July 15th-19th 2013 2013 INTERNATIONAL SWAT Toulouse - France
WORKSHOPS & CONFERENCE

An integrated modelling of interactions between human decision-making and hydrological processes: The MAELIA multi-agent platform

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Outline

- **Low-flow management issues and the water crises management in the Adour-Garonne Basin**

- **The MAELIA project and the agent-based approach**

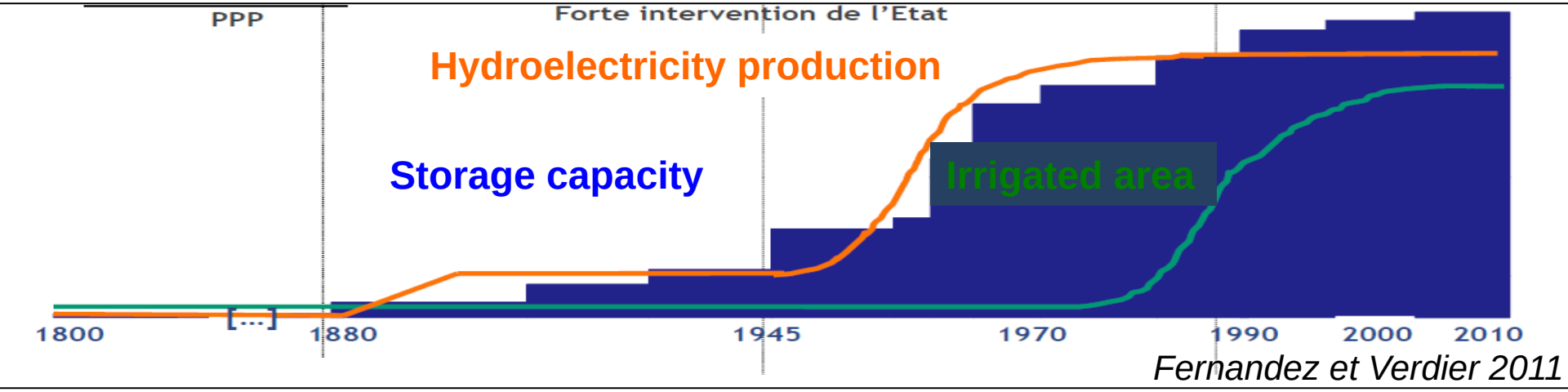
- **The MAELIA platform: structure and dynamics of the socio-hydrosystem**

- **Representation of human activities and ecological processes (crop growth and hydrology)**

- **The GAMA platform for development and simulation of spatially explicit agent-based model**

- **MAELIA agenda and perspectives**

The Adour-Garonne Basin: a structural water deficit



Fernandez et Verdier 2011

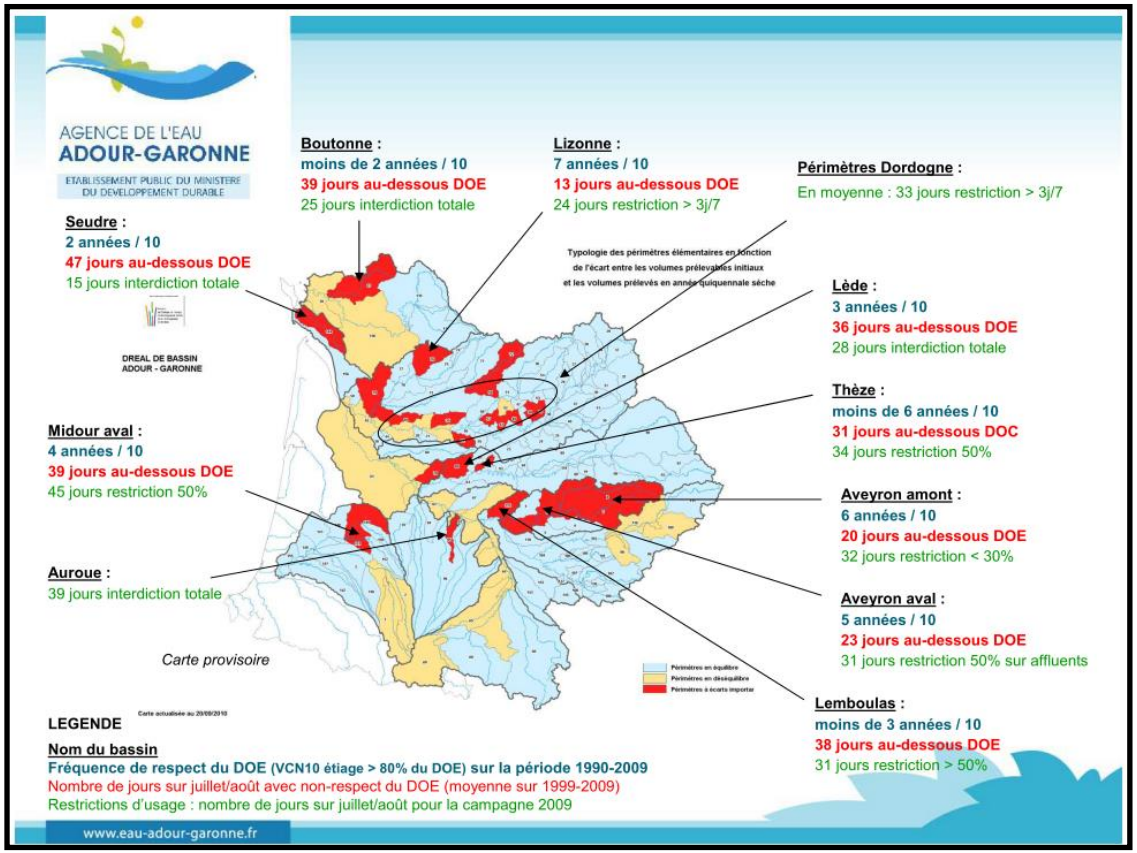
Since 1950-60 development of water storage in dams for hydroelectricity : water releases in winter

Since 1980 development of important irrigated areas: agricultural water consumption in summer is up to 80 % of total consumption during the low-flow period

Current **water storage capacity is inadequate to meet temporal and spatial distributions of water needs**

Water crises

During low-flow periods in some watersheds, ***river flows are regularly measured under the regulatory threshold (DOE)*** which guarantees a normal functioning of the aquatic ecosystems



Watersheds with recurrent river flow < the regulatory threshold (DOE)

Water crises management

State services have **two levers** to manage water crisis (flow < DOE):

Water release possibilities and efficiency depend on characteristics of dams (e.g. min and max flow, possible period of release)

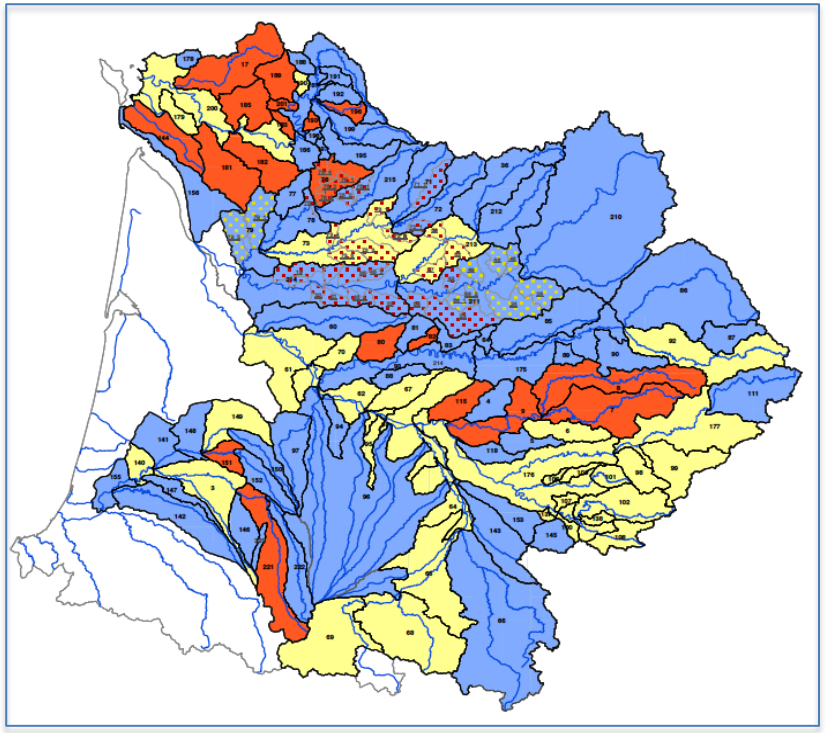
Water use restrictions: "drought decrees" are set up for specific locations (some districts) and durations (at least one week) and may cause significant crop yield reductions

Evolution of the water management gouvernance

Since 2009, to avoid regular water crisis French government is instituting a new regulation of agricultural water withdrawals

Determination of new:

- water volumes available for agriculture (VAA) at watershed level
- Allocation rules between farmers



Yellow watersheds: VAA < water withdrawn in driest year
Red watersheds: VAA << water withdrawn in driest year

In main irrigated watersheds new authorized volumes are (much) under the water volume currently withdrawn

➔ **vehement protests of farmers that claims the need to account for socio-economic impacts**

Water management issues of AGB

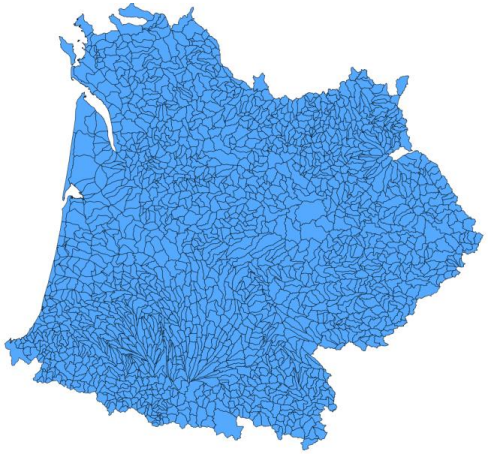
No « panacea » (a single generic solution)

Necessity to account for:

- Diversity of farming systems (sensitivity and adaptation capacity), water resources: heterogeneity within watersheds
- Effect of water volume allocation and crises management on farm income
- Effect of numerous hill-lakes (about 20 000 in the AGB)

For policy-makers and water manager necessity to:

- have information on the dynamics of the socio-hydrosystem at the level of management actions and policy decisions: *Elementary Watersheds*
- implement pro-active vs. reactive water management strategies
- deal with the medium-term climate changes effects



1980 Elementary Watersheds in AGB defined by Water Agency

The MAELIA project (2009-2013)

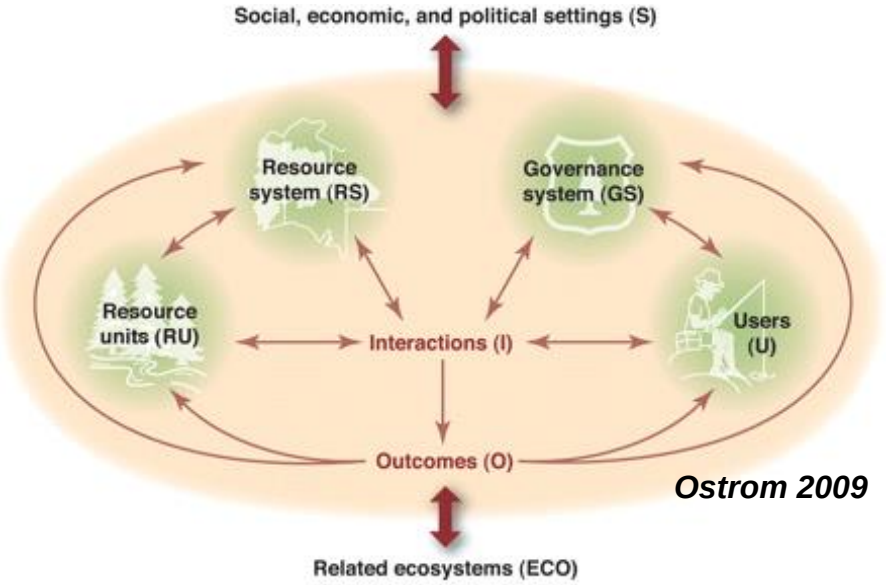
MAELIA « *Multi-Agents for EnvironmentaL norms Impact Assessment* » :

Partners: GET et AGIR, IRIT, ECOLAB

Development of an **agent-based simulation platform for integrated assessment of impacts** of scenarios regarding water management strategies and policies, land use and climate change

End-users: water managers and policy-makers acting at local level

Multi-level and multi-domain modeling of **Social-ecological systems** **==========>** at the water management level



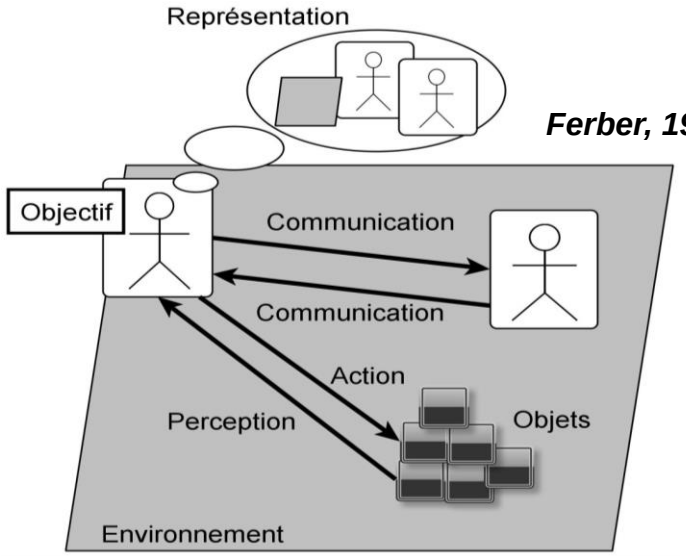
Ostrom 2009

Multi-Agent System

- Agent-based systems allow to model **autonomous agents** with a representation of their environment, **able to perform actions and interact with other agents** (Becu, 2006)

- Widely used in the field of natural resources management (Bousquet and Le Page, 2004)

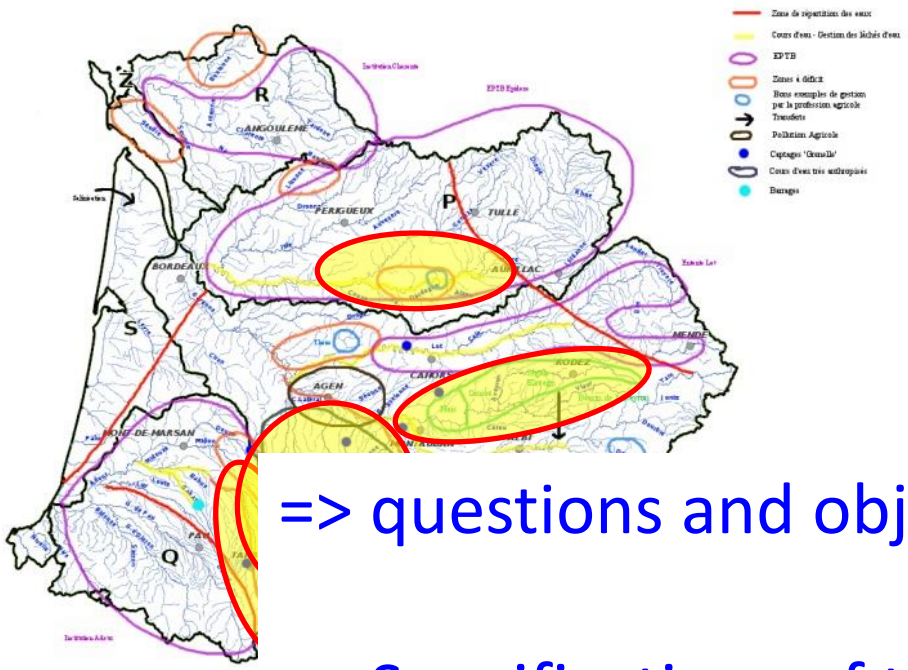
- Representation of specific individual situations (e.g. farmer, dam manager) and up and down stream effects

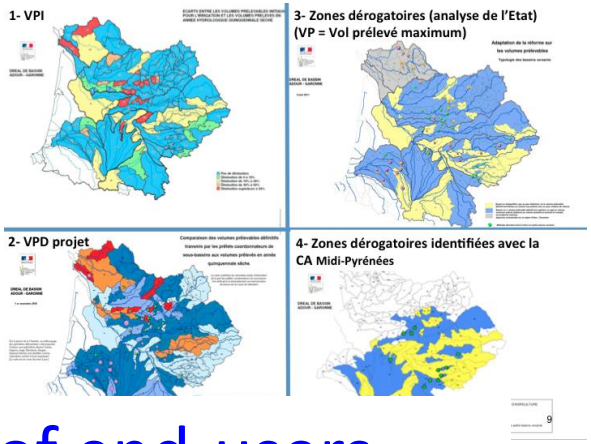


Ferber, 1995

- **Simulation of emergent properties** at watershed level resulting from interactions between individuals and between individuals and the environment

Water management issues/situatons, systems and decision processes

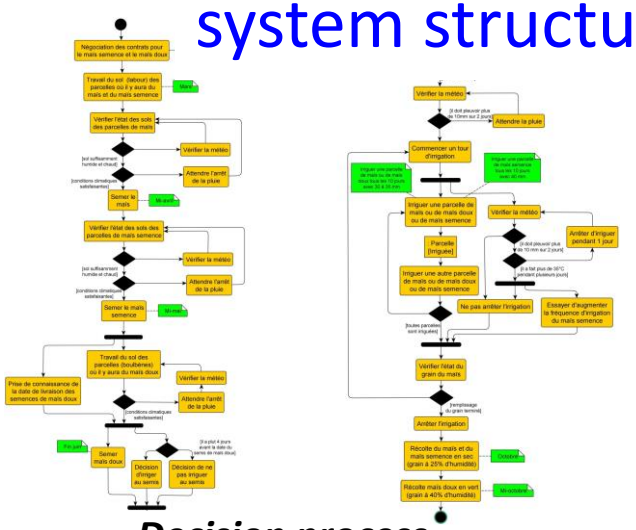




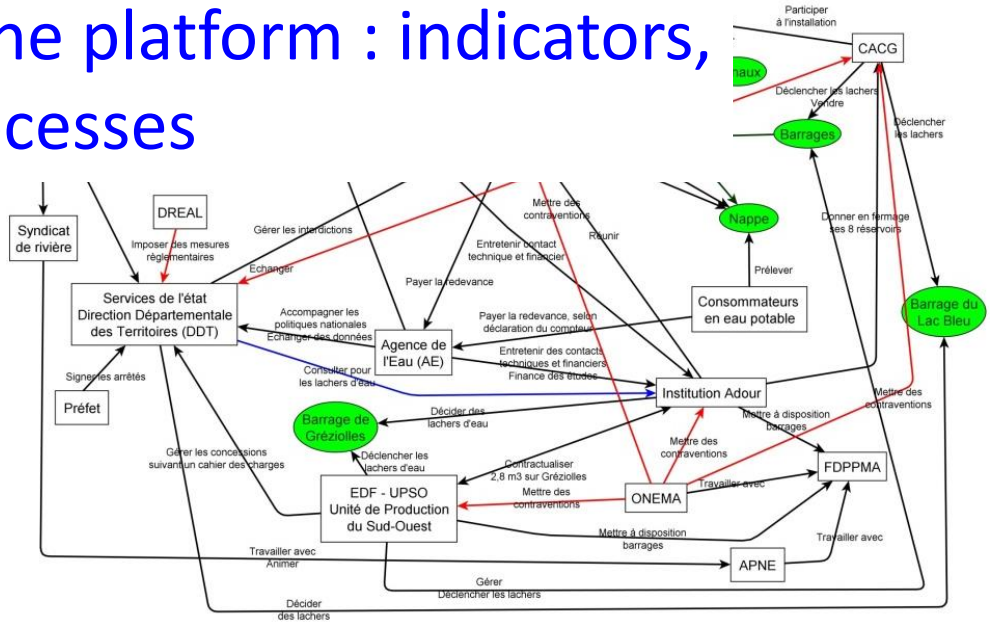
=> questions and objectives of end-users

Zoning mac

=> Specifications of the platform : indicators, system structure, processes



Decision process



Water management systems

The MAELIA questions

Main questions to be handled with the MAELIA platform:

- What are the social, economic and environmental impacts of the various alternative of definition and management of (new) water Volume Available for Agriculture?
  - Robustness to climate variability?
  - Technical feasibility and social acceptability?

MAELIA: assessed indicators

Time and spatial scales of the indicators

Biophysical:

- **Water flow** at the regulaytory points: daily / decade, hydrological node
- **Surplus or deficit of water** (volume and ratio/DOE): decade / year, sub-basin
- **Yield of irrigated crops**: year, multi-level (from field to watershed)
- **Agricultural biodiversity** (diversity of crops): year / period, watershed, small agricultural area

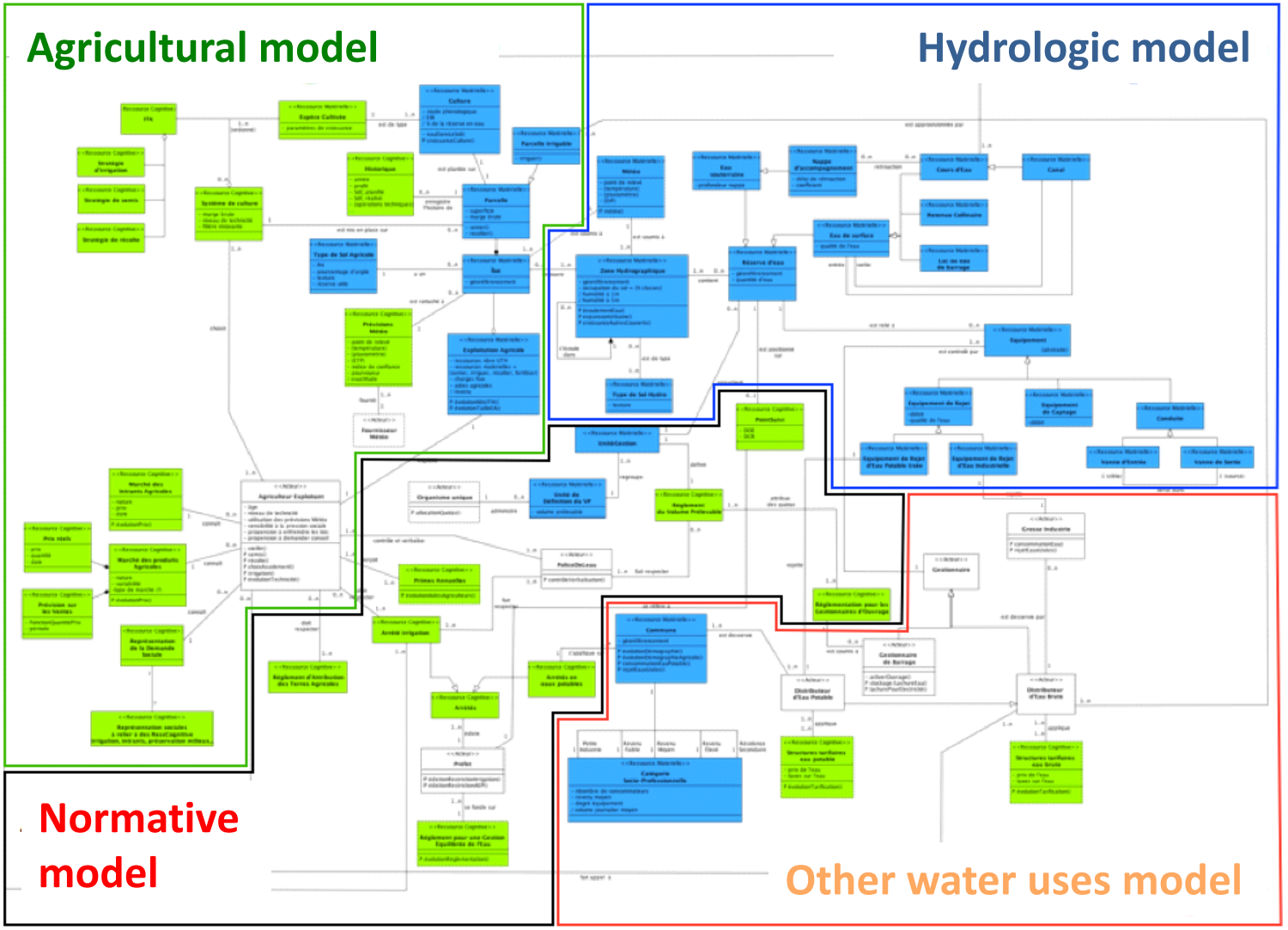
Economic:

- **Agricultural production** (€ / ha): year , farm/ sub-basin
- **Viability of farms**: irrigated farming income ratio / total income (per year)
- **Irrigated and total surfaces of farms**: time horizon, sub-basin
- **Number of Farms**: time horizon, sub-basin

Social:

- **Frequency and timing of crises**: year / decade probability-month, sub-basin,
- **Severity of the crisis**: time under DOE, water volume under DOE
- **Level of satisfaction** of water needs of other water users (industrial ...): decade, common industrial site
- **Acceptability** (norm compliance or violation, satisfaction level of various groups of actors): years with/without crisis, by stakeholder group and by sub-basin

MAELIA: the structure of socio-hydrosystems for low-flow management

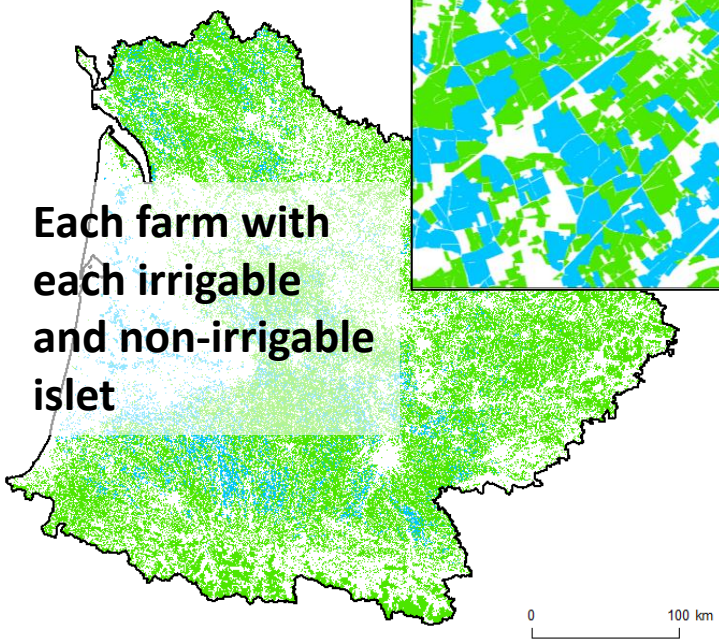


Cognitive Resources

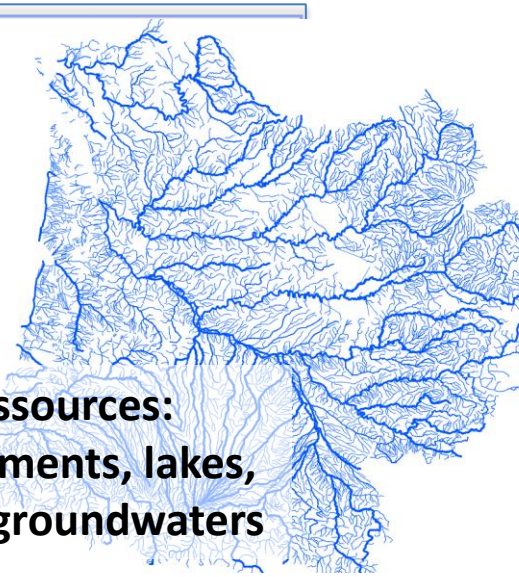
Material Resources

Actors

MAELIA: the structure of socio-hydrosystems for low-flow management

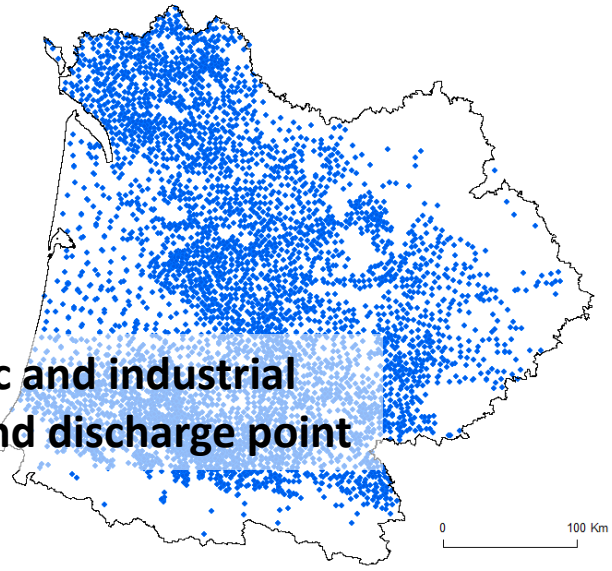


Each farm with each irrigable and non-irrigable islet



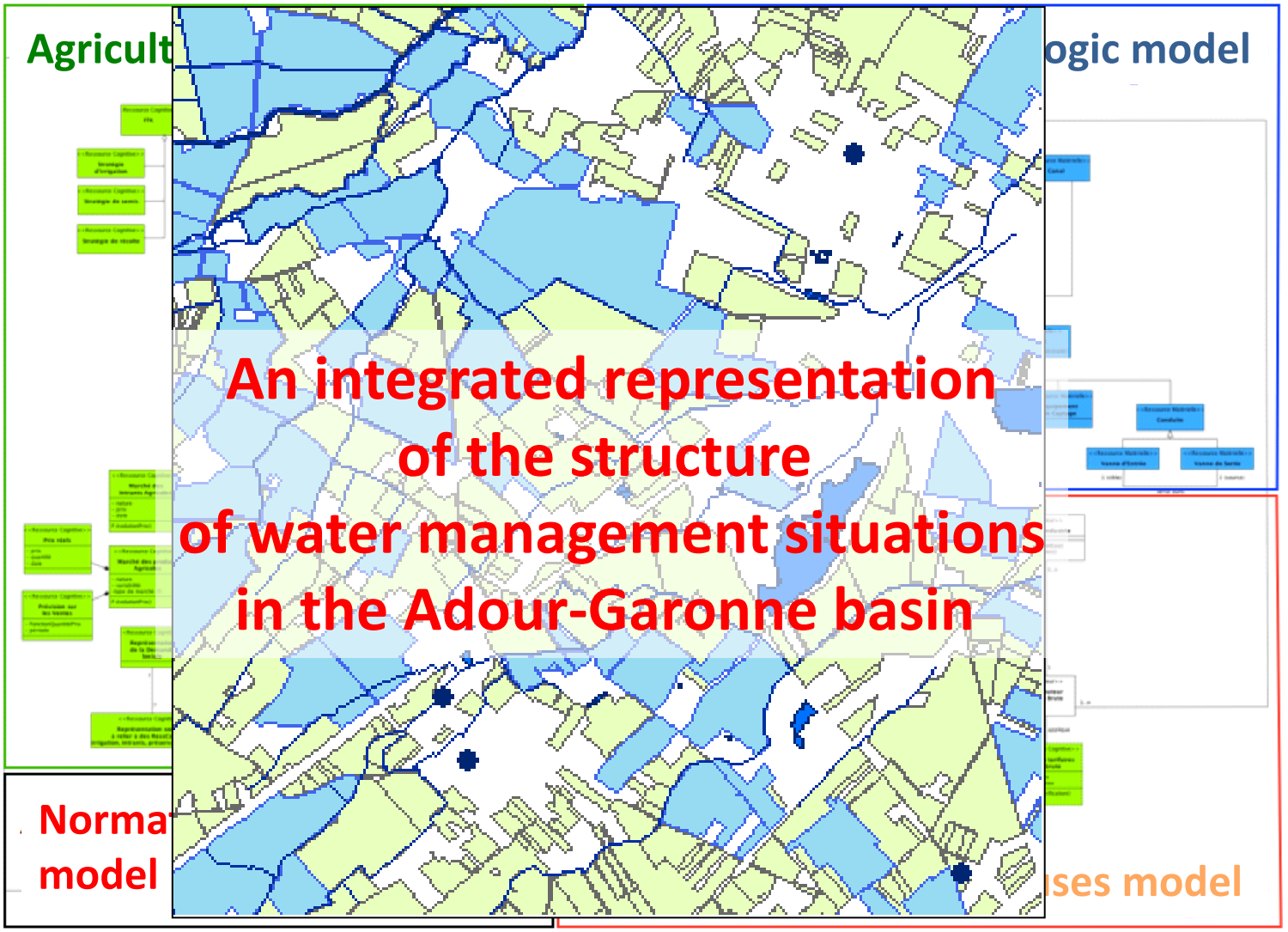
Water ressources: River segments, lakes, pounds, groundwaters

Each dam and regulation sectors



Each domectic and industrial withdrawal and discharge point

MAELIA: the structure of socio-hydrosystems for low-flow management



MAELIA: spatial processes

Ecological processes

- **Soil-crop model**
- **Hydrologic model**

Socio-economic processes (phenomena)

- **Demographic changes** (INSEE, municipality level)
- **Land Cover changes** (Corine Land Cover database)
- **Drinking Water Consumption**
- **Industrial Water Consumption**

Human activities (Decision process)

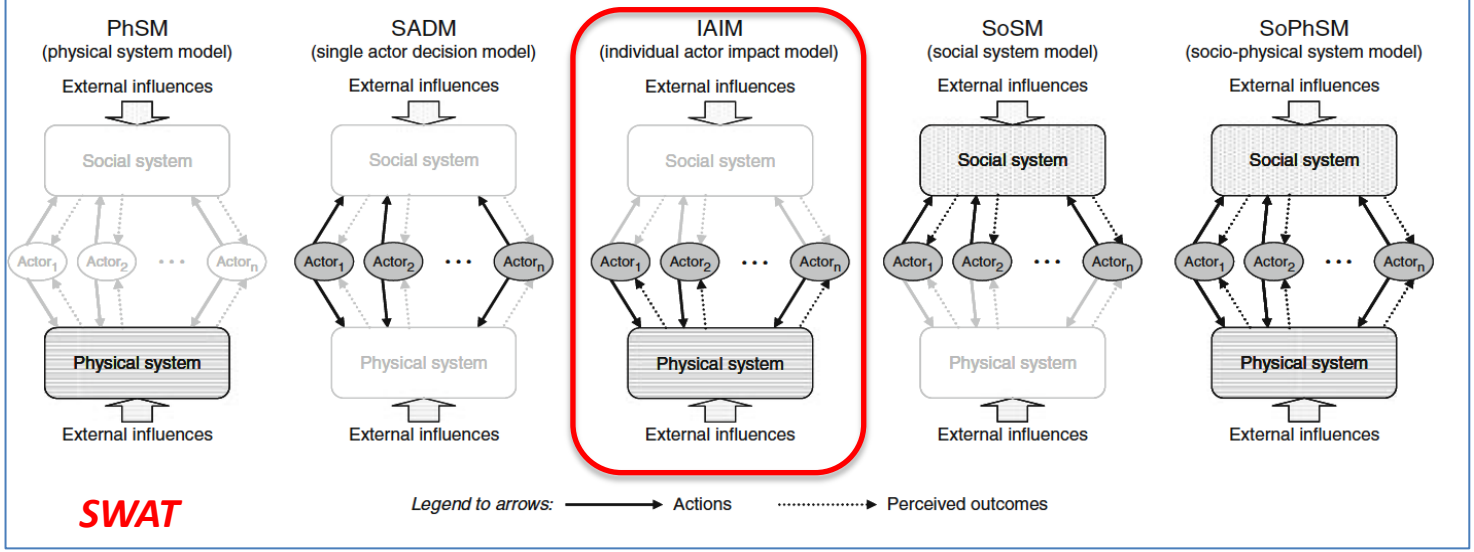
- **Farmer decision**
  - crop allocation plan
  - crop management
- **State services decision:**
  - decree of water-use restrictions (severity & spatial extension)
- **Dam Manager decision:**
  - water releases

Modeling of the social-ecological system

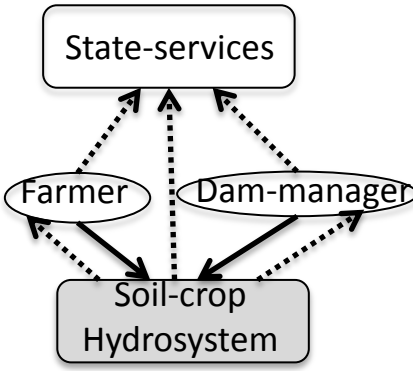
Processes interact in space (field, farm, sub-watershed) and time (day)

➔ internal coupling (vs. external coupling) of social and ecological processes

Main types of Natural Resource Management model (Bots and Daalen, 2008):



MAELIA

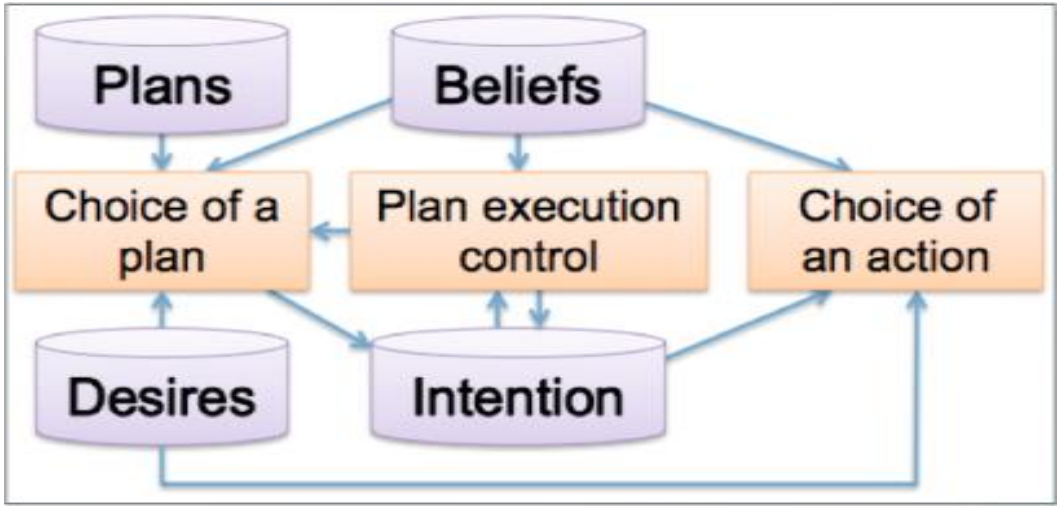


MAELIA : Farmer decision model

A Belief-Desire-Intention architecture to represent the farmer's:

- **Strategic decision** (year): multi-criteria choice of the cropping plan according the belief theory on 4 criteria : profit, variability of profit, workload and similarity to the last cropping plan

- **Operational decision** (day): crop management strategies taking into account working time and spatial distribution of fields:
  - Sowing strategy
  - Irrigation strategy
  - Harvest strategy



MAELIA : ecological models

No dedicated development but selection of models:

(i) robust, to be applied on the wide range of biophysical conditions of the AGB,

(ii) (semi-)empirically founded to be likely to provide realistic outputs

(iii) quite simple in terms of number of equations and parameters to be not too time-consuming in calibration, recoding and computing

(iv) with adapted space (Field and Elementary Watershed) and time resolutions (day)

MAELIA : soil-crop model

Priority to simulate realistic crop yields over the Adour-Garonne Basin without great and often problematic calibration work

➔ Empiric crop model developed by INRA in Toulouse called "Jeu d'O"

Developed step by step according results of agronomic experiments in the AGB during the last 20 years

It represents effect of

- climate, soil and cropping system on water soil dynamics and yield for the eleven main crops of the AGB
- cropping system: tillage, sowing date and irrigation

MAELIA : the hydrologic model

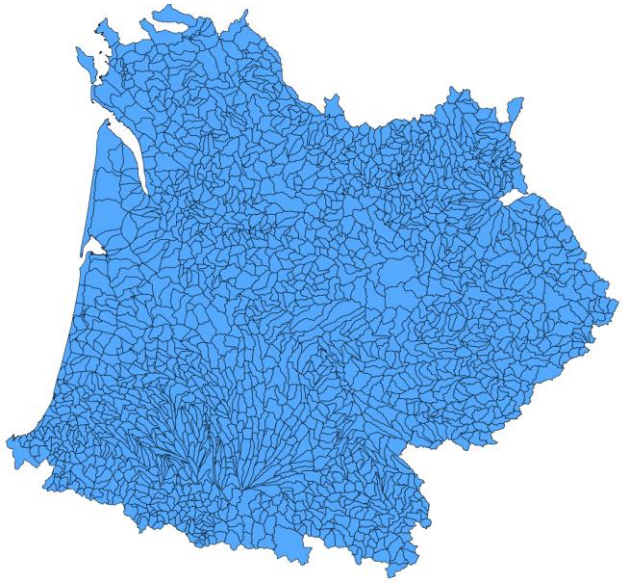
Selection of the SWAT model :

- applied to various contrasted situations
- a great user/developer community
- open-source
- possibility to define the size of sub-watersheds to adapt the model to the investigated agro-hydrological issues

Re-implementation into MAELIA of the SWAT formalisms representing :

- The snow accumulation and smelt
- The land phase
- The routing phase
- The hydrology (input) of dam and pound

Elementary Watersheds used as “sub-watershed”



Elementary watersheds used as SWAT’ watershed

(see Hong et al., this conference)

The MAELIA case study

First application of MAELIA to the up-stream part of the Garonne river

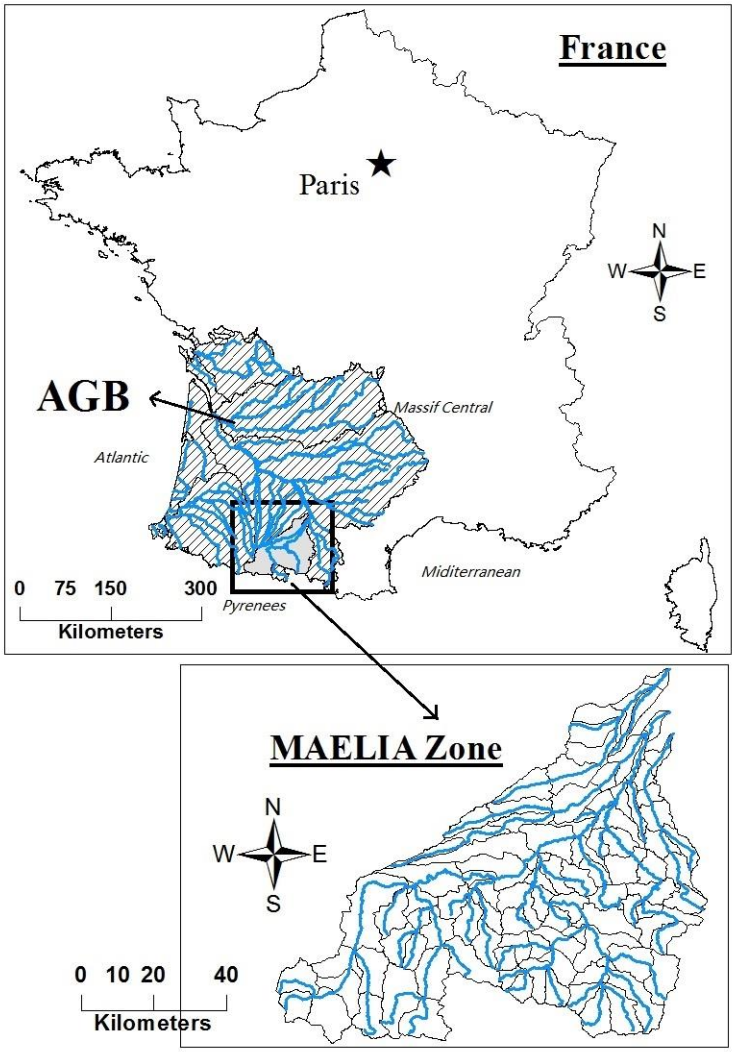
(from Pyrénées mountains to Toulouse)

Drainage area: 6000 km2
Length: 140 km

104 Elementary Watersheds

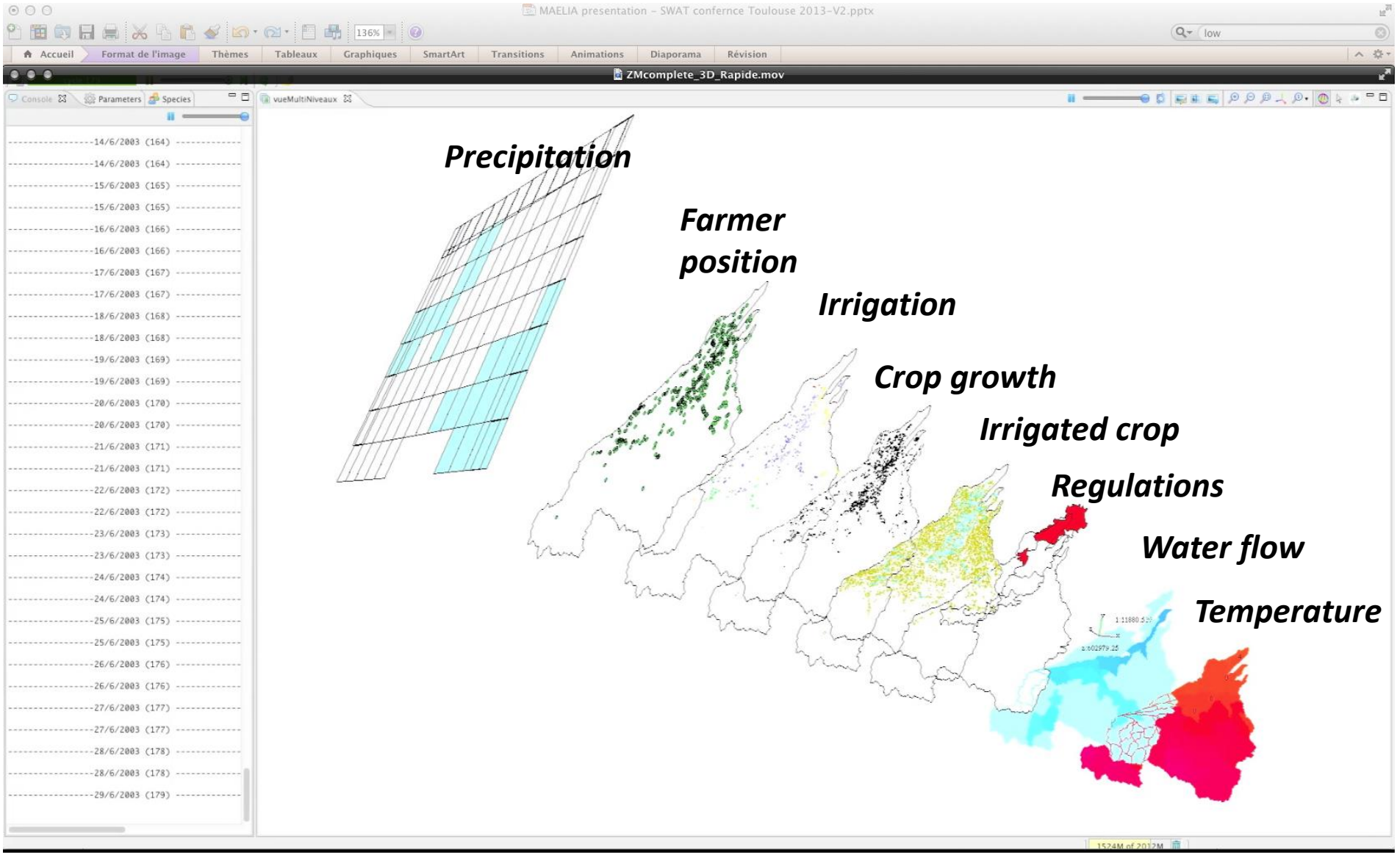
1194 *farm(er)s*

26 000 *active field plots (with crops)*



The GAMA multi-agent Platform

A platform dedicated to the development of spatial multi-agent models and simulations



Developed by IFI (Hanoi) under the UMMISCO framework (IRD/UPMC) since 2007

Project agenda and perspective

2013-2014

- Adaptation of SWAT formalisms to simulate hydrology of more than 15 000 (small) individual or collective hill-lakes used for irrigation in the Adour-Garonne basin (see Poster Payoux et al., this conference)
- Calibration-evaluation of MAELIA (including SWAT formalisms)
- Re-factoring of code to ensure modularity

2014

- Application of the MAELIA platform in different watersheds

http://maelia1.wordpress.com/

Thank you for your attention

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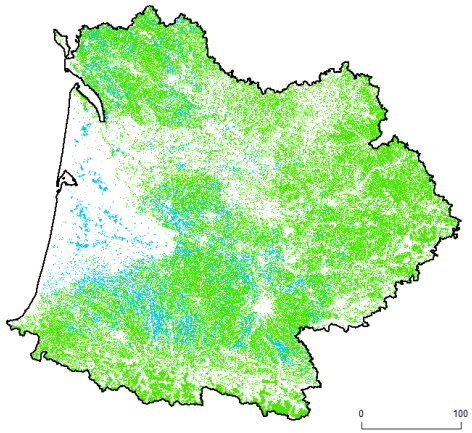
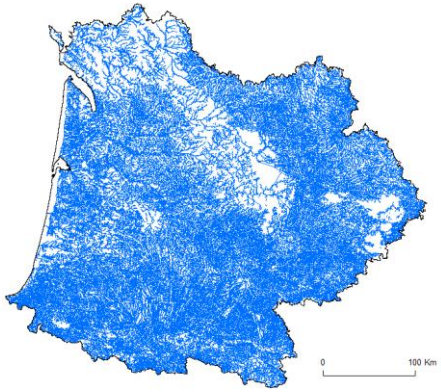
Laboratoire écologie fonctionnelle
et environnement

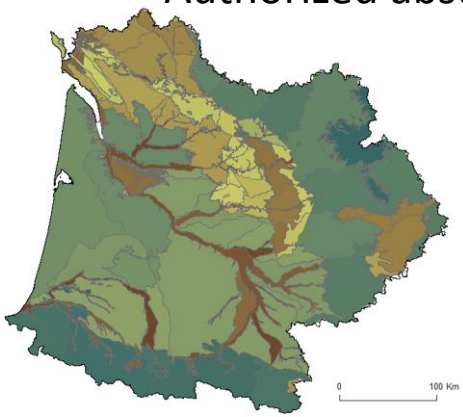


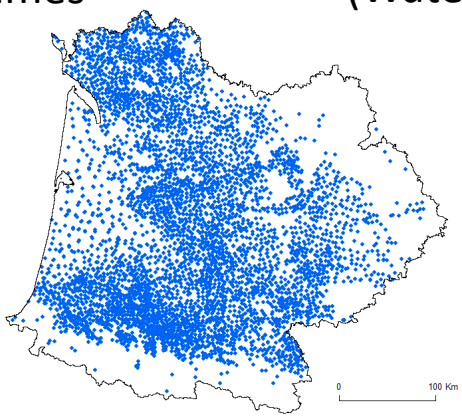
Data Integration

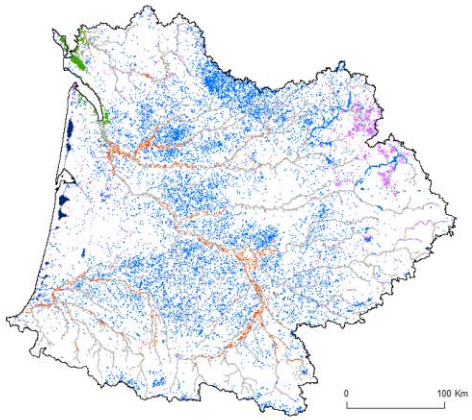


- Administrative boundaries (IGN)
- French Land Parcel Identification System (crop, Islets)
- LUCC: Corine Land Cover (+ cellular automata)
- Demography: scenario of OMPHALE (model from INSEE)
- Decree extensions (State Services)
- Authorized abstraction volumes

- DEM (IGN-25 m)
- Soil (map 1/1 000 000)
- Climate (observed and scenarios)
- Hydrological layers
  - Rivers (IGN)
  - Groundwaters (BRGM)
  - Dams and hill lakes (IGN)
- Water withdrawals and rejections: agricultural, domestic, industry (Water agency)







Introduction to GAMA

- **Web site of the project**
http://code.google.com/p/gama-platform/

- **Blog**
http://gama-platform.blogspot.fr/

- **Documentation**
http://code.google.com/p/gama-platform/wiki/Documentation

- Mailing-lists
- General mailing-list
https://groups.google.com/forum/?fromgroups#!forum/gama-platform
- Developers mailing-list
https://groups.google.com/forum/?fromgroups#!forum/gama-dev

SWAT hydrology in MAELIA