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Using ABM to explore the role of socio-environmental interactions on Ancient Settlement Dynamics

Frédérique BERTONCELLO¹, Marie-Jeanne OURIACHI¹, Célia DA COSTA PEREIRA², Andrea TETTAMANZI², Louise PURDUE¹, Rami AJROUD², Jérémy LEFEBVRE²

¹Université Côte d'Azur, CNRS- Univ. Nice Sophia Antipolis, CEPAM - UMR 7264, Nice (France)

²Université Côte d'Azur, Univ. Nice Sophia Antipolis, I3S - UMR 7271, Nice (France)

Analysing long-term dynamics of the settlement system

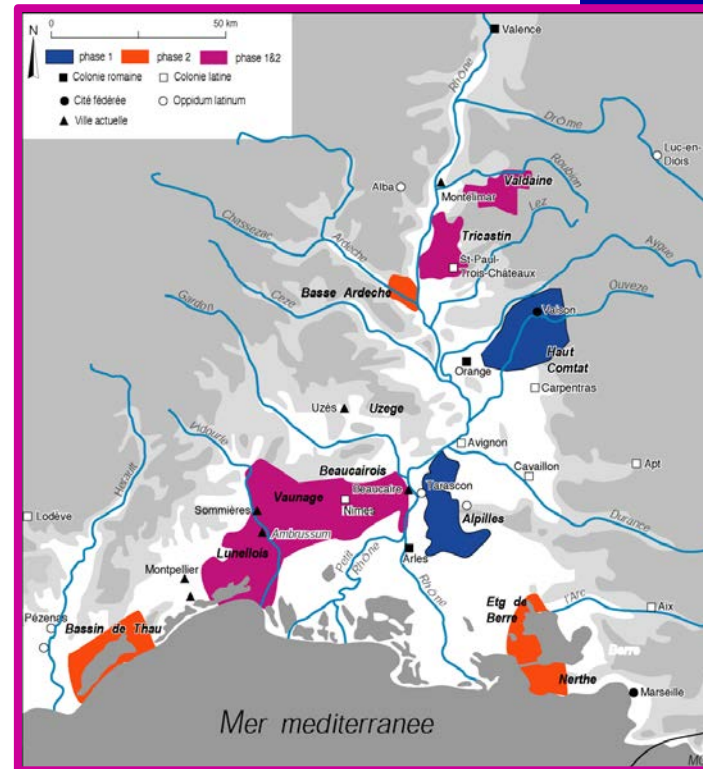
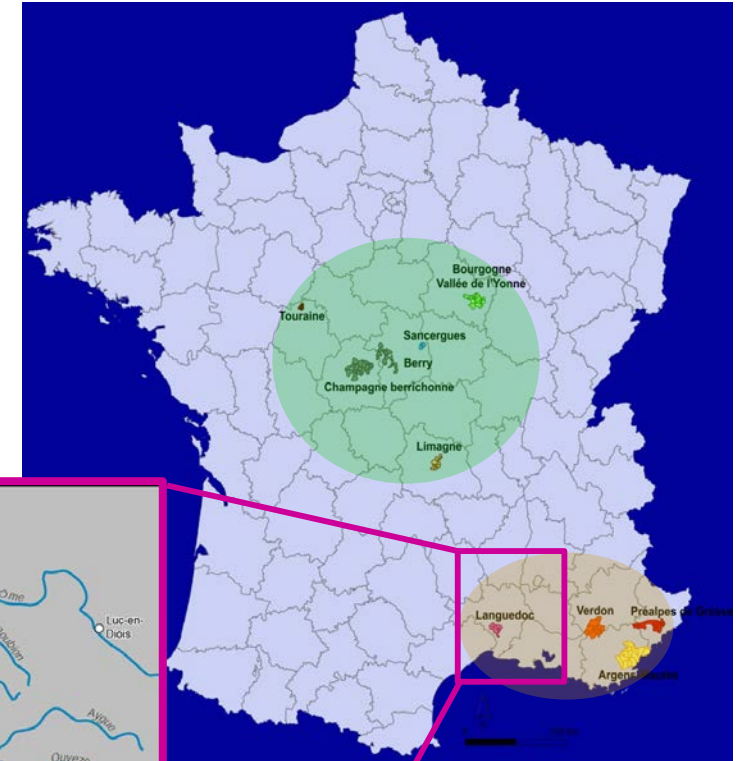
- A collective and long-term research agenda: describe and compare the settlement pattern in various area:

1) Identify and describe the intensity, structure and stability of the settlement system from the Iron Age to the Middle Age

⇒ Develop common quantitative, hierarchical and spatial indicators of the settlement

⇒ Interregional analysis

2) Understand the underlying processes (social / environmental) leading to the transformation of the settlement system

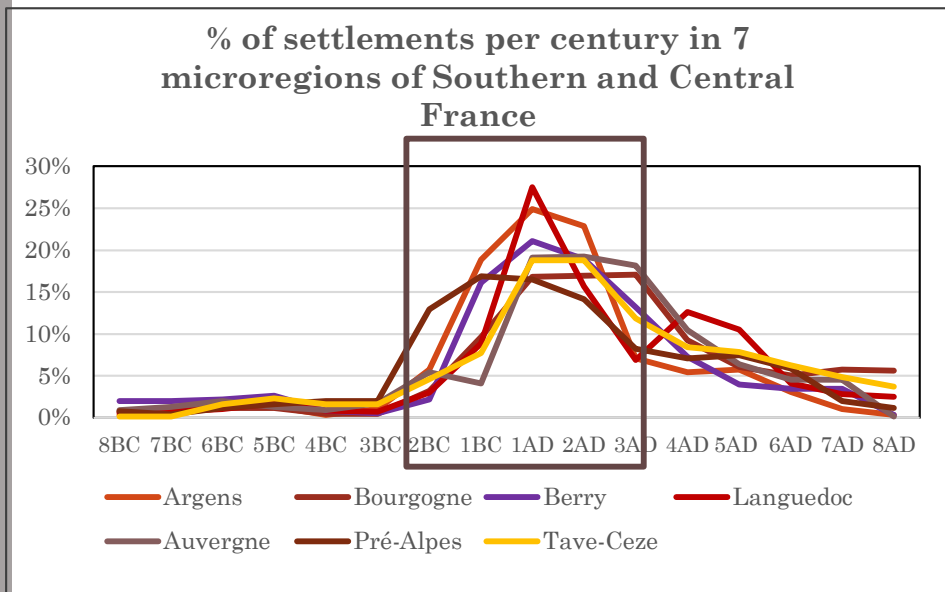


ArchaeDyn project
(2005-2012)

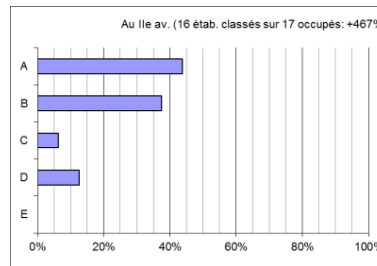
Archaeomedes project
(1992-1998)

Analysing long-term dynamics of the settlement system

- Observed regularities in the settlement pattern in Southern and Central Gaul:
 - 2nd c. BC – 1st c. AD:
 - Strong increase in the number of rural settlements => more concentrated spatial distribution
 - Development of a Roman type of rural settlement: the *villa* => more hierarchised settlement system
 - From the end of 1st c. AD:
 - Steep reduction of the the number of rural settlements => more dispersed distribution
 - Reduction of the hierarchy

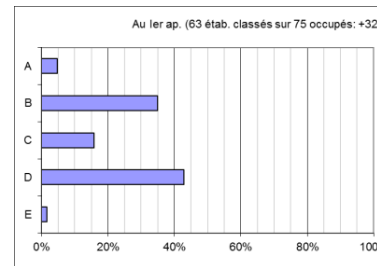


2nd c. BC



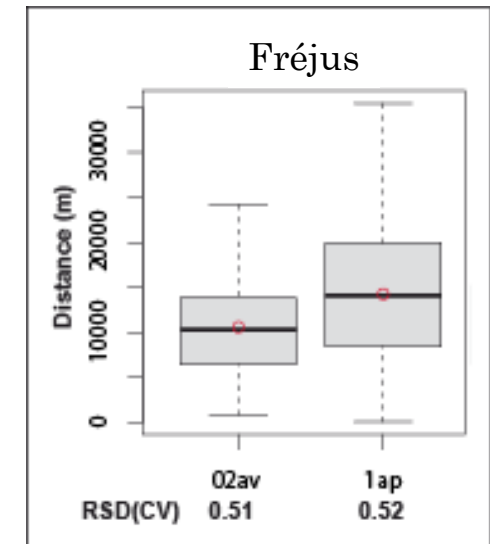
Asymetrical sup.:
Majority of settlements of high hierarchical level

1st c. AD



Bimodal:
As many settlements with high hierarchical level and low hierarchical level

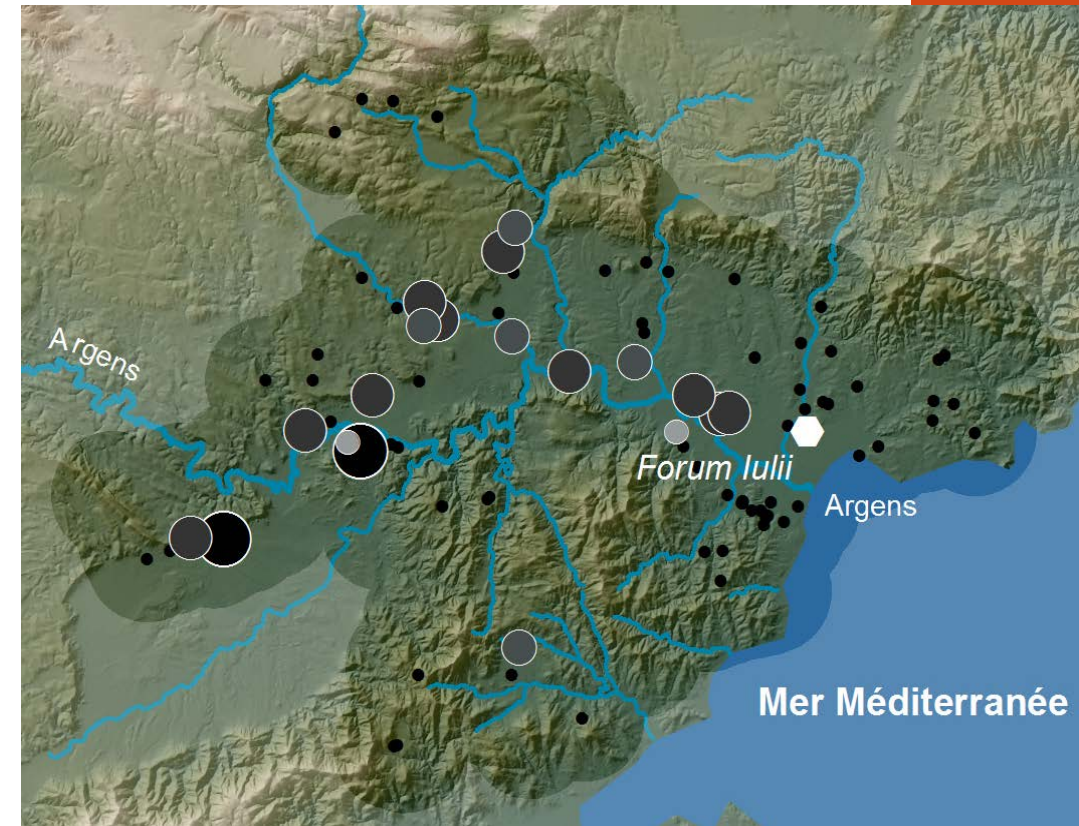
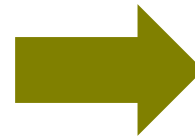
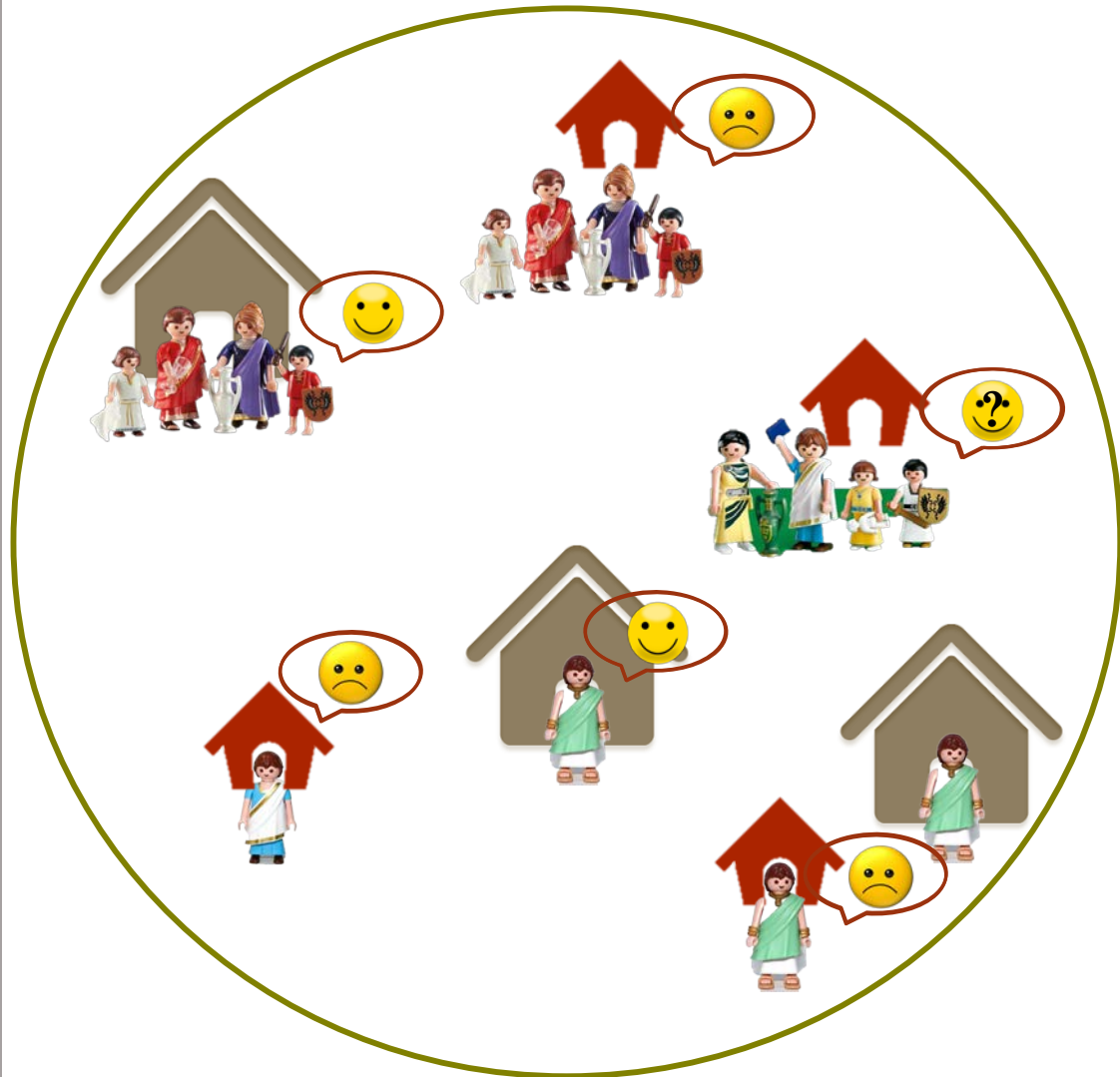
Evolution of the hierarchical structure of the settlement system in the Fréjus area (Var, France)



Statistical dispersion of the distance values between all settlements in the Fréjus area, 2nd c. BC & 1st c. AD

From agents' behaviour to systems' transformation

From states to processes : use agent based modelling (ABM) to simulate the processes of creation, abandonment or maintenance of the rural settlements.



The agents

- **3 types of landowners**, with different socio-economical status:
 - Farmers
 - Big landowners
 - Aristocrats: magistrates who play a political role in the city
 - **2 types of rural exploitations:**
 - Farms (10-50 ha)
 - Villas (50-500 ha)
 - **5 possible actions of the landowners:** maintain, enlarge, improve, abandon or create a villa and/or farm
- ⇒ **Their decision depends on:**
- 1) Their socio-economical status
 - 2) The profit they derive from each of their rural exploitation(s) or expect to derive if they create a new one

The model hypotheses and parameters

1) The socio-economical status of the landowner defines:

- His initial economical power
- The number and type of rural exploitation he can own
- His behaviour and perceptions

	Max number and type of exploitation	Initial economical power	Spatial behaviour for the location of their exploitations	Perception of land productivity	Perception of the impact of existing land management	Perception of the macro-eco context
Gallo-Roman farmers	1 (farm)	500-1000 (token)	Restrained to their own exploitation	Based on their experimental knowledge => limits the creation of new exploitations to the landscape units they already exploit	Strong impact	None
Gallo-Roman big landowners	3 (including at least 1 villa)	1000-2000 (token)	Within a radius of 20 km from any of their exploitations		Strong impact	Limited knowledge
Gallo-Roman aristocrats	6 (including at least 3 villas)	>2000 (token)	No spatial constraint (can create exploitations anywhere); Attraction by the city capital : try to have at least 1 of their exploitations close to the city capital (10 km)	Based on their theoretical knowledge about agrarian techniques and their economical capacity to implement them to increase the fertility of a landscape unit => can exploit all the landscape units	Low impact	Deep knowledge

The model hypotheses and parameters

2) The profit derived from each rural exploitations depends on:

- The production capacity of the rural exploitation, depending on the type of environmental context
- The accessibility costs to the nearest market place (towns)

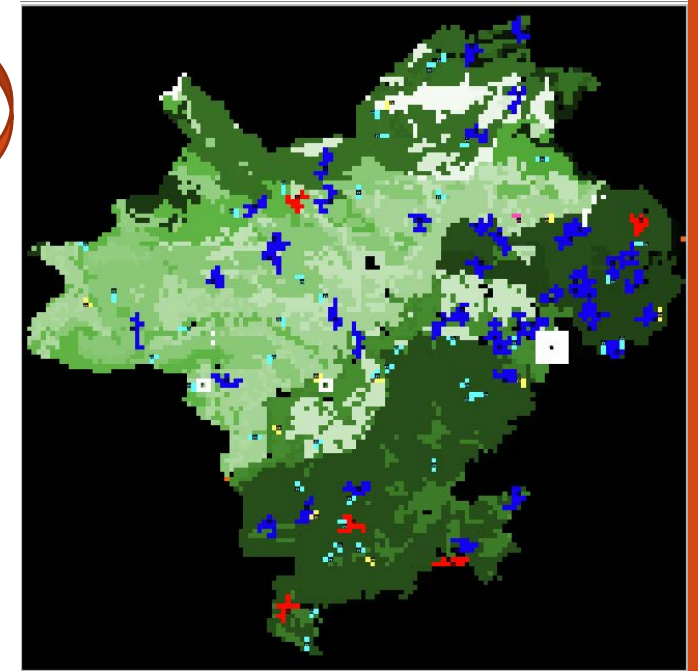
5 stylized types of environmental units • 2 types of towns:

- Alluvial plain
 - Foothills
 - Plateaux
 - Sedimentary basin
 - Hillslopes
- 1 city-capital
 - 3 other towns



3) The production capacity of the exploitation is influenced by:

- Changing climatic conditions
- The macro-economical context



Instanciación of the model: the territory of the Roman colony of *Forum Iulii* (Fréjus, Var, France)

The dynamic of the model

Landowner economical power (t+1)	Profit derived from each exploitation		Possibility of creating new exploitation (only for big landowners and aristocrats)
	High profit (Farm : > 600 token ; Villa : > 6000 token)	Low profit (Farm : < 600 token ; Villa : < 6000 token)	
Equivalent (=)	Maintain	Maintain	No
		Abandon	Yes
Higher (>)	Enlarge or Maintain	Improve or Maintain	Yes
Lower (<)	Maintain	Abandon	No

The choices of action of the landowners according to the evolution of their economical power and to the profit derived from each exploitation.

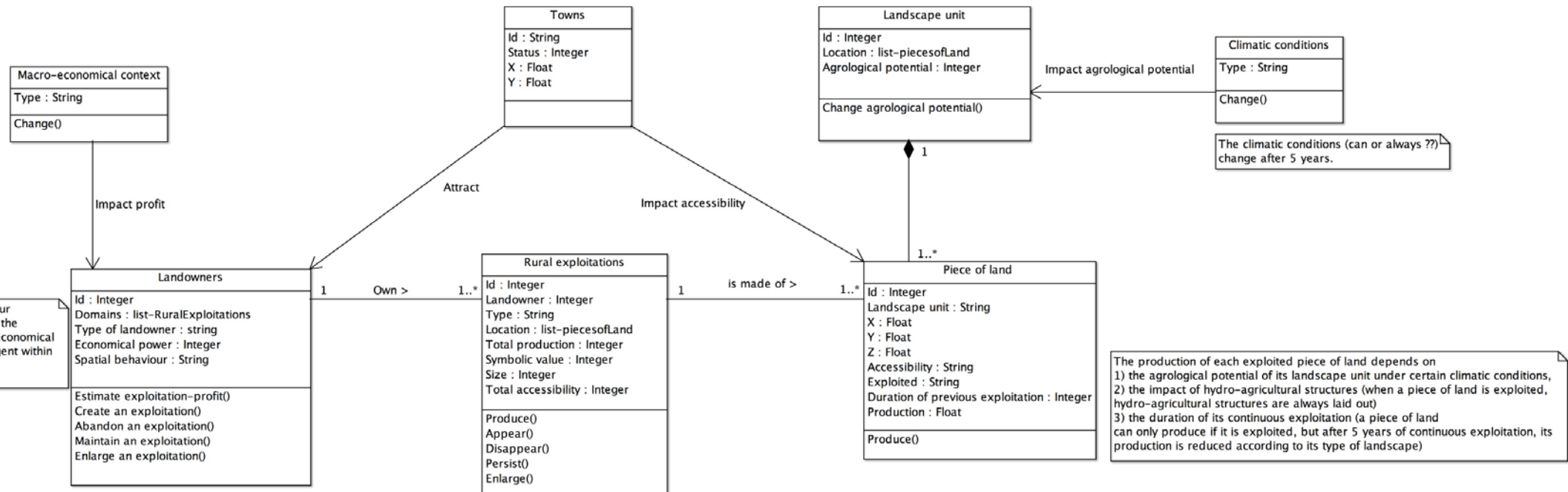
The dynamic of the model

- **Improvements:** hydro-agricultural structures (irrigation, drainage ditches, land terraces, stone clearance, etc.) to improve the production of the piece of land.
- Land productivity is degraded after 5 years of consecutive exploitation
- ⇒ **Feedbacks loops** between agents' behaviour and the properties of their environment
- **Symbolic value:** attachment of the landowner to a specific exploitation (i.e. the familial domain, or a domain close to the city capital).



Repeated landowners decision making produces a changing macro-level settlement pattern in terms of number, type and location of the settlements

Description of the model: ODD protocol and UML diagrams



The economical power, spatial behaviour and attachment to the land depend on the type of landowner. For each type, the economical power is randomly allocated to each agent within a specified interval.

The climatic conditions (can or always ??) change after 5 years.

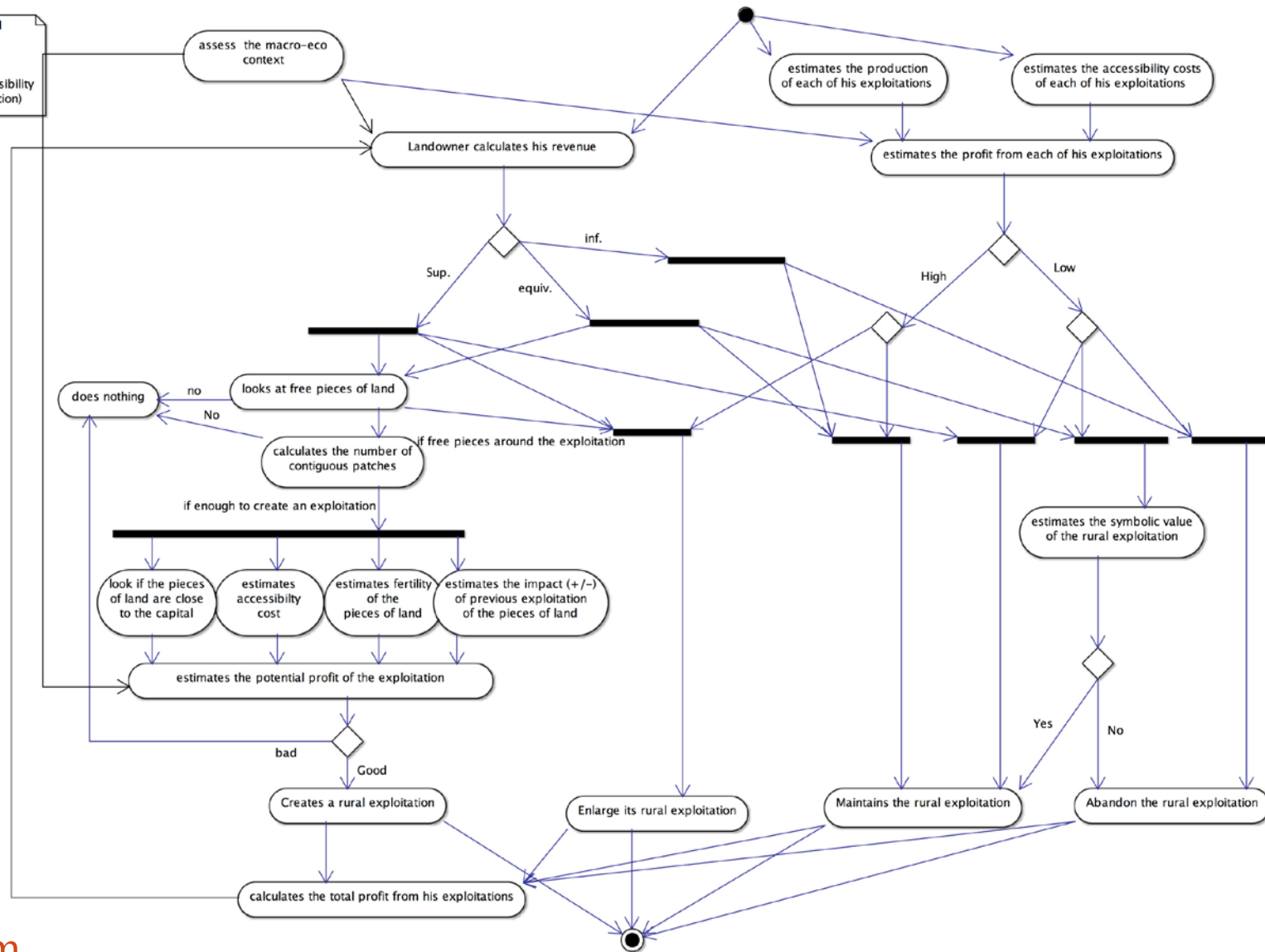
The production of each exploited piece of land depends on
 1) the agrological potential of its landscape unit under certain climatic conditions,
 2) the impact of hydro-agricultural structures (when a piece of land is exploited, hydro-agricultural structures are always laid out)
 3) the duration of its continuous exploitation (a piece of land can only produce if it is exploited, but after 5 years of continuous exploitation, its production is reduced according to its type of landscape)

Total production of the rural exploitation = cumulated production of the pieces of land belonging to one exploitation

The landowner estimates :
 - the profit of each of his rural exploitation by looking at its total production, its accessibility costs, its symbolic value and the macro-eco context.
 - the potential profit of a set of pieces of land by looking at their fertility, their accessibility, the impact (+/-) of previous exploitation and the macro-eco context.

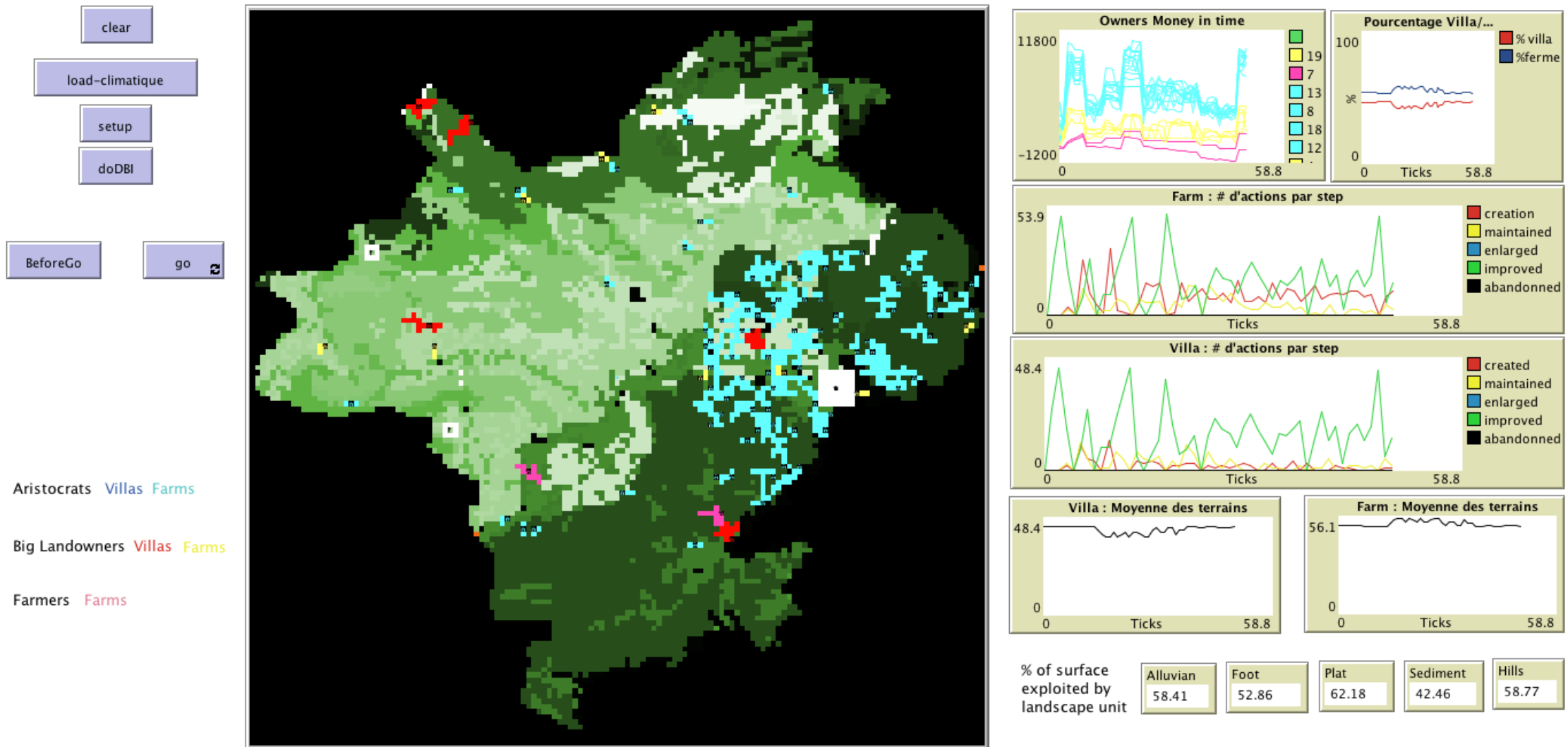
Description of the model: ODD protocol and UML diagrams

The macro-eco context impacts the value of fertility and accessibility cost necessary to create an exploitation, and to decide whether an existing exploitation should be maintained or abandoned (if the macro-eco context is defavourable, the fertility must be higher and the accessibility costs lower to be able to create or maintain an exploitation)



UML activity diagram

1st version of the implemented model



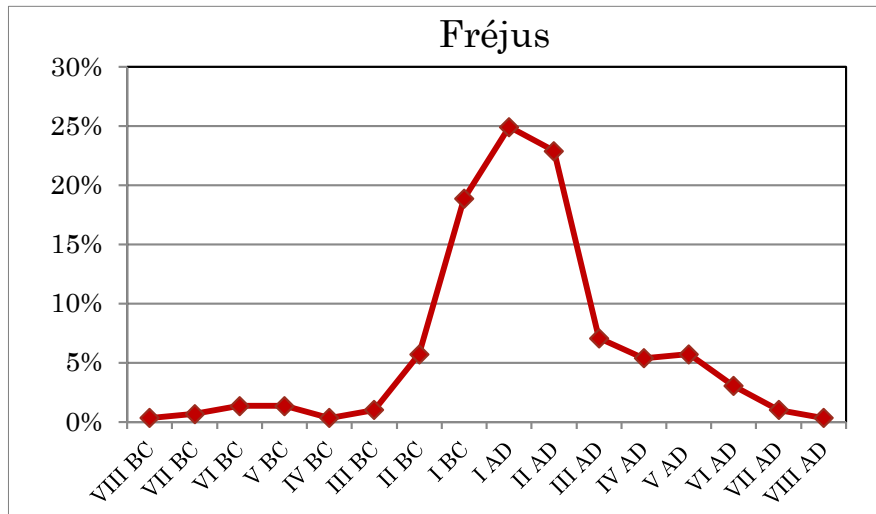
ABM prototype (Netlogo, Jérémy Lefebvre & Rami Ajroud)

Models and reality

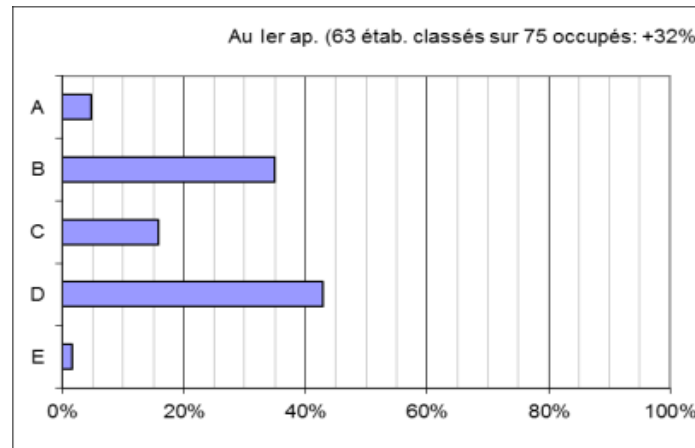
- **Model: a simplified representation of a reality**, which gives sense to this reality and hence allows to understand it
 - ⇒ No reproduction of past reality but help selecting the most plausible hypothesis about past dynamics
 - ⇒ Models: « tools to think »: to test and elaborate hypothesis

Models and reality

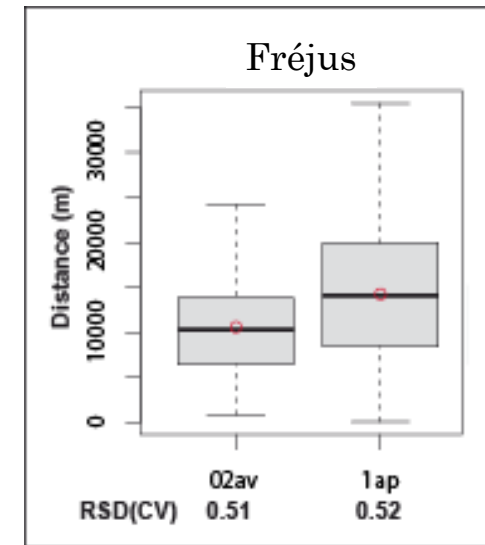
- But the question of the realism of the model always arises, especially during
 - 1) **The model building:** how to use insufficient data to define precise parameters value without over-simplification ?
 - 2) **The model validation:** implies to compare the simulated outputs with archaeological records: a good match is not enough
 - ⇒ Different processes can create similar patterns
 - ⇒ Focus on statistical outputs more than spatial patterns



% of settlements per century in the Fréjus area between the 8th c. BC and the 8th c. AD



Hierarchical structure of the settlement system in the Fréjus area, 1st c. AD



Statistical dispersion of the distance values between all settlements in the Fréjus area, 2nd c. BC & 1st c. AD