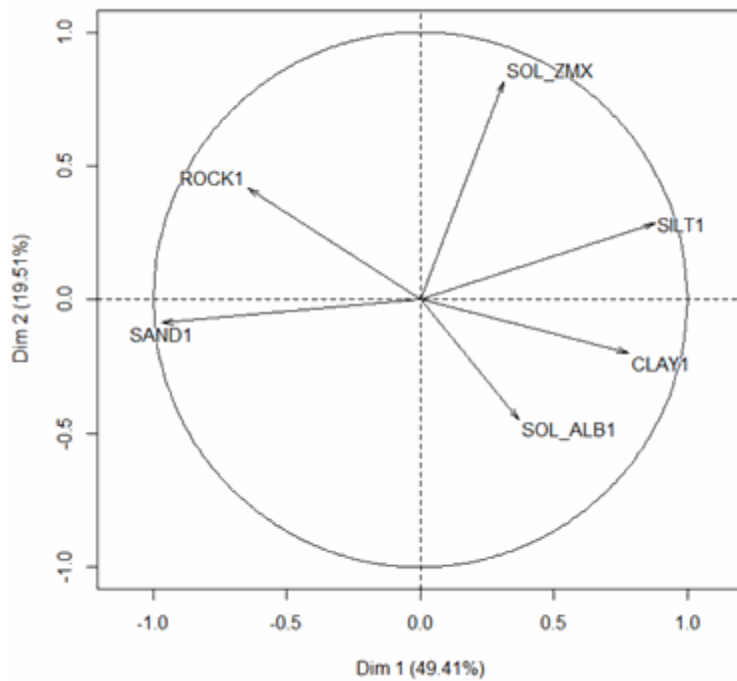
Spatial disaggregation interest



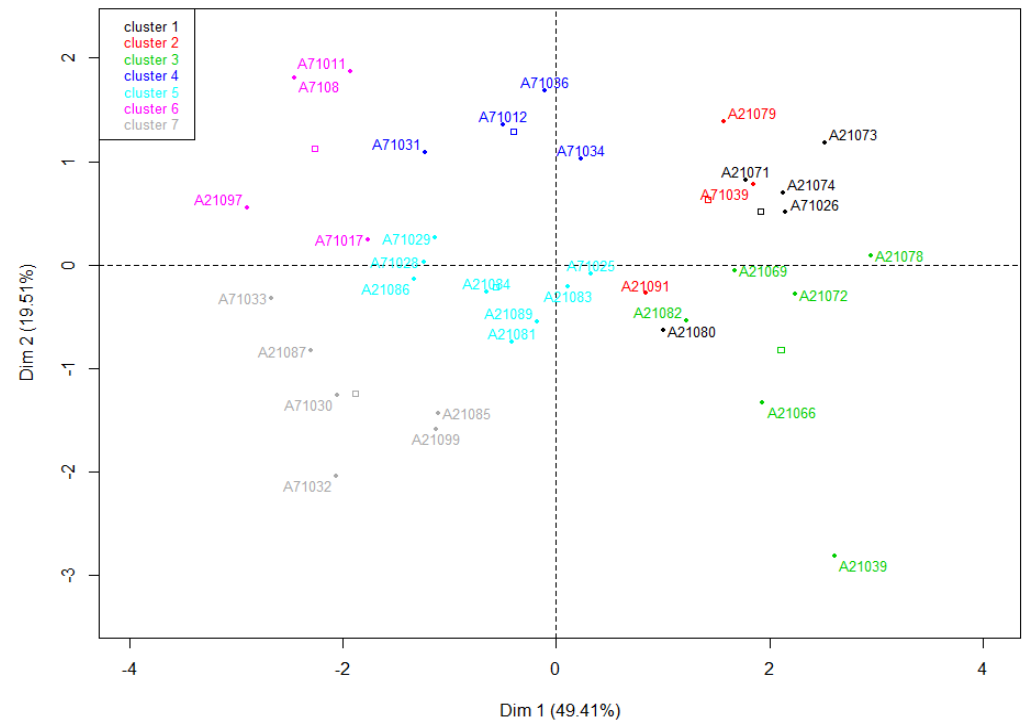
Vischel et al. 2007

Soil aggregation (PCA & HCPC)

Variables factor map (PCA)

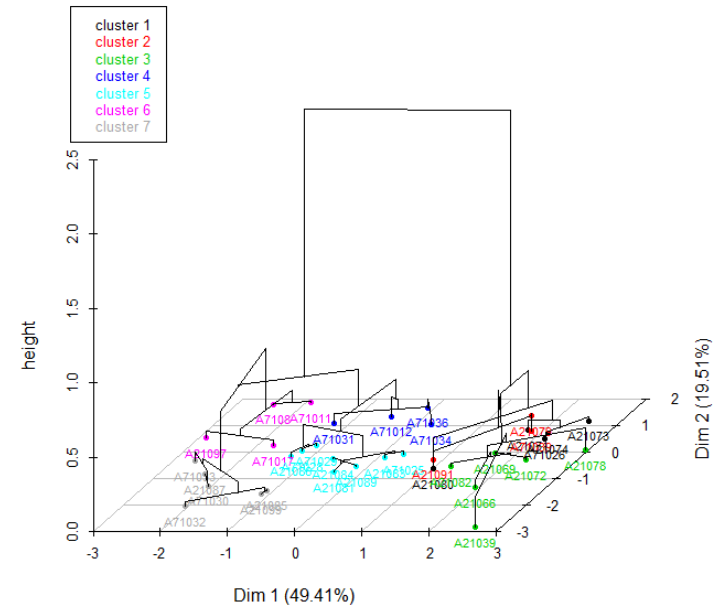
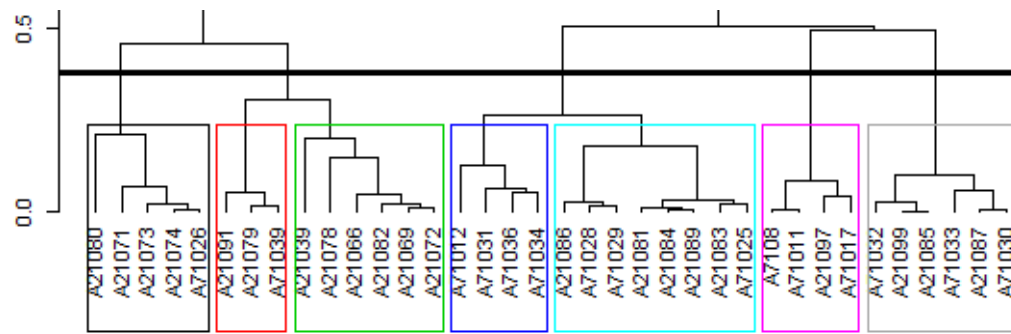


Factor map



Soil aggregation (PCA & HCPC)

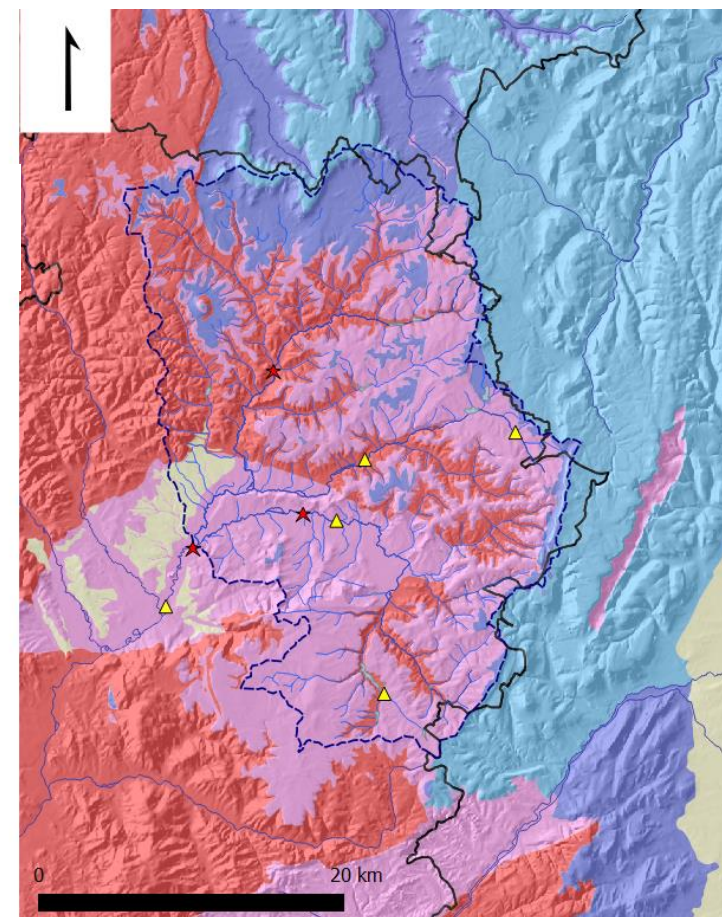
Hierarchical clustering on the factor map



Arroux watershed

- Weakly anthropized watershed
- Mainly on granitic basement
- 3 hydrometric stations
- 7 points of climate simulation

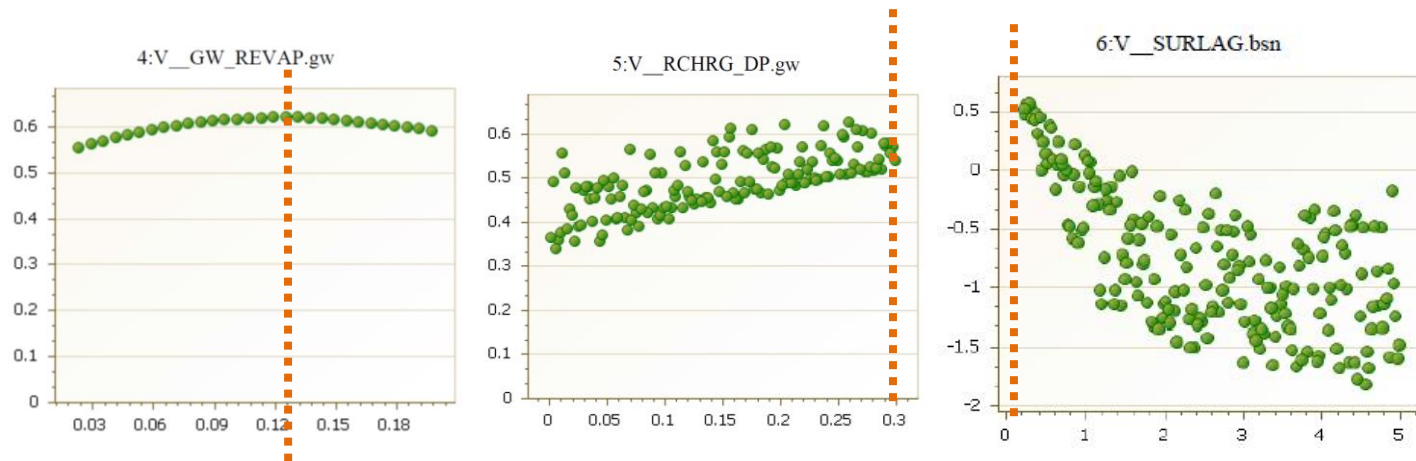
- ▲ Water quality stations
 - Water ponds
 - ★ Hydrometric stations
 - Watershed limit
- Lithology
- Recent alluviums
 - Sand and Chalk of the Cretaceous
 - Calcareous of the upper Jurassic
 - Calcareous of the middle Jurassic
 - Clay and Calcareous of the lower Jurassic
 - Schist and Sandstone of Permian/Trias
 - Granitic and metamorphic basement of Morvan



Modification of plant database

		Default value	Modified value
FRSE	T_OPT (°C)	30	15
	T_BASE (°C)	10	5
	MAT_YRS (years)	30	40
FRSD	T_OPT (°C)	30	15
	T_BASE (°C)	0	0
	MAT_YRS (years)	10	50

Parameters calibration



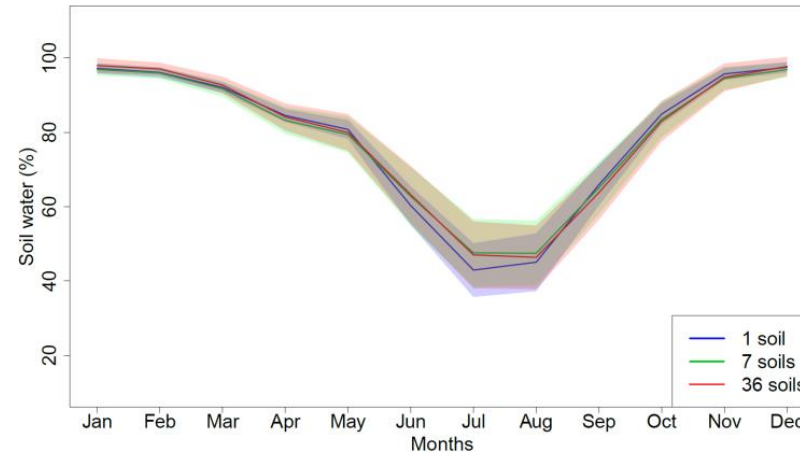
Hydrometric station	ALPHA_BF	GW_DELAY
Arroux at voudenay	0.107	21.5
Drée at Saint-Léger	0.0903	25.47
Arroux at Dracy-St-Loup	0.0807	28.51

Results

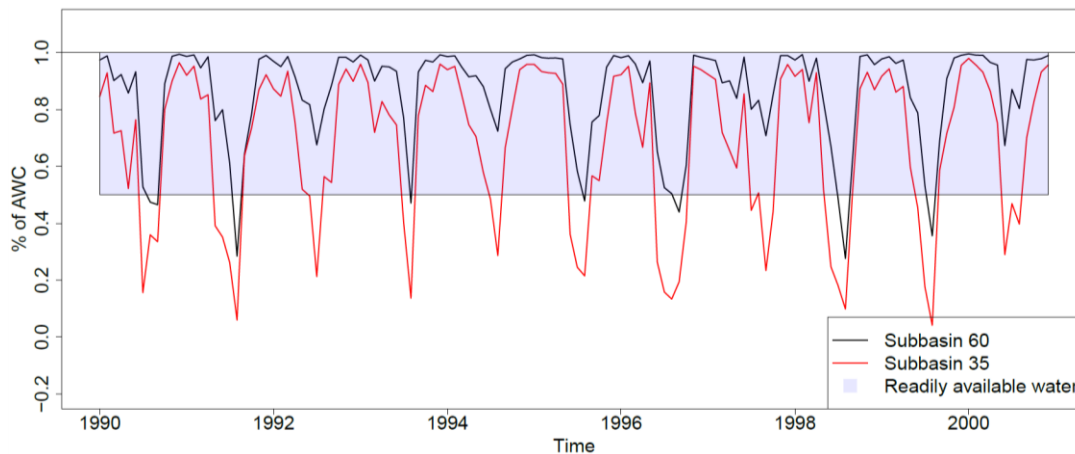
1. Model performance : Available Water Content (AWC)

- 1-soil database is the less filled
- Low differences between 7 and 36-soils databases

Seasonal soil water content



Differences between subbasins

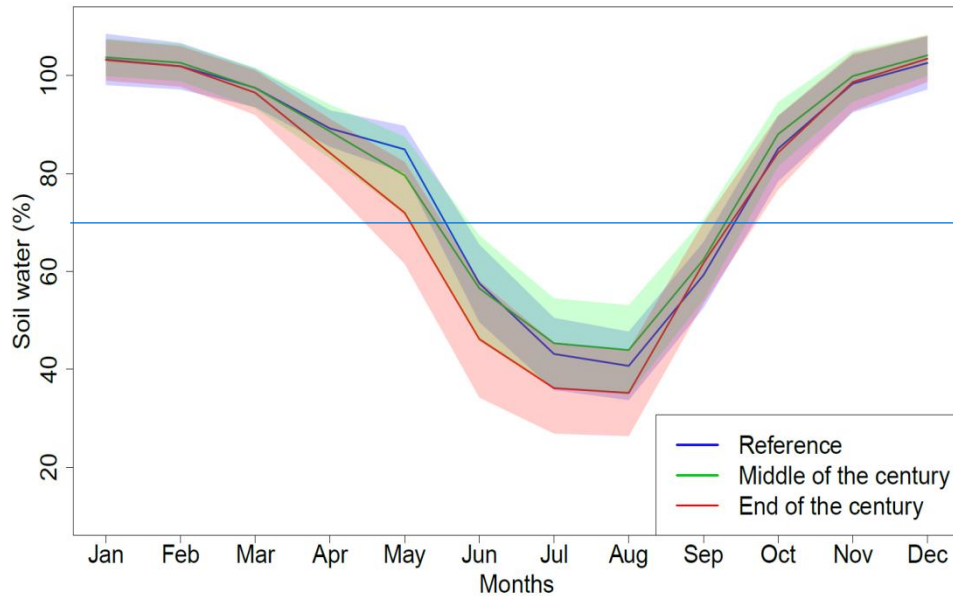


- Evolution of soil water content of 2 subbasins (with 36-soils database)
- Subbasin with low water capacity are dryer all along the year

Results

2. Impact of climate change: Available Water Content

Some months show strong decrease in AWC for the end of the century

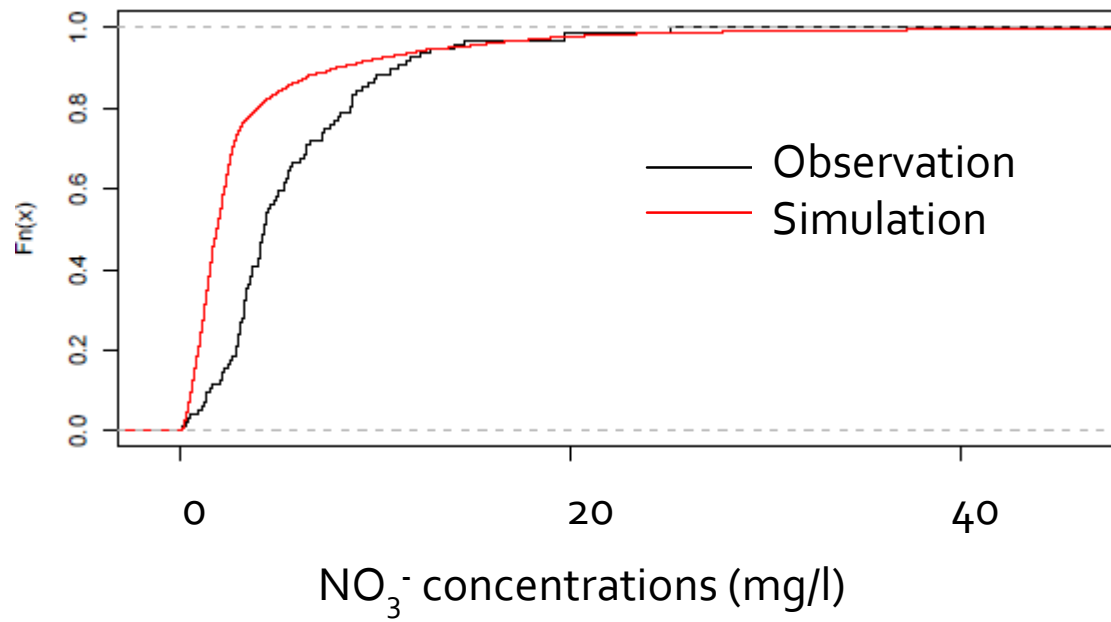


-September to March: no obvious changes in AWC

- Mid-century period:
Decrease in AWC from April to June, but increase from July to November

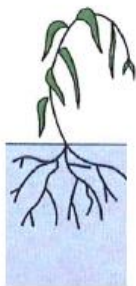
- End of century: Strong decreases from March to August

1. Rossi, A. *et al.* Impact du changement climatique sur l'évolution de la ressource en eau en Bourgogne, France (1980-2100) - Analyse des paramètres hydroclimatiques simulés à haute résolution par un modèle climatique régional. in **AIC**, 170–175 (2014).



Legend:

■ Available water capacity is quite empty
< 50% of AWC



■ Readily available water capacity is empty
50-70% of AWC



■ Available water capacity is full
> 70% of AWC

