Climate and agricultural productivity in southern Roman Gaul: the contribution of agent-based and agrosystemic modelling

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Climate and agricultural productivity in southern Roman Gaul: the contribution of agent-based and agrosystemic modelling[1]

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[1] RDMed project

*CEREGE, Aix-en-Provence, **IMBE, Aix-en-Provence, ***CEPAM, Nice

Goals and Objectives Presentation

What was the impact of climate change on agriculture and agricultural yields in the south of France between the Iron Age and the Late Roman antiquity ?

- Contribution of Agrosystemic and Agent-Based models to this question.

Roman Climate Optimum (RCO) or Roman Warm Period (RWP)

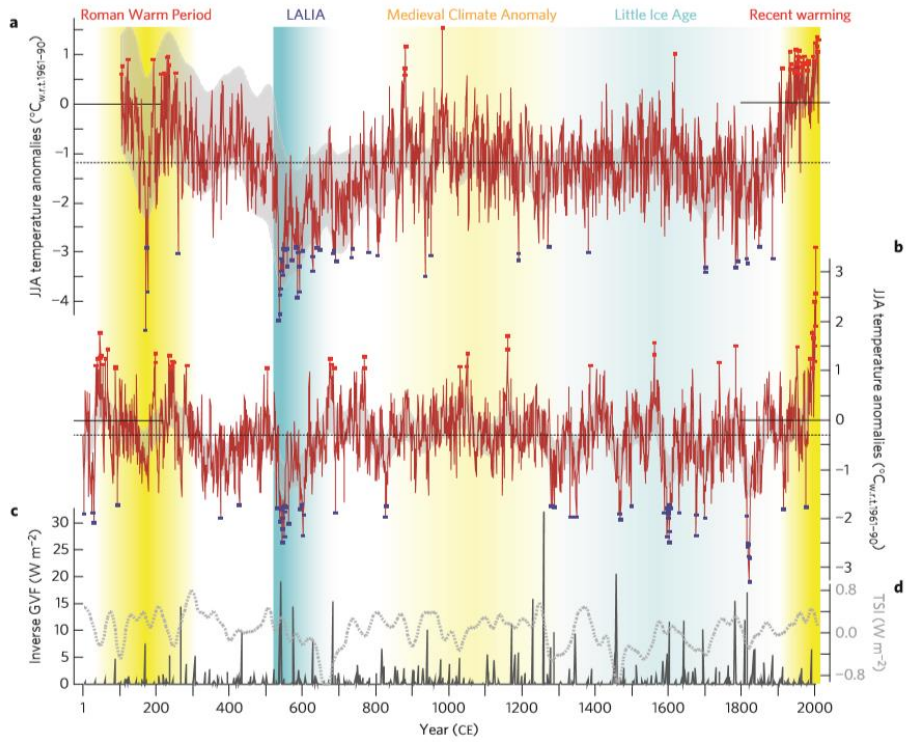


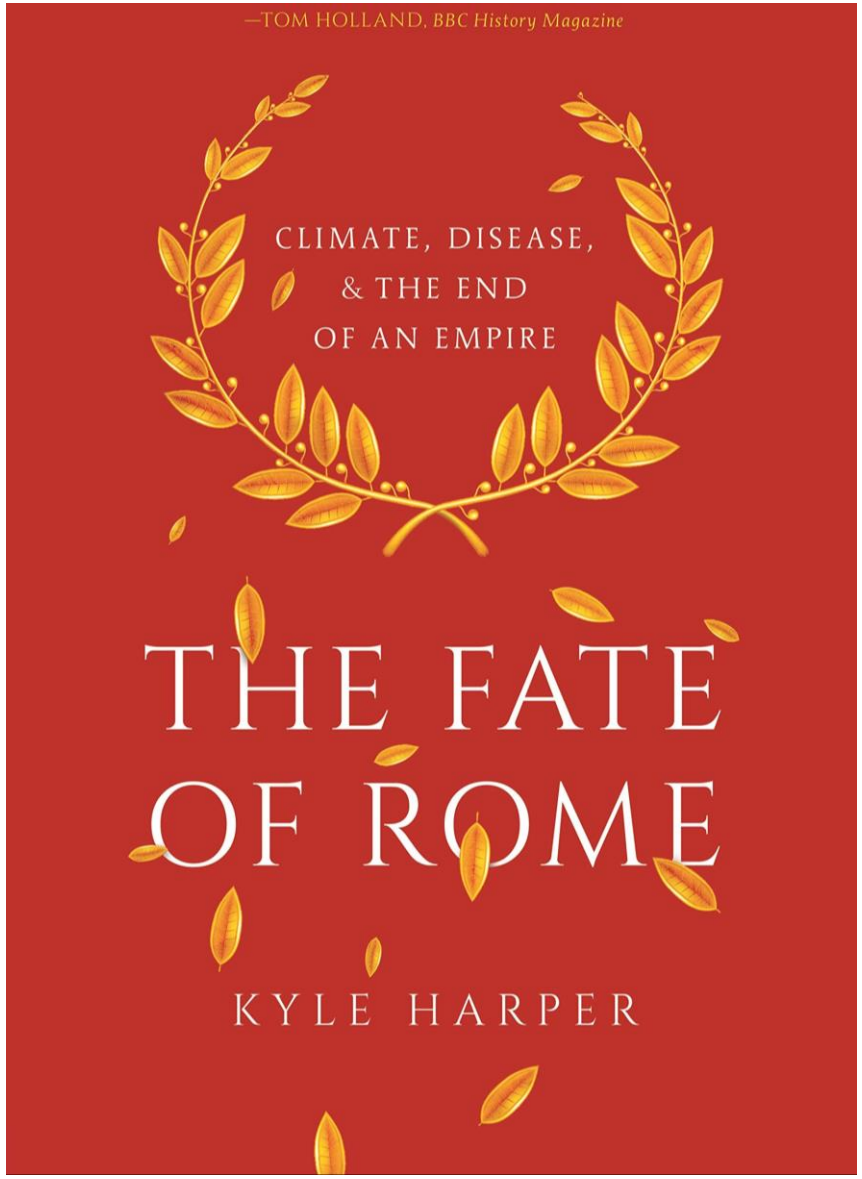
Figure 2 | Eurasian summer temperature variability. a,**b**, Reconstructed temperatures from the Russian Altai (**a**) and the European Alps[5] (**b**), with blue and red squares indicating (51/47) positive and (53/57) negative annual extremes (>2 standard deviations), respectively. Grey background shadings denote reconstruction uncertainty after 80-year low-pass filtering (Supplementary Fig. 9). **c**,**d**, Ice-core-derived global estimates of volcanic[14] (GVF; dark grey; **c**) and total solar irradiance[17] (TSI; light dashed grey; **d**) forcing. Black dashed lines refer to the long-term reconstruction mean of the Common Era.

- III c. BC – II c. AD
- High summer temperatures
- High precipitations

Büntgen et al. 2011

"The Climate was the enabling background of the Roman miracle.
The RCO turned the lands ruled by Rome into a giant greenhouse"

- **"The RCO was a boon to the fecundity of Mediterranean wheat farming"**
- **The RCO "fueled the agricultural engine of the economy" (Harper 2017, 52; Cf. McCormick et al. 2012; Manning 2013, 169).**



Did really the RCO makes the prosperity of the Roman Empire ?

Climate change and the productive landscape in the Mediterranean region in the Roman Period (draft paper by P. Erdkamp, Vrije Universiteit Brussel)

- “Many recent studies claim that climate change and its impact on agriculture determined the fate of past societies. The prosperity of the Roman Empire at its height is attributed to the *Roman Climatic Optimum*, which “fueled the agricultural engine of the economy” (Harper 2017, 52; Cf. McCormick et al. 2012; Manning 2013, 169)”

- « It seems very unlikely that the impact on agriculture in the Roman world was as dramatic as often assumed »

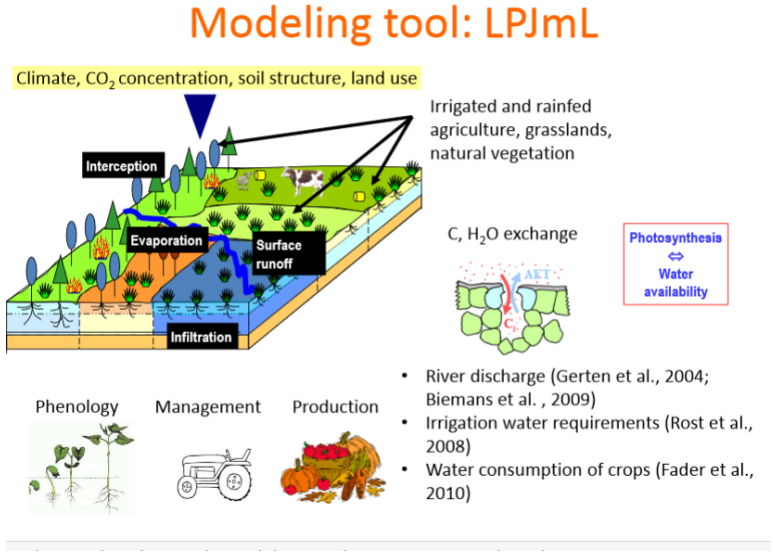
- “However, a thorough analysis of **the causal links between climate change and agricultural productivity is generally missing”**

How to link climate and agricultural productivity ?

Lund-Potsdam-Jena managed Land (LPJmL) *Process-based agriculture, vegetation and hydrology model*

- **MODEL INPUTS**
- Monthly climate : temperatures, precipitations, rainy days, cloud cover
- Global atm. CO2-concentrations
- Soil structure
- Land use dataset

- **MODEL OUTPUTS**
- Yields (t/ha), production (t), growing period
- Carbon cycle
- Soils evaporation, plant transpiration,…



Modeling ancient yields with paleoclimatic data

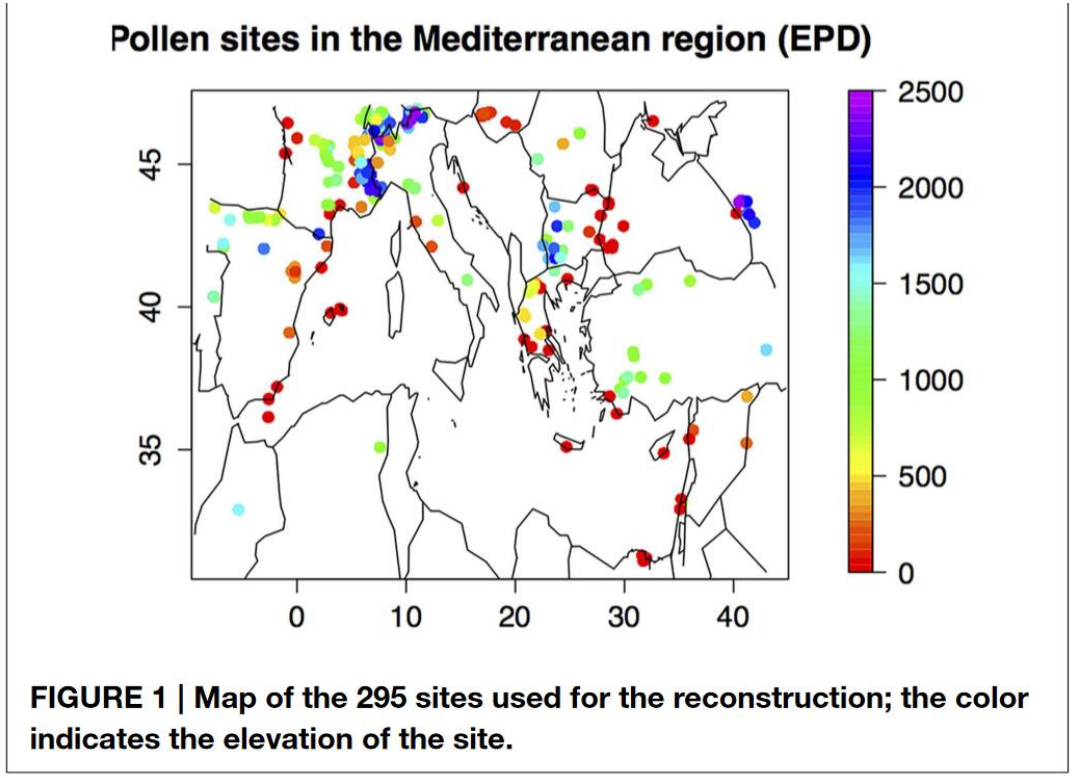
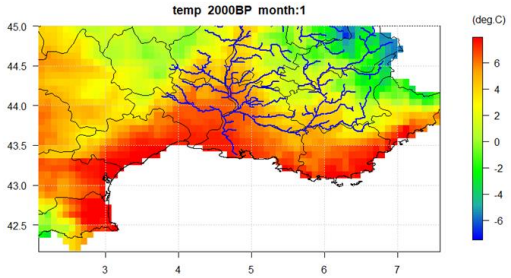


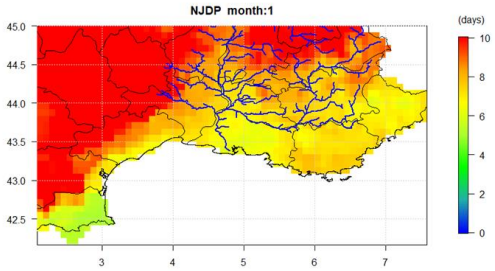
FIGURE 1 | Map of the 295 sites used for the reconstruction; the color indicates the elevation of the site.

- Joël Guiot, David Kaniewski. The Mediterranean Basin and Southern Europe in a warmer world: what can we learn from the past ?. Frontiers in Earth Science, Frontiers Media, 2015, 3

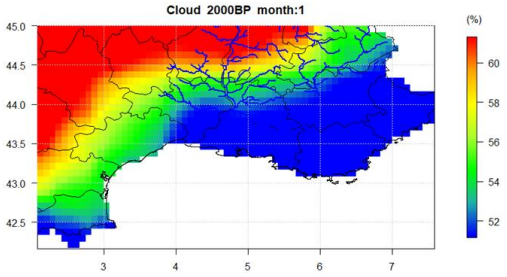
Using LPJmL for reconstructing agricultural yields of the past



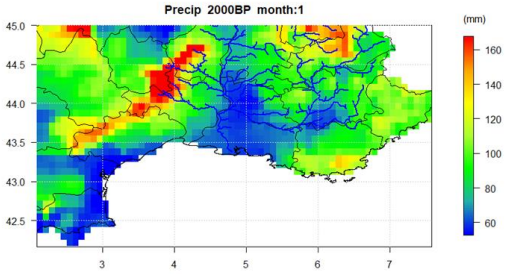
Temperatures



Number rainy days

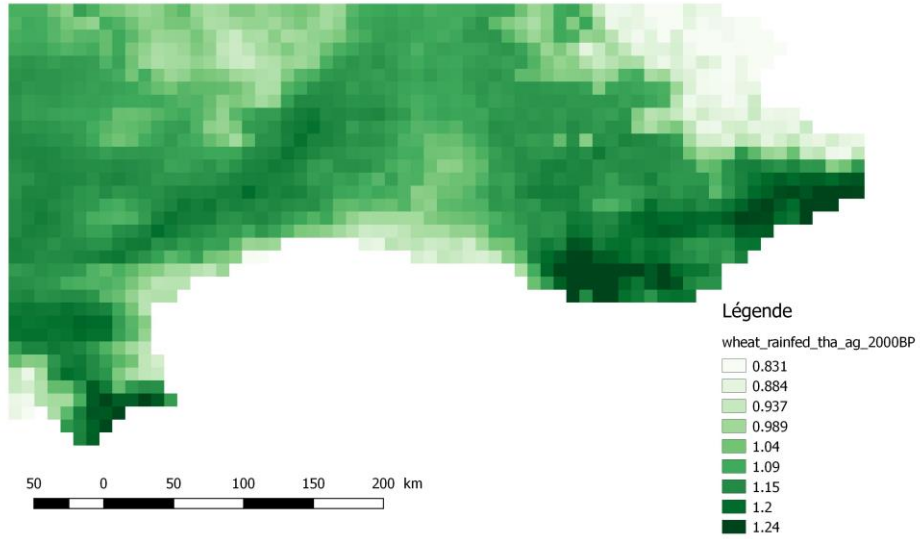


Cloud cover



Precipitations

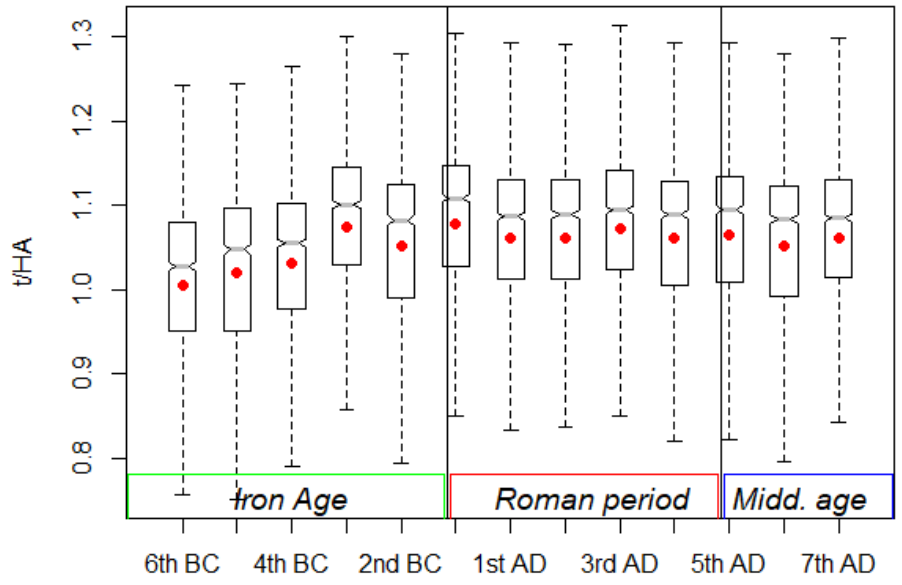
Reconstruction of potential yields in Ist c. BC

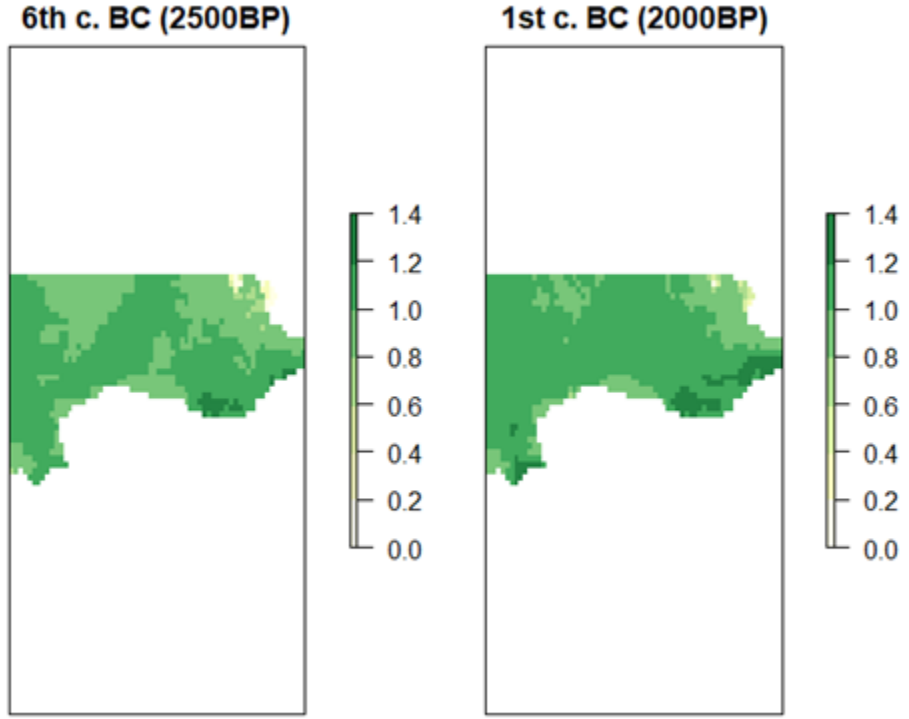


Wheat yield per T/ha (2000 BP)

LPJmL results

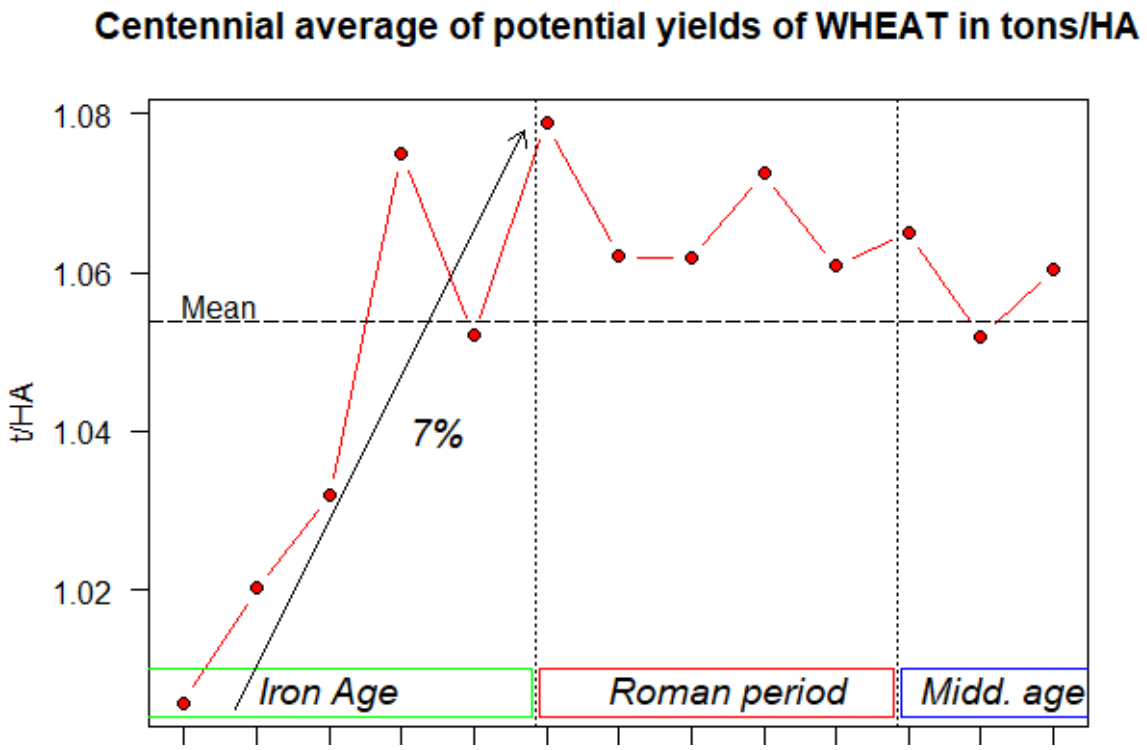
Centennial variations of **WHEAT 's** potential yields in t/HA
6th c. BC - 7th c. AD

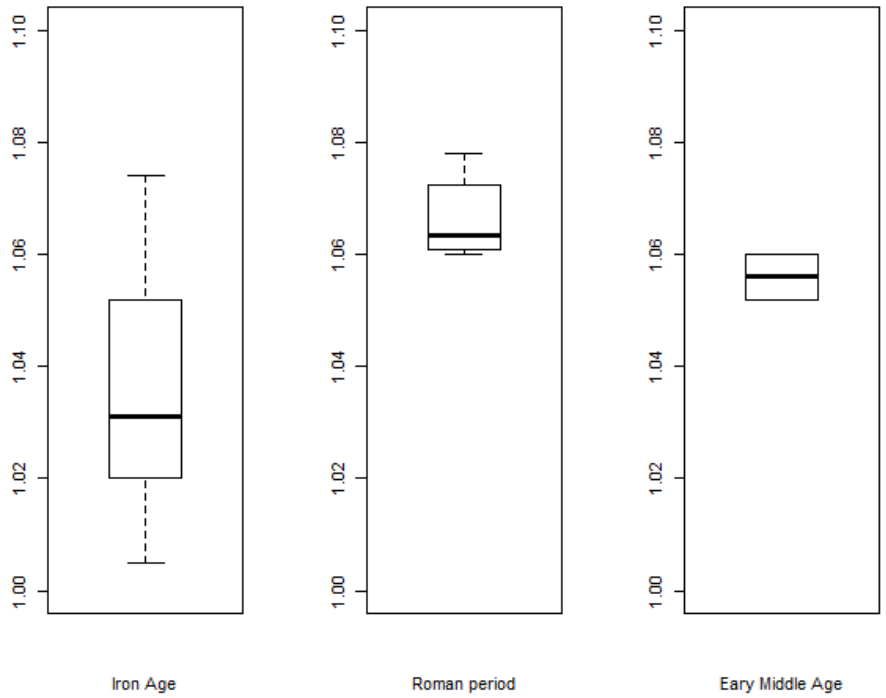




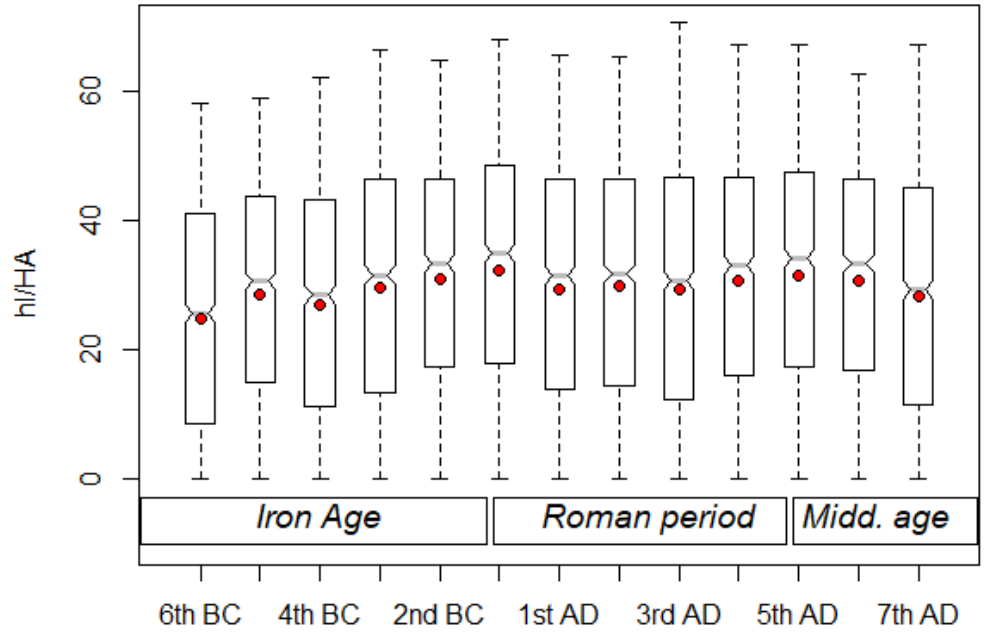
Centennial variations of **WHEAT 's** potential yields in t/HA
6th c. BC - 7th c. AD

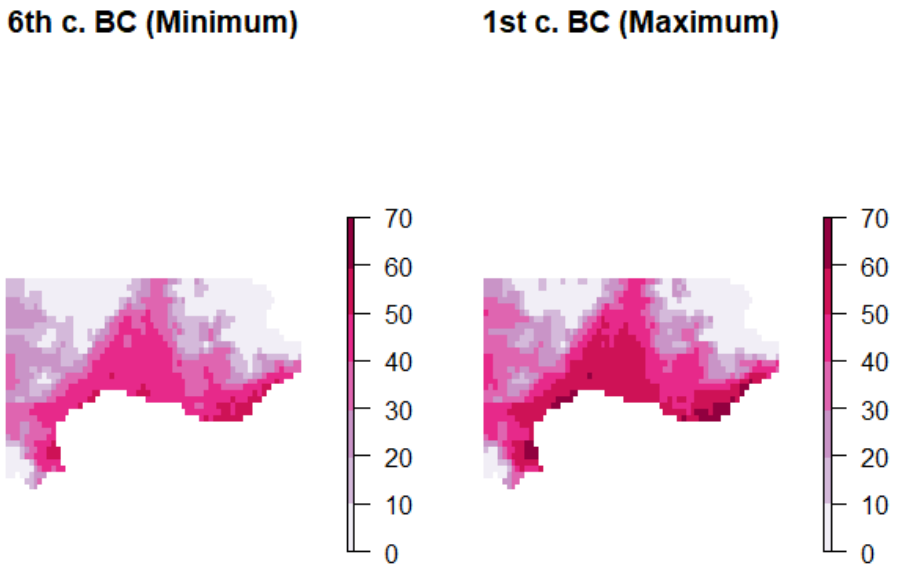
- Increase of yields during Iron Age
- Noticeable peak in 3rd c. BC
- High yields during Roman period
- Decrease during early Middle age





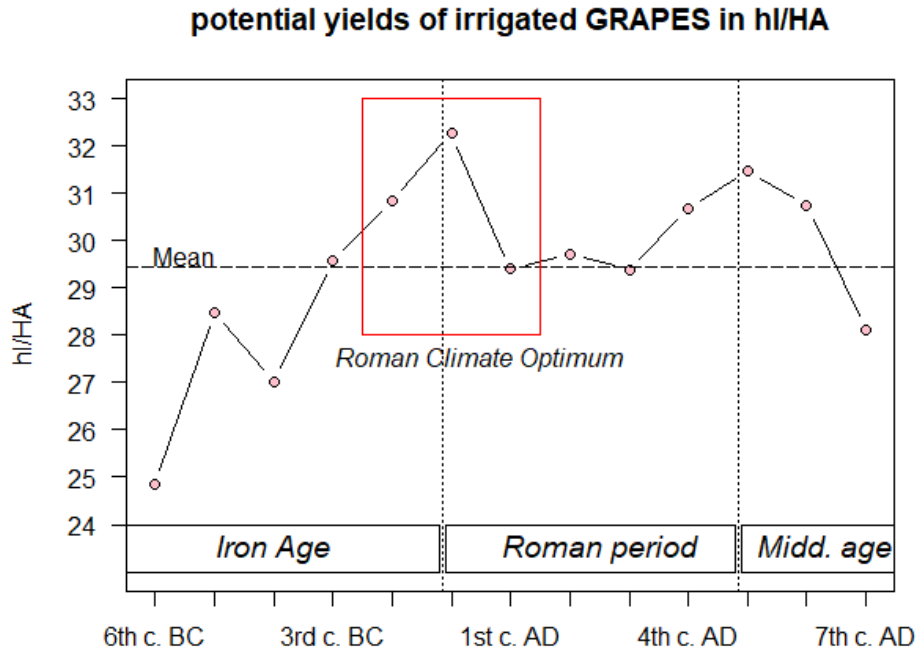
Centennial variations of **GRAPES's** potential yields in hl/HA
6th c. BC - 7th c. AD

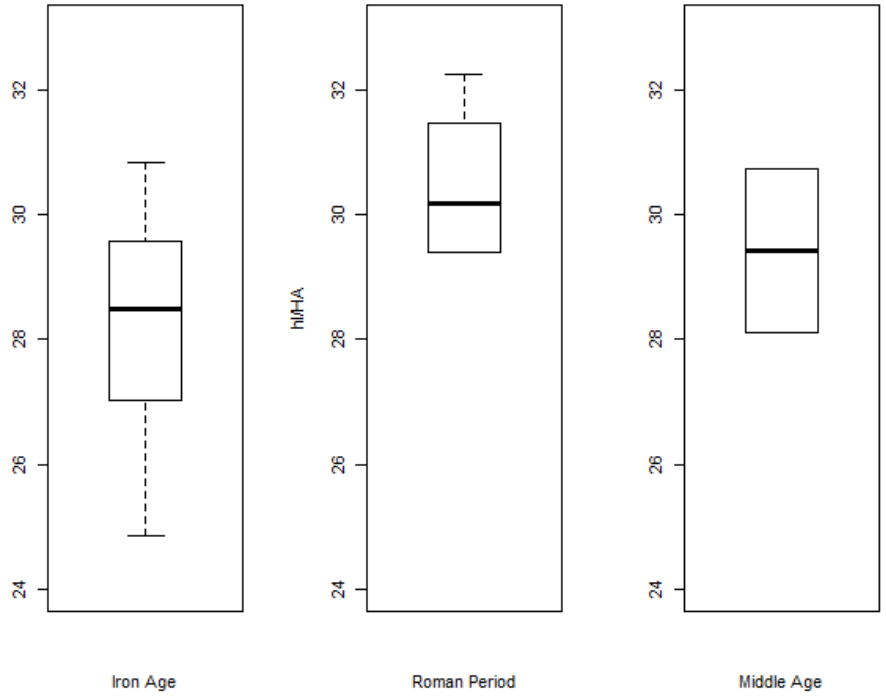




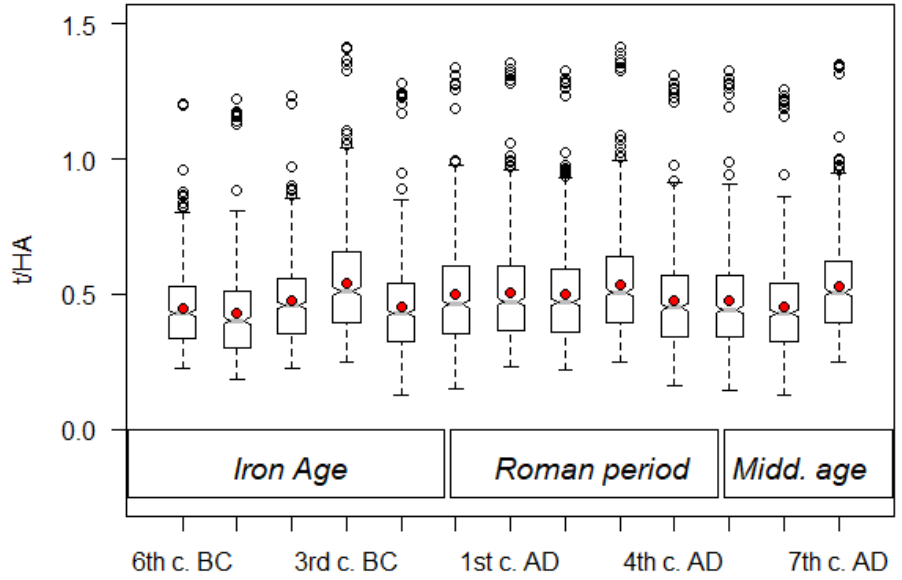
Centennial variations of **GRAPES's** potential yields in hl/HA
6th c. BC - 7th c. AD

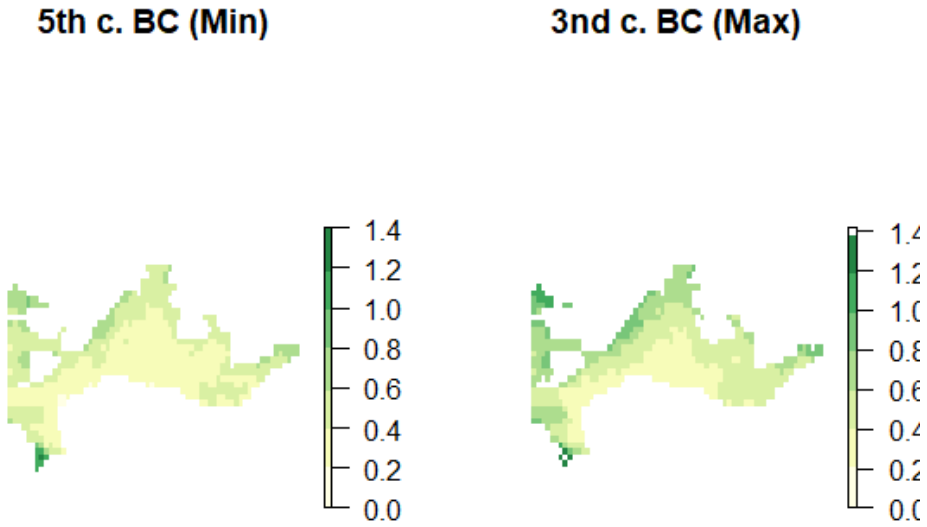
- **1st peak : 3rd c. BC – 1 st. c. BC**
- **2nd peak : 4th c. AD – 6th c. AD**
- **Highest value : 1st c. BC = 32 hl/HA**
- **Lowest value : 6th c. BC = 24 hl/HA**
- **Yields of Roman period more stable than others**





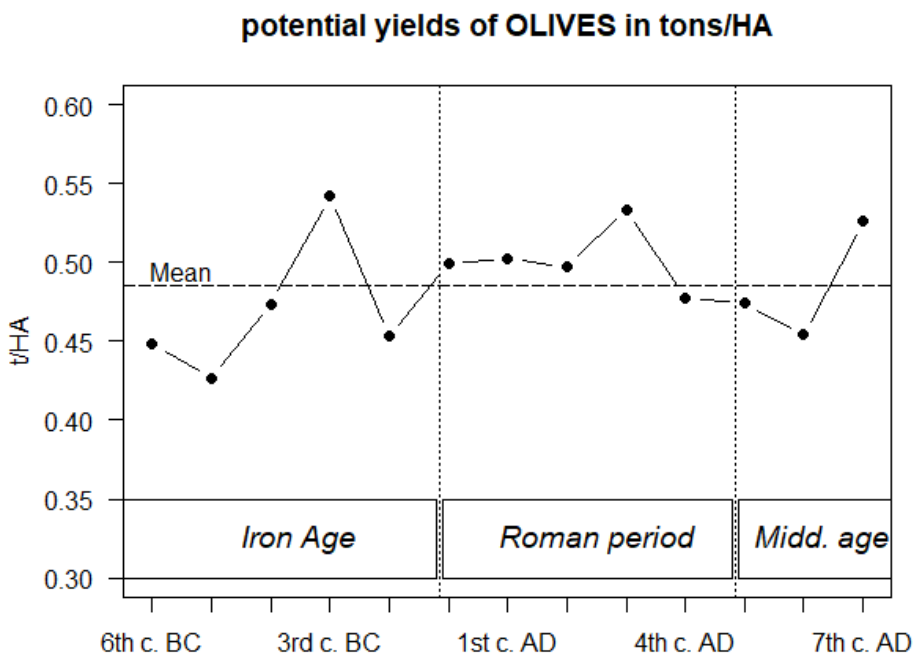
Centennial average of potential yields of rainfed **OLIVES** in t/HA 6th c. BC - 7th c. AD

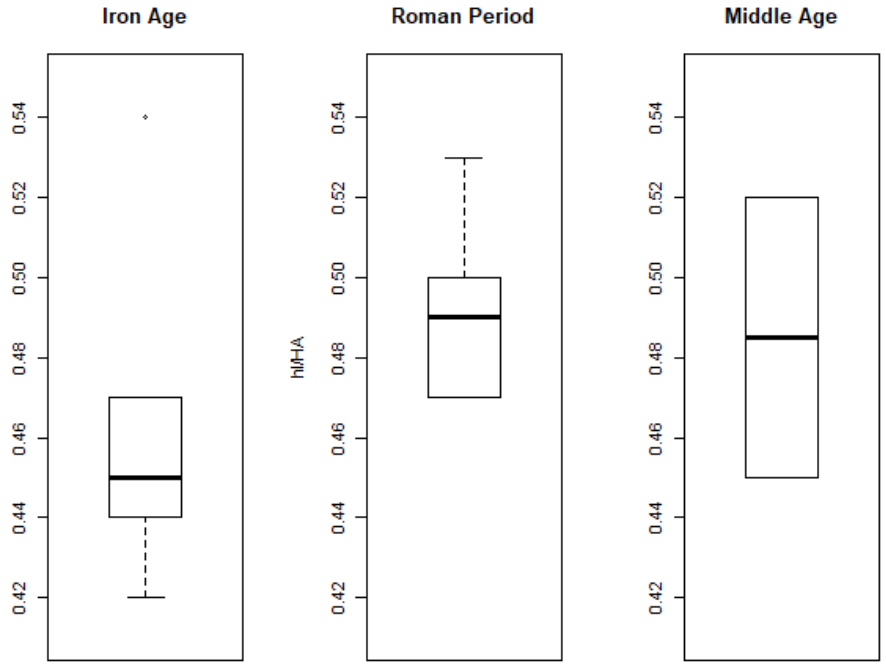




Centennial average of potential yields of rainfed **OLIVES** in t/HA 6th c. BC - 7th c. AD

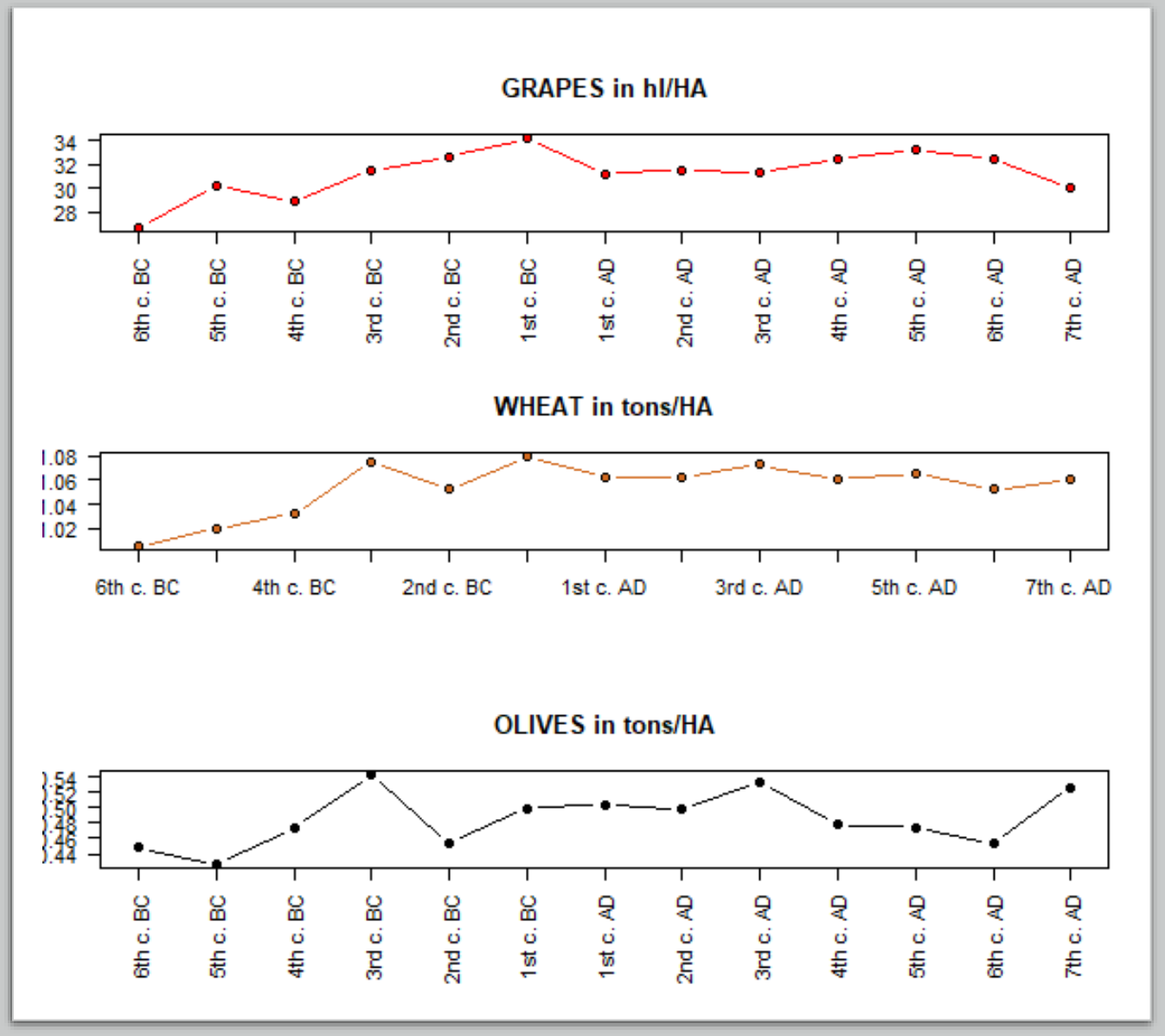
- Irregular yields during Iron Age with noticeable peak in 3rd c. BC
- Relative high yields during Roman period
- Irregular yields during early Middle age



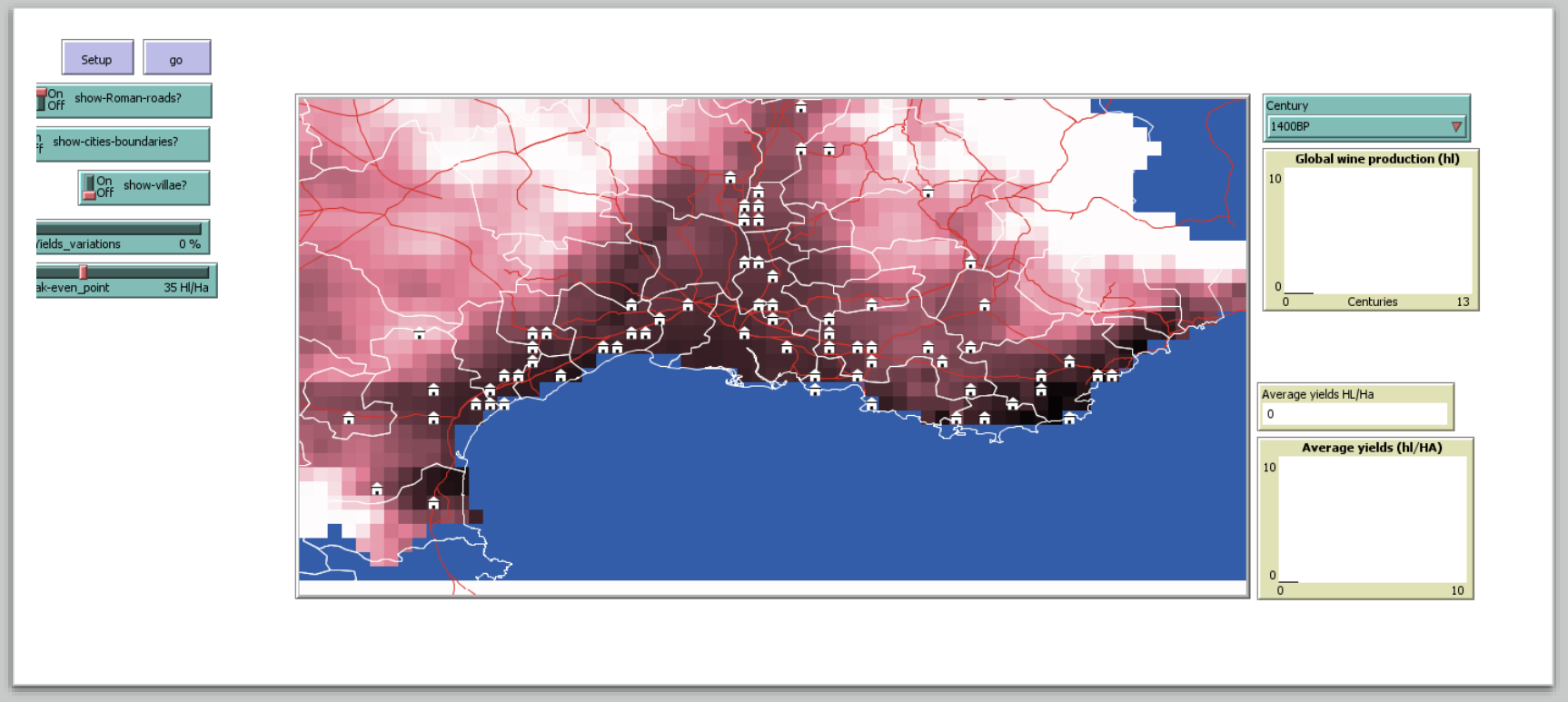


Comparison of centennial averages of POTENTIAL yields

Climate change does not have the same effect on the yields of different plant species



From POTENTIAL YIELDS to POTENTIAL PRODUCTION : working with agent-based modeling

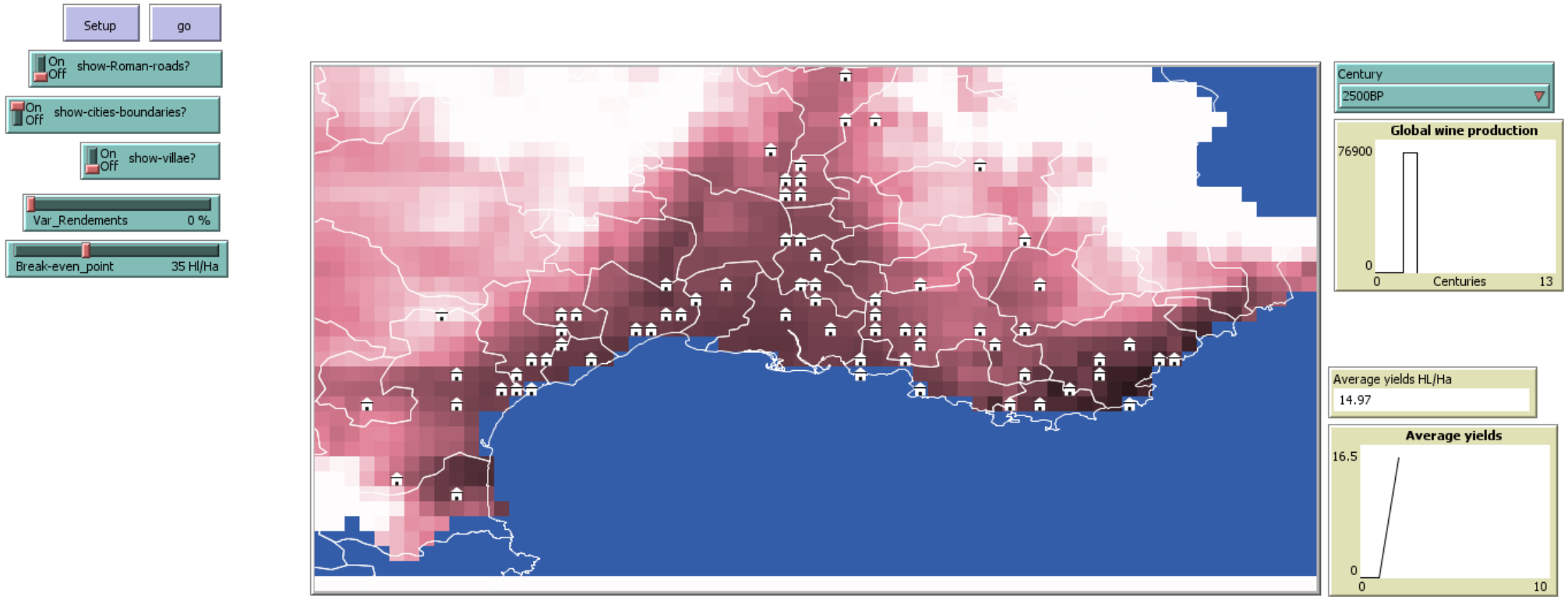


Agent-based Model “LPJmL-vine” (NETLOGO)

- Integrate LPJmL results + archeological data (sites, roads, towns,…)
- Agents are wineries attested by archaeological data
- Allows to calculate a global wine production according to centennial potential yields

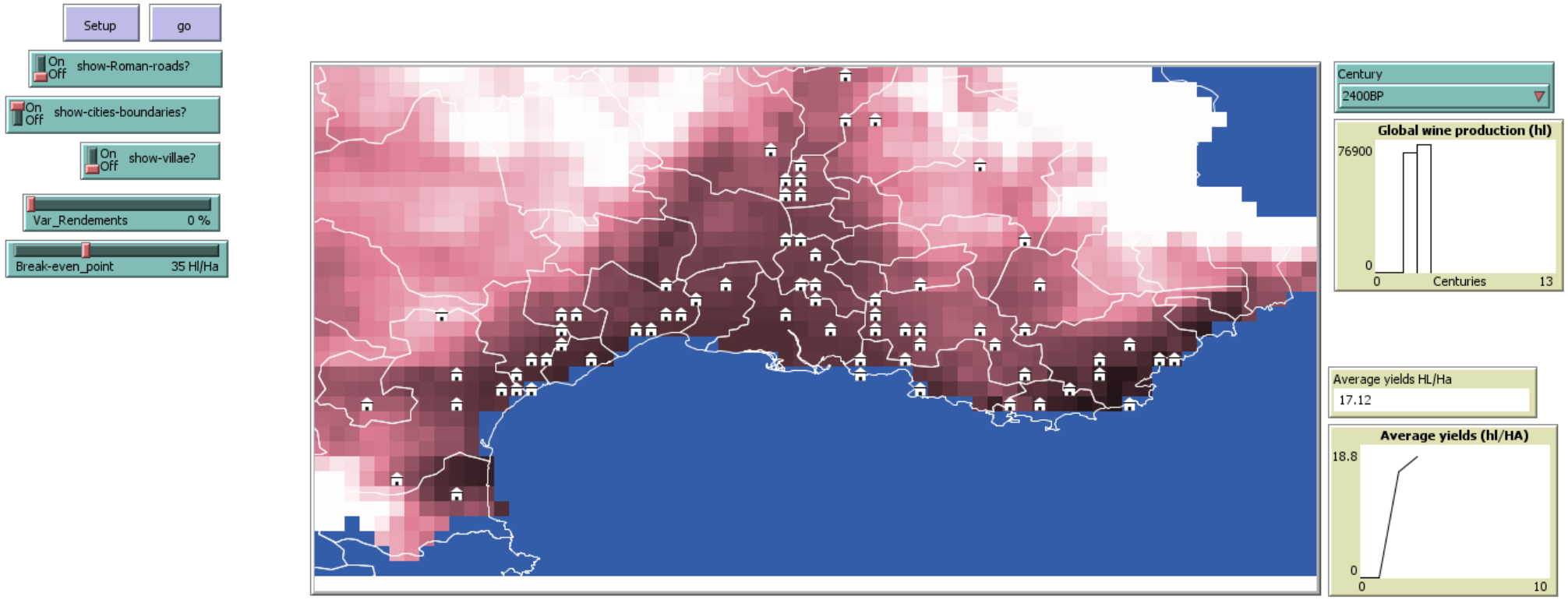
6th c. BC

2500BP



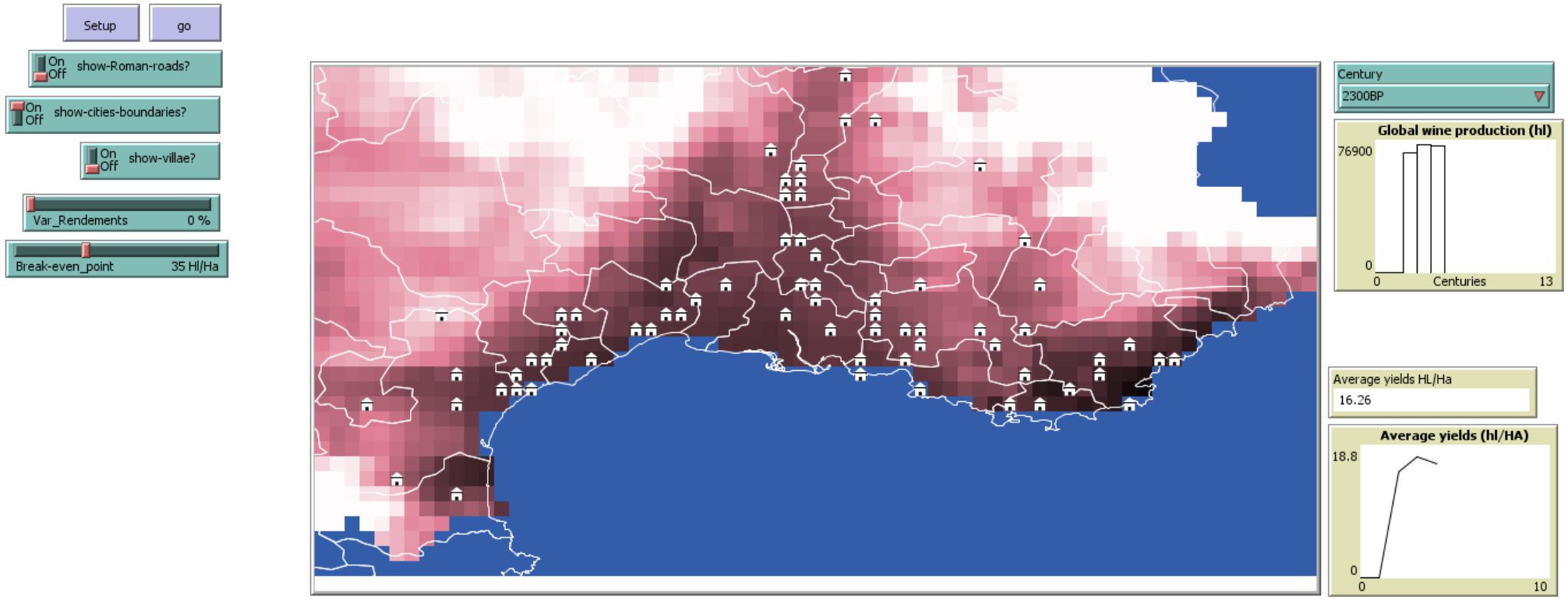
5th c. BC

2400 BP



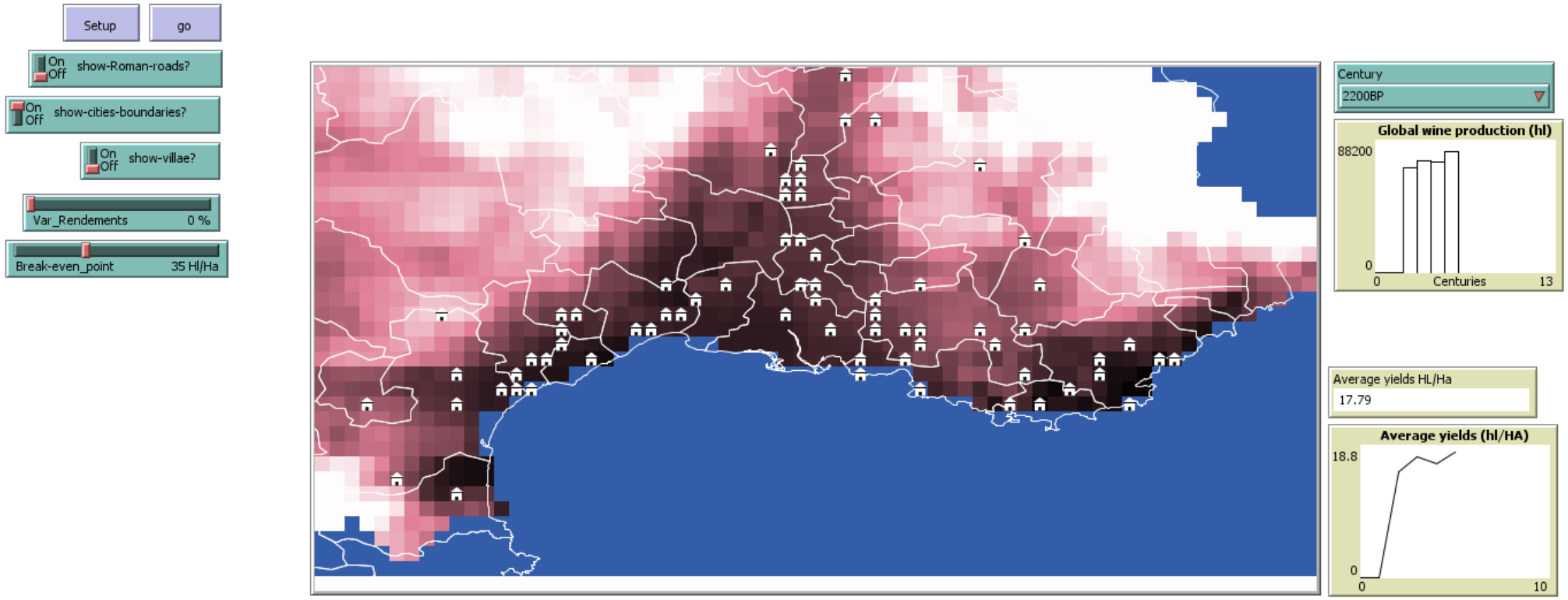
4th c. BC

2300BP



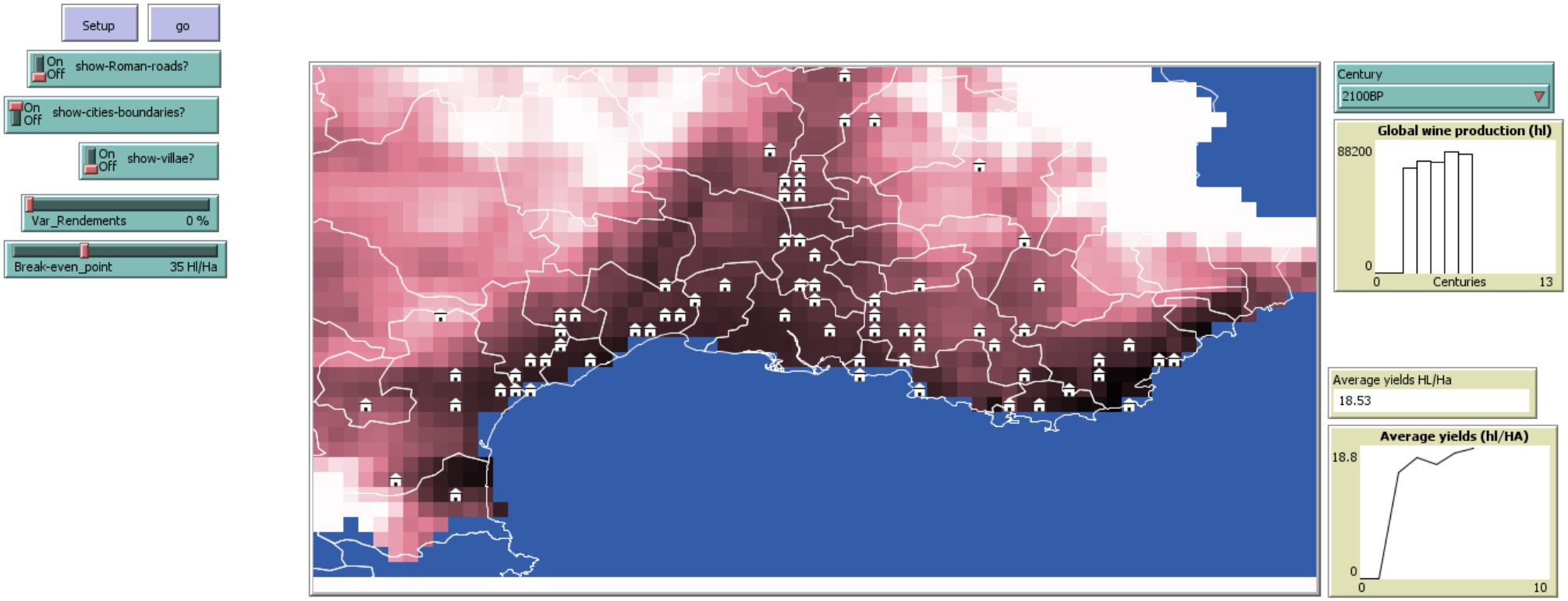
3rd c. BC

2200BP



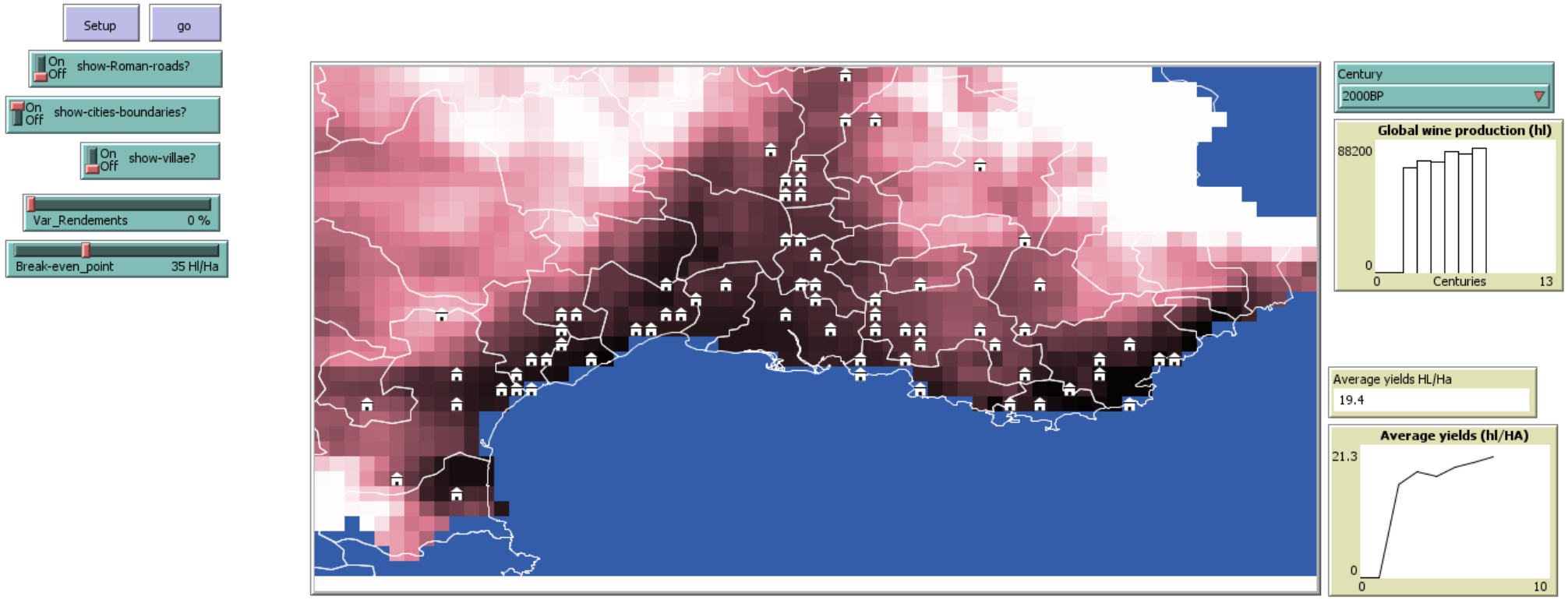
2nd c. BC

2100BP



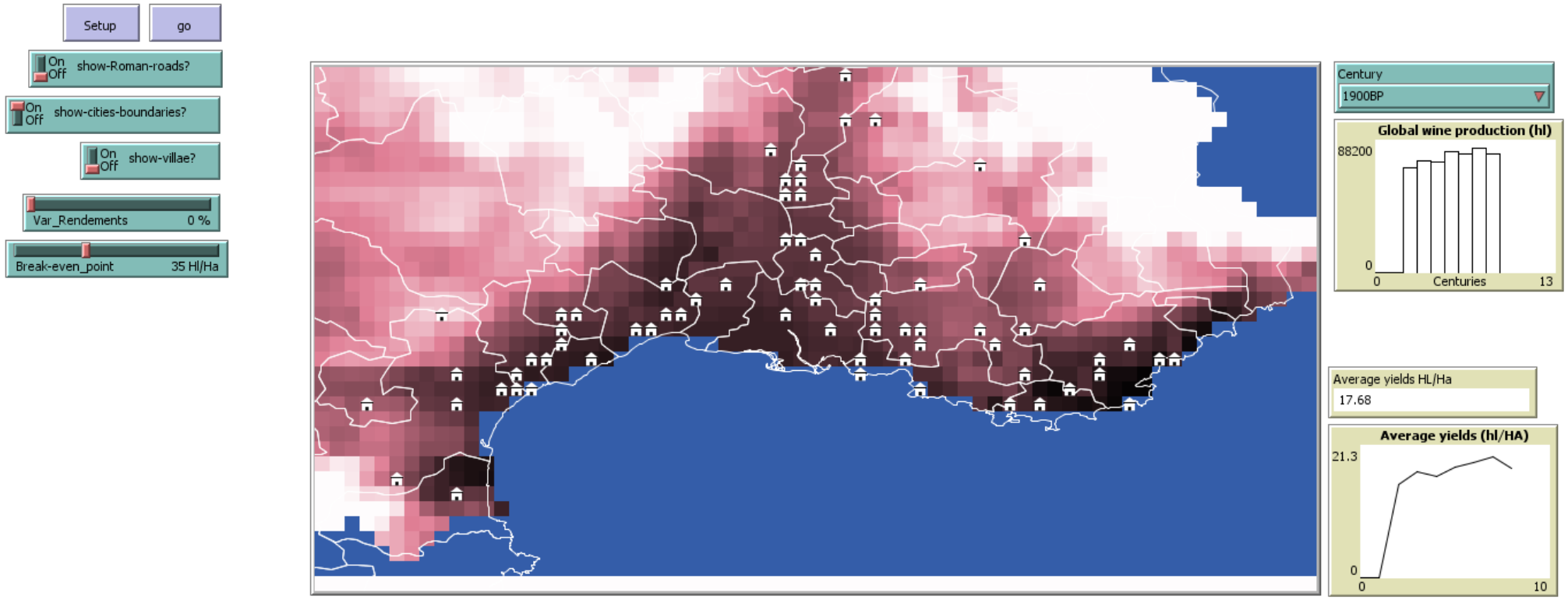
1st c. BC

2000BP



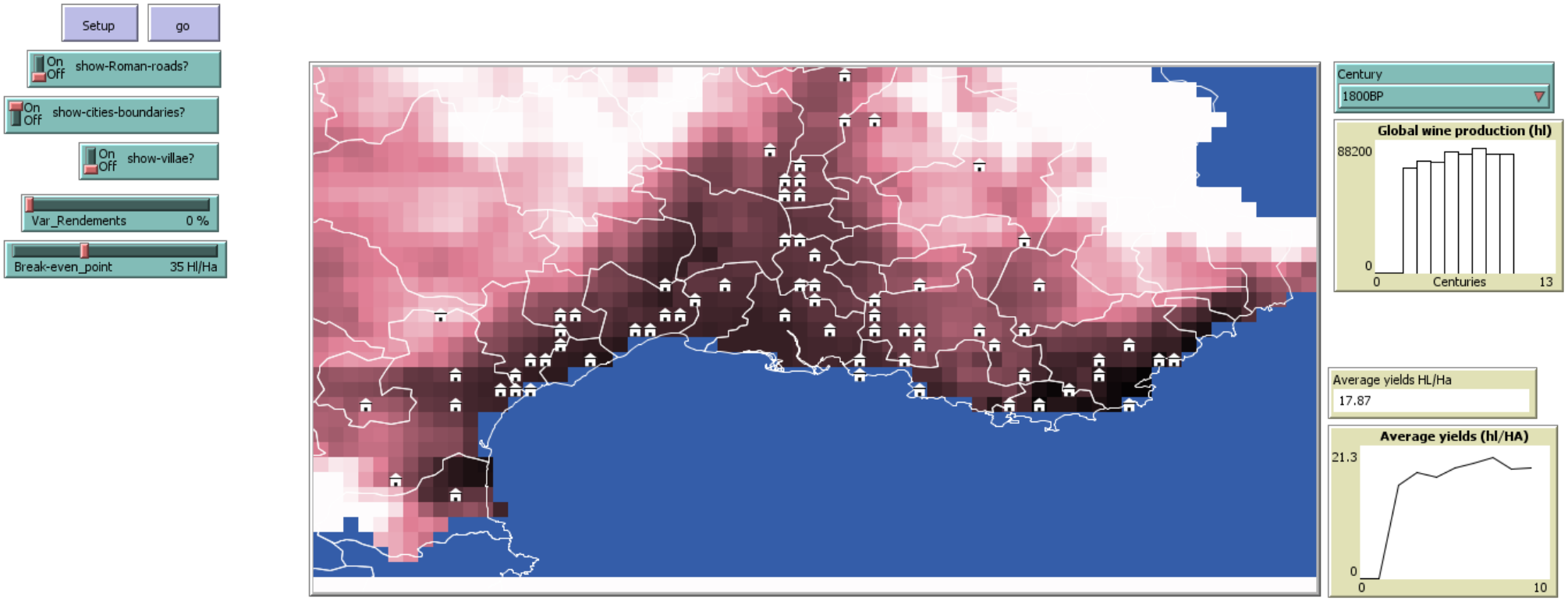
1st c. AD

1900BP



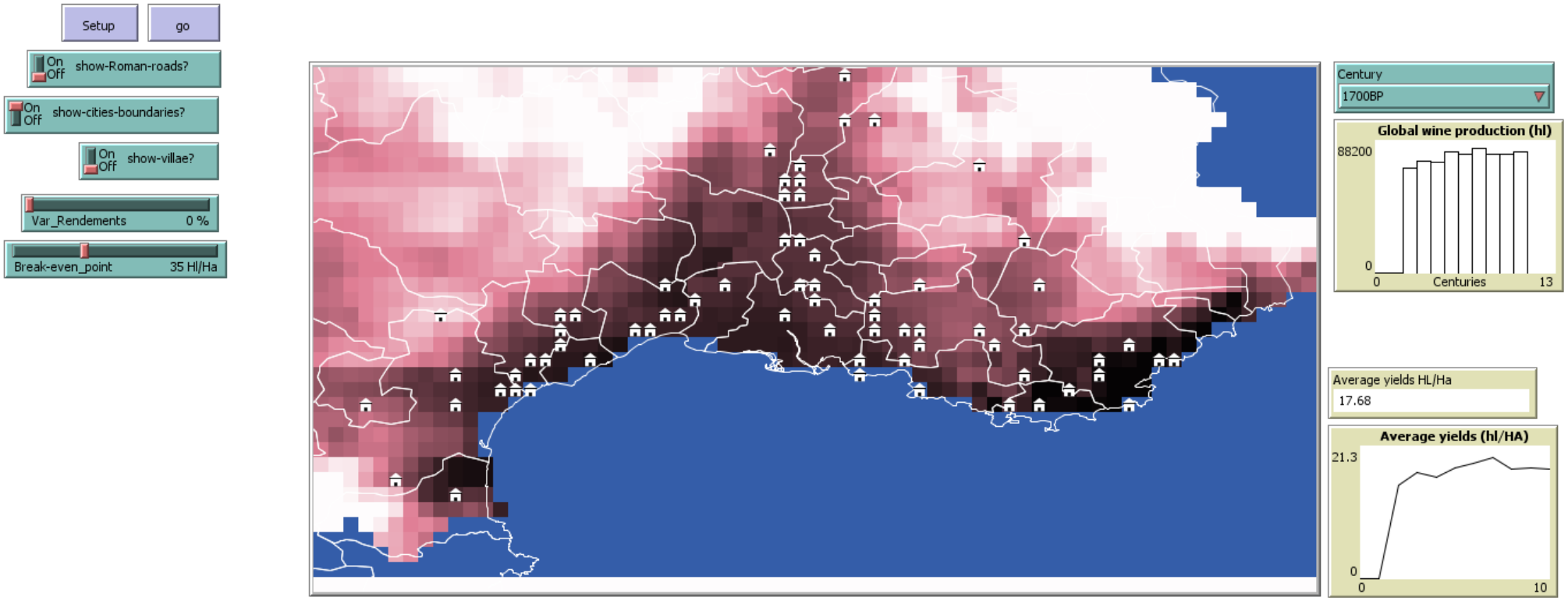
2nd c. AD

1800BP



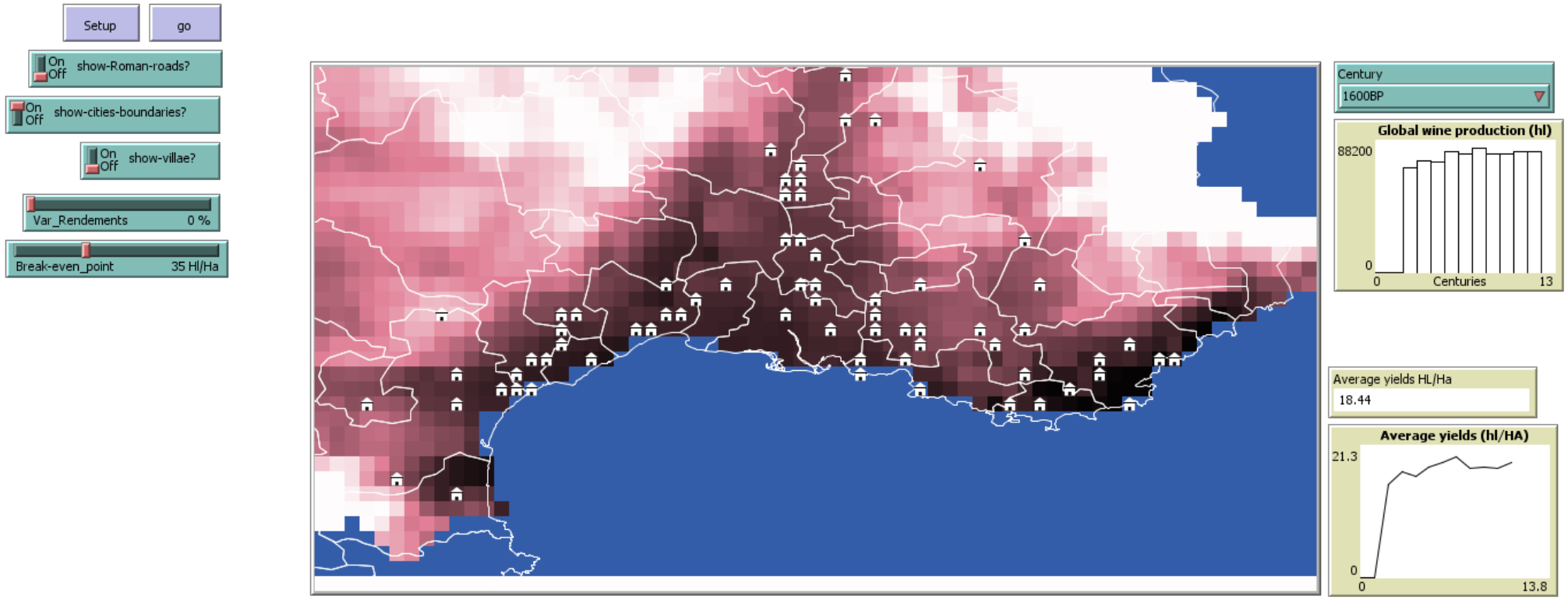
3nd c. AD

1700BP



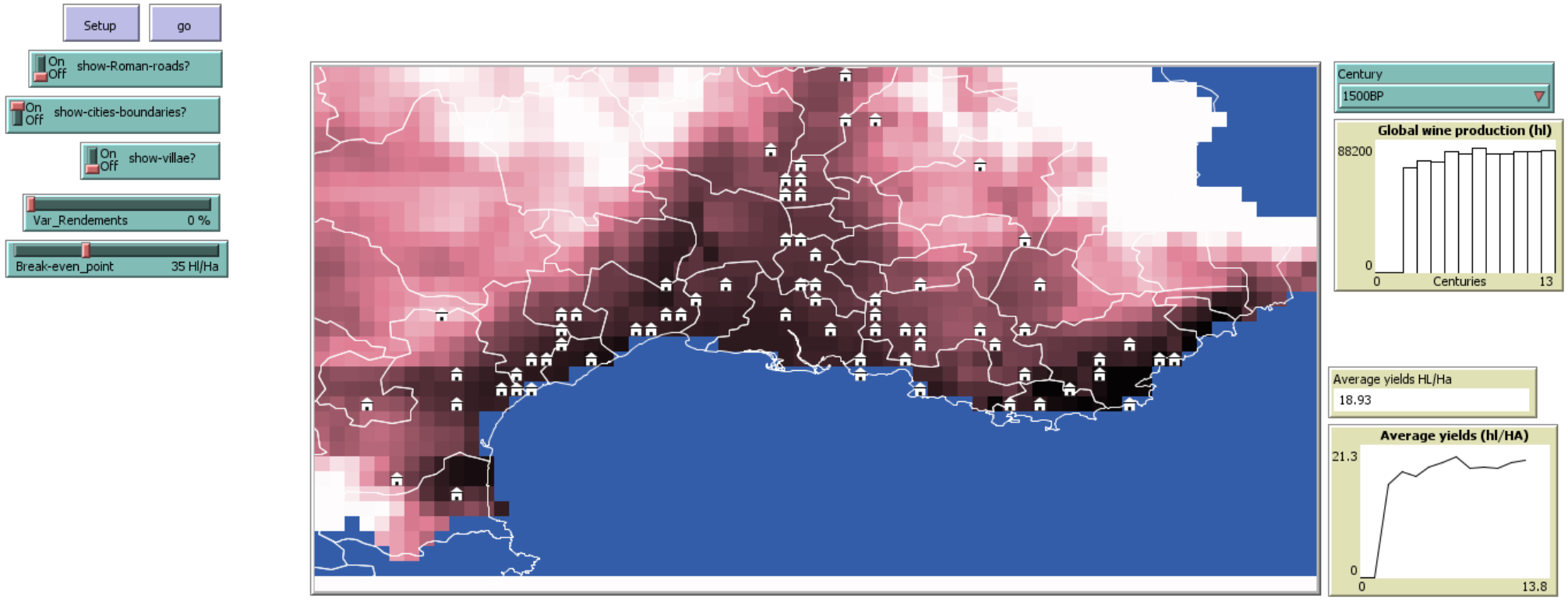
4th c. AD

1600BP



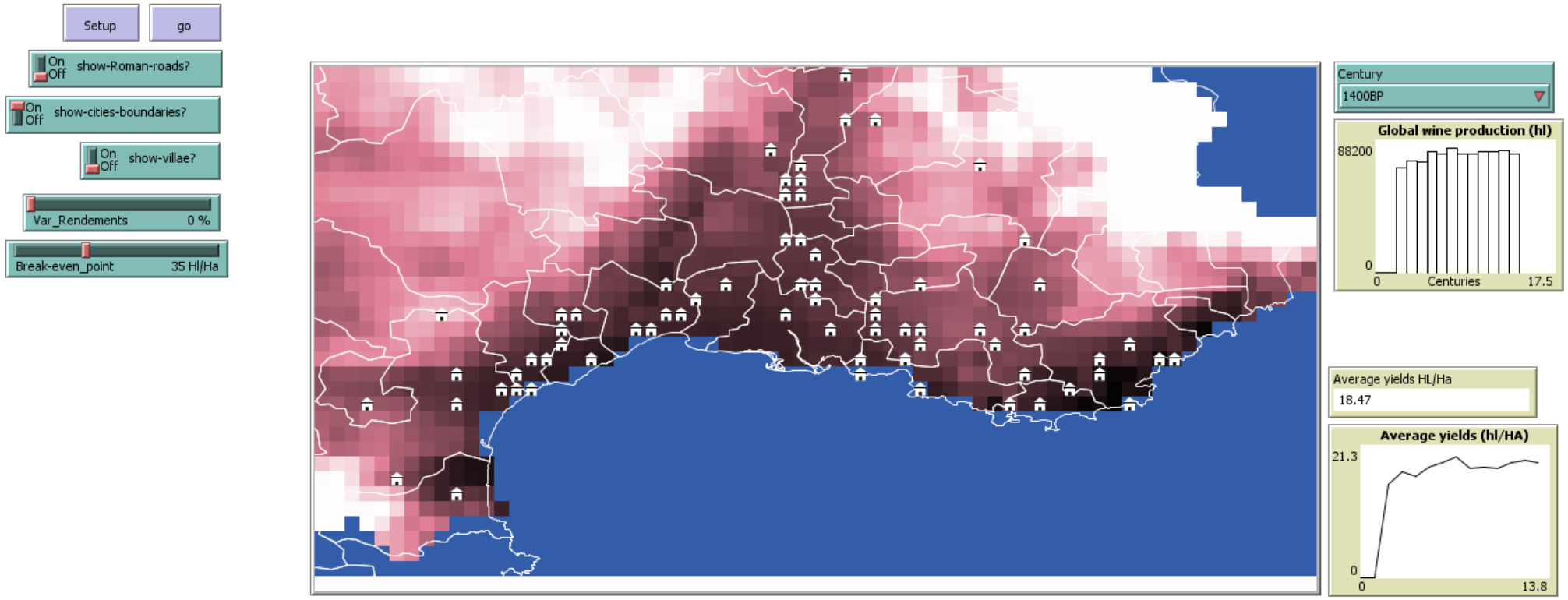
5th c. AD

1500BP



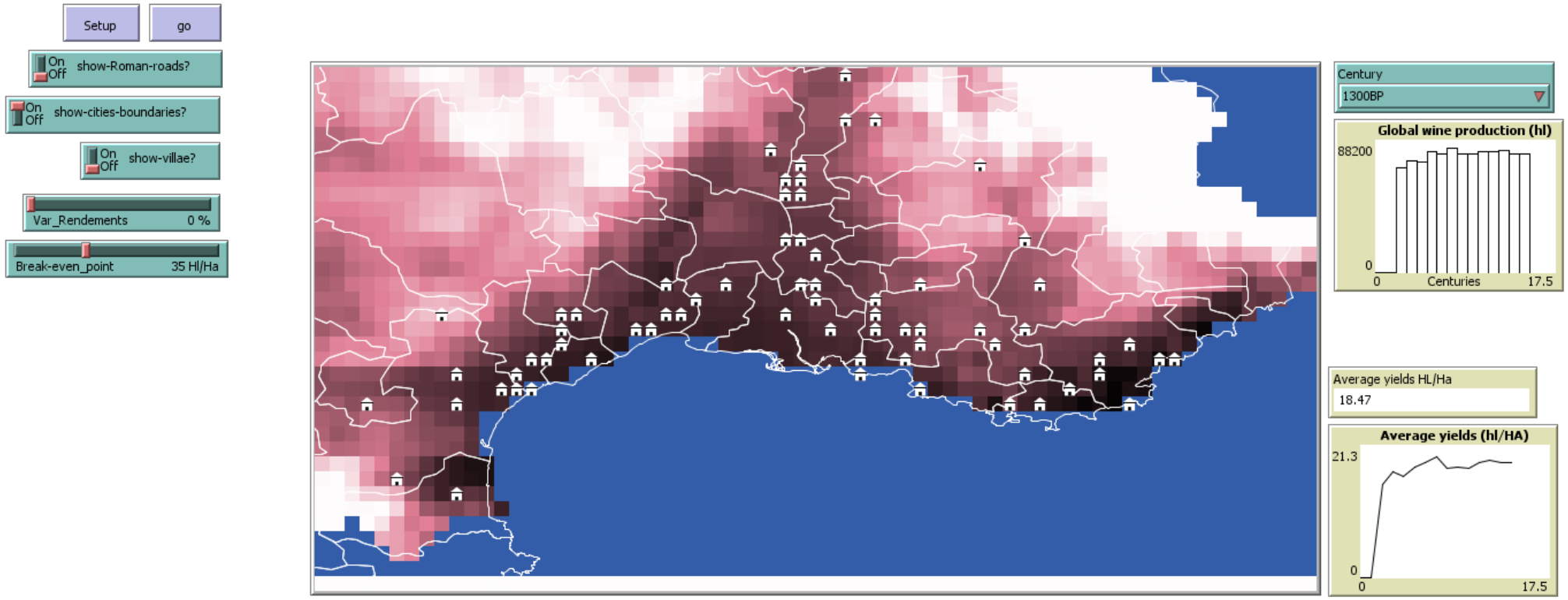
6th c. AD

1400BP



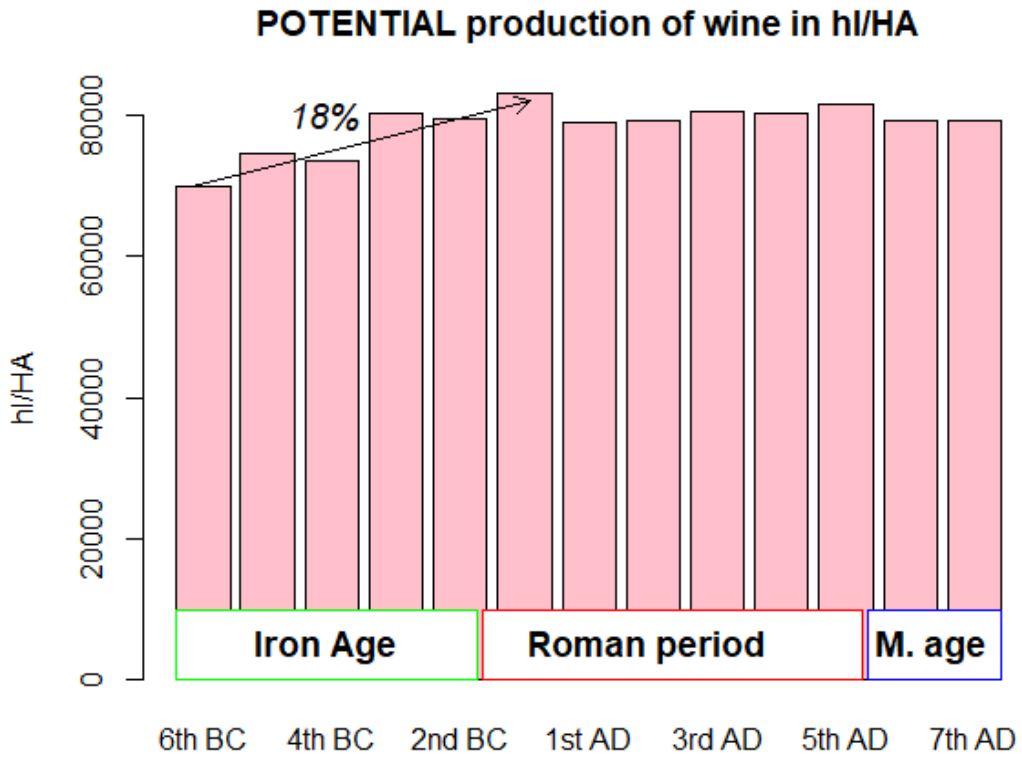
7th c. AD

1300BP



POTENTIAL wine production (according to NETLOGO model)
6th c. BC – 7th c. AD

- Progressive increase of 18 % during Iron Age until the 1st c. BC
- Decrease after the 1st c. BC but stabilization of production level during Roman period, with a new increase in the Late Antiquity (5th c. AD)
- Slight decrease during early Middle Age, but no collapse of the production



Conclusion

- *Did the Roman Climate Optimum have had a significant effect on agricultural production* ?

According to the results of our models, the potential yields and production was indeed higher in the Roman period than Iron Age and early Middle Age.

- Increase of 7% of wheat potential yields
- Increase of 18 % of potential wine production