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

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

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« Complex Systems » Academy of Excellence

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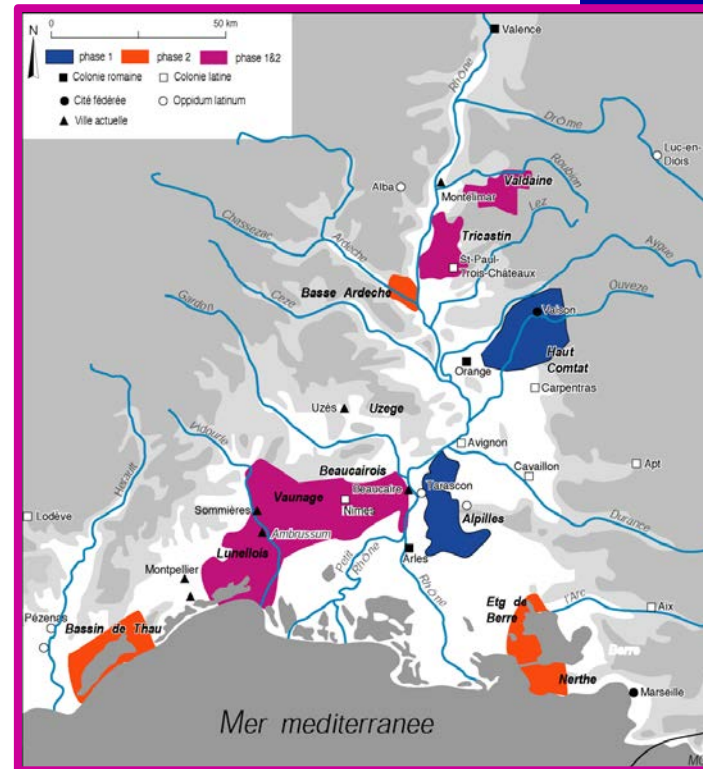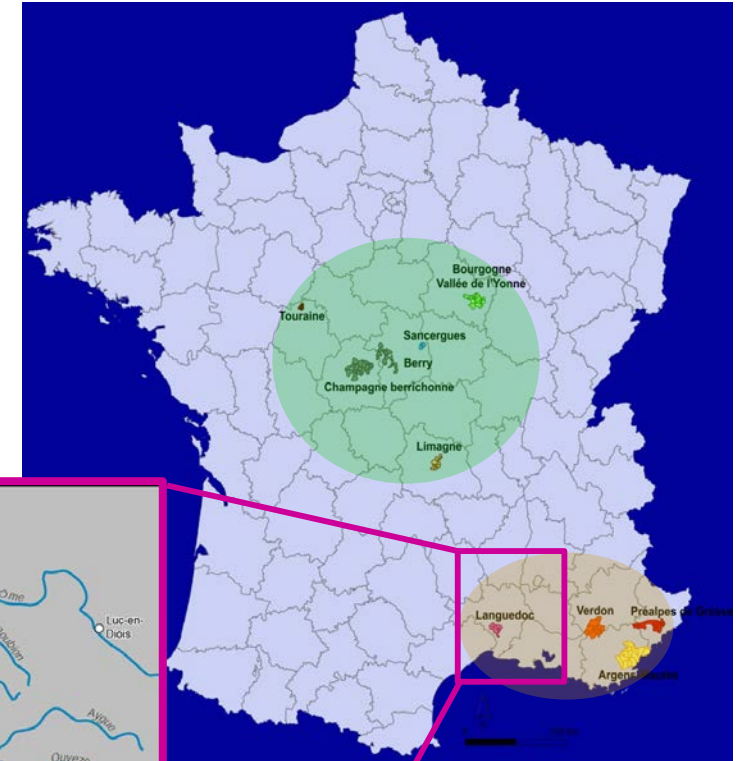# Analysing long-term dynamics of the settlement system

- 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
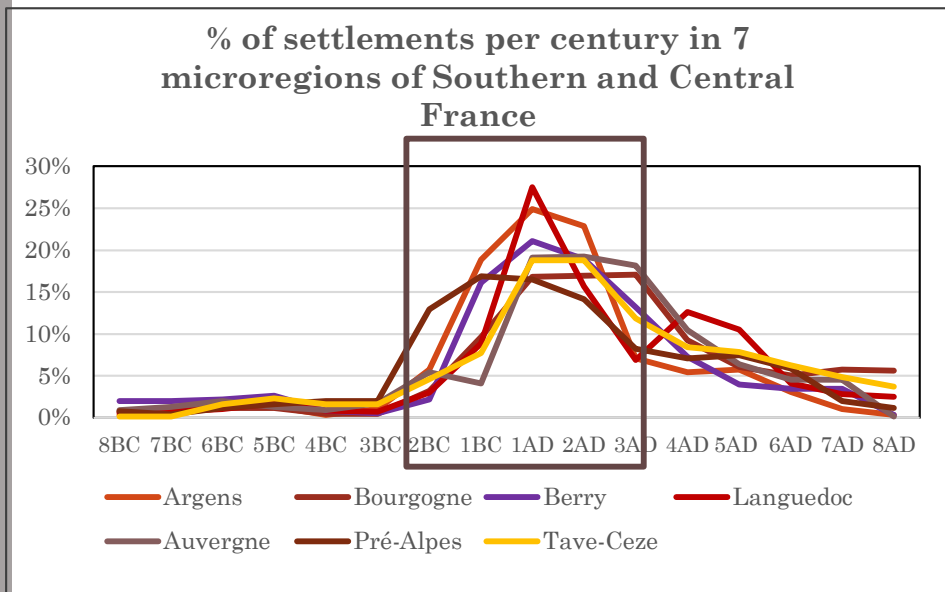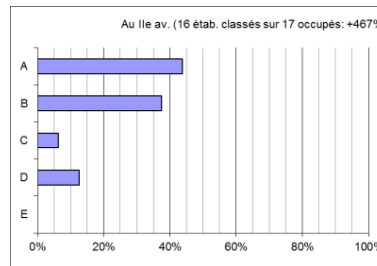

ArchaeDyn project (2005-2012)

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
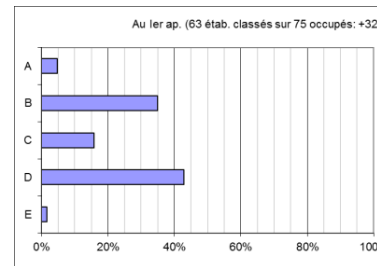   - Reduction of the hierarchy

**% of settlements per century in 7 microregions of Southern and Central France**

Argens — Bourgogne — Berry — Languedoc — Auvergne — Pré-Alpes — Tave-Ceze

2nd c. BC

Au IIe av. (16 étab. classés sur 17 occupés: +467%)

Asymetrical sup.:
Majority of settlements of high hierarchical level

1st c. AD

Au Ier ap. (63 étab. classés sur 75 occupés: +32%)

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)
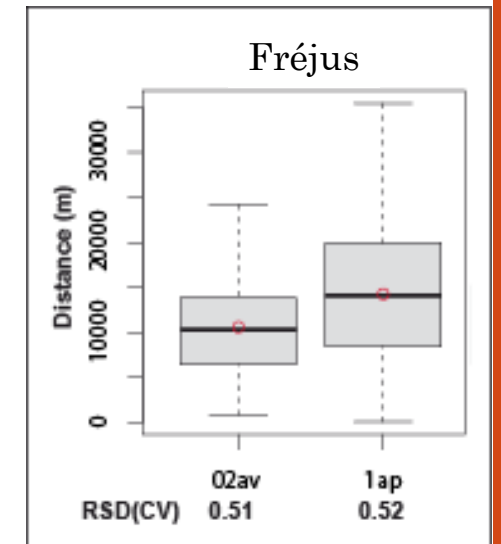
Fréjus

	02av	1ap
RSD(CV)	0.51	0.52

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.
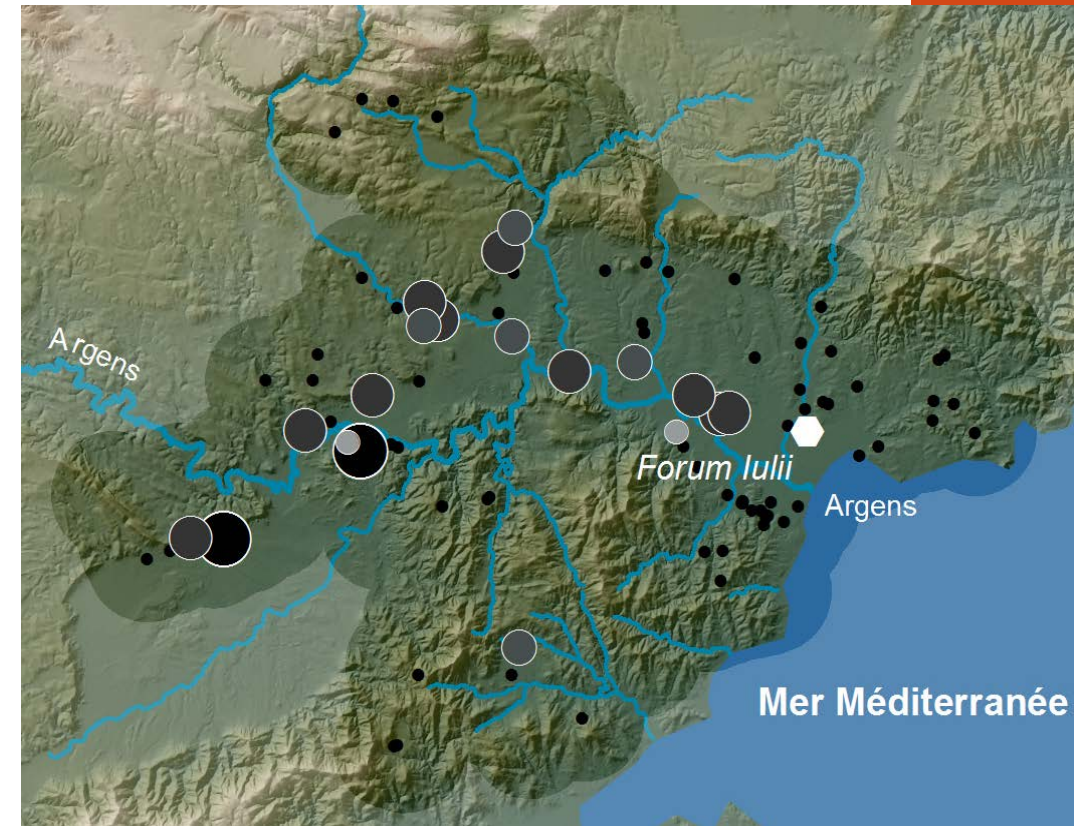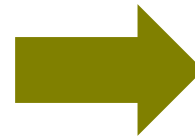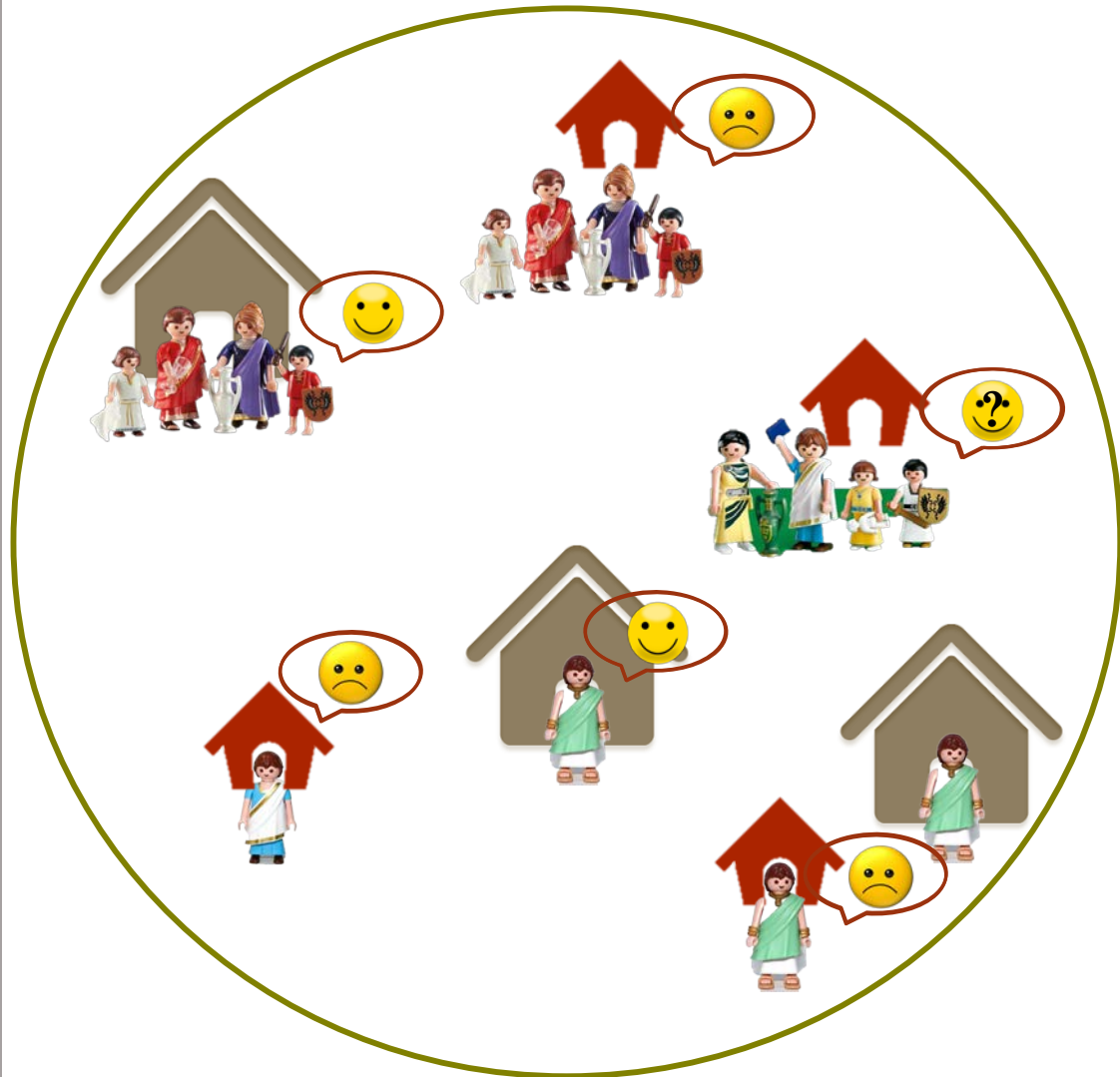
The agents

- **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
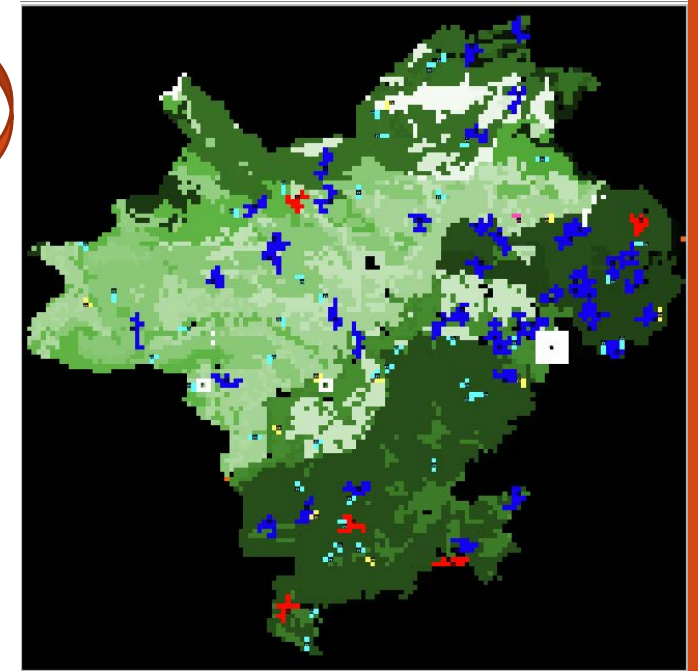- The accessibility costs to the nearest market place (towns)

5 stylized types of environmental units:

- Alluvial plain
- Foothills
- Plateaux
- Sedimentary basin
- Hillslopes

• 2 types of towns:

- 1 city-capital
- 3 other towns

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

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

- Changing climatic conditions
- The macro-economical context

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

UML class diagram

Description of the model: ODD protocol and UML diagrams

UML activity diagram

1st version of the implemented model
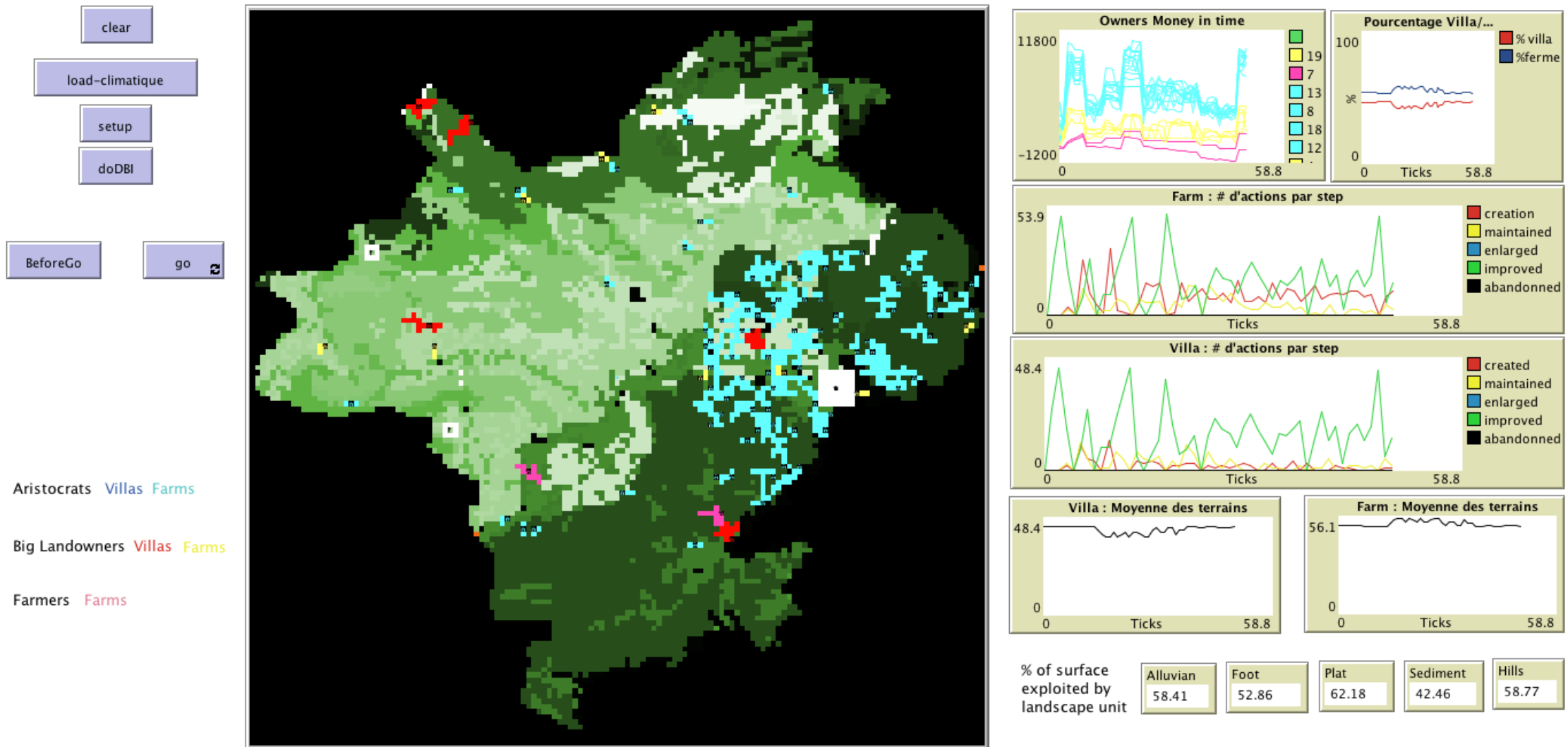

ABM prototype (Netlogo, Jérémy Lefebvre & Rami Ajroud)

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

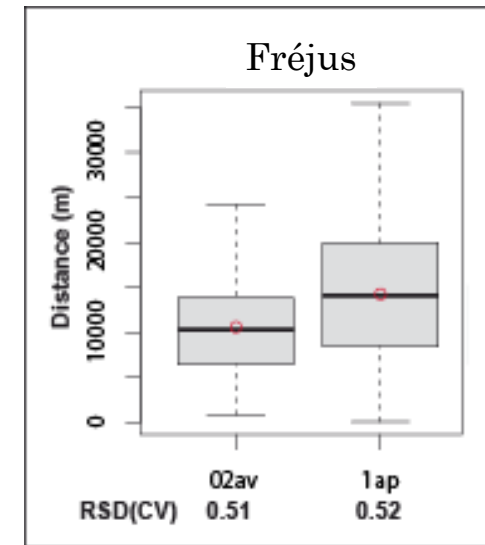 ⇒ Models: « tools to think »: to test and elaborate hypothesis

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
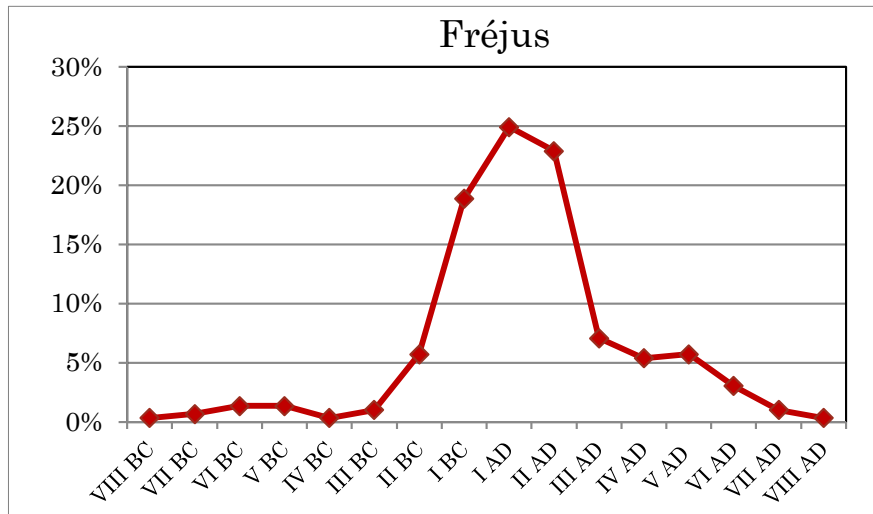
% of settlements per century in the Fréjus area between the 8th c. BC and the 8th c. AD
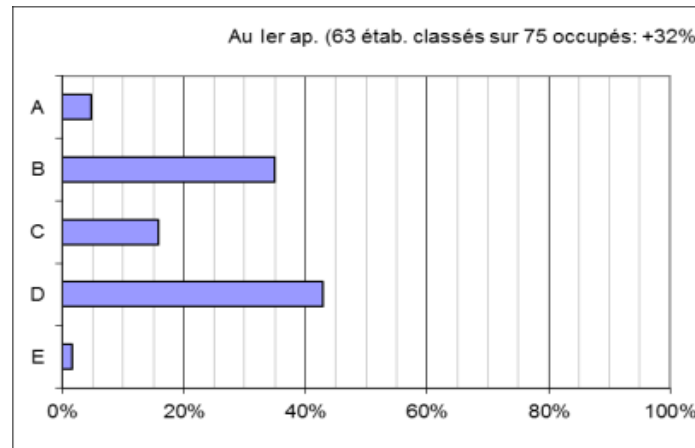
Hierarchical structure of the settlement system in the Fréjus area, 1st c. AD

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