Simulating the viability and profitability of Roman farms and villas in Southern Gaul by an agent-based model

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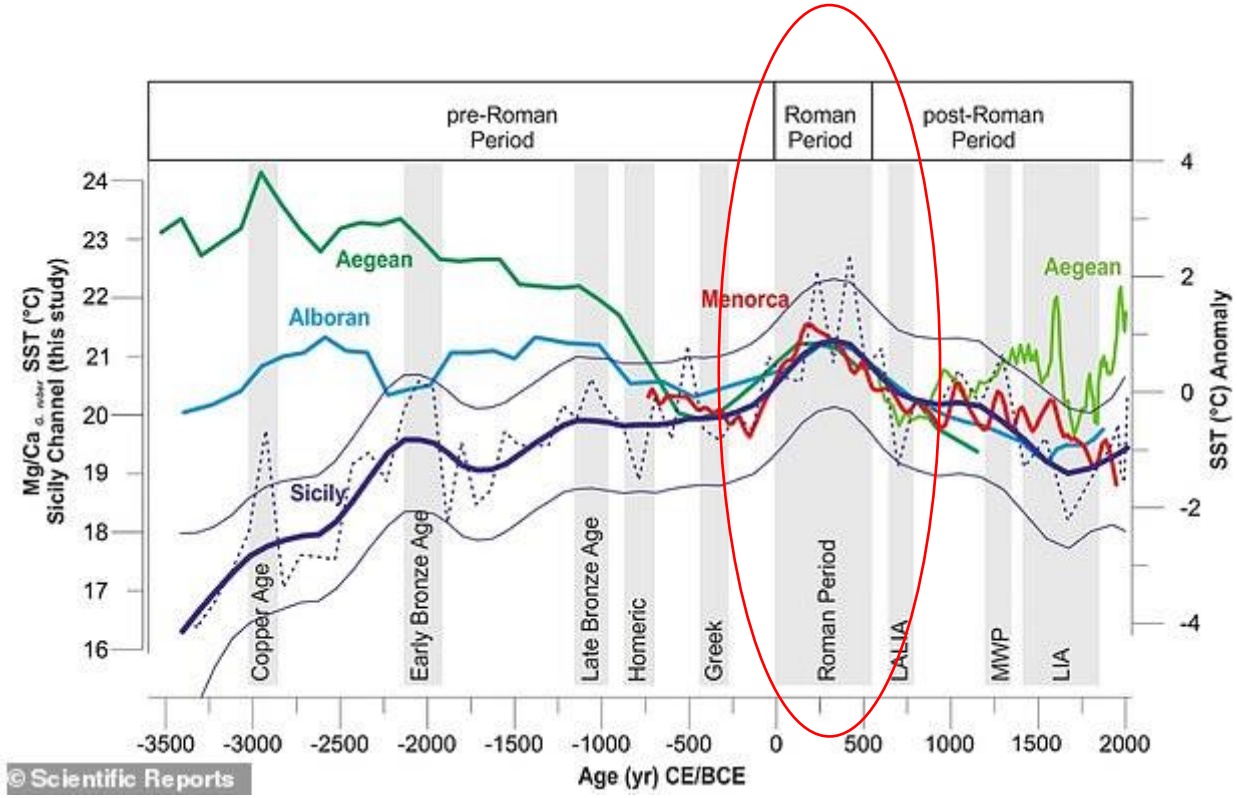
RDMed project

(1) CEREGE – UMR 7330, (2) IMBE – UMR 7263, (3) CEPAM – UMR 7264, (4) U. Strasbourg (5), CCJ – UMR 7299, (6) U. Aix-Marseille

Introduction

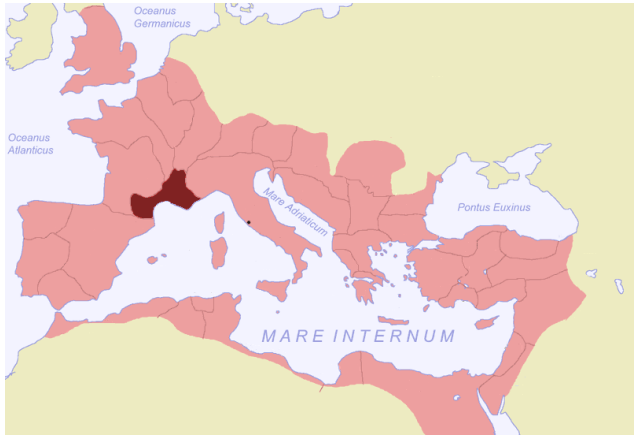
- For more than a century, the negative role of climate cooling in late antiquity has been discussed on a fall in agricultural yields and the decline of the Roman Empire (HUNTINGTON 1917; BÜNTGEN et al. 2016)
- More recently, the evidence of global warming at the beginning of the Roman period (MCCORMICK et al. 2012) suggests now that climate may have been very favorable to the development of the Roman Empire around the beginning of our era (HARPER 2017).
- However, these interpretations are controversial as it remains difficult to perceive from historical and archaeological sources what the actual impact of these climatic variations may have been on yields.
- Modelling now offers the opportunity to design complex models and test different hypotheses



Evolution of the surface temperature of the Mediterranean sea over the past 5500 years

MARGARITELLI et al. 2020

Study area : Gallia Narbonensis

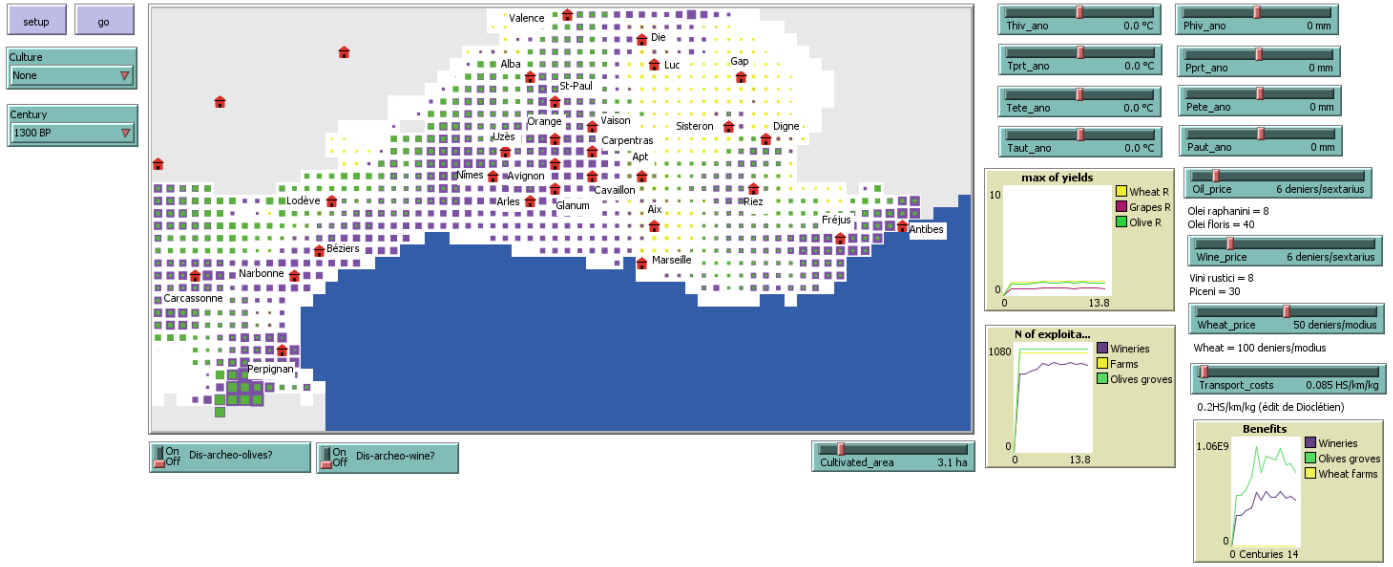


"In all of Gallia Narbonensis, the agricultural products are exactly the same as in Italy, while as one advances north toward the Cévennes, one no longer sees olive or fig trees; the other crops, it is true, continue to thrive, but, if one advances a bit more in the same direction, one sees that grape vines, in turn, only grow with great difficulty."

Strabo (*Geography*, IV, 1)

The ROMCLIM agent-based model

- Simulates the potential yields for wheat, wine and olives (agrosystemic emulator)
- Calculates the benefits of different types of villas and farms producing these crops in function of climatic and economics factors
- Model works for each century between 6th c. BC and 7th c. AD
- Every “patch” sprouts each type of agent : wheat farm, olive grove, winery



Paleoclimatic data → LPJmL emulator : reconstructing yields → ROMCLIM : agent-based model = simulating impact of climate on ancient societies → **OUTPUTS**:
-number of exploitations
-sum of the benefits of the agricultural exploitations
-Harvests

Lund Potsdam Jena managed Land (LPJmL)

LPJmL (Lund-Potsdam-Jena for managed Land)

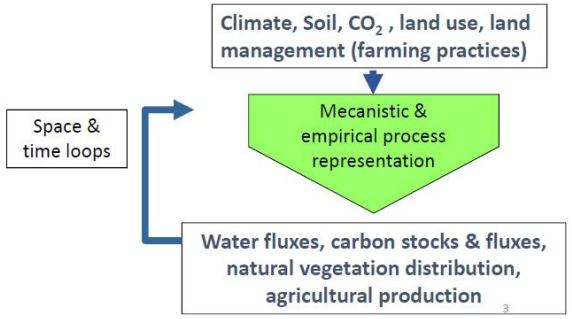
What is LPJmL?

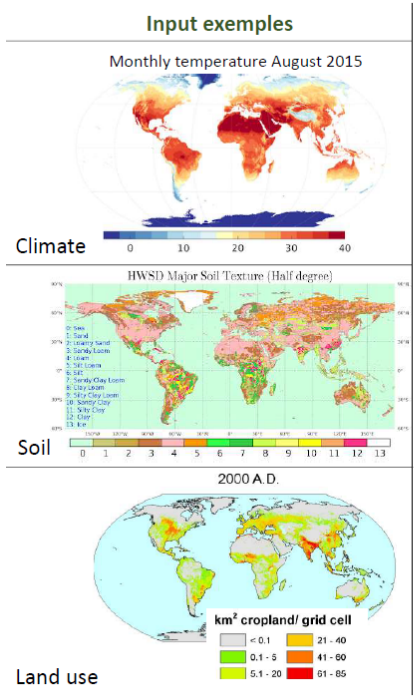
- a Dynamic Global Vegetation Model (DGVM)
- an agroecosystem model
- a global gridded crop model (GGCM)
- a global hydrological model (GHM)

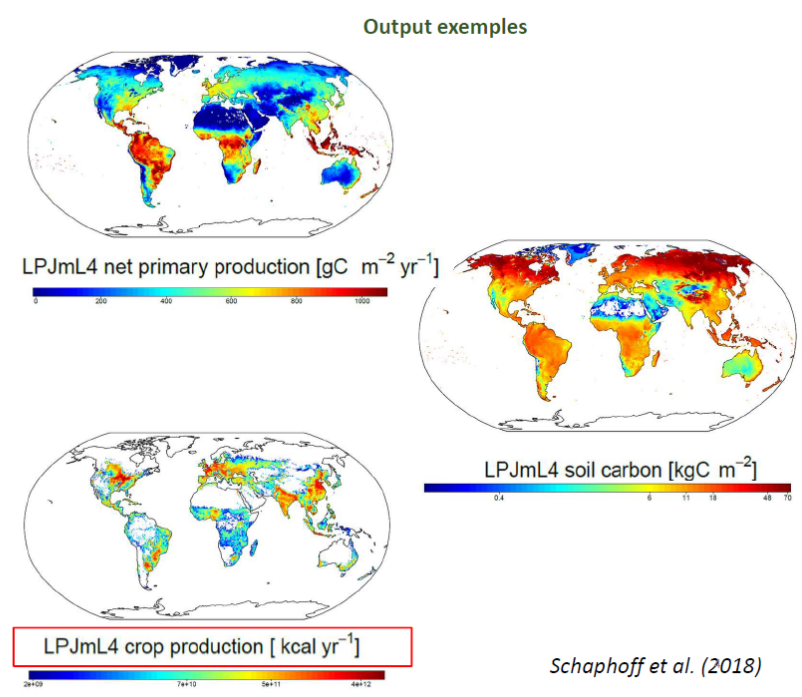
What does LPJmL do ?

It translates environnemental and management inputs into carbon and water budget.
For that, it simulates daily energy, carbon, and water fluxes between the atmosphere, the vegetation, and the soil.

For both potential natural vegetation and agriculture



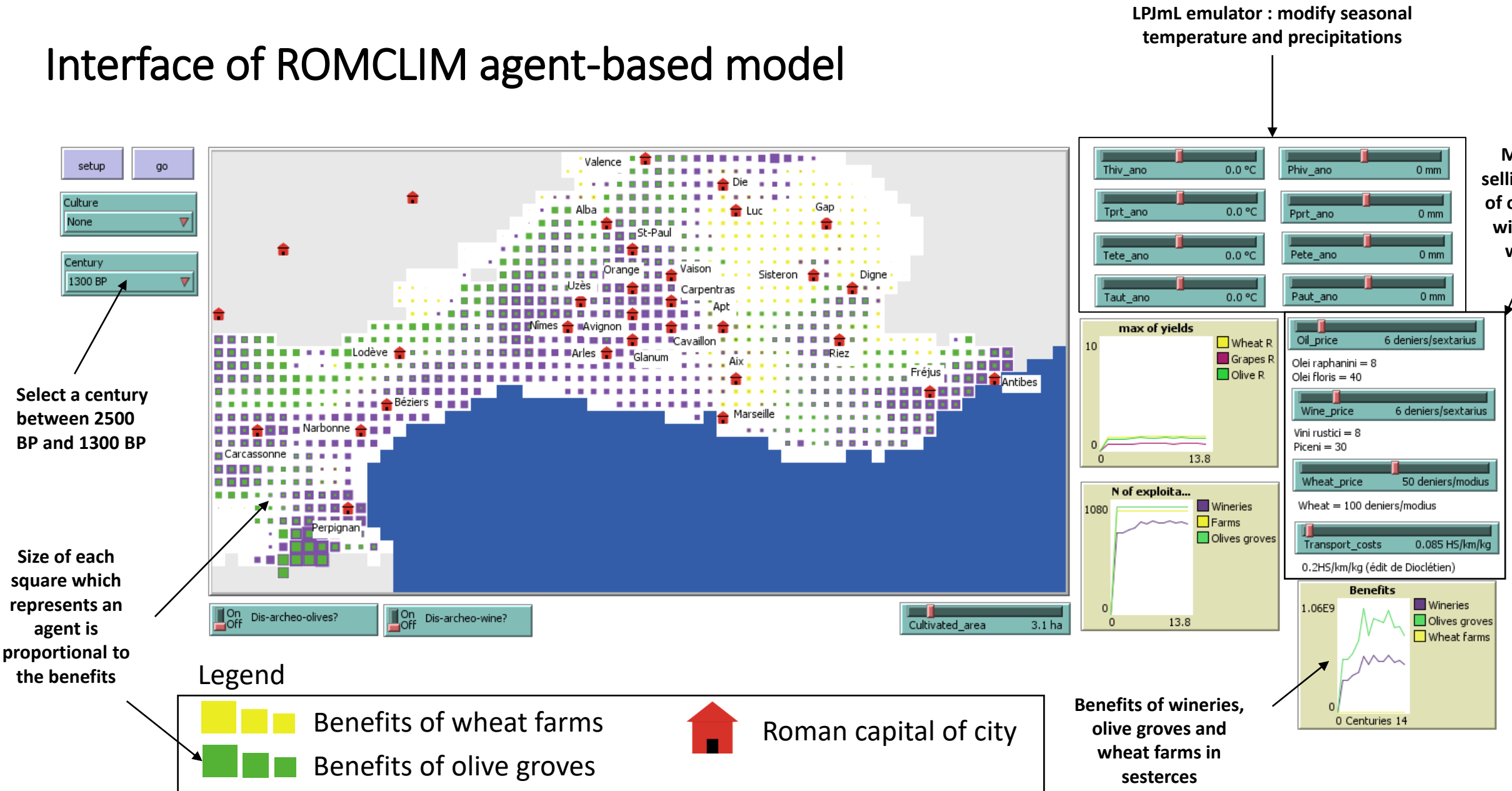




Schaphoff et al. (2018)

A. Bondeau/IMBE

Interface of ROMCLIM agent-based model

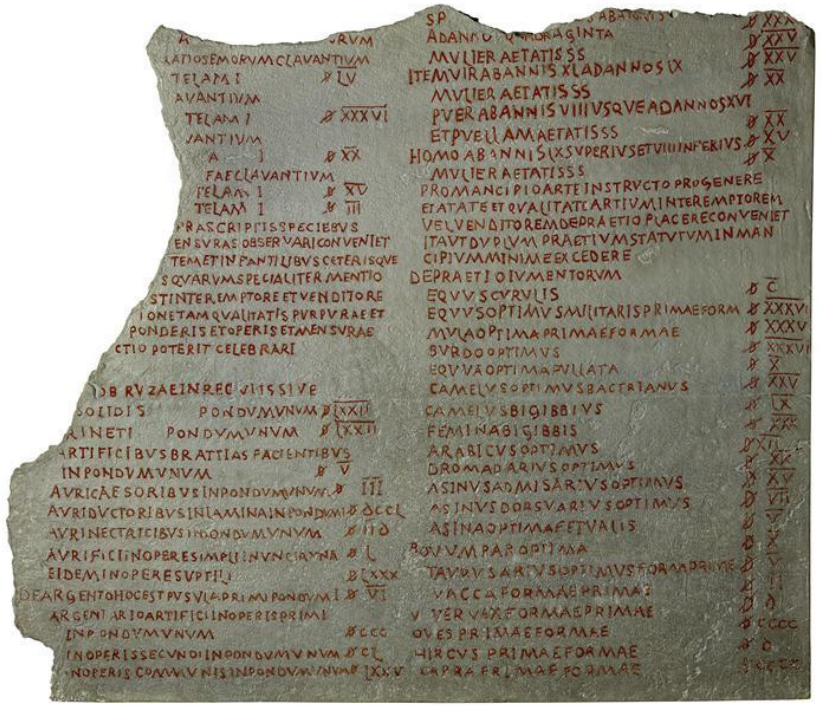


Main characteristics of the agents:

Agents :	Wheat farm	Olive grove	Winerie
Number of farmers	6	13	14
Cultivated area	0-2 ha	240 *jugera* (60 ha) (Caton)	100 *jugera* (25 ha) (Columelle)
Yields	Returned by LPJmL emulator calculation/climate		
Harvest	Cultivated area * LPJmL yield		
Price of harvest	0-100 denarius/modius*	0-40 denarius/sextarius**	0-30 denarius/sextarius**
Costs of exploitations	Quantity of grain necessary for feed the family + necessary seed for next year	Number of persons * 140 sesterces/year	140 sesterces/year/slave
Distance to the nearest capital of city	Calculated by the model		
Cost of transports	0-1 sesterce/kg/km * Distance to the nearest capital		
Benefits	Surplus price – costs	Harvest price – costs	
Action	Disappear if annual harvest can’t feed the family	Disappear if benefits < 0	

Examples of prices in denarius given by the Edit on Maximum price of Diocletian (301 AD)

Cereal/Pulses	Price*	Wines	Price**	Olive oil	Price**
Wheat	100	*Piceni*	30	*Olei floris*	40
Barley	60	*Rhosati*	20	*Olei sequentis*	24
Lentil	100	*Vini Rustici*	8	*Olei cibari*	24
		Zythi	2	*Olei raphanini*	8



Transport costs = 20 denarius/mille/1200 livres

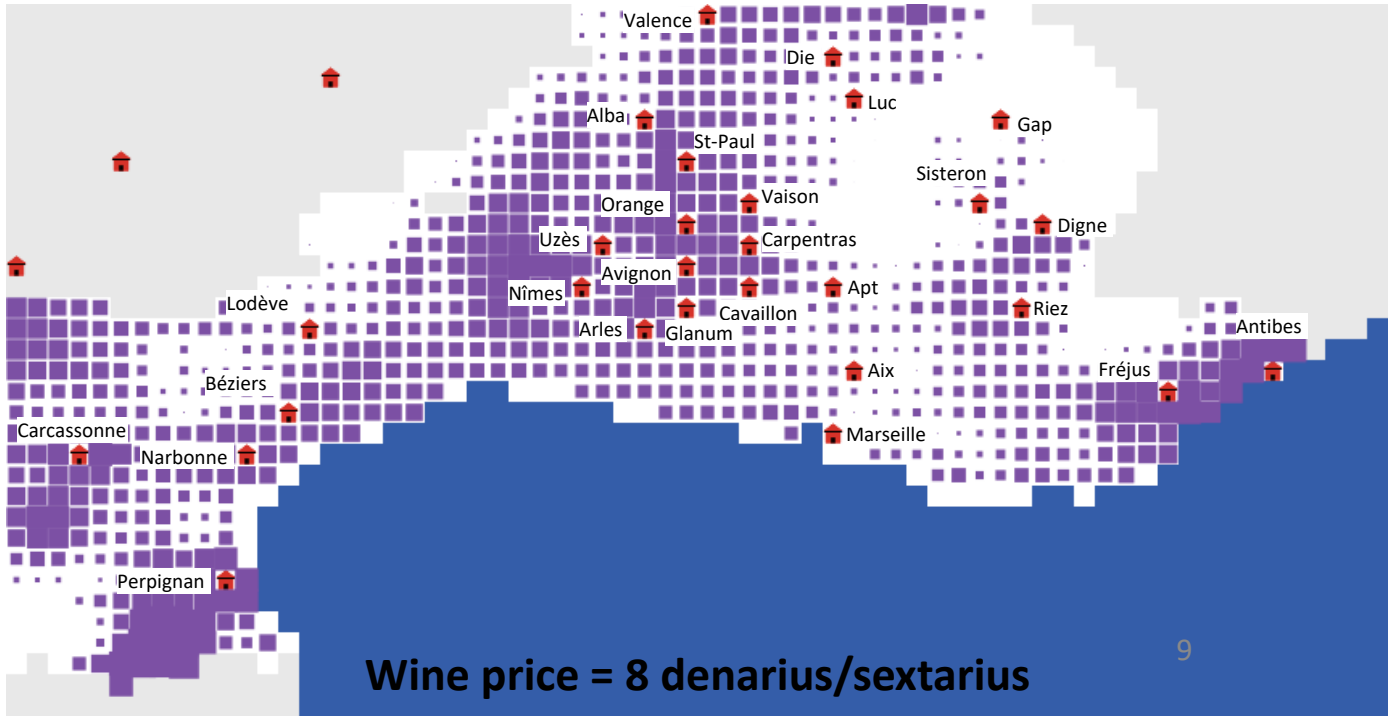
* denarius/modius 1 modius = 8,67 liter

** denarius/sextarius 1 sextarius = ½ liter

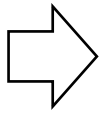
Simulating changes in **PRICES** of agricultural goods on roman villas and farms profitability

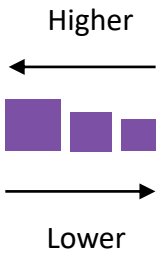
Simulation of wineries' profits in 3rd c. AD

- Price of 4 *denarius/sextarius*



- Price of 8 *denarius/sextarius* wich is the maximum for the price of *vini rustici* in Diocletian edict



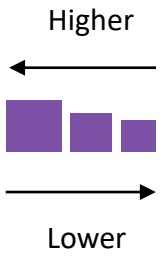


Wineries' profits

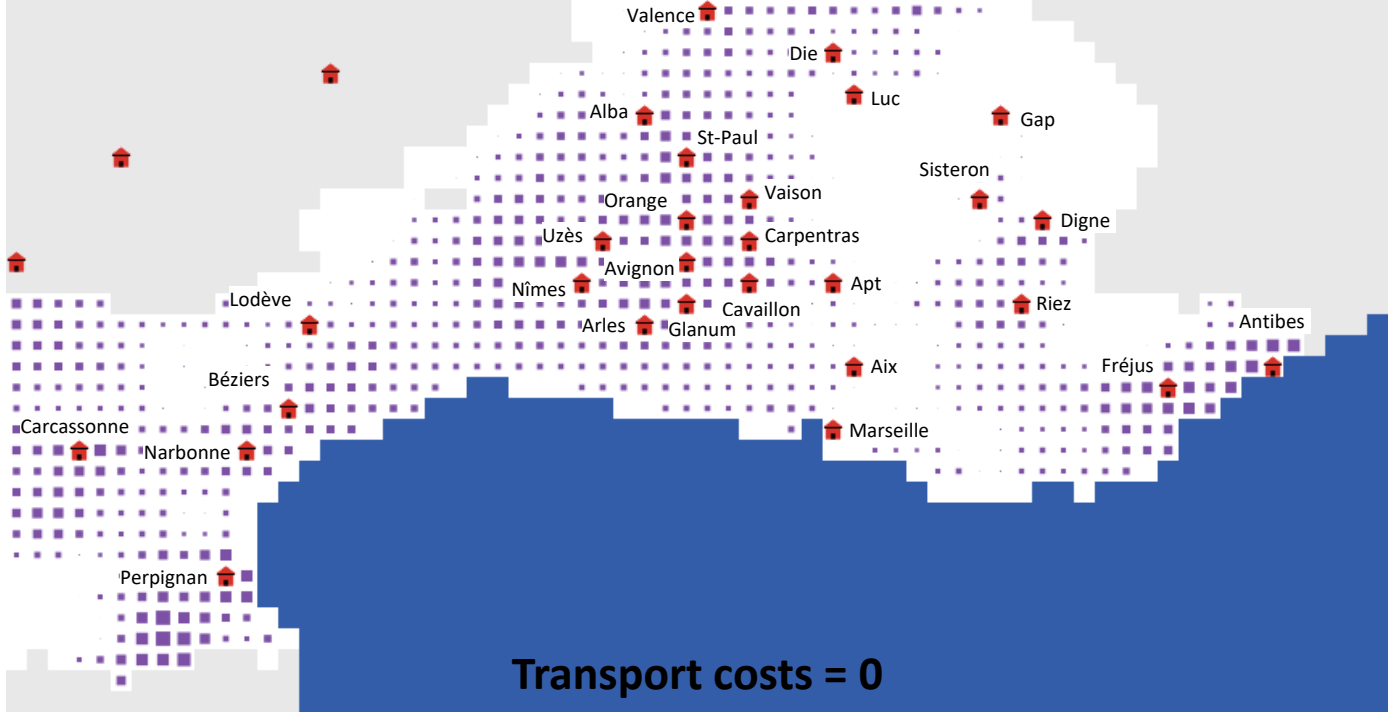
Simulating changes in **TRANSPORT COSTS** on roman villas and farms profitability

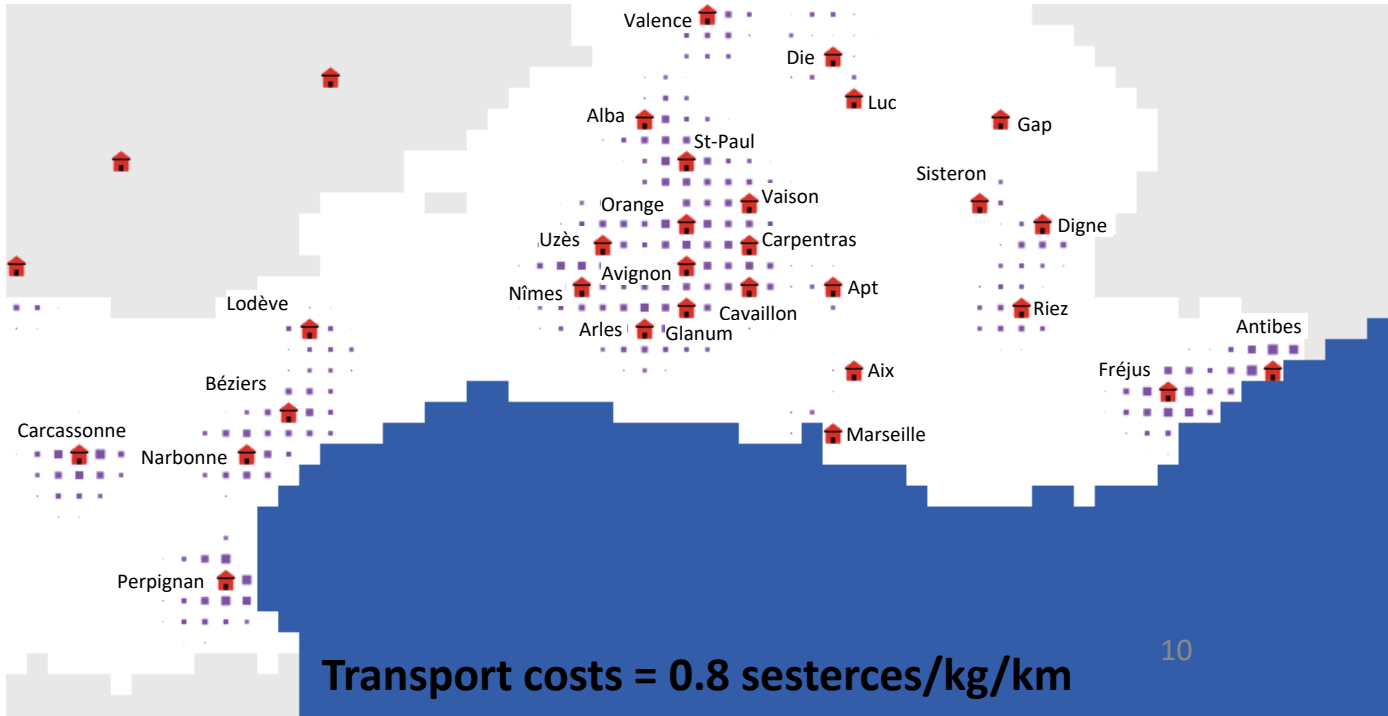
Simulation of wineries' profits in 3rd c. AD

- Transport costs = 0 (top)
- Transport costs = 0.8 sesterces/kg/km (bottom)



Wineries' profits

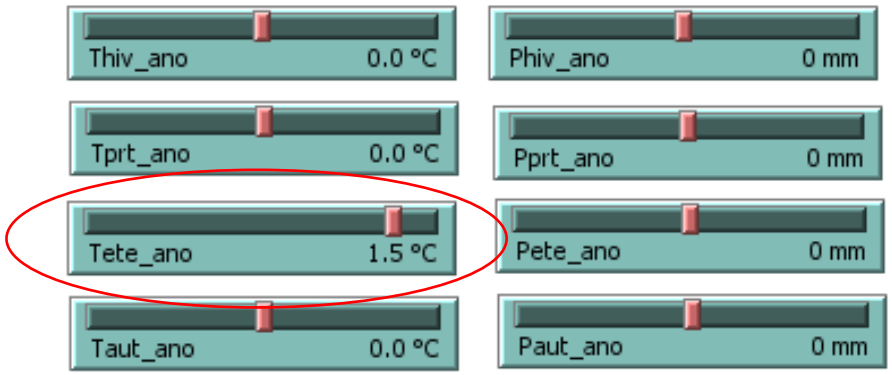


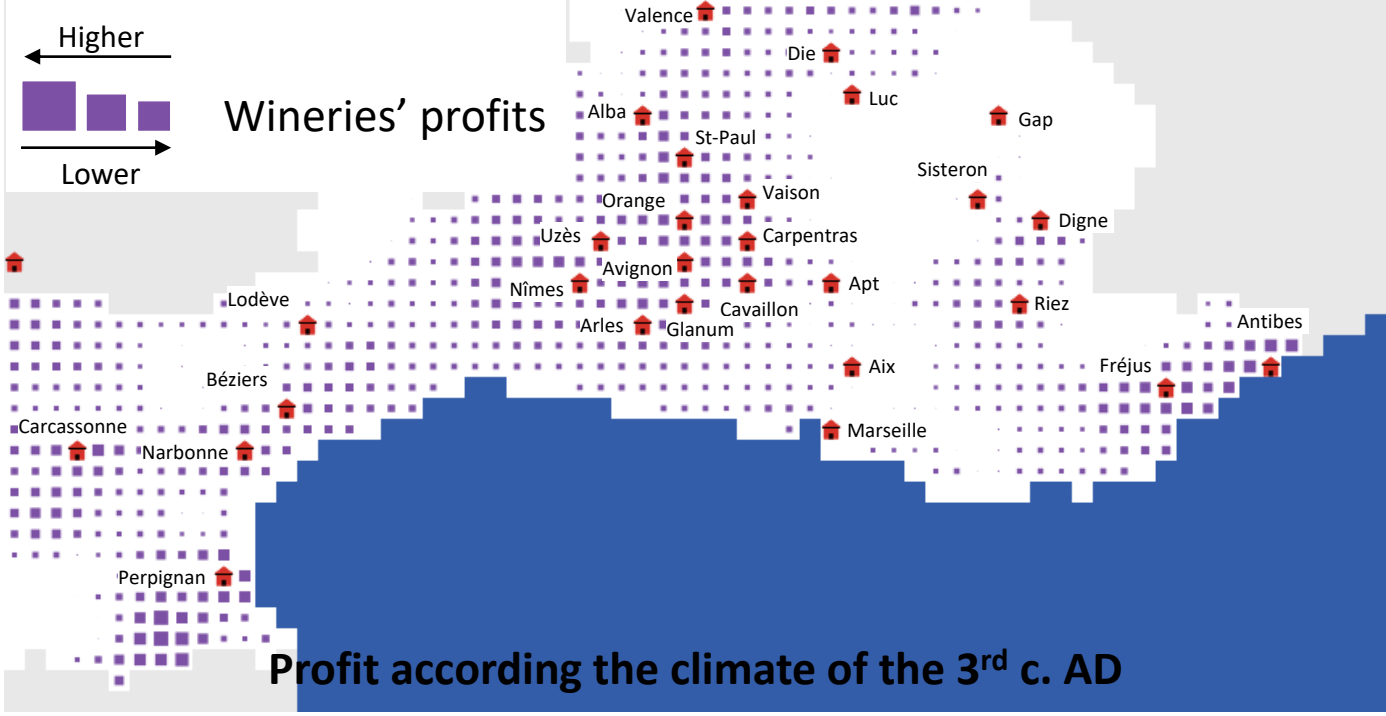


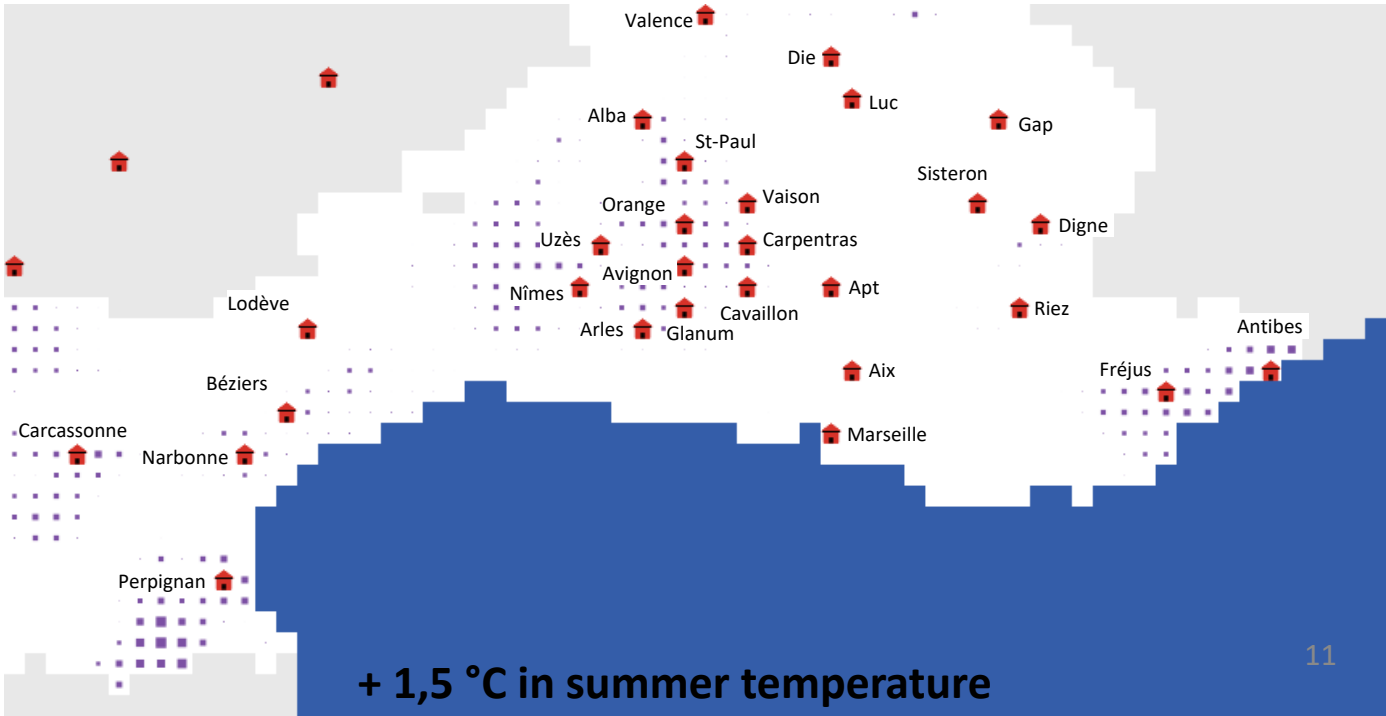
Simulating variations of SEASONAL TEMPERATURES AND PRECIPITATIONS on agricultural goods profitability

Simulation of wineries' profits in 3rd c. AD

- Negative effect of an increase of + 1,5 °C in summer temperature on wineries' profits
- Decrease of the sum of profits from 451 to 184 millions of sestertius

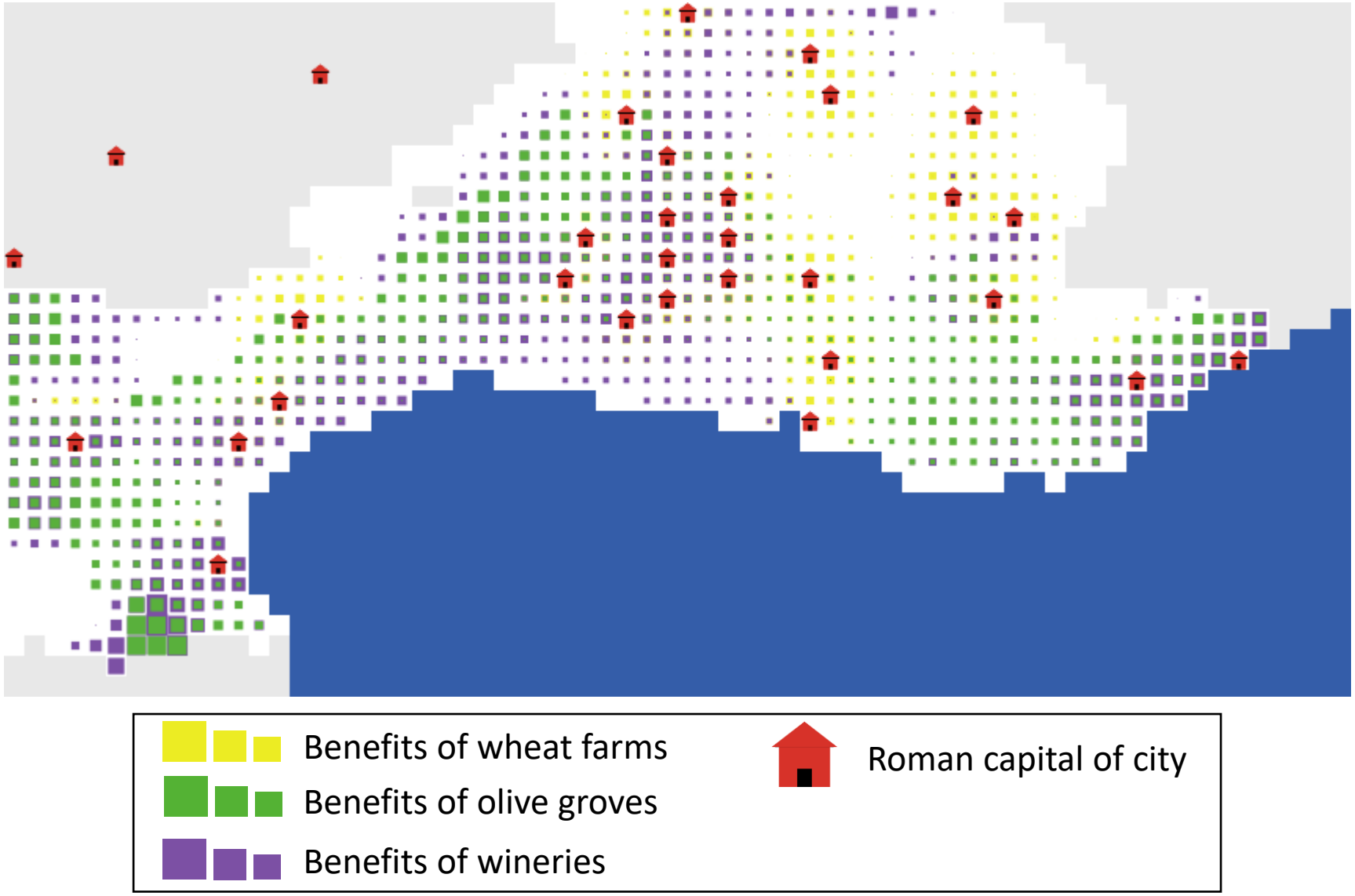






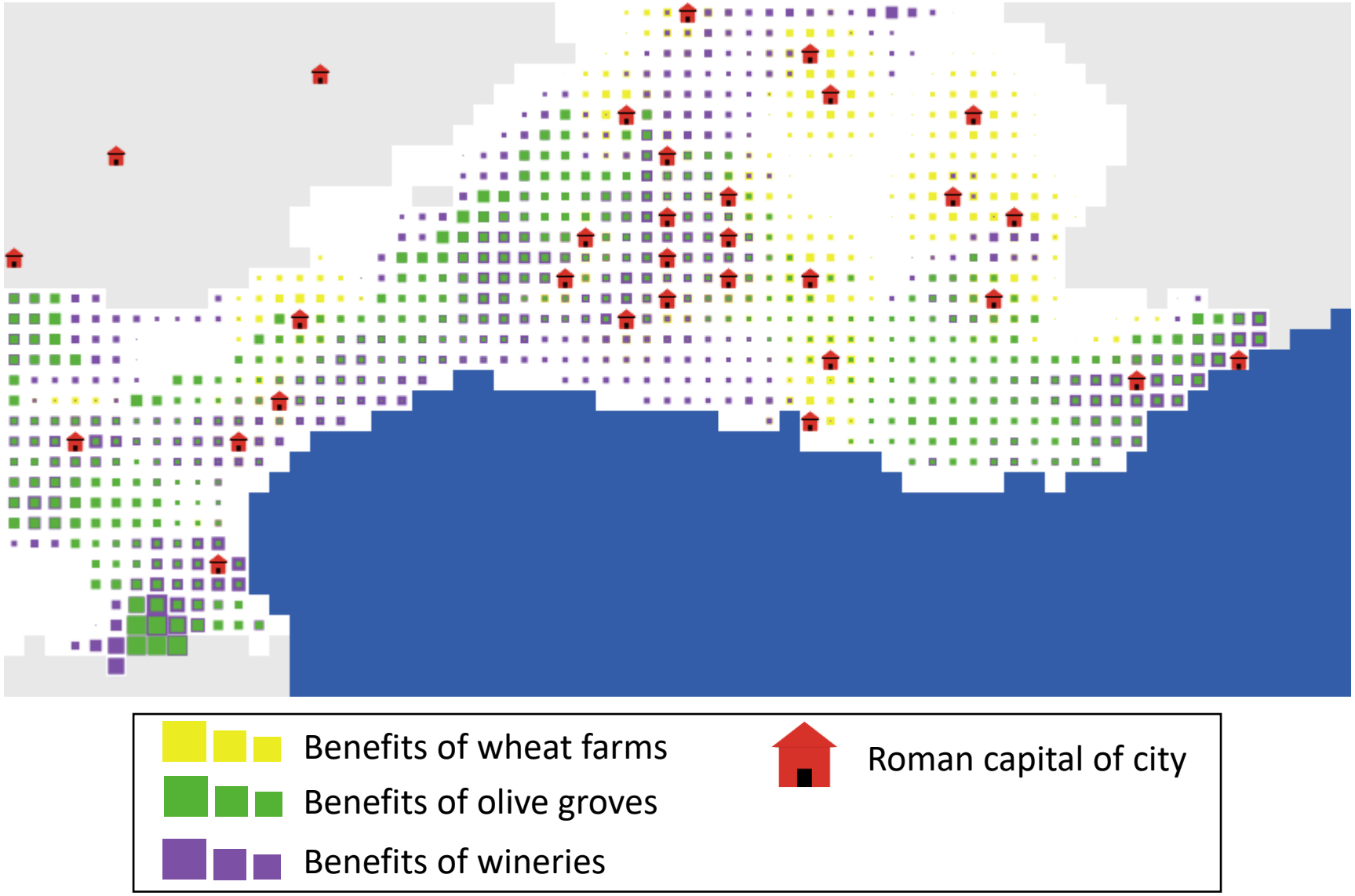
2500 BP

6th c. BC



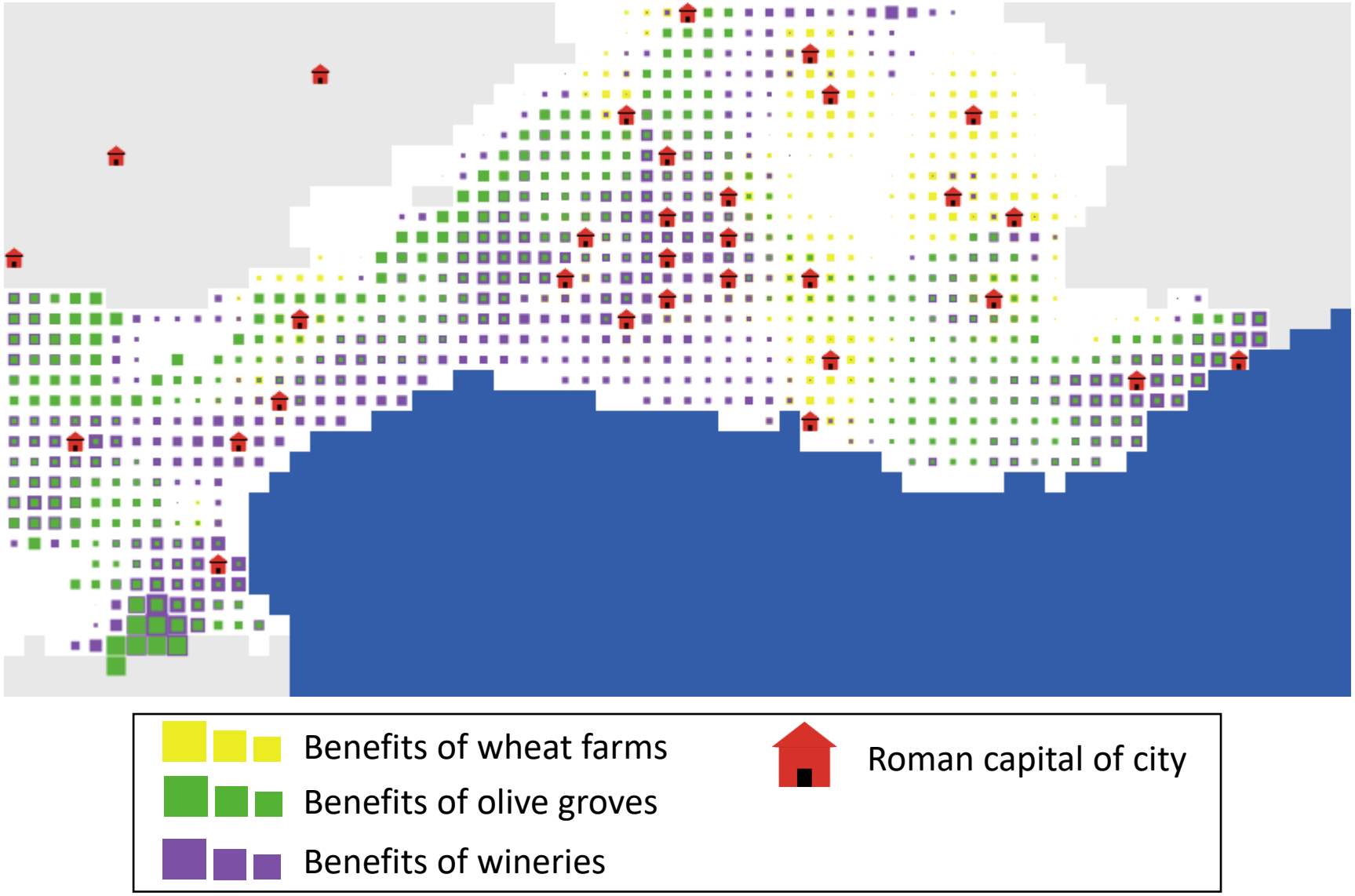
2400 BP

5th c. BC



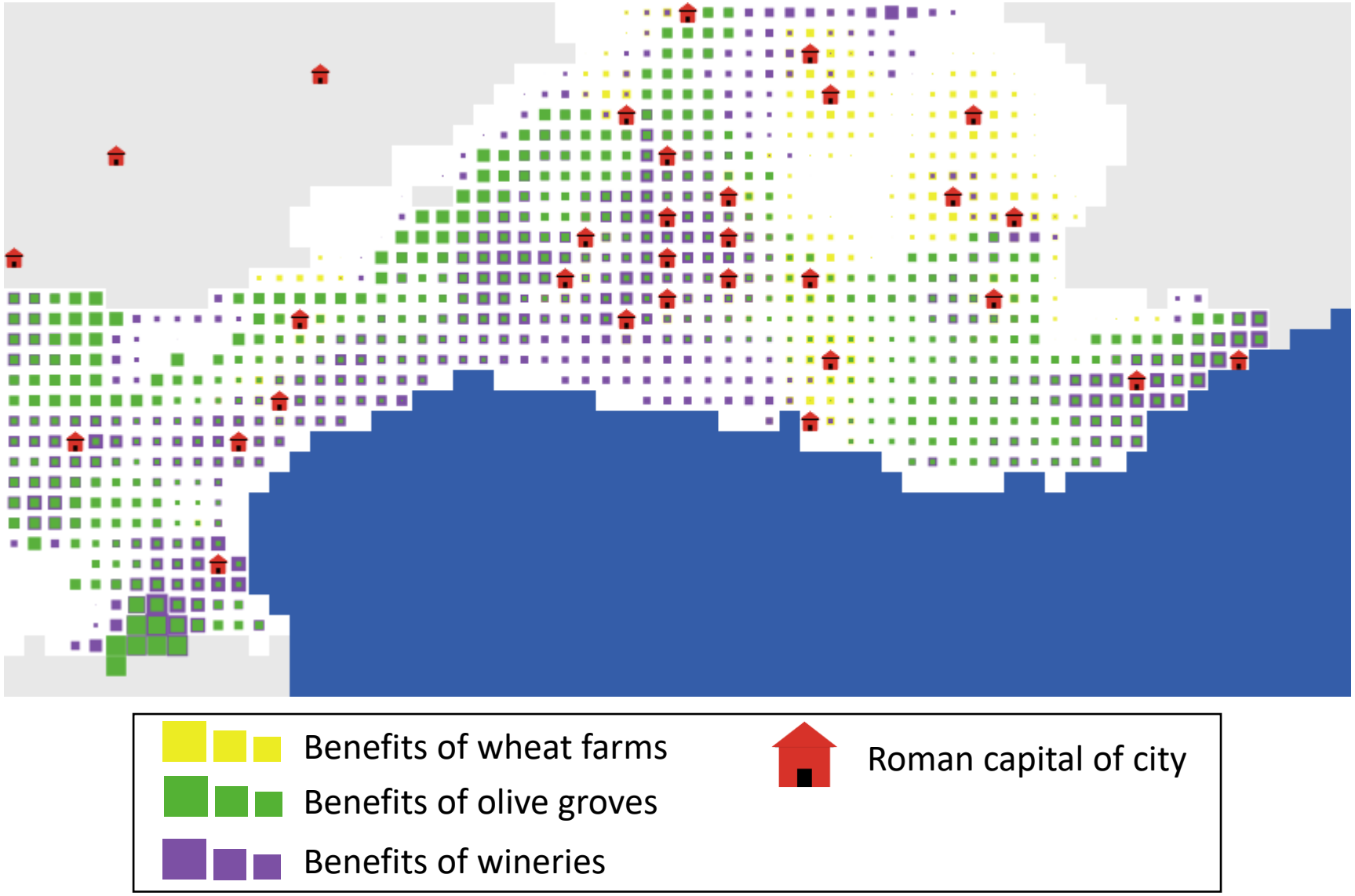
2300 BP

4th c. BC



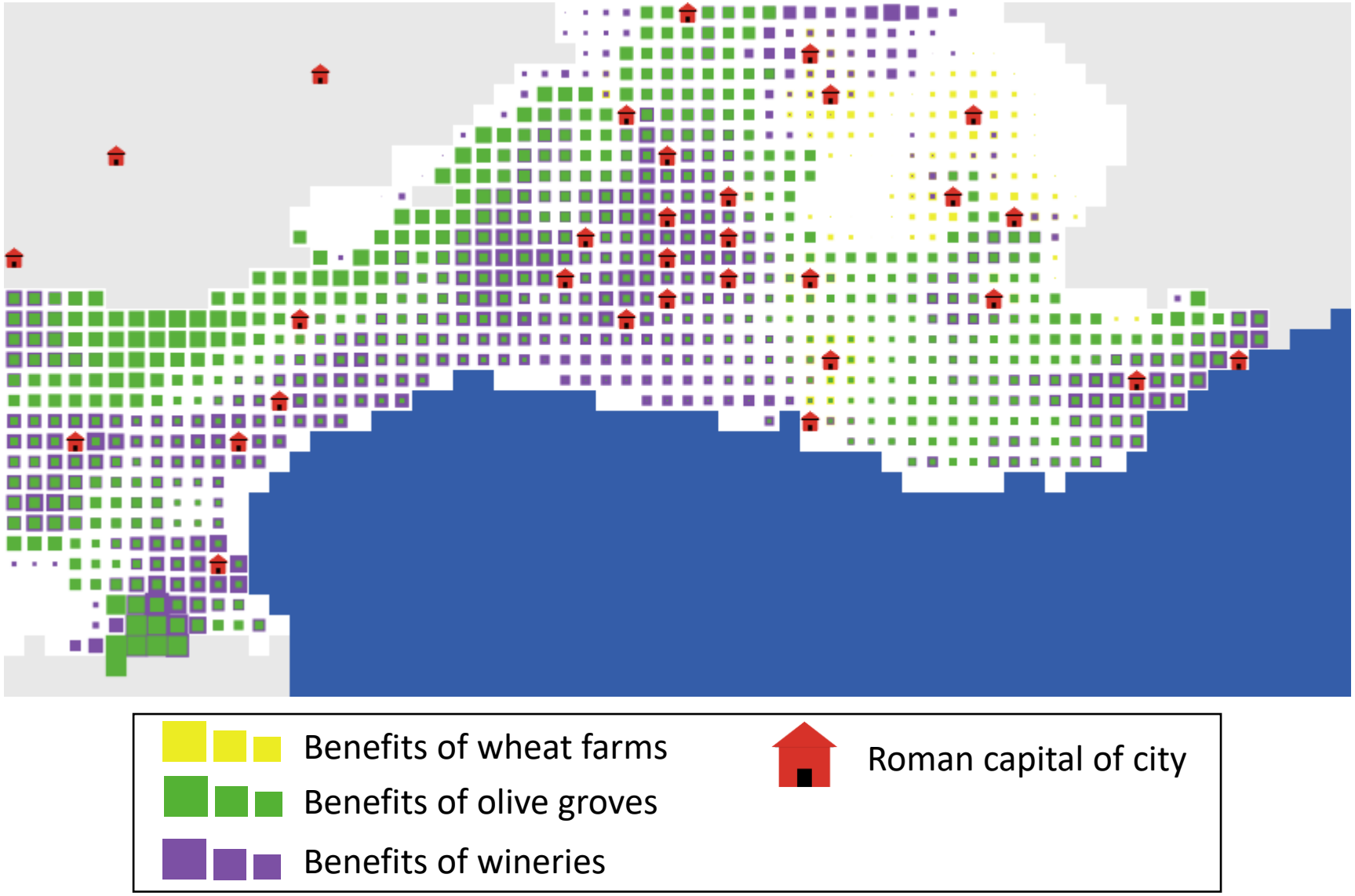
2200 BP

3rd c. BC



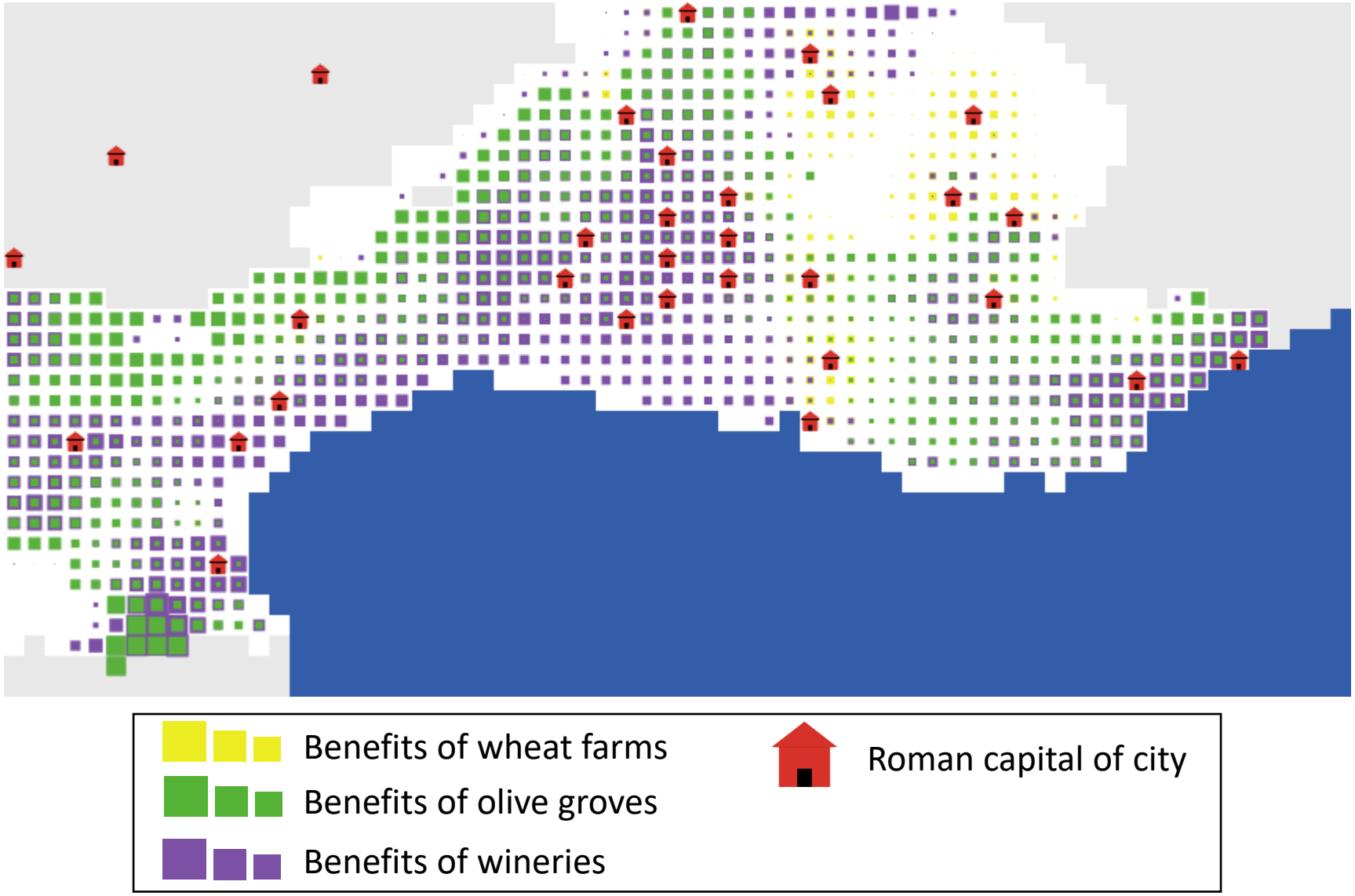
2100 BP

2nd c. BC



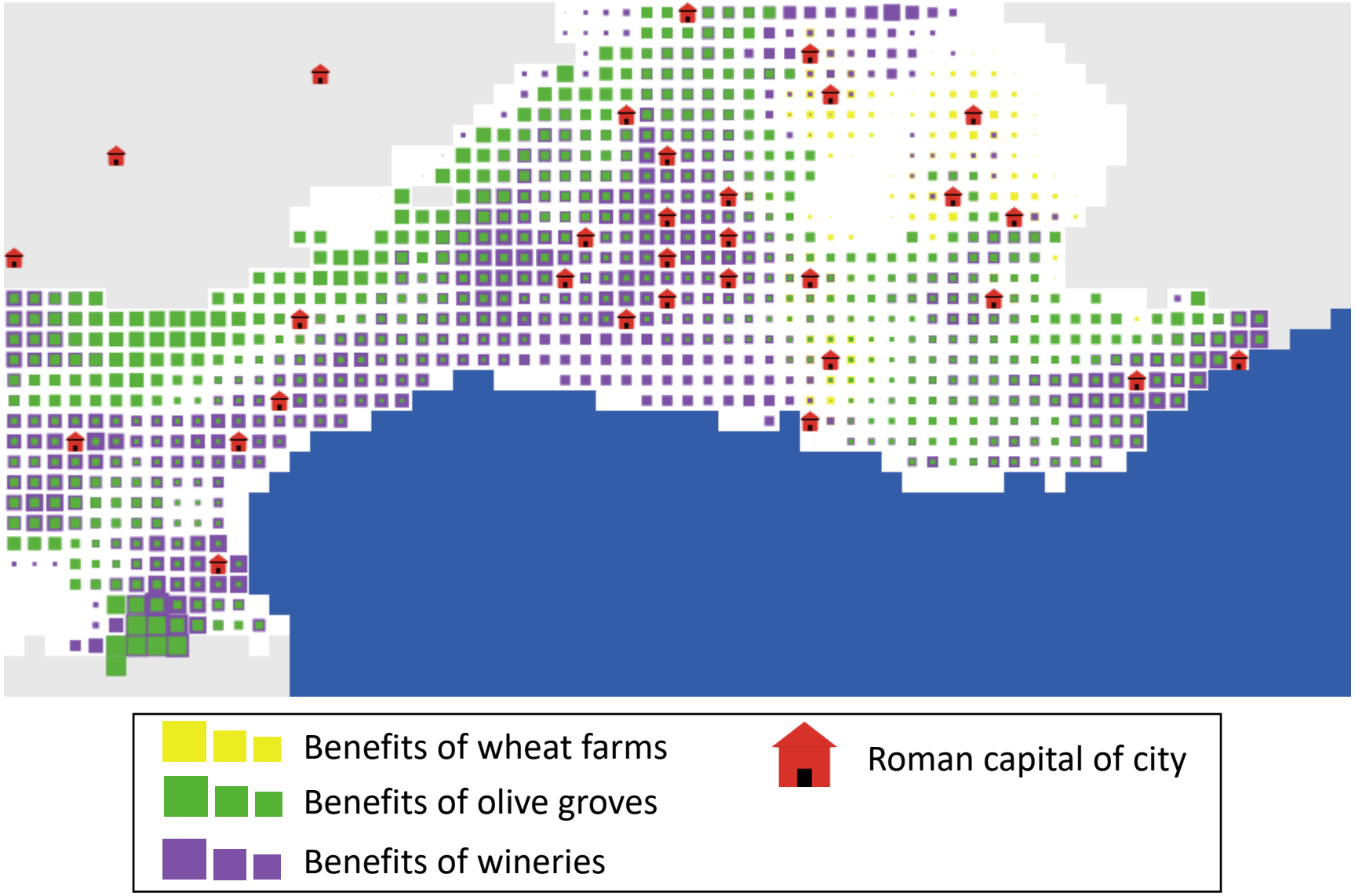
2000 BP

1st c. BC



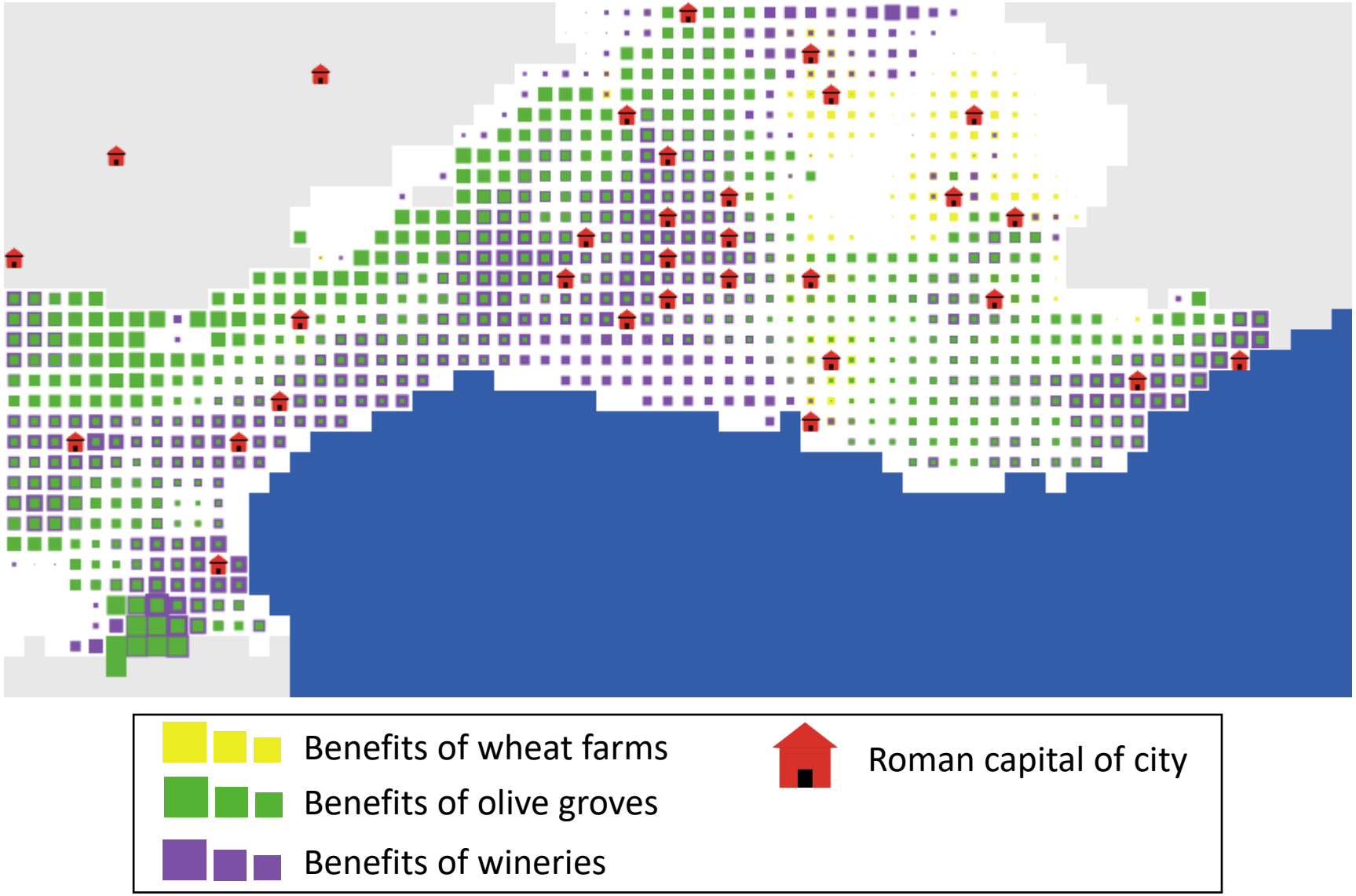
1900 BP

1st c. AD



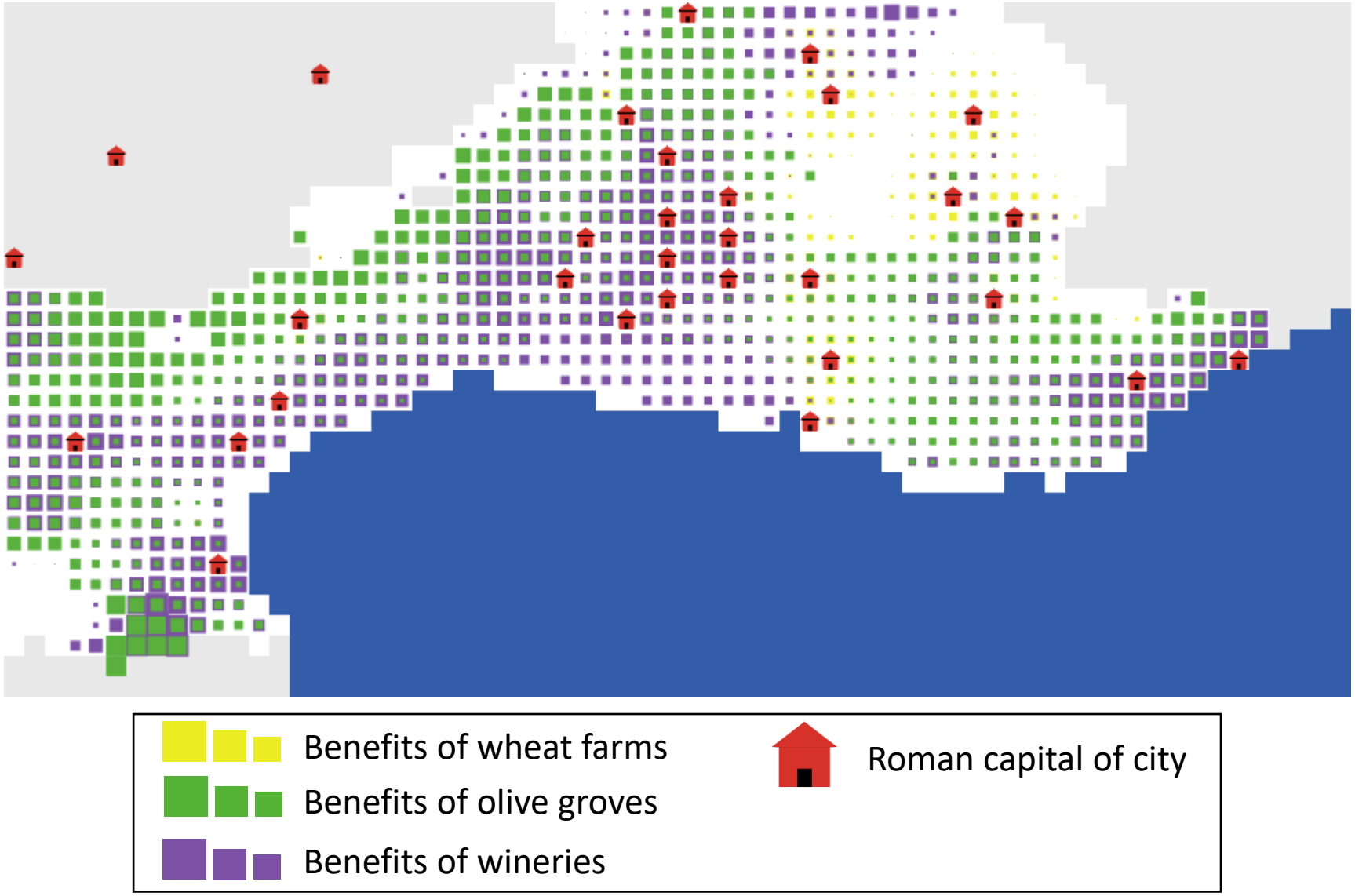
1800 BP

2nd c. AD



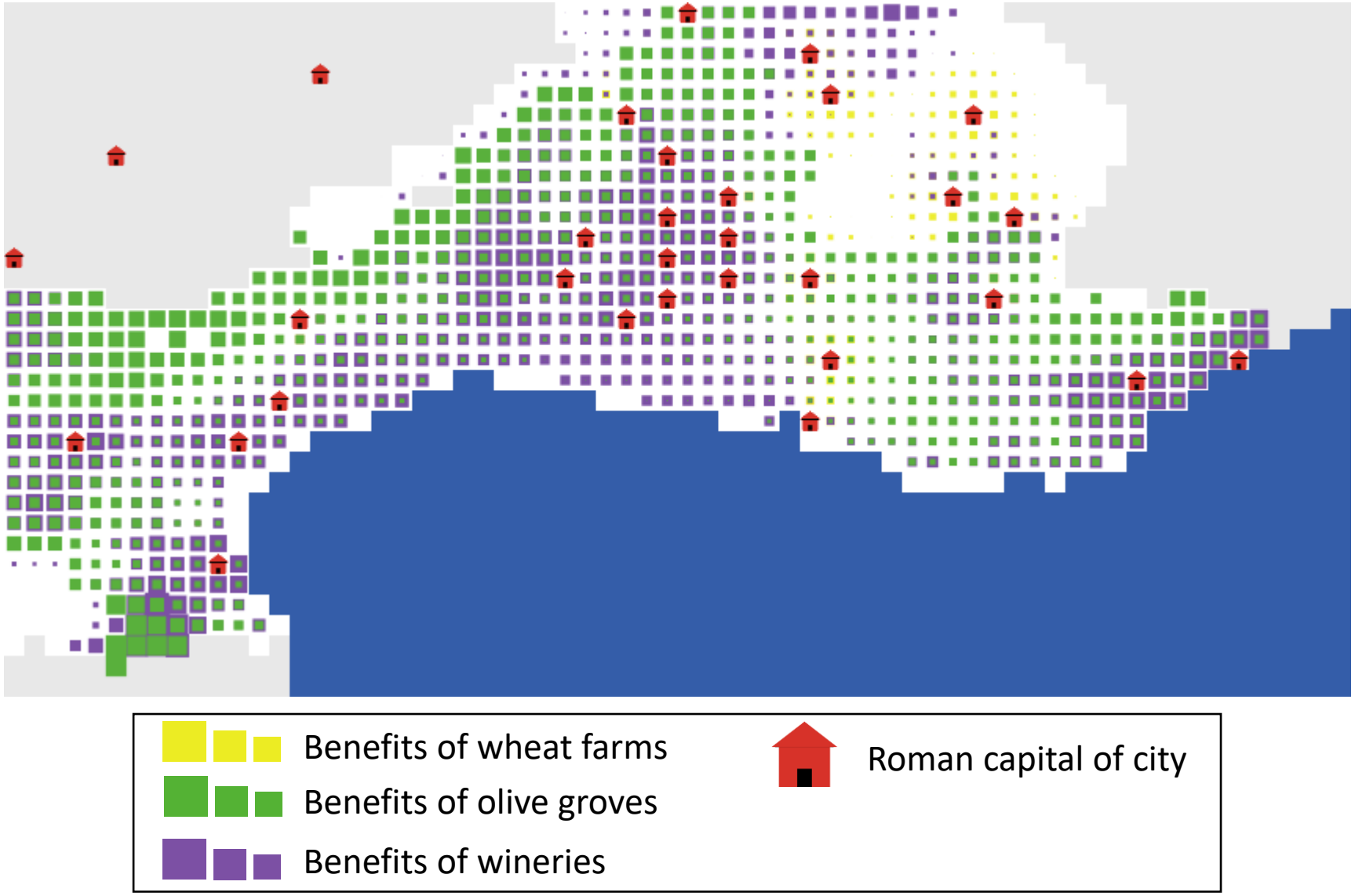
1700 BP

3rd c. AD



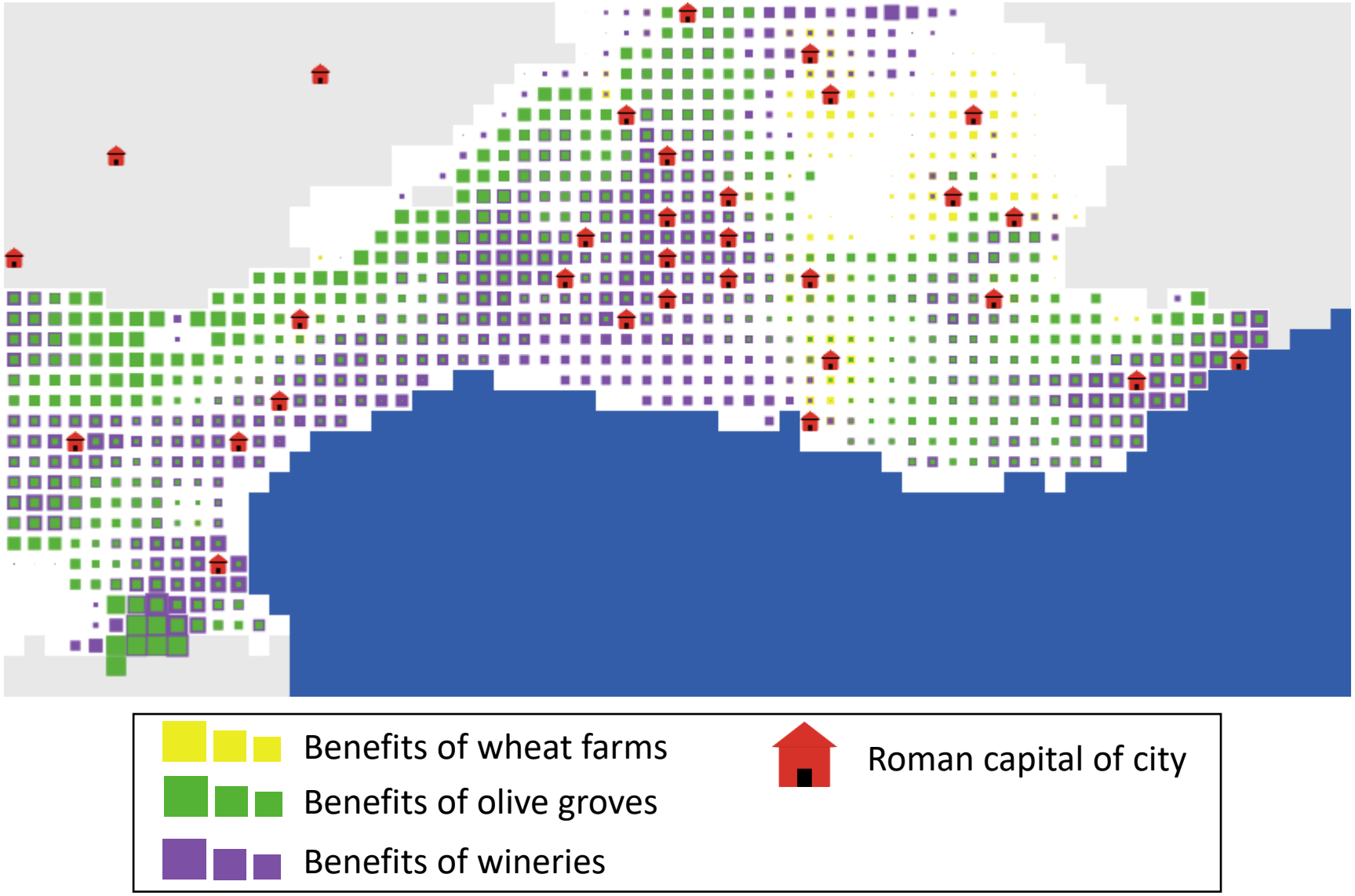
1600 BP

4th c. AD



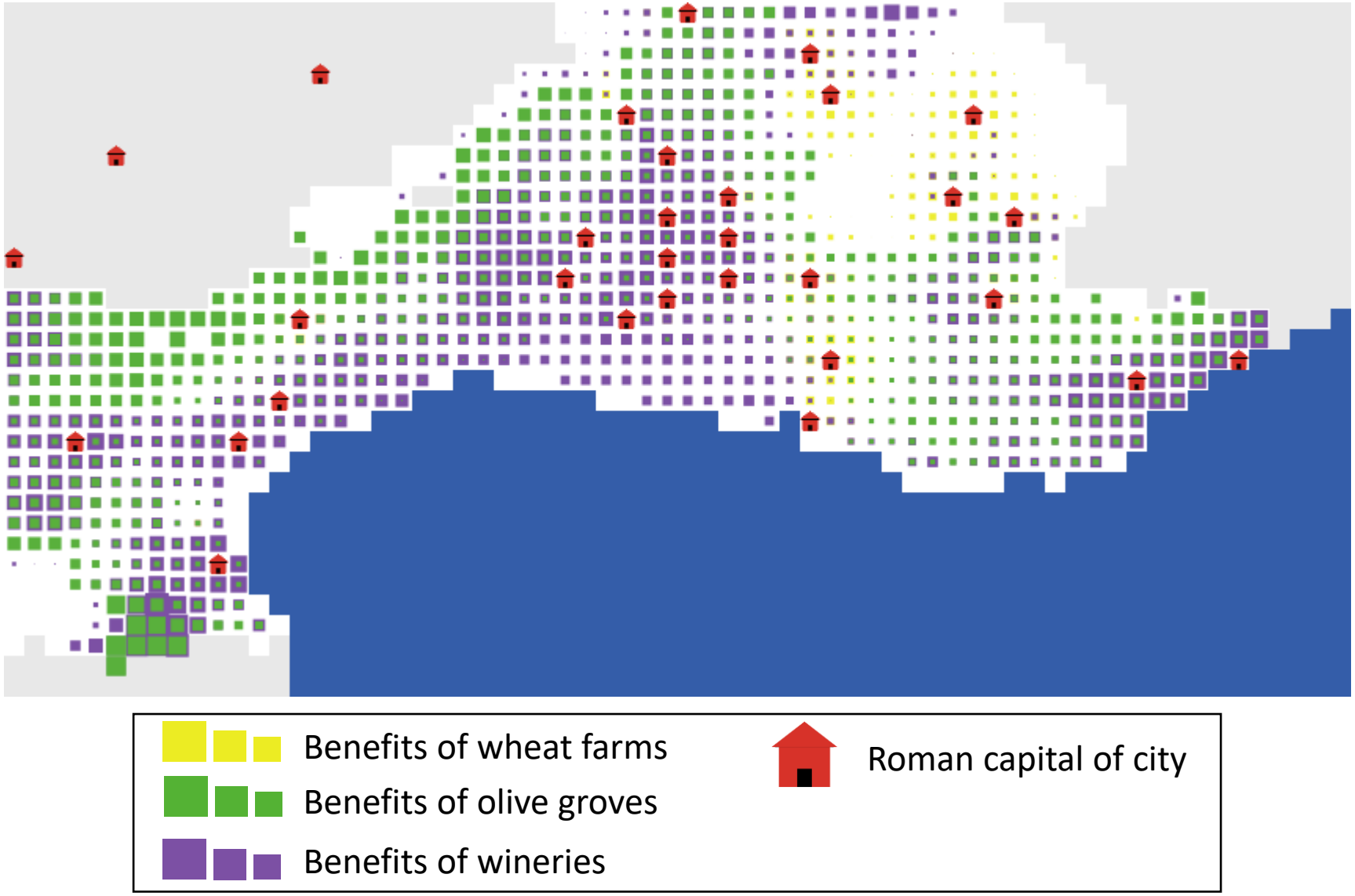
1500 BP

5th c. AD



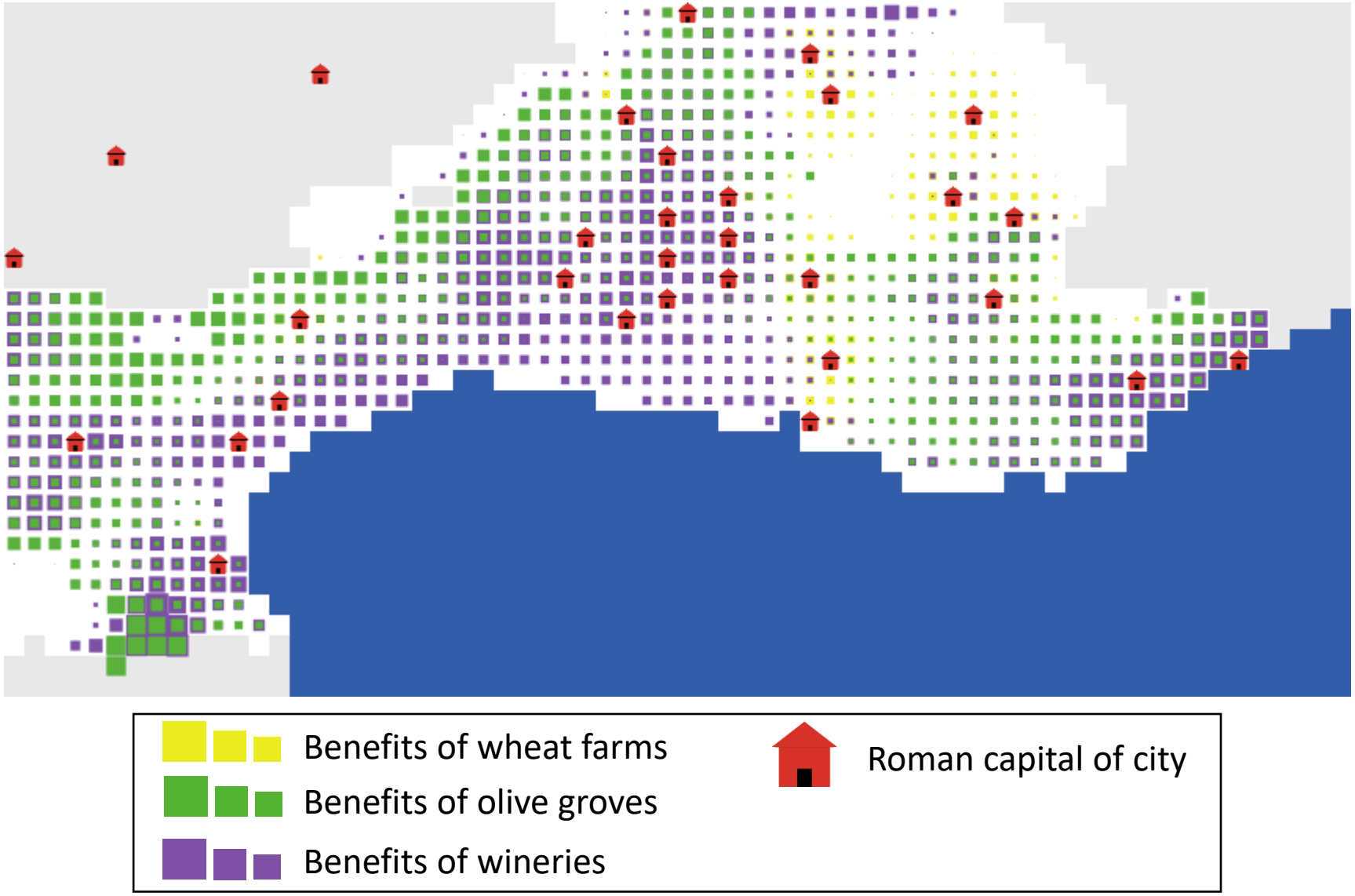
1400 BP

6th c. AD



1300 BP

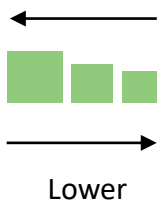
7th c. AD



Profitability of olive groves /climate of 6th c. BC vs 1st c. AD

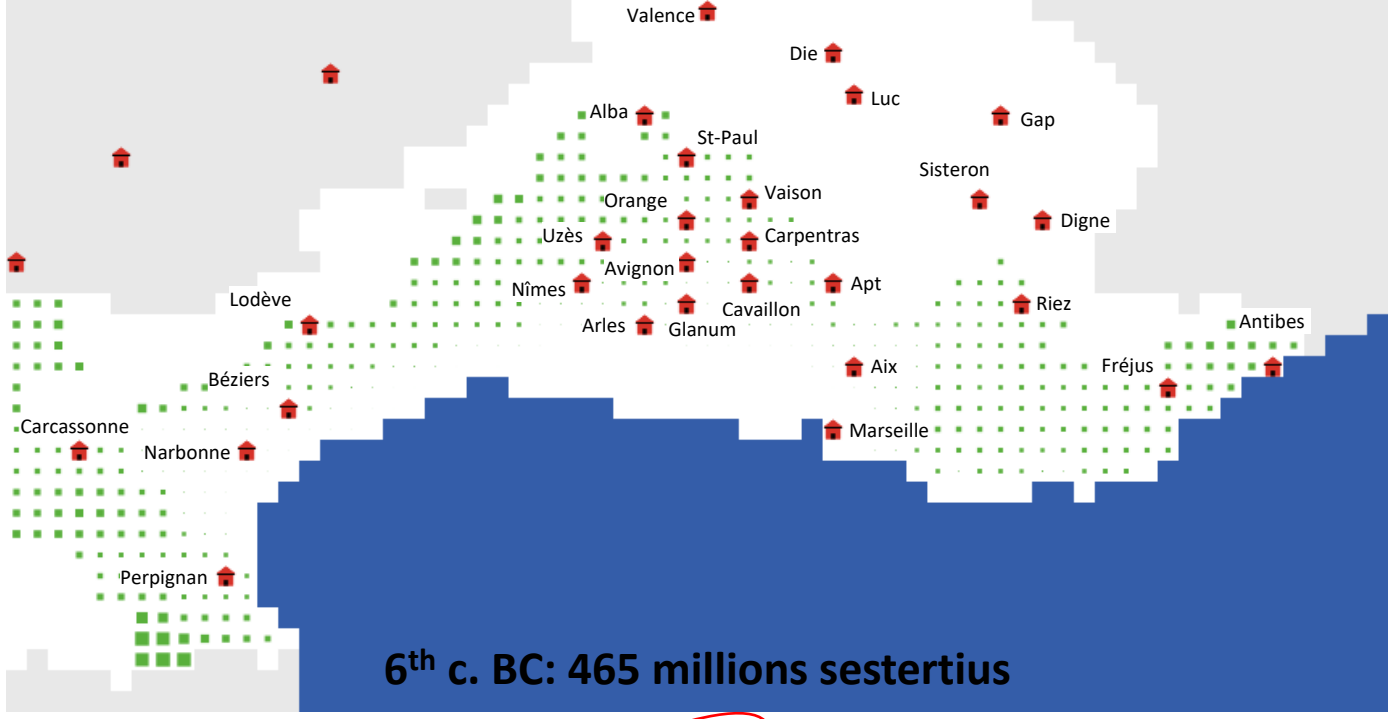
- Higher profitability of olive groves in the 1st c. AD compared to 6th c. BC , noticeably in the languedocian hinterland
  - **Olive oil price = 6 *denarius/sextarius***
  - **Transport costs = 0.2 sesterces/km/kg**
  - **Area cultivated = 240 *jugera* (60 ha)**
  - **Number of farmers/exploitation = 13**

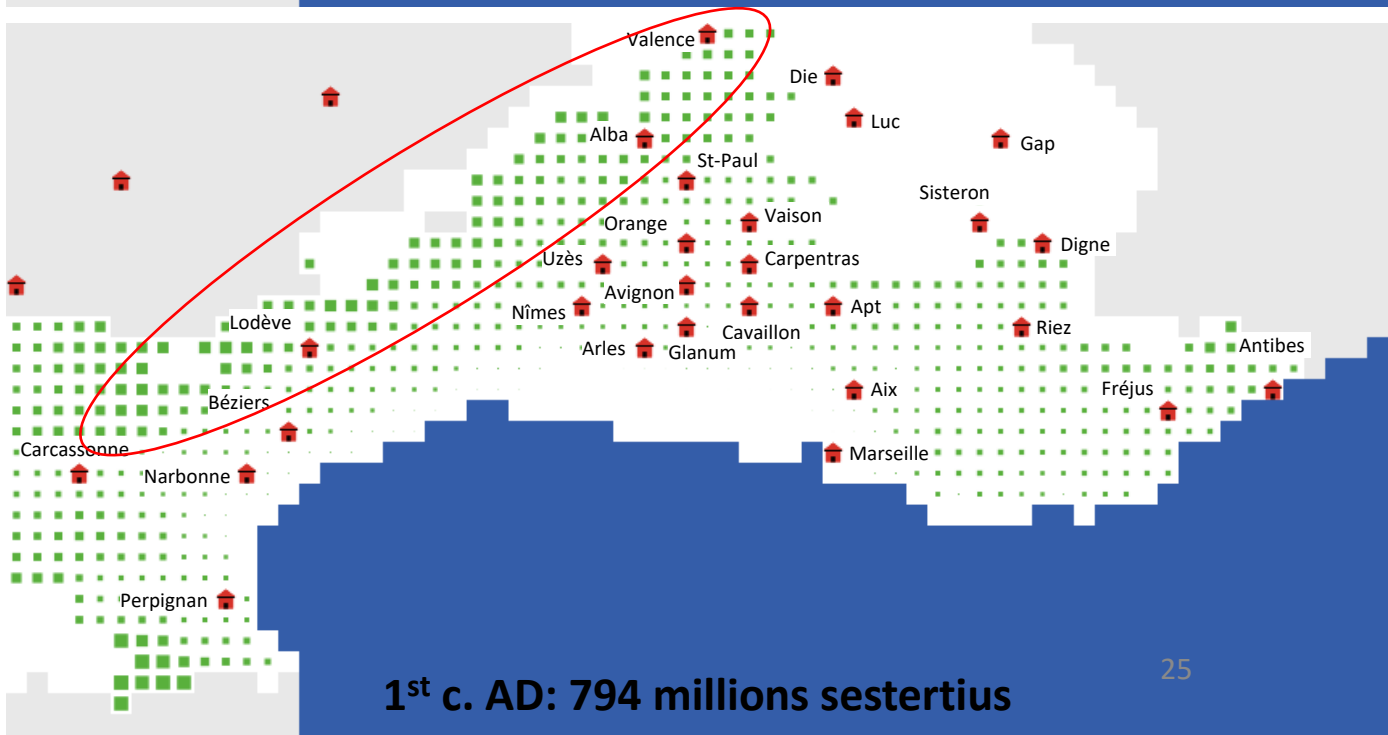
Higher



Lower

Olives groves' profits

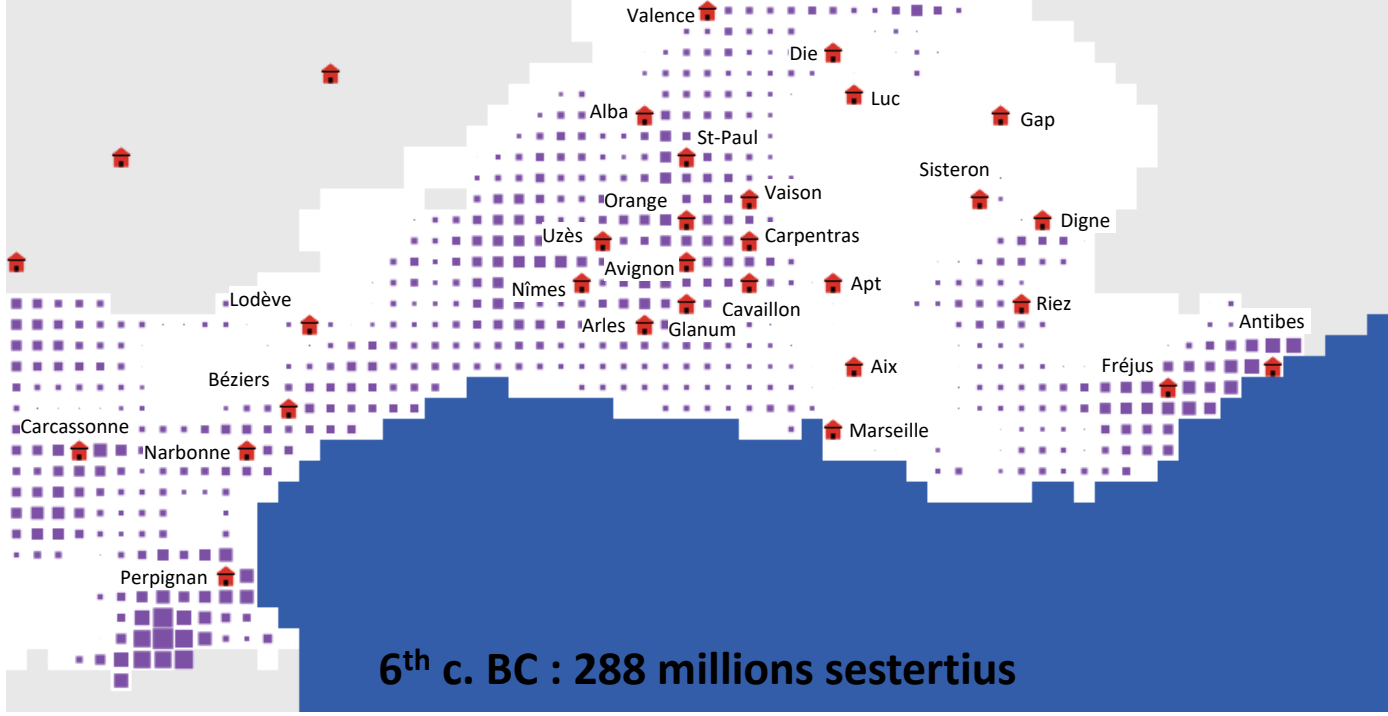


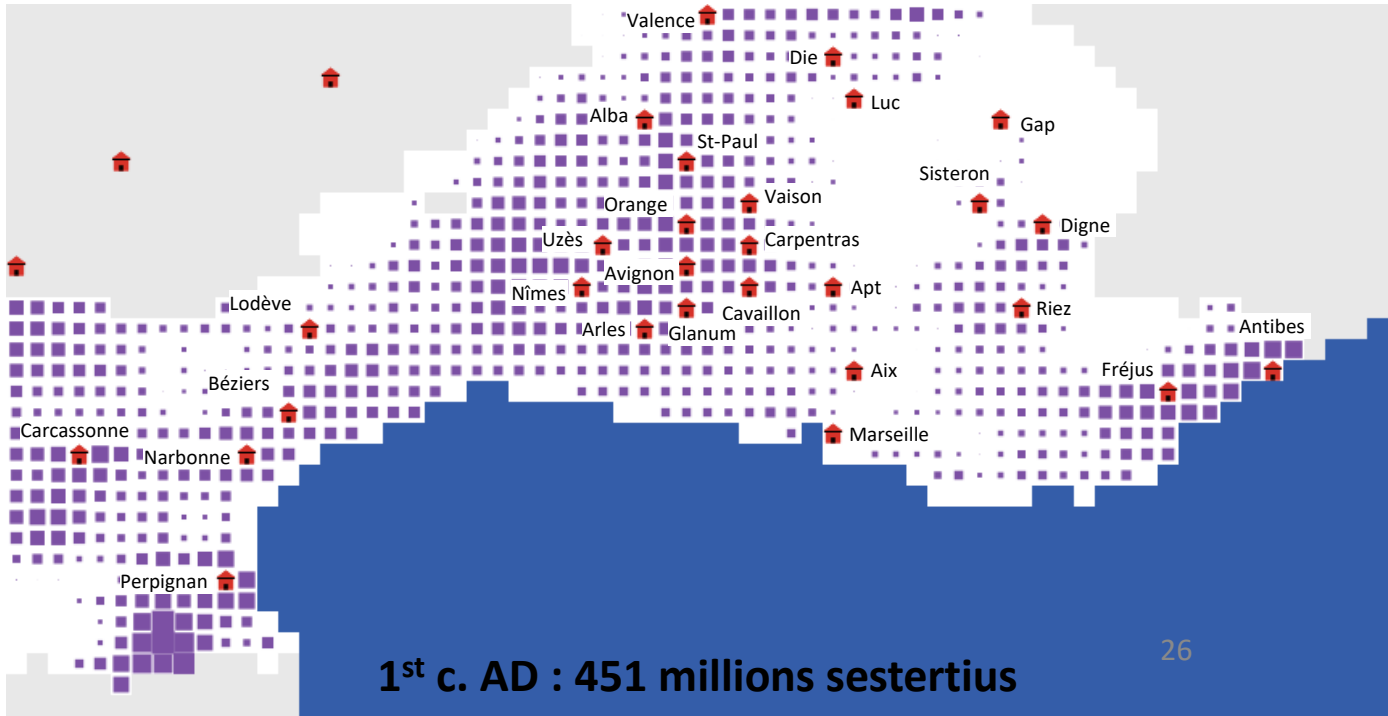


Profitability of wineries /climate of 6th c. BC vs 1st c. AD

- Higher profitability of wineries in the 1st c. AD (451 millions sestertius) compared to 6th c. BC (288 millions sestertius), noticeably in the middle Rhone Valley
  - **Wine price = 6 denarius/sextarius**
  - **Transport costs = 0.2 sesterces/km/kg**
  - **Area cultivated = 100 *jugera* (25 ha)**
  - **Number of farmers/exploitation = 14**

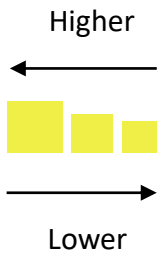
Wineries' profits



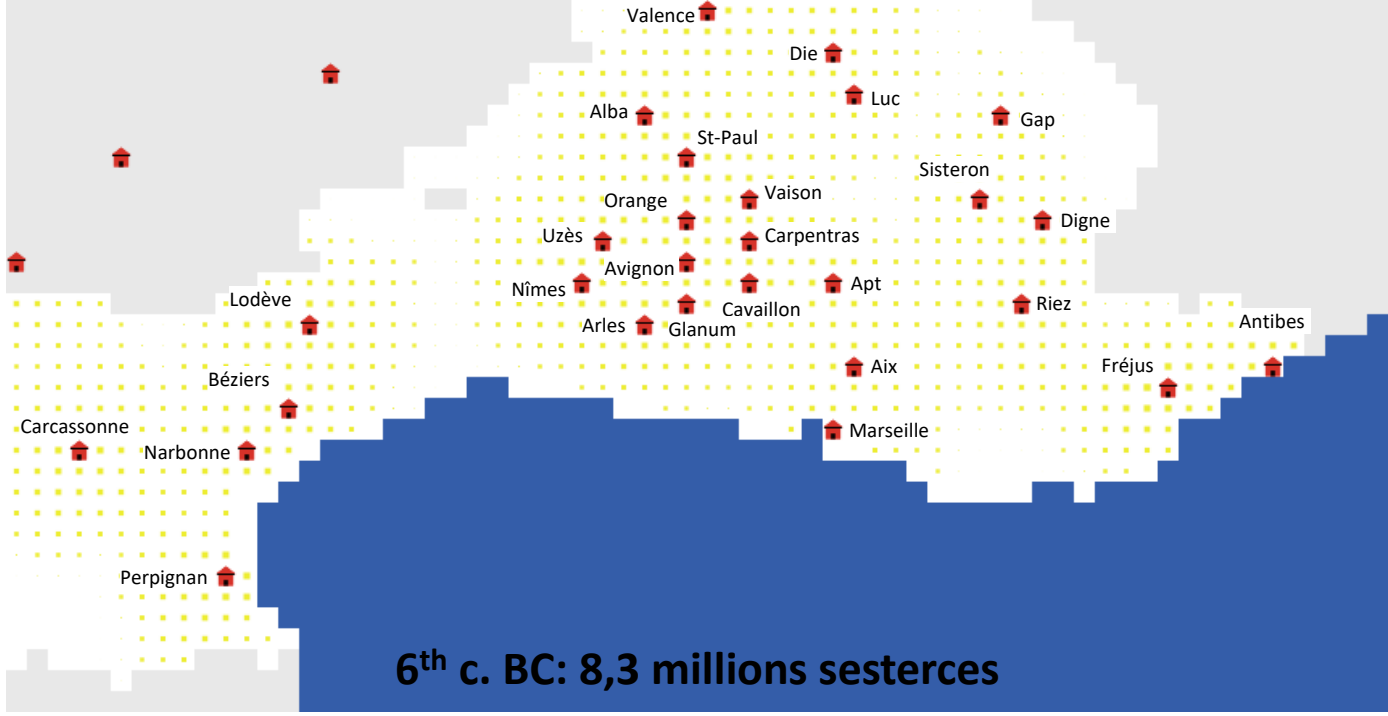


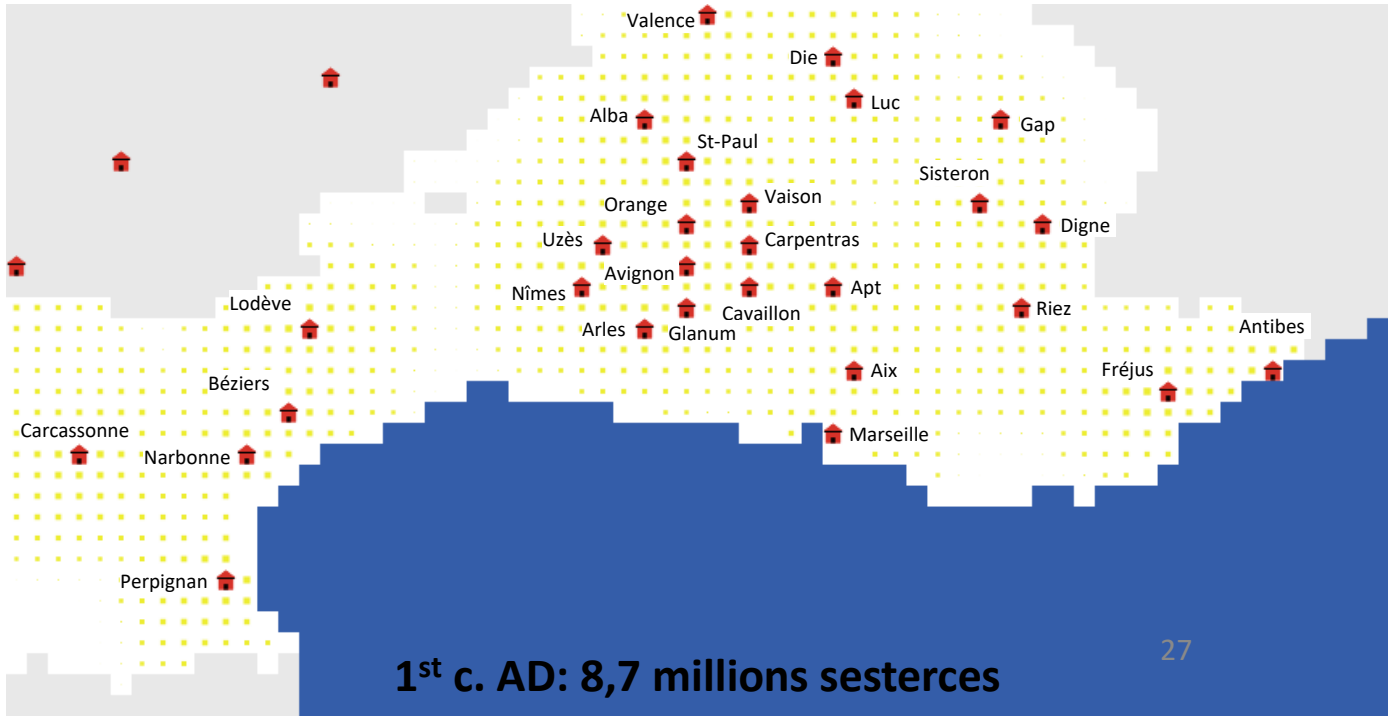
Profitability of wheat farms /climate of 6th c. BC vs 1st c. AD

- Increase in the profitability of wheat farms in the 1st c./6th c. BC appear very less important (0,04 %)
  - **Area cultivated = 2,8 ha**
  - **Wheat price = 50 denarius/modius**
  - **Transport costs = 0,2 sesterces/km/kg**
  - **Number of farmers/exploitation = 6**



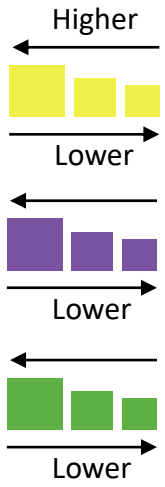
Farms wheats' profits





Profitability of wineries, olive groves & wheat farms /climate

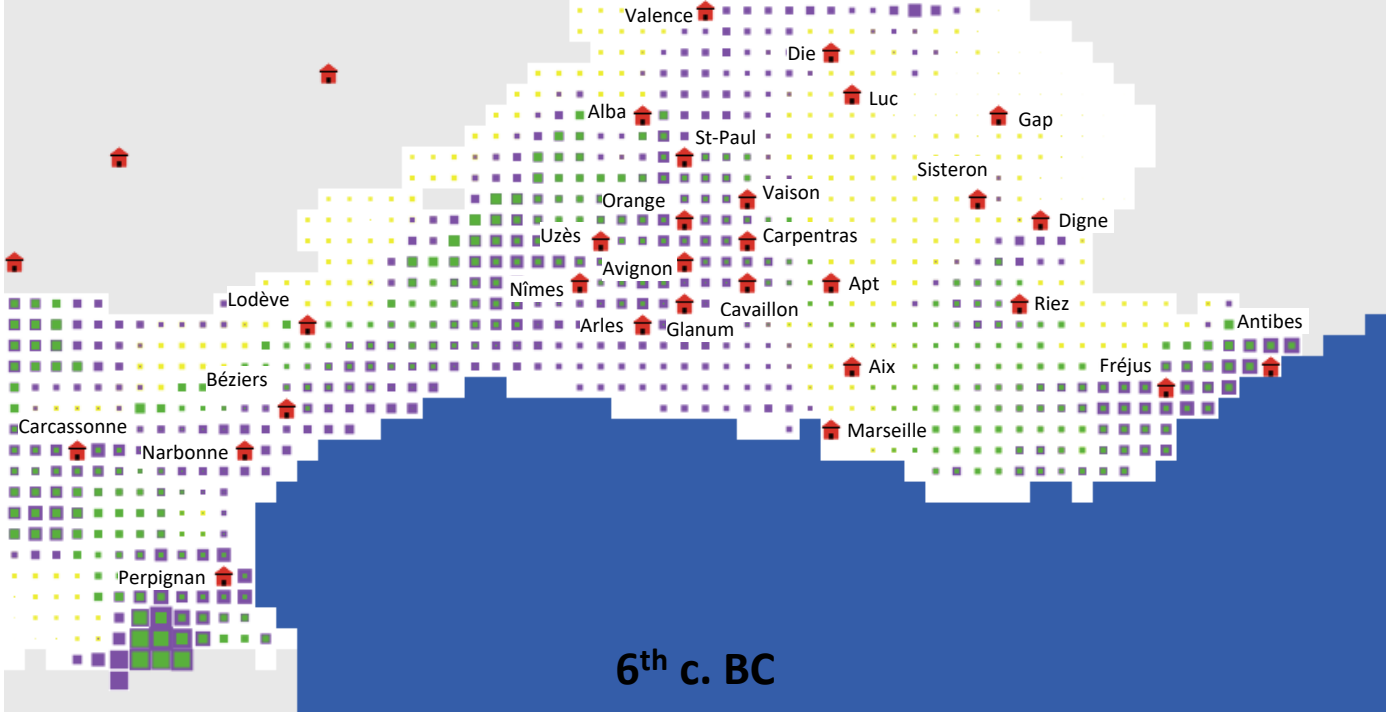
- Higher profitability for the productions according to the climate of the 1st c. AD (bellow) /6th BC (top)
- Model produces a virtual land use map with areas specialized in a specific type of production

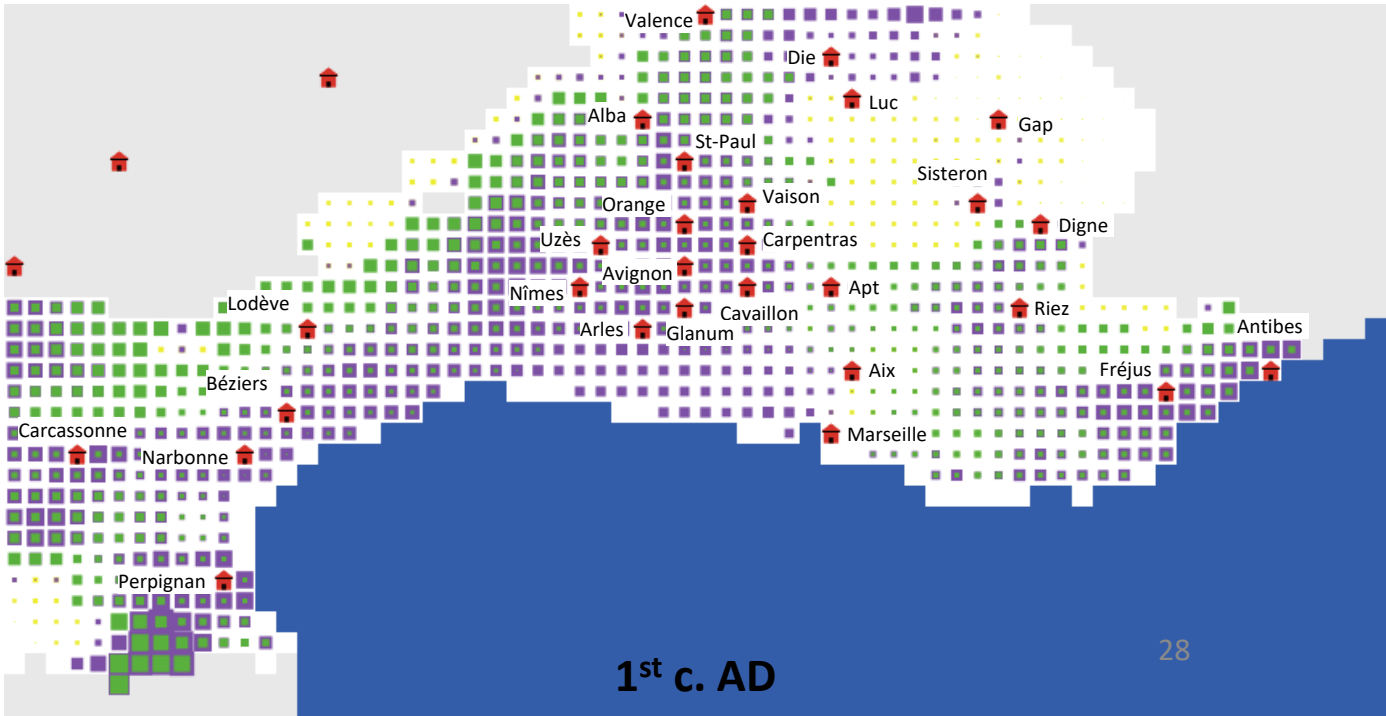


Wheat farms' profits

Wineries' profits

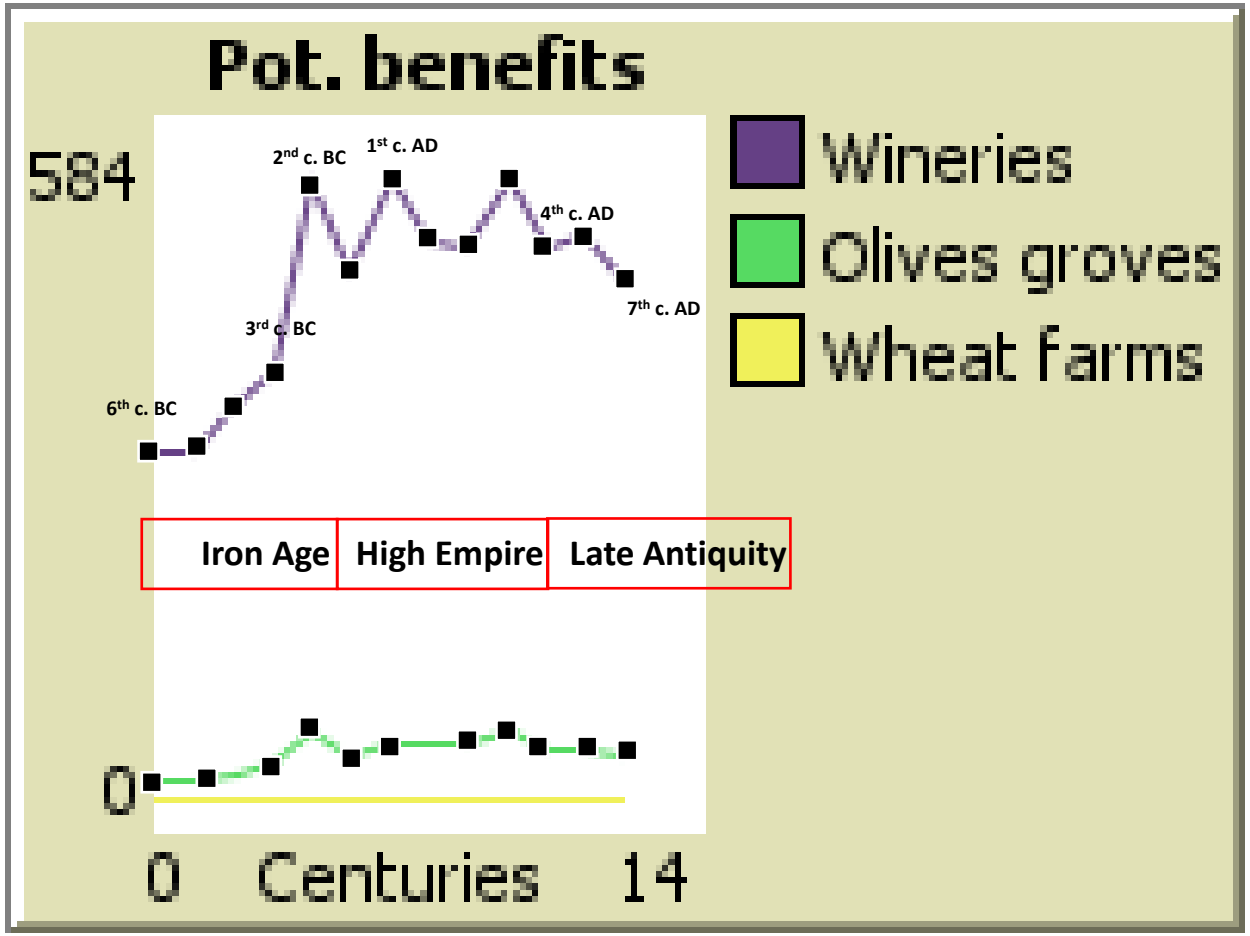
Olive groves' profits





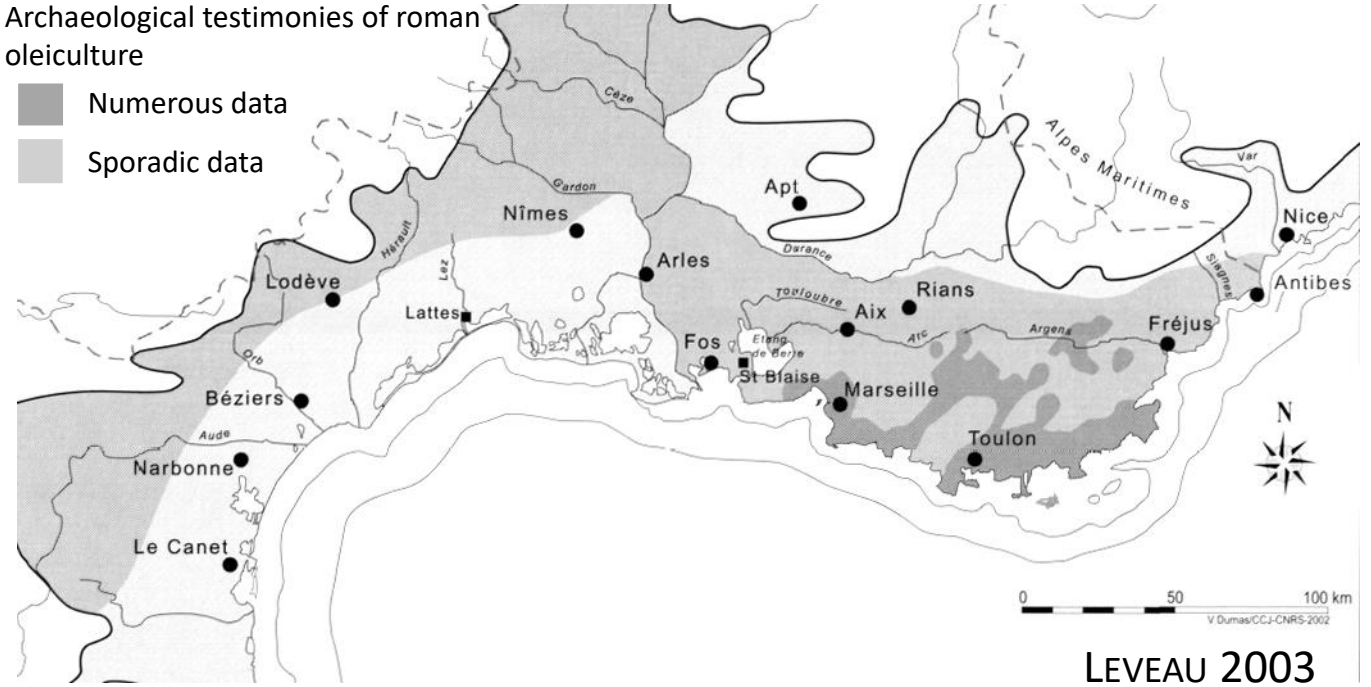
Output of the model: potential benefits (in millions *sestertius*)

- Increase of potential benefits since 6th c. until 2nd c. BC which marks an important peak
- Highest level during late Iron Age and Roman period (2nd peak in 3rd c. AD)
- Decrease during Late Antiquity (4th-7th c. AD)
- Wheat is less sensitive to climate change than wine and olive production

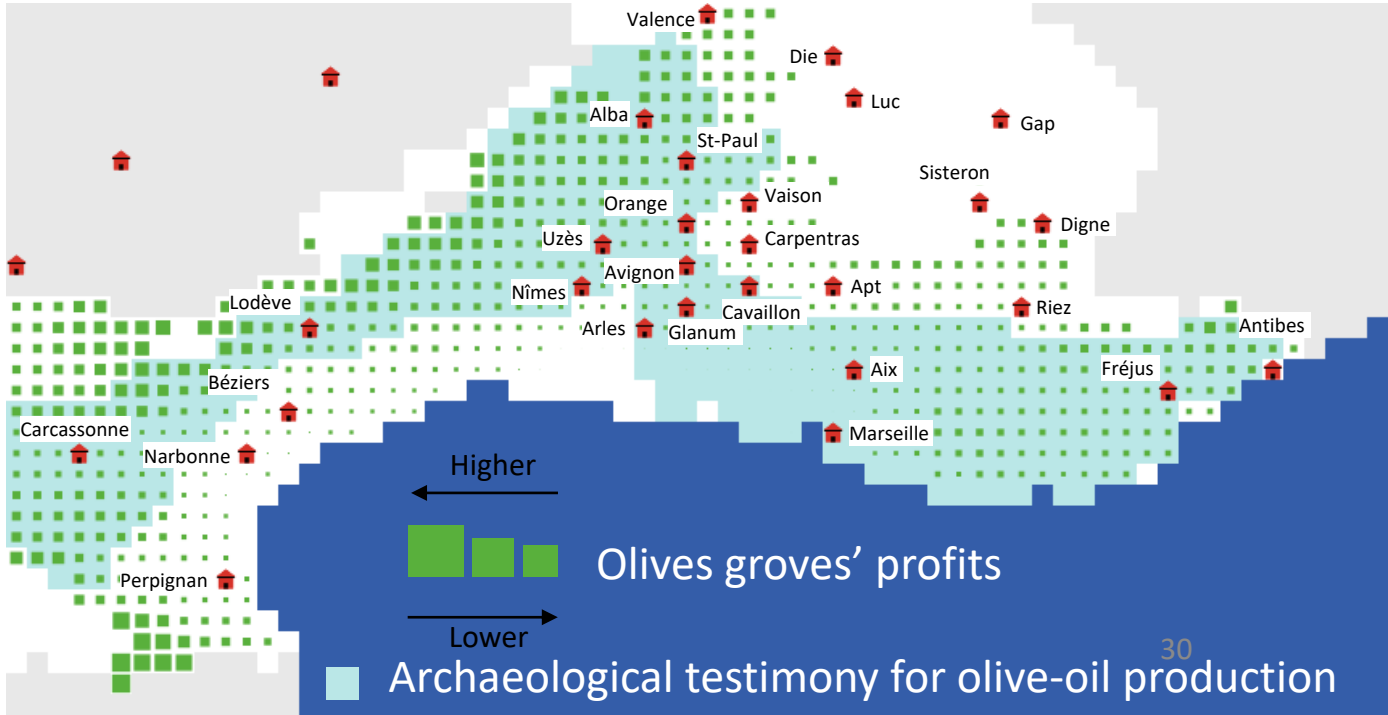


Olive growing: model vs archaeological data

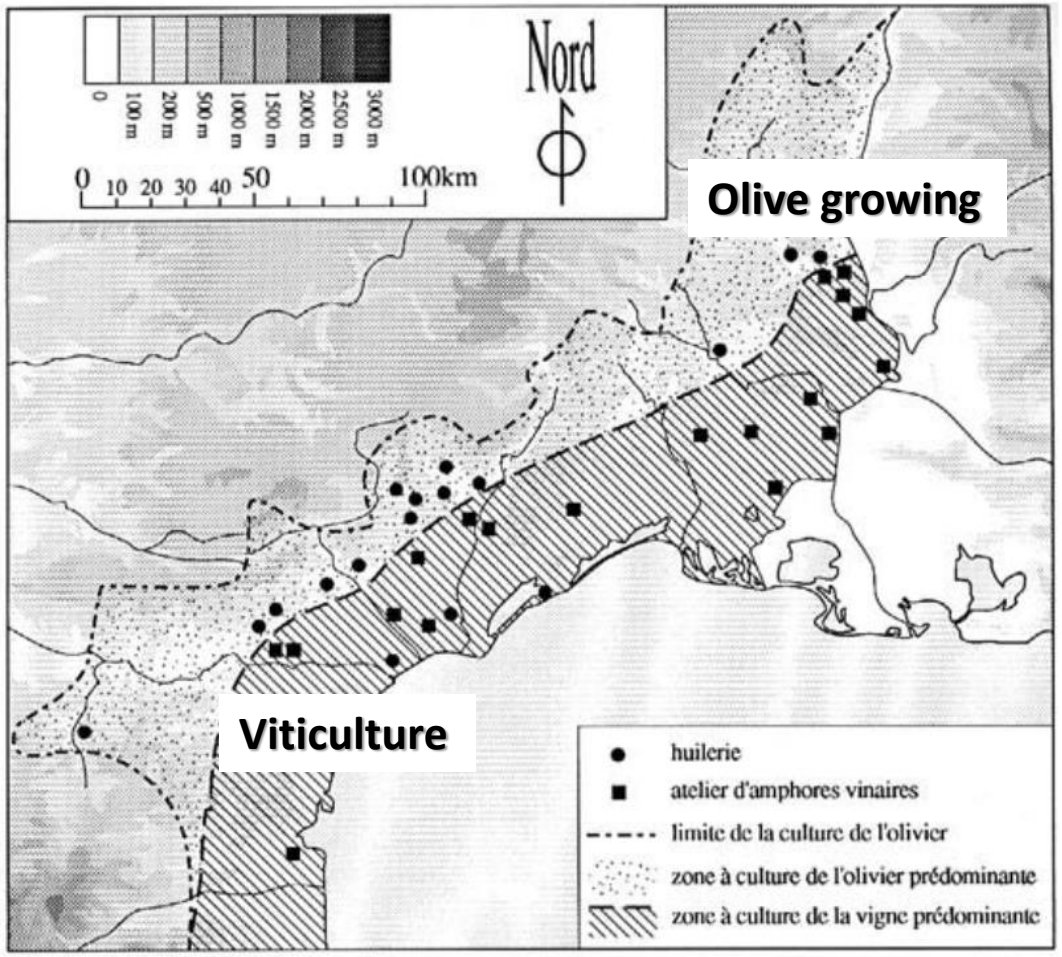
- According archaeological data, roman olive growing was important in Provence, especially in the Var region. But some data indicate also this activity in the languedocian hinterland (LEVEAU 2003)
- The model displays a map similar than the repartition of archeological data, but some differences are noticeable. For the 1st c. A.D. the potential appears good for olive groves in several area where archeological data are lacking: Digne/Riez area, languedocian coast, etc.
- Is importance of roman oleiculture still underrated by archaeological researches in these areas ?
- Or is it an artifact of the model ?



LEVEAU 2003

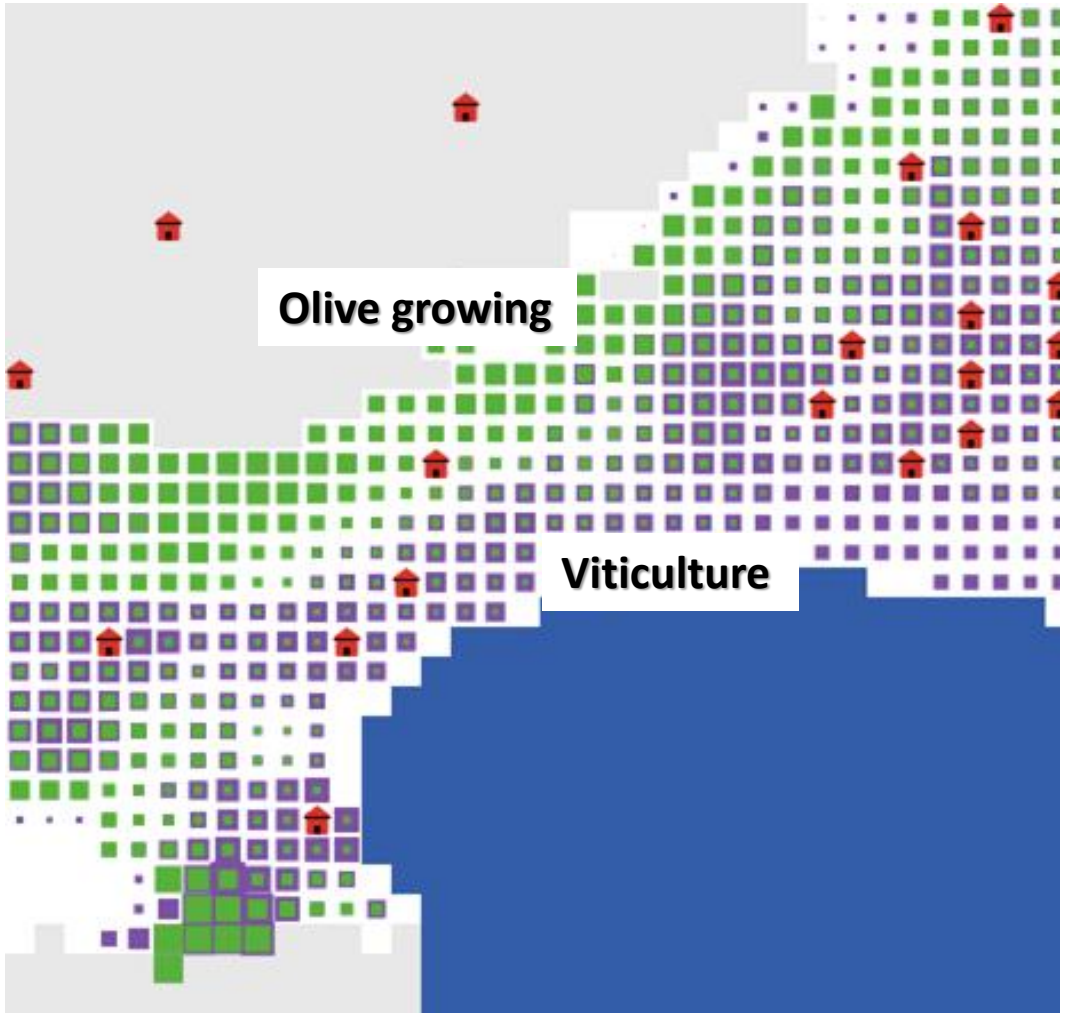


Olive growing: model vs archaeological data



• **28:** Carte de localisation des installations de pressurages et des ateliers d'amphores vinaires.

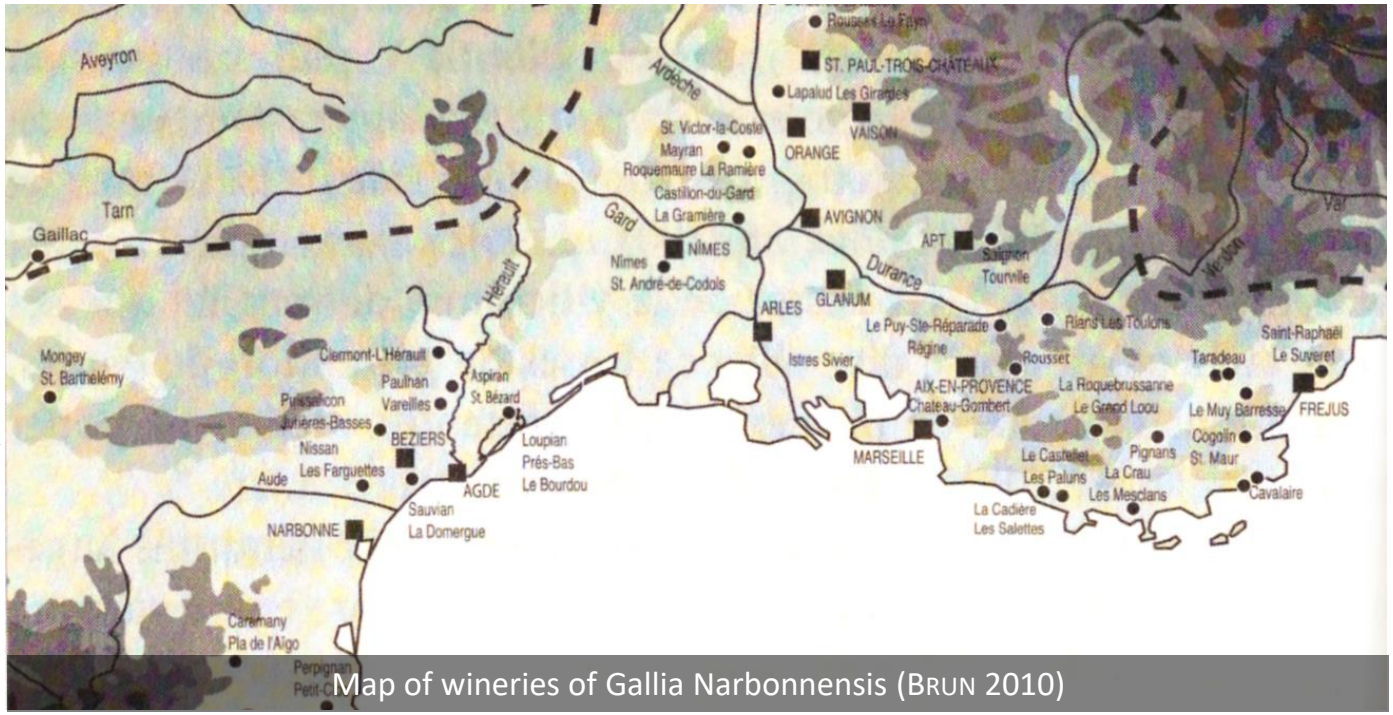
After Garcia 1992



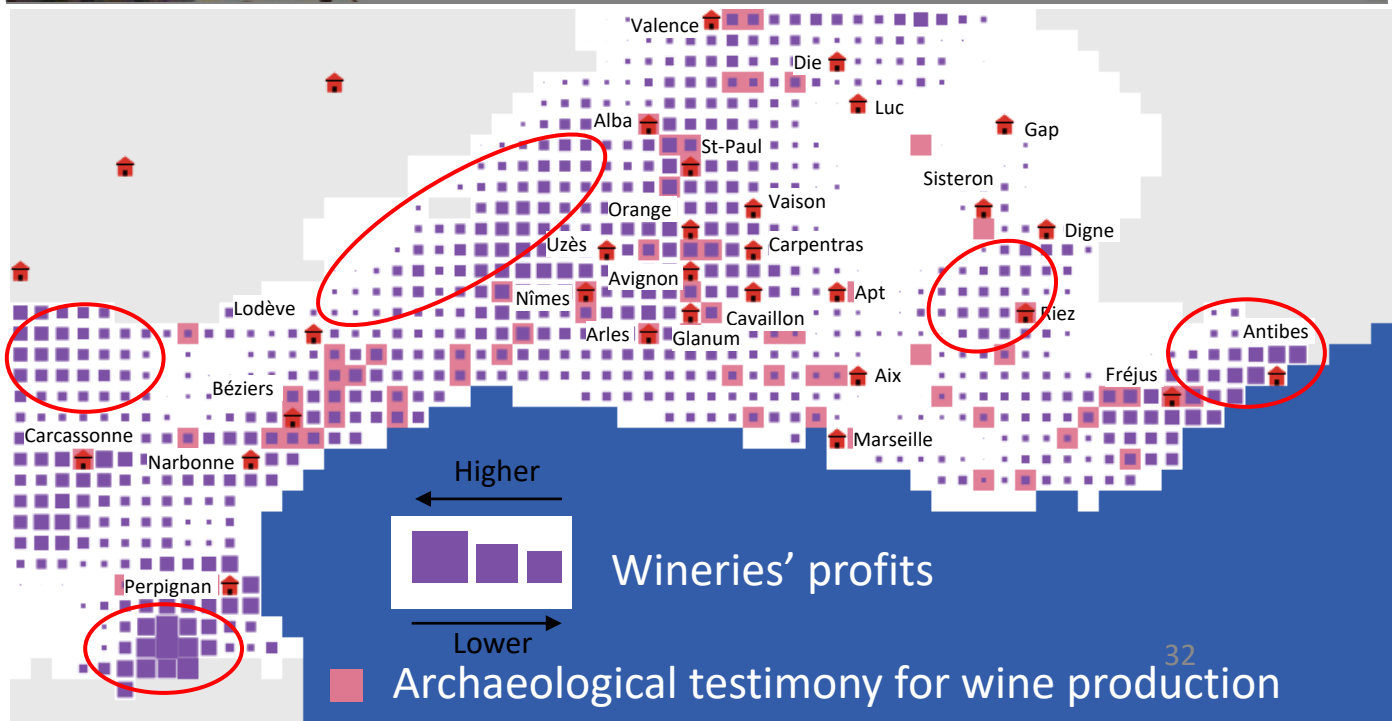
ROMCLIM model

Viticulture : model vs archaeological data

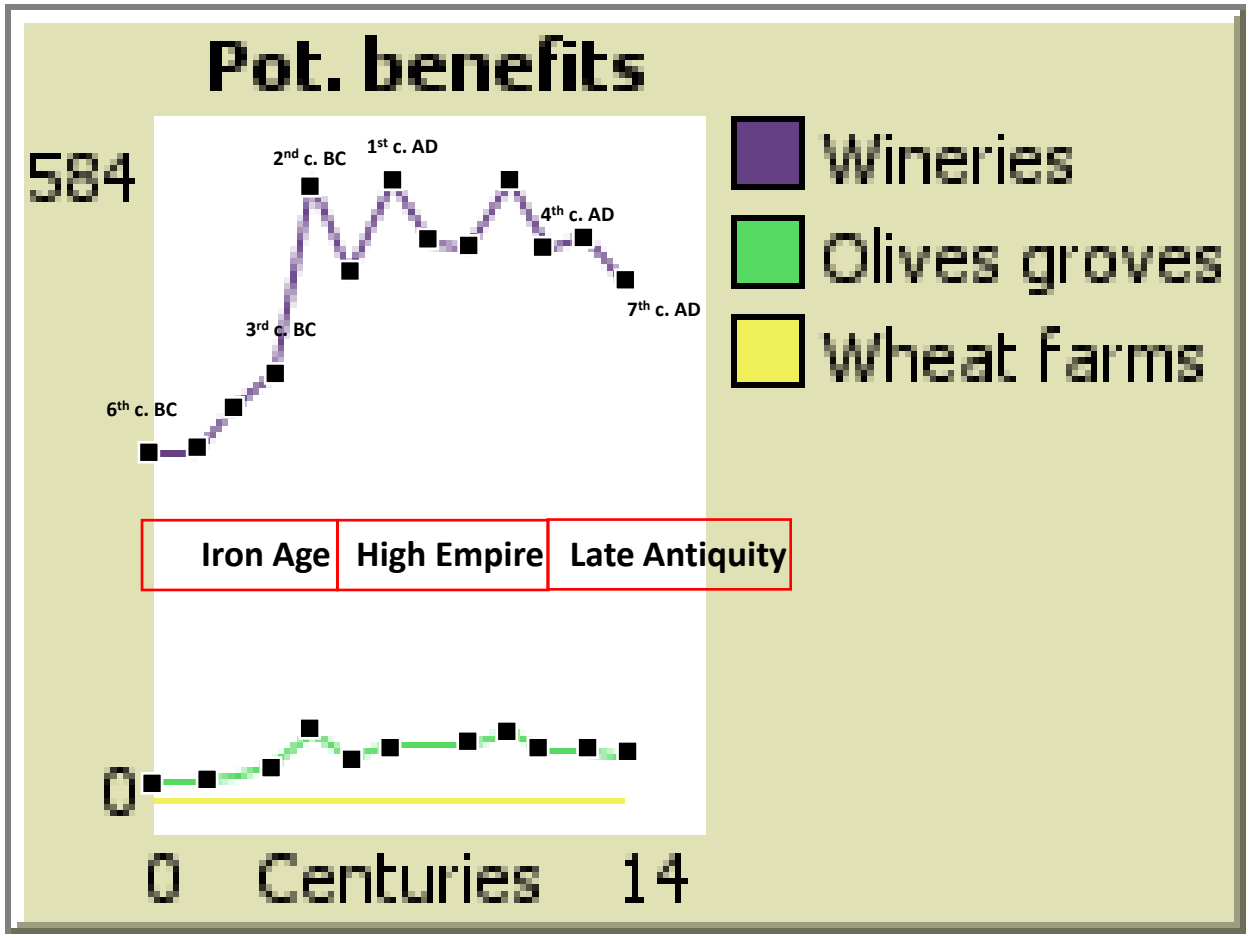
- Archeological data on roman viticulture are well represented in Provence, in the middle Rhone Valley (Nîmes, Avignon, Orange) and the region of Béziers
- Results of the model for the 1st c. AD seem to match with archaeological data which appear still relatively scarce (bellow)
- But some areas with a good potential present a lack of archaeological data : e.g. Gard, Antibes area, Riez/Digne area…(red oval areas)
- Artifact of the model, or lack of archaeological researches ?



Map of wineries of Gallia Narbonnensis (Brun 2010)



Conclusion



- Agent-based model RomClim coupled with agrosystemic model shows that the Roman Climate Optimum has had probably a strong and favorable impact on wine production and olive growing, but not so much on wheat production
- RCO was most beneficial for viticulture than others crops
- The strong economical development of Gallia Narbonensis in High Empire was supported by the development of the villa system (agricultural rentier) largely invested in wine production
- But why the takeoff of this economy don't start more frankly in the 1st c. BC, where climatic conditions where already good ?

Conclusion

- The ROMCLIM agent-based model validates the hypothesis of a significant impact of the so-called “Roman Climate Optimum” on the productivity and profitability of agricultural exploitations and thus on the roman economy in general
- According to our model, climatic conditions were already favorable as early as the 2nd century BC in Gaul to the development of commercial agriculture. But historically, it did not develop until the 1st c. BC, after the Roman conquest
- The model also shows a negative impact on the profitability of agricultural exploitations during Late Antiquity/early Middle Ages (4th-7th c. AD), but the decrease appears not particularly strong for wheat production.
- The idea of a collapse of agriculture in Late Antiquity due to the cooling of the climate (cf HARPER 2017, BÜNTGEN et al. 2012) has been maybe exaggerated.
- One of the interesting results of this model is to show that climate change hasn’t the same effect on the different cultures. We can see here that olive and wine are more sensitive to these changes than the wheat. In other words, agricultural subsistence is less impacted by climate than commercial productions. But if the agricultural system is 100% turned toward speculative agriculture, the change can create a societal collapse indeed.