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New modeling tools for the study of vineyards and viticulture in the Roman Empire

How to simulate geography, potential yields and benefits of wine-making ?



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Spatial analysis : modeling geography of vineyards

In order to modeling the spatial extension of vineyards in roman Gaul, we have built a map of potentiality*.

The cumulative model (beside) is processed under R (raster package) by the addition of raster layers (map algebra) of criteria judged favourable to the establishment of commercial vineyards.

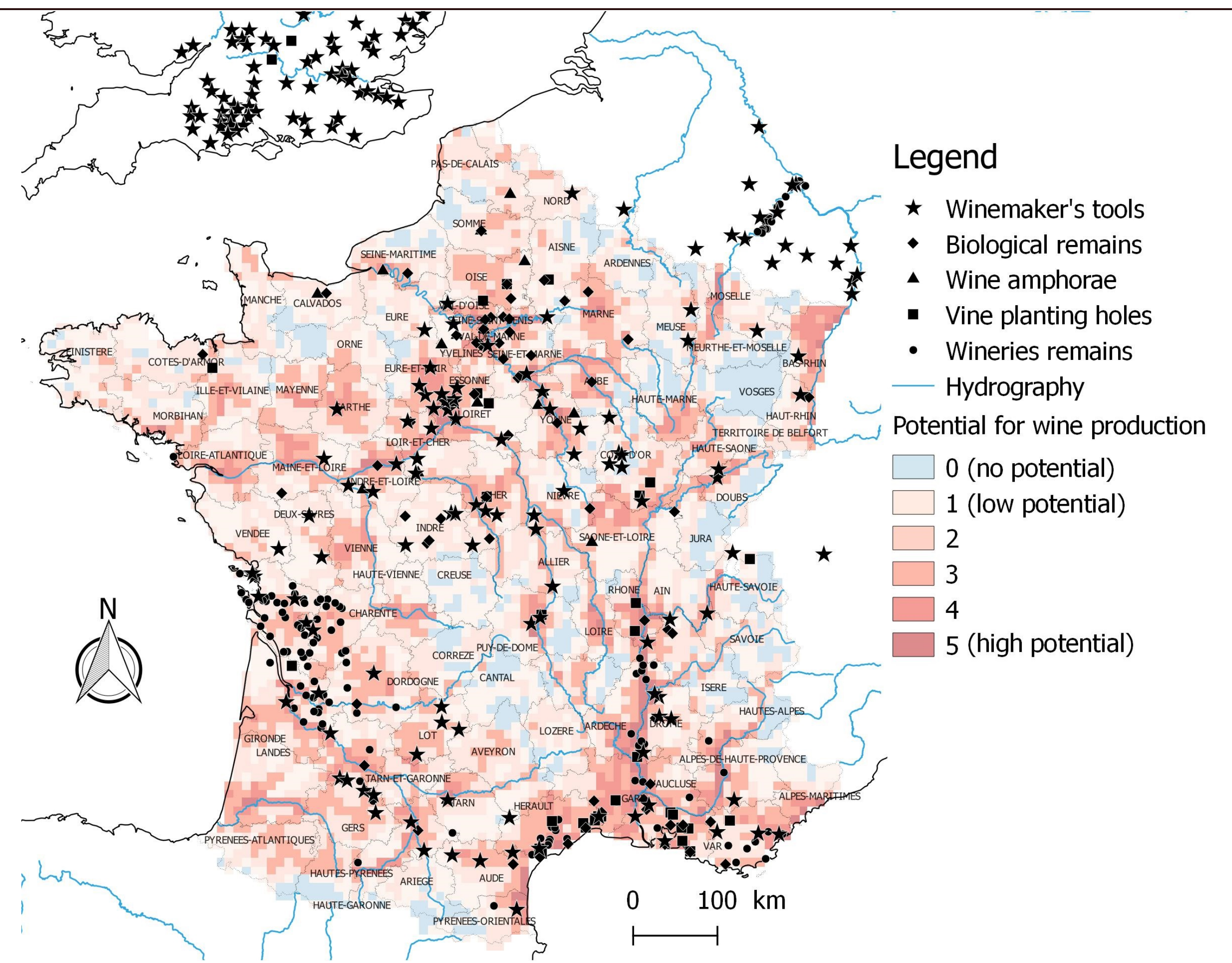
We have selected 6 geographical, historical and environmental criteria which were stacked:

- climate (1): areas with mean of temperatures in July > 18°C according paleoclimatic data (vineyards are very difficult to cultivate under this temperature).
- land exposition(2): land facing south and east (according Columelle De Re Rust., III, 12).
- Proximity of a market (3): land around 30 km of the capitals of cities.
- Proximity of a trade route: land around 10 km of the main roads (4), large rivers (5) and coastline (6).

The results show a very good potential (in red) in the south of Gaul, the Rhone-Saone valley, the Paris Basin and the south-west of France where numerous archaeological data testify of wine-growing. But a very good potential appears too in regions where no archaeological data are still known, noticeably in north-west of France (Brittany), but also in the Pyrenees area.

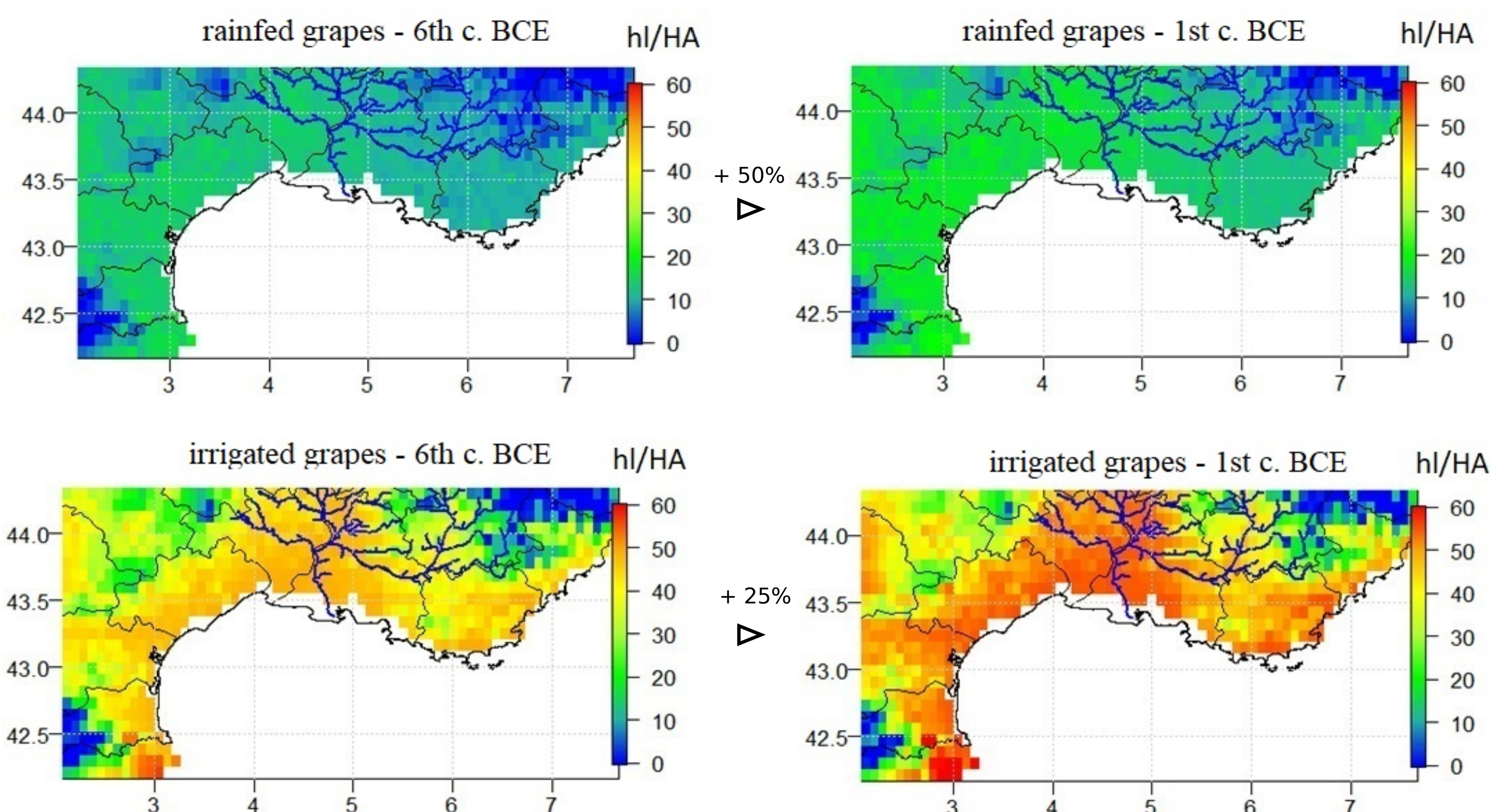
Would roman wine-making be difficult to perceive by archaeology in these areas ?

*Bernigaud N., Bondeau A., Guiot J., Understanding the development of viticulture in Roman Gaul during and after the Roman climate optimum: The contribution of spatial analysis and agro-ecosystem modeling, Journal of Archaeological Science: Reports, Vol. 38, 103099, 2021.



Map of potentiality for the location of vineyards in Roman Gaul (according the climate of the 1st c. CE)*. The (bio)archaeological data concerning wine-making are overlapped.

Agroecosystemic modeling LPJmL : simulating potential yields



Exemples of potential yields (hl/ha) processed by LPJmL model for the 6th c. BCE and the 1st c. BCE (simulation with rainfed and irrigated cultures were distinguished)

Developed by agronomists, the agro ecosystemic model Lund-Potsdam-Jena-managed-Land simulates potential yields of main cultivated crops worldwide using climate data in entry. LPJmL runs for rainfed and irrigated cultures. This kind of modeling has been recently adapted for the study of the past with paleoclimatic data*.

The figure beside shows potential yields for grapes (in hectoliters/hectares) for two centuries which climate was very different: the 6th c. BCE (very cold and dry) and the 1st c. BCE (very hot and wet).

According to the model and paleoclimate data, the potential yields of the 1 c. BCE appear very higher (25%-50%) than for the 6th c. BCE.

This result supports the hypothesis that the so-called Roman Climate Optimum or Roman Warm Period (2nd c. BCE-3rd c. AD) would have been very favorable for the development of vineyards in Gaul.

*Contreras D. A. Hiriart E., Bondeau A., Kirman A., Guiot J., Bernard L., Suarez R., Van der Leeuw S., Regional paleoclimates and local consequences: Integrating GIS analysis of diachronic settlement patterns and process-based agroecosystem modeling of potential agricultural productivity in Provence (France), Plos One, 2018. <https://doi.org/10.1371/>

Agent-based modeling (ABM) : simulating the benefits of winemaking

For calculating potential benefits of wineries, we have programmed an ABM model (ROMCLIM under Netlogo) which integrates an emulation of LPJmL model presented above.

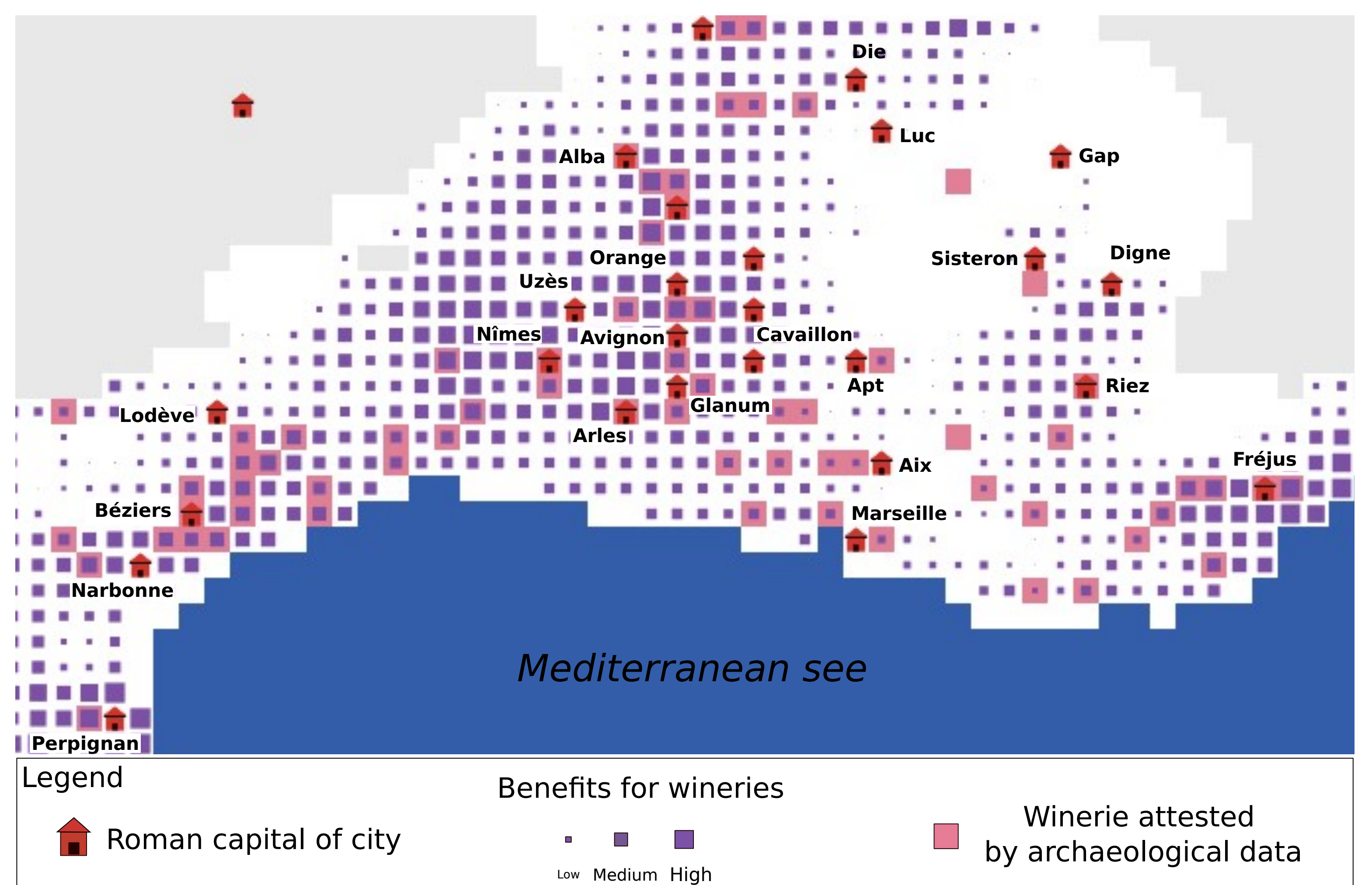
The agents programmed are wineries with number of characteristics (area cultivated, number of exploitants, costs of exploitations, etc.) for which some information are given by Latin texts (mainly agronomists).

During the simulation launched with this ABM, the annual production of wine is calculated by the model for each winery by the multiplication of potential yield (returned by LPJmL) by the area cultivated. Then, the profits are calculated by the sale of the production on the closest urban market, according to a selling price chosen by the user. The costs of exploitation and transports are deduced from the profits to estimate the benefits (proportional to the size of purple squares on the map beside).

The output map for the 1st c. CE shows a very good potential for the benefits of winemaking in languedocien plains (around Béziers), in the middle Rhone valley (Arles, Orange, Avignon, etc.) and in eastern Provence (Fréjus), where Roman wineries are known by archaeological data.

However, the model highlights to some regions with a high potential (Nîmes hinterland, Riez area), where nonetheless nothing is known about Roman viticulture. These results could have a predictive value which encourages further upcoming archaeological researches.

Map of potential benefits for wineries in southern Gaul (1st c. CE)



Vine-growing and Winemaking in the Roman World New data, trends and approaches to Roman viniculture,

An international conference in honor of Jean-Pierre Brun, organized by D. Van Limbergen, E. Dodd & M. S. Busana, Rome, October 27-29, 2021