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

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 water withdrawn in driest year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 water withdrawn in driest year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 (*Multi-Agents for Environmental norms Impact Assessment*): 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.

⇒ What needs to be modelled?
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

**DOE***
- 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

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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

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

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

Formalism for crop management: if/then rules
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

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”)

Irrigation
Irrigation material
Irrigation groups

Cultural system
Crop management (expertise)
Culture sequences (LPIS)

Farming system
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

Climate (SAFRAN / Arvalis – ClimBox®)

Soil (BDGSF, IGCS)

*DOE: Low flow target (“débit d’objectif d’étiage”)

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

• 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

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

• Dam water release (dam manager)
• Drought irrigation restriction decree (prefect)
Description of MAELIA

A geo-referenced database

**Soils**
**Cultural systems**
**Irrigation material**
**Hydraulic systems**
**Water resources**
**Administrative area**

**Farming**
A platform of dynamics models and multi-agent systems

- AqYield + farming model
- 1150 Farmers

**Climate**

**Norms**
- 1 Manager

**Hydrology**
- SWAT

**Administrative area**
- 1 Prefect
Description of MAELIA
MAELIA conception

Metamodel ~ shared conceptual framework

Metamodel of socio-ecologic systems

UML model of MAELIA

maelia-platform.inra.fr
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 km²;
• Structural deficit of 5 hm³;
• ~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
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 management 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

Total irrigation (m³)

Irrigated surfaces (ha)

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)
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
⇒ New partnership that expands over new projects and new domains
Amplification of application domains

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

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

**BESTS:** biomass energy, bioeconomic sectors

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

**DiversIMPACTS:** intercropping, sectors...

**PhD / BioSERPPA:** Landscape Composition/ configuration and biological regulation

**ARAA-CRAGE:** runoff-erosion

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

**PhD:** production allowed by ecosystem services, vulnerability/resilience

**MASTER GIS HPEE:** Ontology and biological regulation (MosaicPest)

**BIODIVERSITE et Pollination (LAE)**

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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...

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