MAELIA: a multi-agent modelling and simulation platform for regional integrated assessment of low-water management issues

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10/2018

maelia-platform.inra.fr

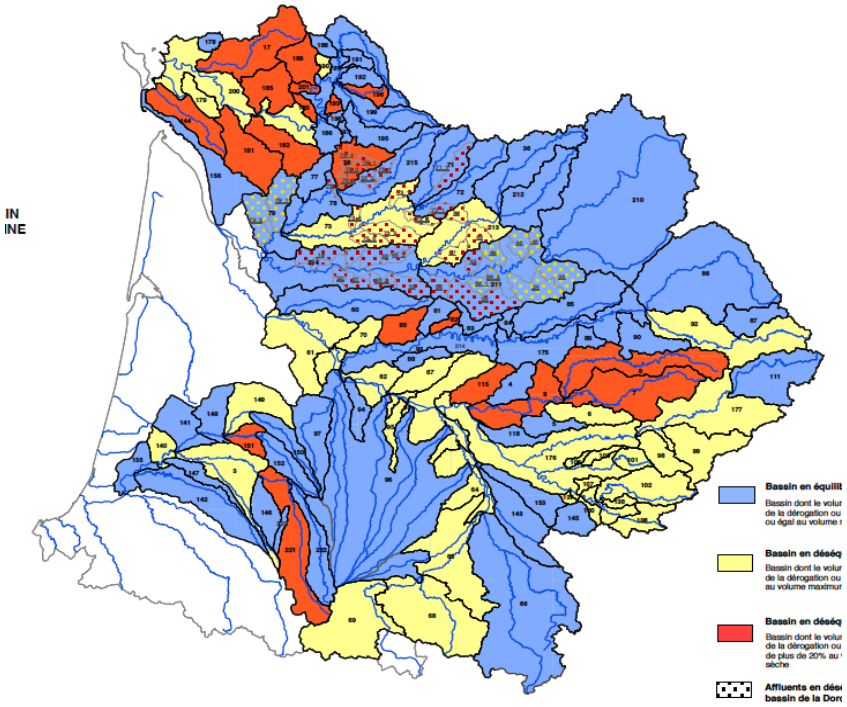
Plan

1. Quantitative water management issue
2. Description of MAELIA
3. Results and ongoing developments

Quantitative water management issue

The Adour-Garonne Basin: a structural water deficit

- Recurrent water deficit in several river basins



- May-October irrigation (mainly maize) = 75% of withdrawal
- Current water storage capacity is inadequate to meet temporal and spatial distributions of water needs

Yellow watersheds: volumes available for agriculture < *water withdrawn in driest year*
Red watersheds: volumes available for agriculture << *water withdrawn in driest year*

Questions for MAELIA

In low water period management:

What are the environmental, societal and economical impacts of the **different alternatives of organisation of the socio-agro-hydro system**:

- **Spatial distribution of cultural systems**
- **Water resources management (dam release, restriction)**
- **Quota repartition**

Which robustness of the different alternative of management, relatively to global changes?

Example study

The Adour-Garonne Basin: a structural water deficit

- 1970-2000 : numerous small agricultural dams built as alternative irrigation resources
  - Since 2000, setting new dams is highly debated with stakeholders
- Agricultural dams :
  - **important additional resources** (e.g. 17% for AG basin) but **potentially significant effect on environment**

Description of MAELIA

Description of MAELIA

Goals of MAELIA

MAELIA (***M**ulti-**A**gents for **E**nvironmenta**L** norms **I**mpact **A**ssessment*): a tool to deal with regional low water management issues

- (initial) Goal: evaluate different water management strategies => (a minima) simulate flows at 'low flow target' points.

$\Rightarrow$ What needs to be modelled?

Description of MAELIA

Goals of MAELIA

- Goal: evaluate different water management strategies => (a minima) simulate flows at ‘low flow target’ points.

⇒ Modelling needs

⇒ Reproduce hydrology:

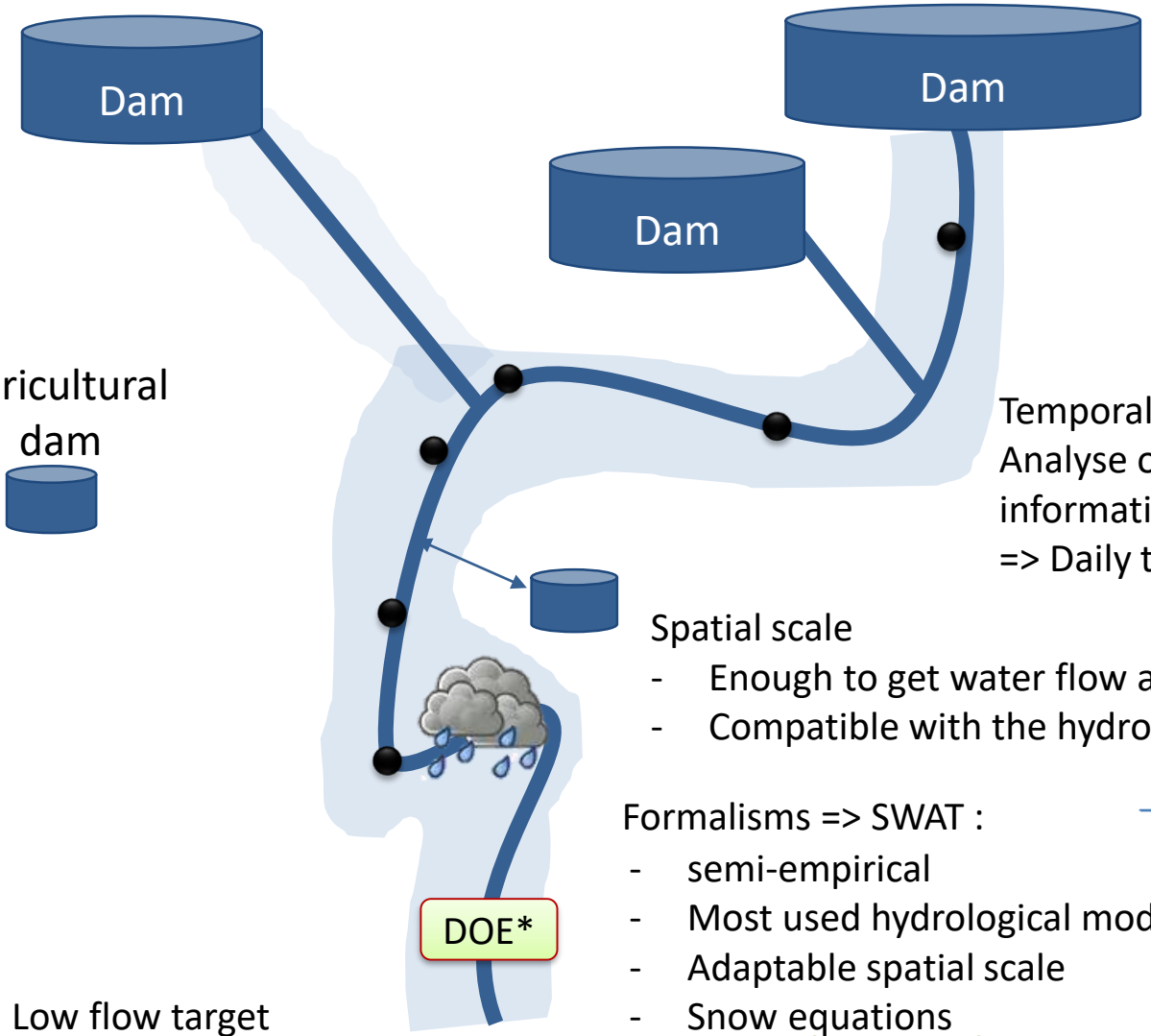
⇒ Which elements?

⇒ At which spatial scale?

⇒ At which temporal scale?

⇒ Which formalisms?

Goals of MAELIA
reproduce hydrology



Elements to model
- Water stream
- Water table
- Agricultural dam
- Dam
- Water canal
- Watershed
- Soils, climate
- HRU (soil x slope x land use)

Temporal scale:
Analyse of DOE* needs daily information
=> Daily time scale

Spatial scale
- Enough to get water flow at DOE* points
- Compatible with the hydrological model

Formalisms => SWAT :
- semi-empirical
- Most used hydrological model
- Adaptable spatial scale
- Snow equations

- Local expert ECOLAB
- Other available formalisms (pollutants,…)

*DOE: Low flow target
("debit d'objectif d'étiage")

Description of MAELIA

Goals of MAELIA

- Goal: evaluate different water management strategies => (a minima) simulate flows at ‘low flow target’ points.

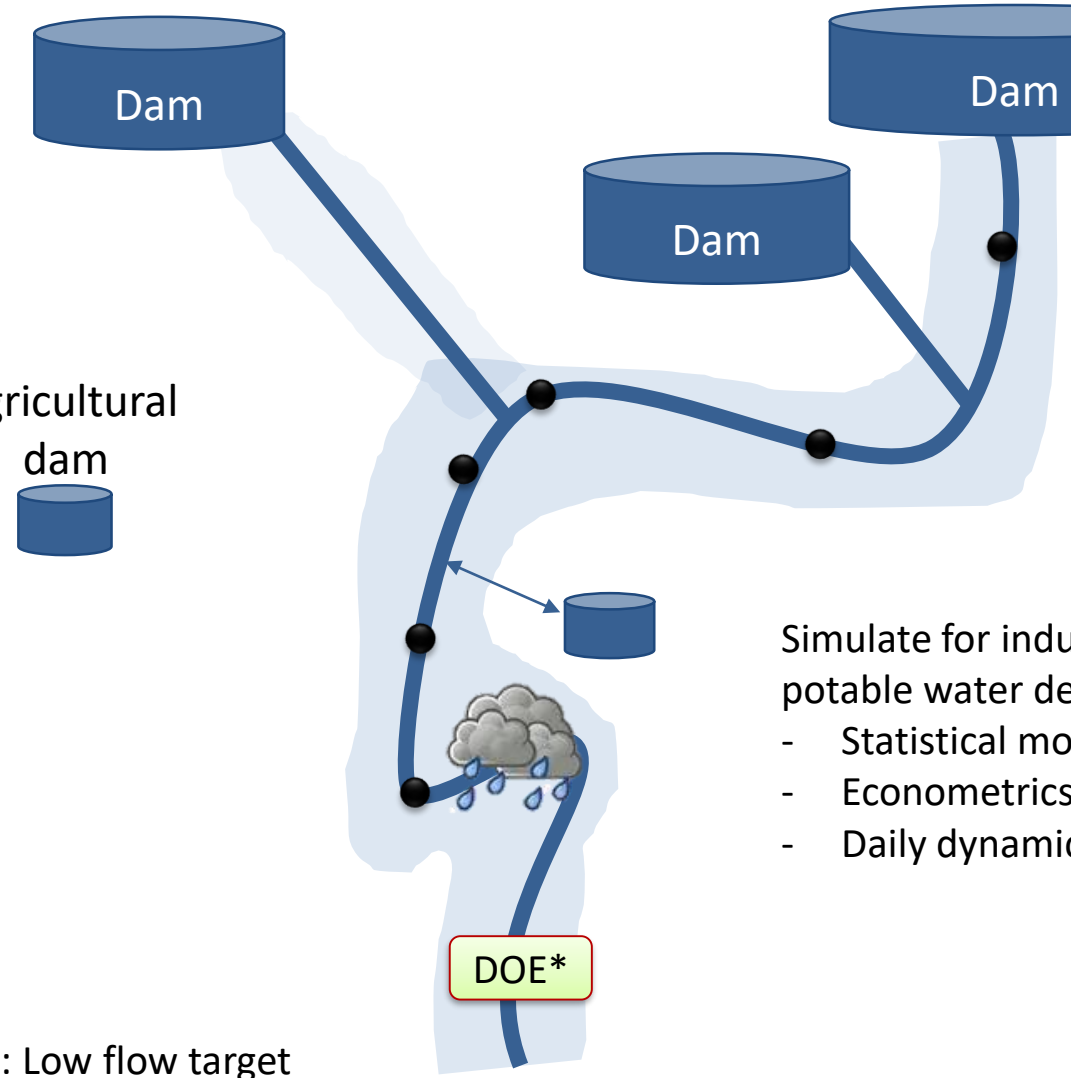
⇒ Modelling needs

⇒ Reproduce hydrology:

⇒ Reproduce irrigation withdrawals

⇒ Reproduce other withdrawals (industrial and potable water)

Goals of MAELIA
reproduce hydrology



Other element to model
- Withdrawal points
- Water rejection points

- Commune areas

Simulate for industrial needs and potable water demand
- Statistical module
- Econometrics module
- Daily dynamics

*DOE: Low flow target ("debit d'objectif d'étiage")

Description of MAELIA

Goals of MAELIA

- Goal: evaluate different water management strategies => (a minima) simulate flows at ‘low flow target’ points.

⇒ Modelling needs

⇒ Reproduce hydrology:

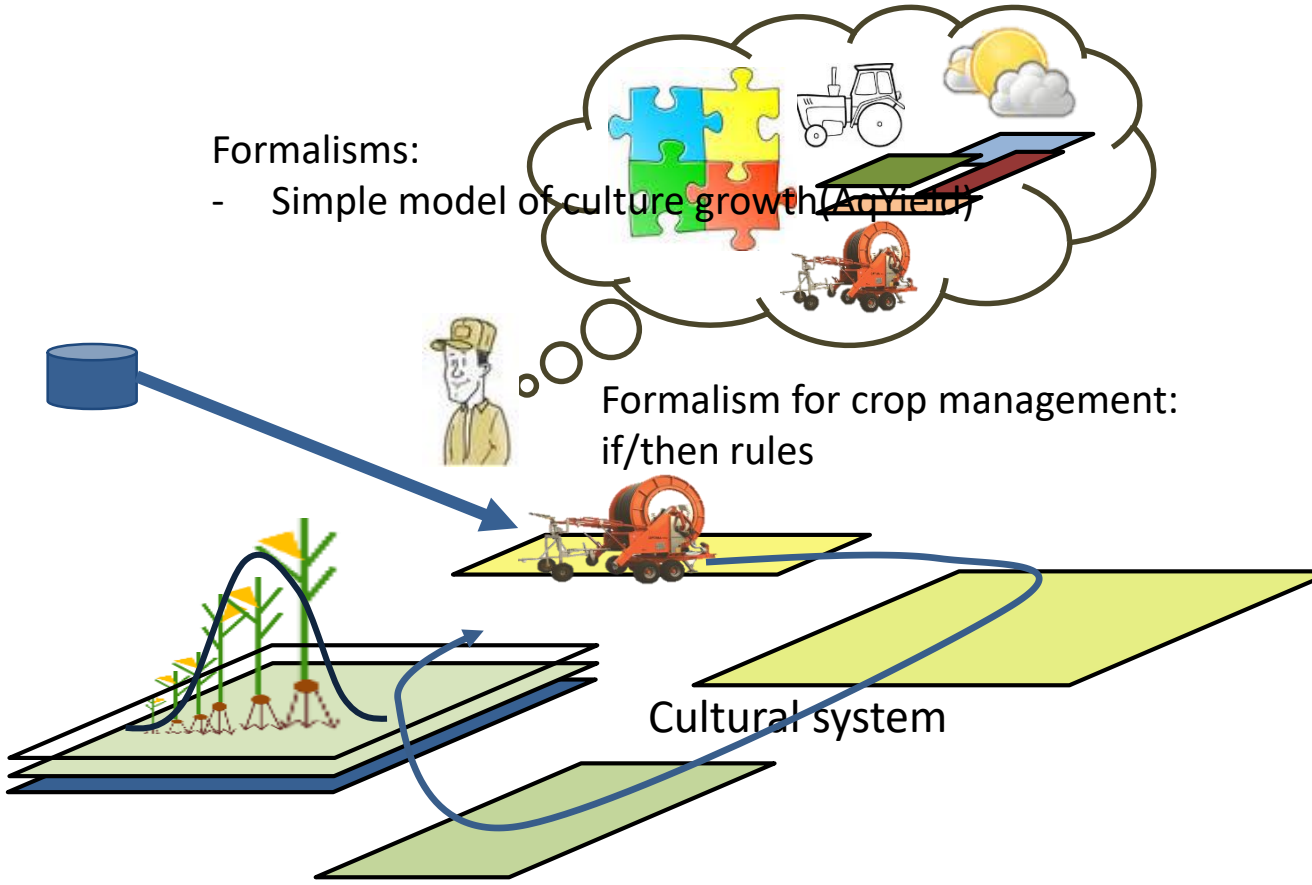
⇒ Reproduce dynamics of irrigation withdrawals

⇒ Reproduce the farming system:

Goals of MAELIA
- Reproduce irrigation withdrawals

Elements to model
- plots
- Cultures
- CAP islet
- Irrigation material
- Irrigation blocs
- Irrigation catchment equipment
- Parcel blocs (same cultural system)
- Exploitations and farmer agents

Formalisms:
- Simple model of culture growth (~~AqYield~~)



Hypotheses:
- Needs to represent plots and irrigation blocs to reproduce daily withdrawal
- Take into account for constraints at exploitation scale

Description of MAELIA

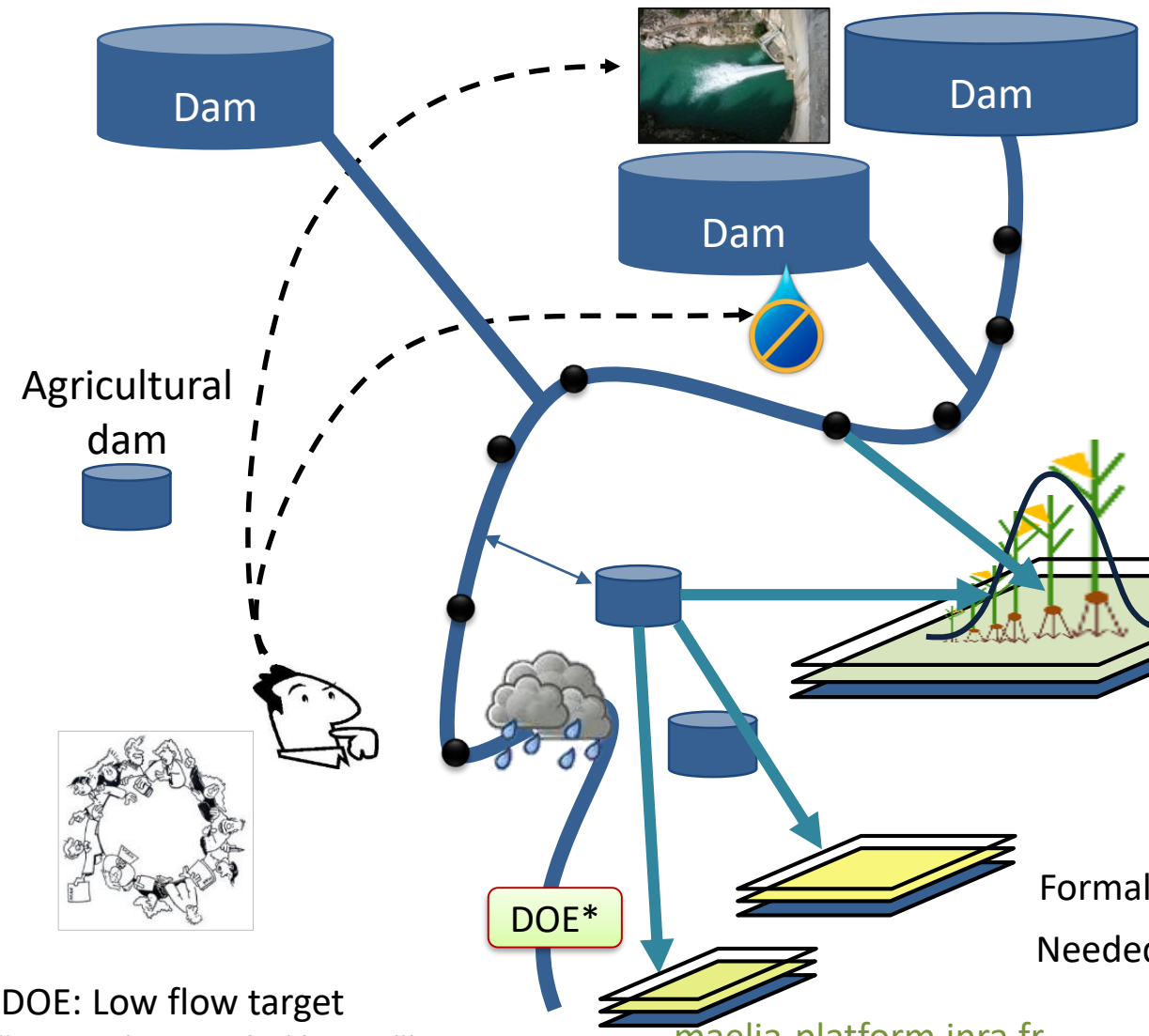
Goals of MAELIA

- Goal: evaluate different water management strategies => (a minima) simulate flows at 'low flow target' points.

⇒ Modelling needs

- ⇒ Reproduce hydrology:
  - ⇒ Reproduce dynamics of irrigation withdrawals
- ⇒ Reproduce the farming system:
  - ⇒ Reproduce the interactions with resources
- ⇒ Reproduce the social system (resource management)

Goals of MAELIA
Reproduce collective water management



Elements to model:
- DOE* points
- Water management units
- Dam agents
- Administrative area and sectors for drought decrees
- Prefect agent
- Irrigation quotas

Formalisms: if/then rules

Needed time step: day

*DOE: Low flow target ("debit d'objectif d'étiage")

Description of MAELIA

Goals of MAELIA

⇒ Modelling needs

- ⇒ Reproduce hydrology:
- ⇒ Reproduce the farming system:
- ⇒ Reproduce the social system (resource management)

⇒ Modelling of the socio-agro-hydrosystems

Hydrological system (SWAT® model)

(CARTHAGE®, SIEAU®, BDTOPO®)

- Water stream
- Groundwater
- Agricultural dams
- Dams
- Water withdrawal and release points
- Watersheds
- Canal

Agricultural dam

DOE*

collective water management

- DOE* points
- Water management unit and irrigation quota
- Dam agents
- Administrative area and sectors for drought restriction decree and prefect agent

MAELIA

Simulations of the dynamics of daily interactions between actors and resources

Other usages

- Potable water
- Industrial water

Climate (SAFRAN / Arvalis – ClimBox®)

Soil (BDGSF, IGCS)

*DOE: Low flow target ("débit d'objectif d'étiage")

Farming system

Irrigation

Irrigation material
Irrigation groups

Cultural system

Crop management (expertise)

Culture sequences (LPIS)

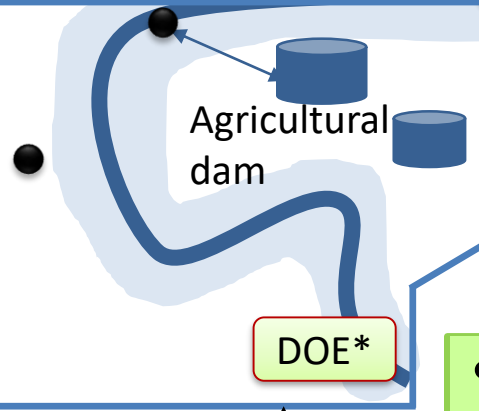
Culture (AqYield, HerbSim)

Plots and islets CAP (LPIS)

Exploitation/ Farmer agent (LPIS)

Hydrological system (SWAT® model)
(CARTHAGE®, SIEAU®, BDTOPO®)
- Water stream
- Groundwater
- Agricultural dams

- Water stream flow
- Water quantity in small water dams



collective water management

- Dam water release (dam manager)
- Drought irrigation restriction decree (prefect)

MAELIA
Simulations of the dynamics of daily interactions between actors and resources

- Withdrawal for domestic and industrial water
- Discharge of treated wastewater

Climate (SAFRAN / Arvalis – ClimBox®)

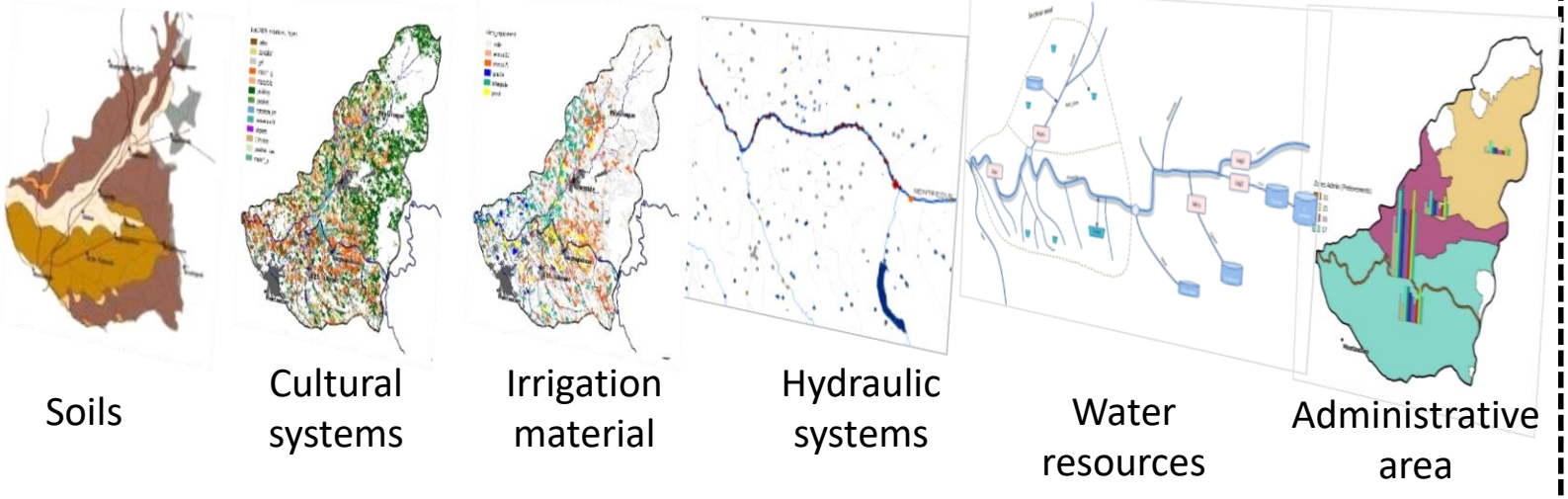
Soil
(BDGSF, IGCS)

*DOE: Low flow target ("débit d'objectif d'étiage")

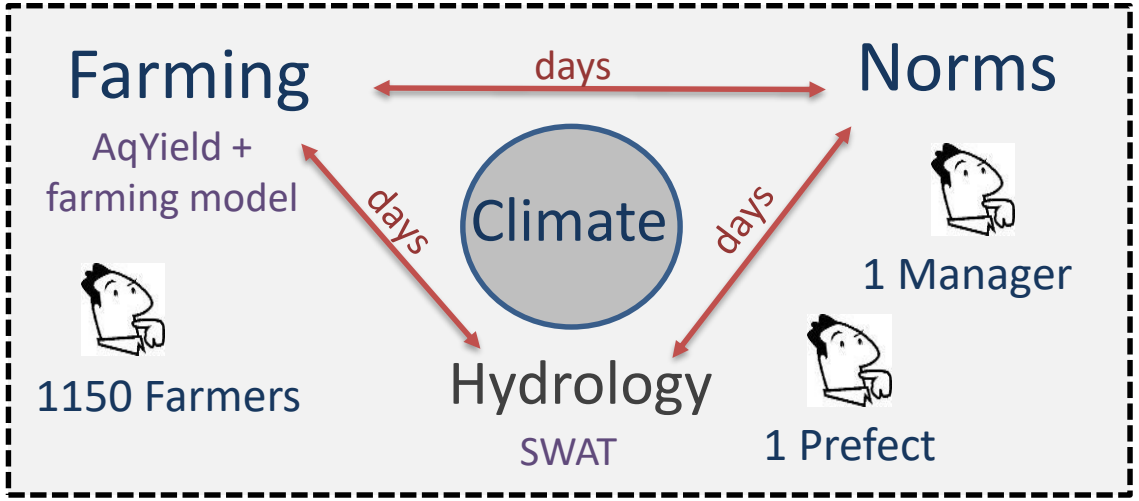
- Cropping plan choice
  - Exploitation level
  - Economic situation
  - Uncertainties on prices, climate, water availability
  - learning
- Cultural growth
  - Phenology, Yield
- Crop management
  - Conditions for : Tillage, sowing, fertilization, irrigation, harvesting
  - Workload management
- Irrigation management
  - In which resource ?
    - Priority between resources
  - Management of restriction

Description of MAELIA

A geo-referenced database



A platform of dynamics models and multi-agent systems



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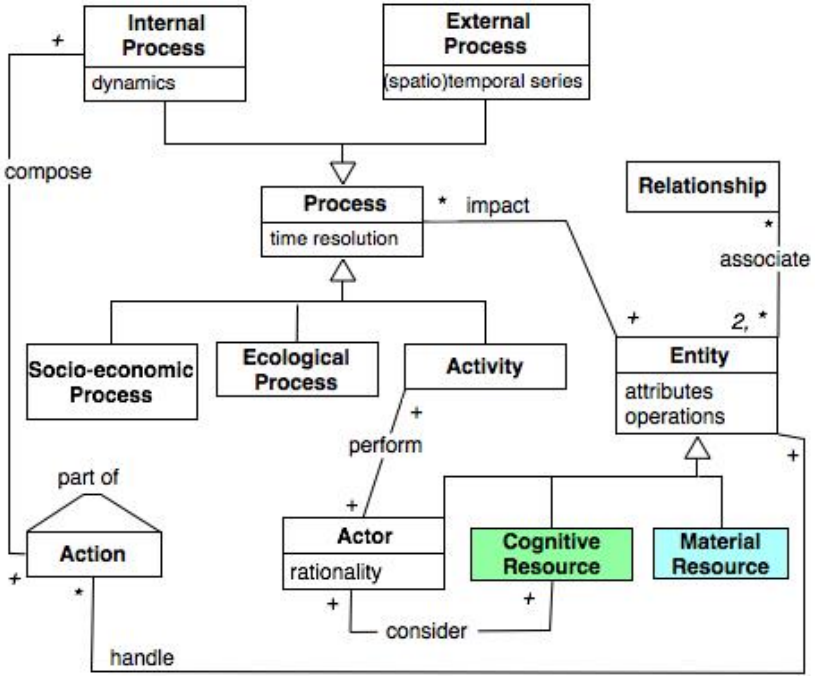
Description of MAELIA

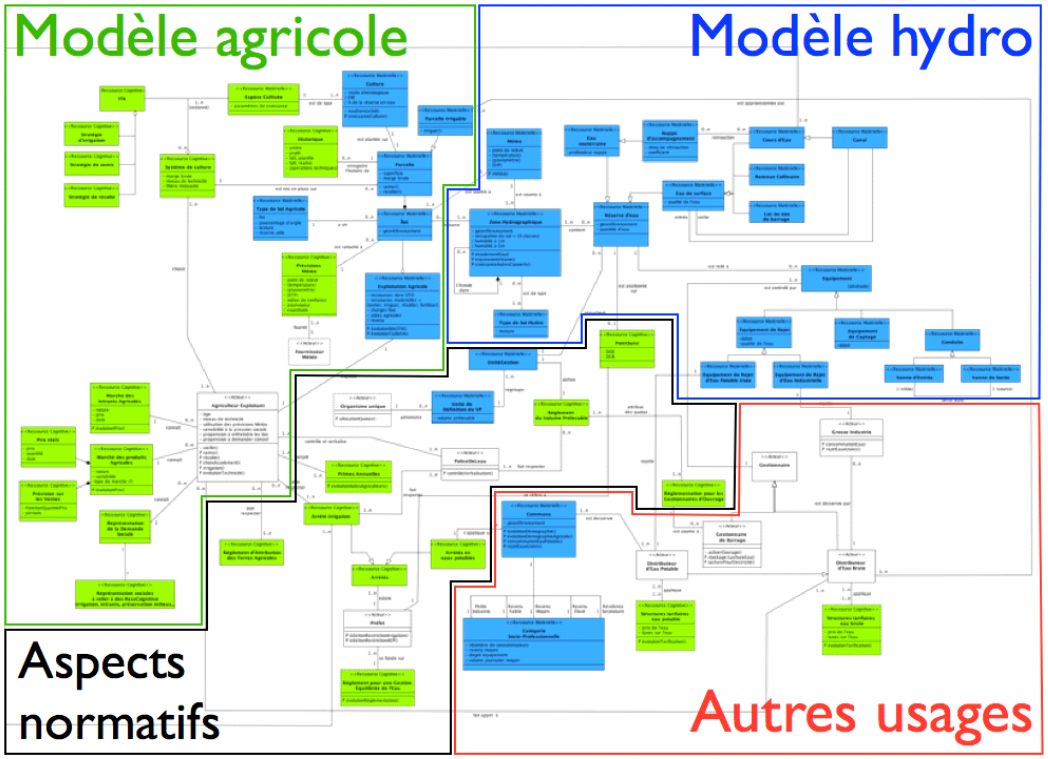
MAELIA conception

Metamodel ~shared conceptual framework

Metamodel of socio-ecologic systems



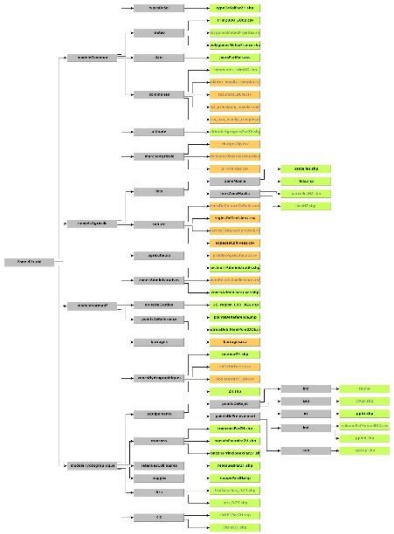
UML model of MAELIA



Description of MAELIA

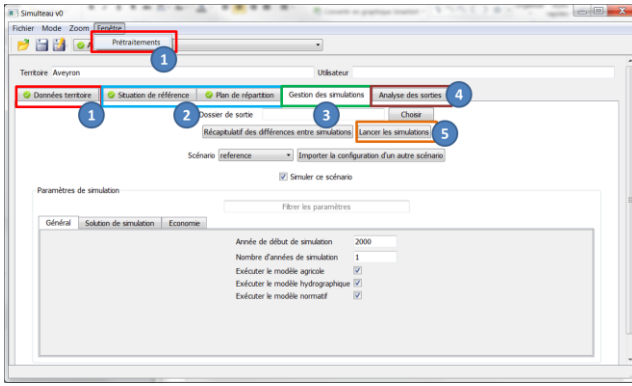
MAELIA software

- Simulator based on the GAMA platform (https://gama-platform.github.io/)
  - multi-agent
  - GIS
  - Platform independent and GPLv3
- “Preprocessing” code (raw database -> MAELIA input)
  - Java
  - Geotools for GIS part
  - Prepare a whole region

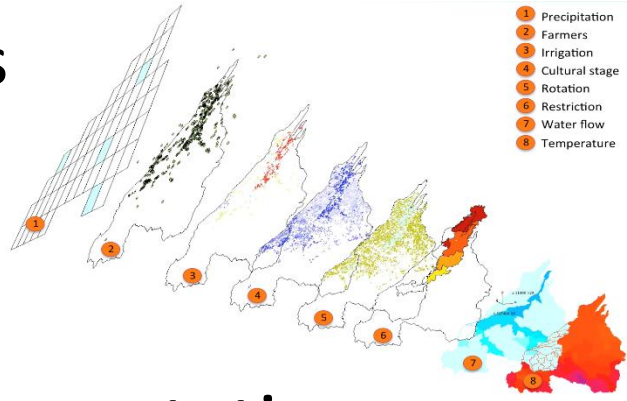


Description of MAELIA

MAELIA software



- Graphical User Interface
  - R package
  - Dedicated software SIMULTEAU
  - From GAMA GUI for simulations



- A complete and up-to-date documentation (maelia-platform.inra.fr)

Description of MAELIA

MAELIA software

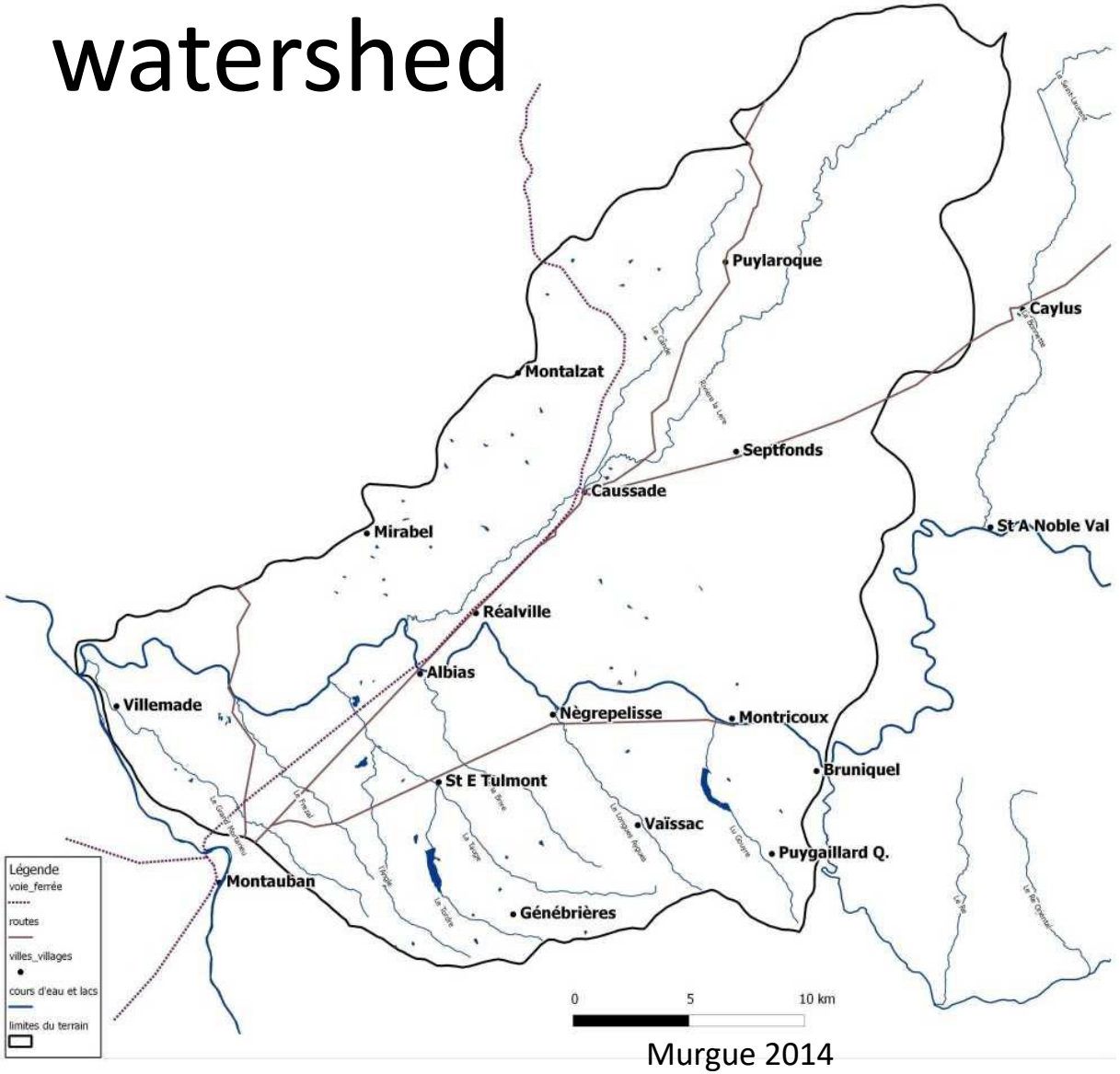
- Computation time, highly depends on
  - region size
  - module used
  - written outputs
  - Examples:
    - 20 minutes for the hydrology of Garonne Amont basin for 20 years (6 150 km² on 104 elementary watersheds), outputs: water flows
    - 4 H for Aveyron basin over 10 years (640 km² on 12 elementary watersheds), full model, output: daily drainage of each plot
- Can use up to 8-10 Go RAM

Results and ongoing developments

Example : Aveyron aval watershed

Key description elements:

- 835 km^2;
- Structural deficit of 5 hm^3;
- ~8 400 islet PAC i.e. 38 900 ha (47% of the surface) including 15 400 irrigable ha
- 23 340 plots
- diversity of irrigated cultures: corn, soy, arboriculture



Murgue 2014

Example : Aveyron aval watershed

MAELIA Parameter:

- 17 crop species (15 irrigable) :

  Very early corn, early corn, half early corn, very late corn, late corn, half late corn, ensilage corn, seed, soy, peas, straw cereals, colza, sunflower, vergers et temporary grassland

- 5 types of irrigation material
- 134 crop managment including 104 irrigated

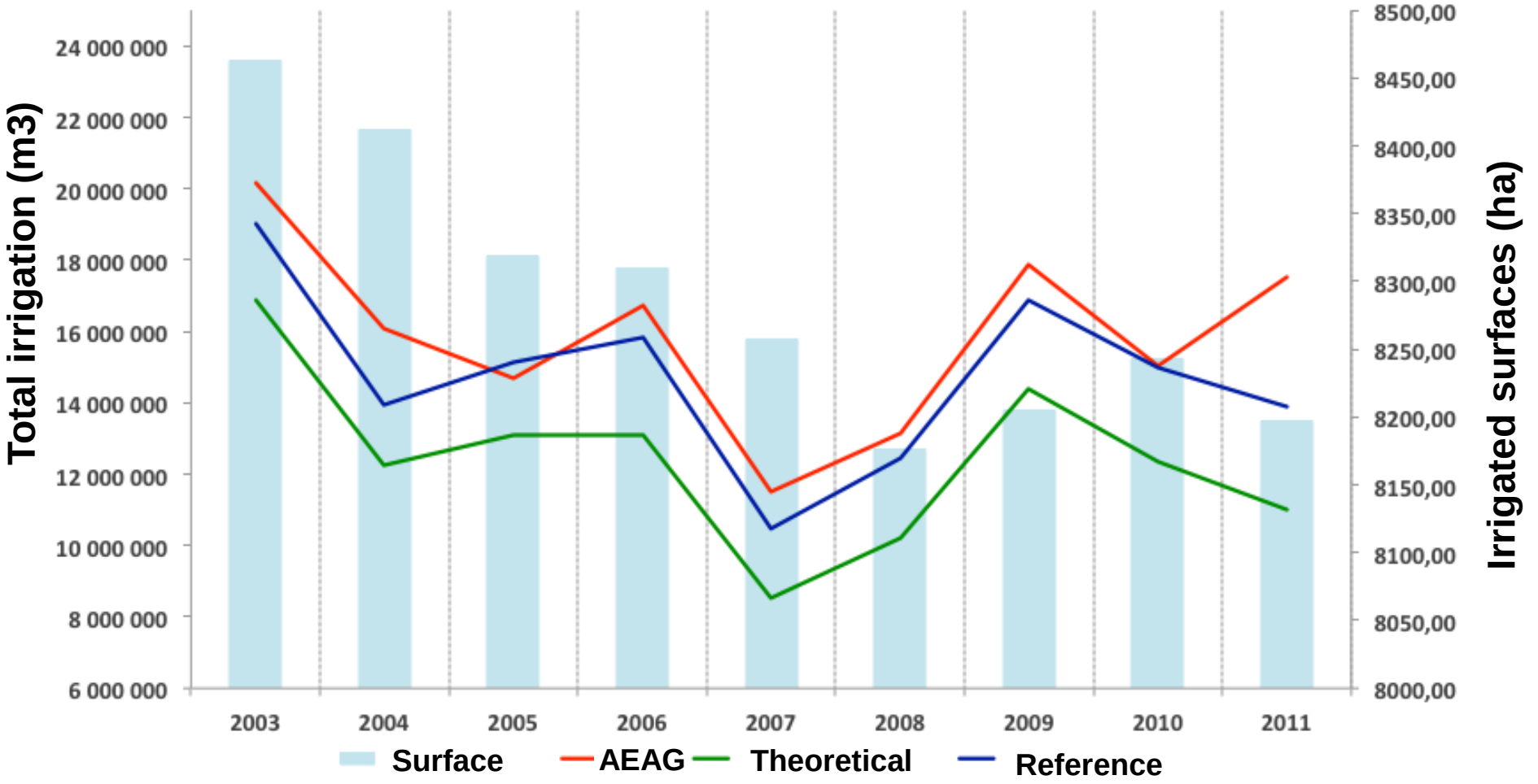
Simulations

- Compare two irrigation strategies
- Reference simulation:
  - If then rules, based on precipitations (past or planned), vegetation stage and soil humidity
  - ~ similar to observed practices
- Theoretical irrigation:
  - Based on threshold of hydric satisfaction for crop (~ETR/ETM)
  - ~ similar to the use of soil sensor and/or Decision support tool

Irrigation results

Comparison of annual withdrawals

Number of exploitation: 1142



AEAG: a French water agency

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Other applications 1/2

- Collective management of regional crop-livestock systems
  - New models: grassland (growth and management), livestock dynamics, animal nutrition, animal rationing, production and management of effluents
- Regional management of biological regulations (including pollination)
  - Indicators of composition and configuration of landscape
  - Mechanistic modelling
- Regional management of erosion
  - Modelling of runoff and erosion: f(soil and cover status of plots)
- Impacts of agro-ecological systems at regional scale
  - Modelling and calibration of intermediate cultures and diversification culture, N cycles (and C cycles)

Other applications 2/2

- Regional management of Organic Residual Products (ORP)
  - Add equations for C, N, GHG cycles, physical and biological quality of the soil
  - ORP sector
- Regional impacts of agroforestry systems
  - Models for tree growth (C cycle) and interactions with crop/grassland for light, water and N

$\Rightarrow$ New partnership that expands over new projects and new domains

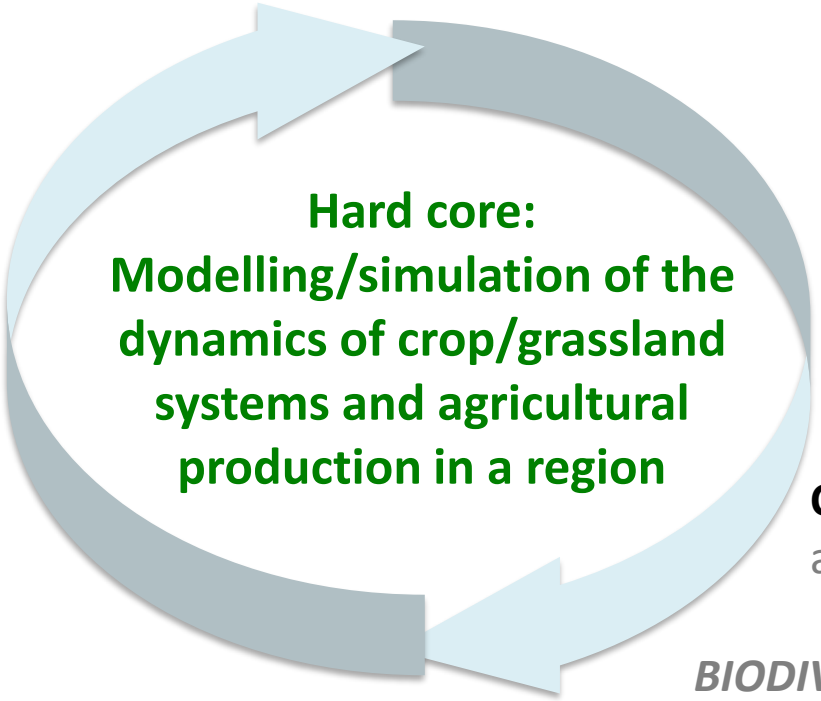
Amplification of application domains

BAG'AGES: N and C cycles, intermediate cultures and diversified rotations

DiversIMPACTS: intercropping, sectors...

PROTERR: N and C cycles, soil quality indicators, **sectors**

PhD: production allowed by ecosystem services, vulnerability/resilience



Pot-AGE : water, N and C cycles for tree, tree – crop/grassland interactions

ARAA-CRAGE: runoff-erosion

Crop-livestock : grassland, animal, effluents..,

***BESTS** : biomass energy, bioeconomic sectors*

BIODIVERSITE et Pollination (LAE)

PhD / BioSERPPA : Landscape Composition/ configuration and biological regulation

MASTER GIS HPEE: Ontology and biological regulation (MosaicPest)

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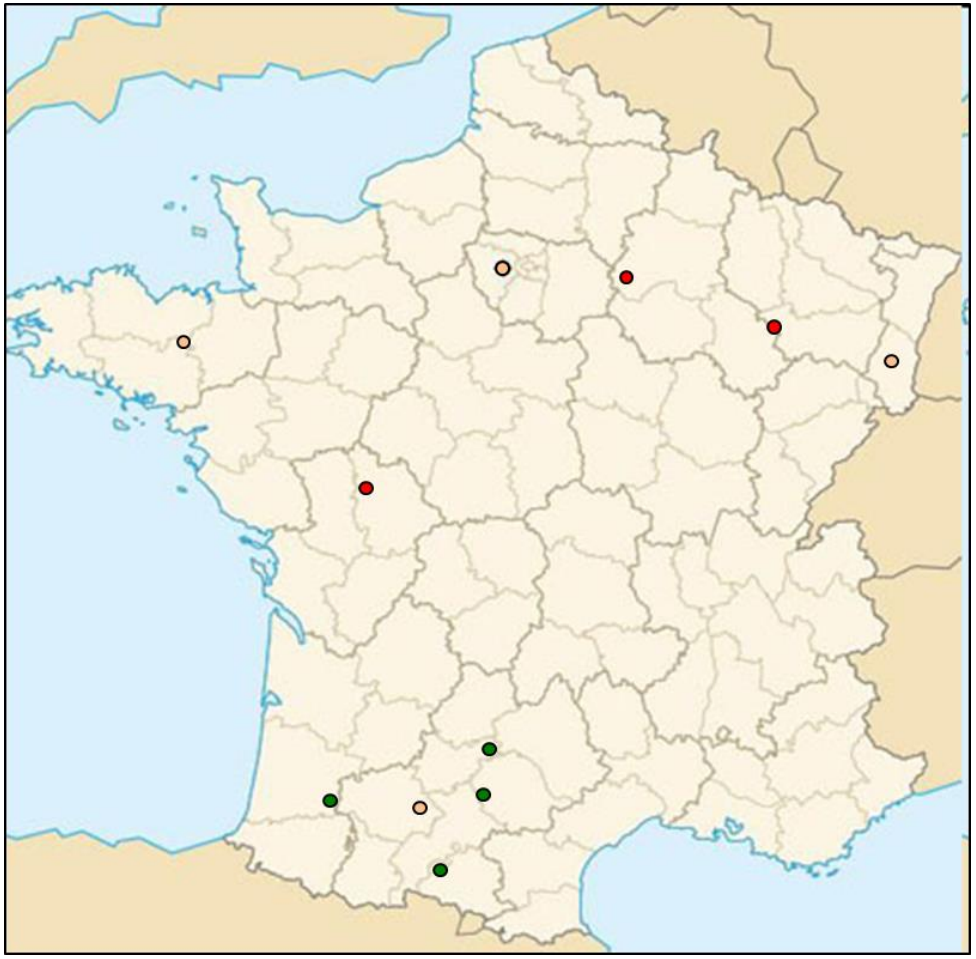
[Olivier Therond, 2018]

Study regions

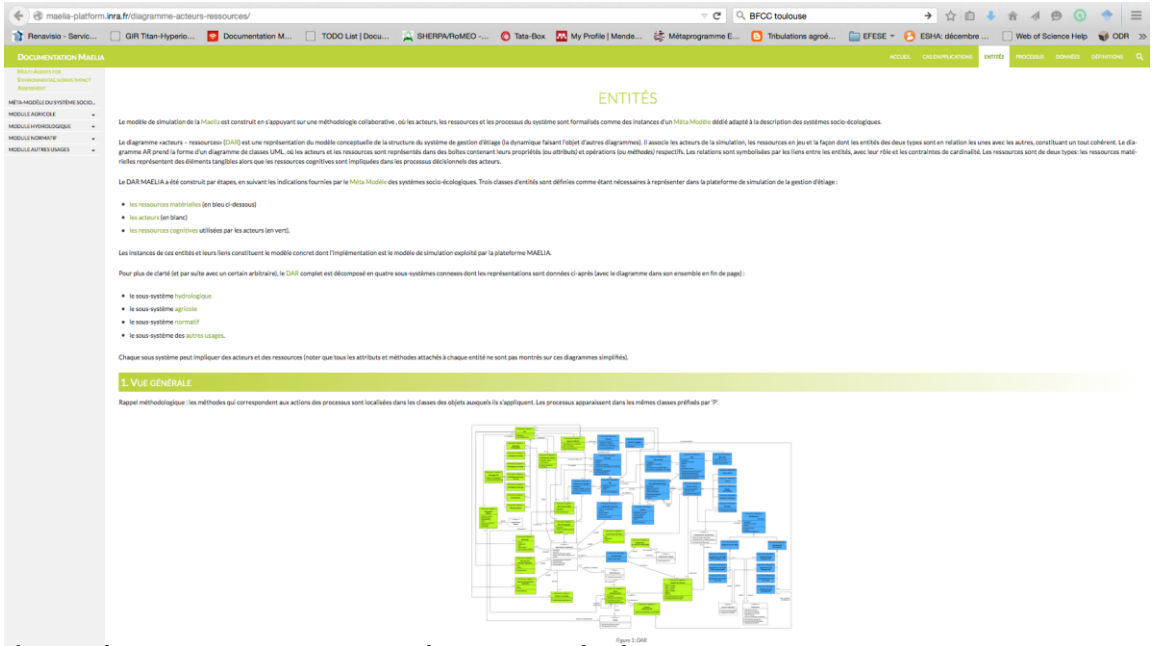


+ Romania, and Germany

Thank you for your attention

A complete and up-to-date documentation

http://maelia-platform.inra.fr/



MAELIA development contributor club:

- Scientist: AGIR, CIRAD, DYNAFOR, ECOSYS, EEF, GET, IRIT, LAE, MIAT, BAGAP,...
- Stakeholders: ARVALIS, CACG, ARAA...