"ALEXANDRU IOAN CUZA" UNIVERSITY OF IAȘI
FACULTY OF HISTORY
INTERDISCIPLINARY CENTRE FOR ARCHAEOHISTORICAL STUDIES

# STUDIA ANTIQUA ET ARCHAEOLOGICA

27/1, 2021

EDITURA UNIVERSITĂȚII „ALEXANDRU IOAN CUZA”
IAȘI — 2018



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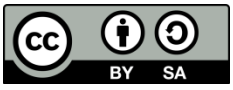



**ISSN 1224-2284**
**ISSN-L 1224-2284**

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INTERVIEW

*Studia Antiqua et Archaeologica* 27(1): 147–171
DOI: 10.47743/saa-2021-27-1-7

# Territorial modelling using Ancient viticulture parameters in Roman Times. A case study in the betic colony of *Hasta Regia*

Pedro TRAPERO FERNÁNDEZ[1]

**Abstract**. *This article analyses the Roman viticulture in Hasta Regia colony, southwest of the Iberian Peninsula, as an ideal place to model historical and economic conditioning factors of this activity. We propose a model that includes an analysis of the territory, the "Riparian" resources necessary for the vineyard, the conditioning factors of the ancient vineyard and finally the economic implications that derive from it. The method allows us to get closer to the management of this economic reality, as well as being able to check whether the various estimates are correct.*

**Rezumat**. *Articolul analizează viticultura romană îm colonia Hasta Regia (Betica). Propunem un mdel care include analiza teritoriului, resursele necesare pentru viticultură, facorii care condiționau viticultura antică și implicațiile economice care derivă din aceasta.*

**Keywords**: ancient viticulture, GIS analysis, Hasta Regia colony, quantitative method.

## Introduction

Although wine production in Roman times was part of the Mediterranean triad, it nevertheless had an important relationship with both *annonae* and luxury goods trade.[2] The different qualities of wine, together with the different complex cultivation techniques required, make it a product with a certain specialization, whose basic parameters are found in the profuse Latin agronomy and specifically in the agriculture books by Lucio Junio Moderato Columella.[3]

In this paper we analyse a study case in the south-west of *Ulterior Baetica* province, the colony of *Hasta Regia*,[4] an actual and past wine-growing area,[5] at the ancient mouth of the Guadalquivir river, an actual marshland that in the past was the ancient coast.[6]

The method combines different materials for create the data modelled, and for that, we analyse:

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[2] Chic 2006; Remesal 1986; Tchernia, Brun 1999.

[3] Tovar 1975; Lagóstena, Trapero 2019.

[4] Montero 2012; Martín-Arroyo 2018.

[5] López, Ruiz 2007.

[6] Roos, Arteaga 1995; Lagostena 2016.

- the archaeological study and location of *villae* in the territory
- the modelling of the possible fundus of each centre, attending to survey criteria
- the agronomic factors for optimum wine areas, using the need for wood, ropes and stakes
- the needs of specific types of soil, elevation and direction of the crops, according to agronomists such as Columella
- the real needs of the various production centres such as labour, hectares of crops or even food for workers.

With all this, we propose an analytic model, which starts from theoretical values collected from classical sources and the assimilation of these typologies with the present day. Despite this possible disjunctive, it is a contrastable model, where each parameter has strong bases about the management of wine production.

The aim is to model the various agronomic parameters, along with their current correspondence in physical conditions, to analyse the potential productivity of the vineyard[7] and be able to know more about the management of this wine economy production.

Therefore, the main contribution of this paper is not the different parameters used, but how they are related to being able to sense new data. It is an inductive model, which gives rise to deductive parameters, with a relative value, but which allow for historical comparisons. In the same way, it supposes a verification criterion to be able to understand if the proposed premises are correct or not. In our case, the main one is if the territorial modelling present in the next chapter has a historical relationship with the supposed wine product for each *villae*.

## Materials and methods

### *Fundi and villae analysis*

We start from the analysis of the Roman rural population to elucidate which are the main *villae* of the territory. These spaces, as production centres, are the reference points for modelling the viticulture in this region, the territory of *Hasta Regia*, whose limits were defined in previous publications.[8]

We have been especially interested in considering which of these spaces can be *villae* in surface surveys, following criteria of size, the appearance of sumptuous materials or

[7] GOODCHILD 2007.

[8] RUIZ et al. 2019.

emerging structures.[9] Most of the information came from few survey prospections without integrative perspective or specific period specialization.[10]

Once we systematized the archaeological information, we wanted to understand how would work the *fundi* of each *villae*.[11] For that reason, we wanted to model the potential area of *fundi* knowing their productive centre.

That is why we start with a simple Thiessen analysis with the software ArcGIS. This shows the average distances between the sites in a mathematical way, not representing reality, but allowing us to have an idea of it. For improve this approach, we adapted this averages tot the natural limits, like the ancient coast, giving a very characteristic distribution of the population, where the farms would be very large, between 250 and 500 Ha, coinciding with the classic agronomists patterns.[12] Several polygons must correspond to gaps in the research or areas that are not part of the farms, in the case of *saltus*.

In any case, this mathematical approximation is not historical, so to propose a possible cadastre, we use the parameters by latin surveyors to delimit pots and farms. The principle is the same as in the case of defining the territory of the civitates.[13] Based on this analysis of average distances, we look for possible natural or artificial boundaries in the area to propose their possible limitation and propose a map for model the potential *fundus* (Fig. 1). In this sense the criteria have been:

- The first natural and clear limit has been the ancient coast itself, although, in the case of small islands, these have been included in the centre of the nearest *villae*.
- The natural criteria to delimit the properties, hills, streams and water basins.
- No human criteria have been recognised, such as the case of boundary markings and similar, although the current roads have been taken into account in the case when they are in natural paths.

This analysis assumes a theoretical framework, based on survey criteria to define the possible maximum *fundus* of these *villae*. Some of those areas would have areas where could be non-discover *villae* or also some parts of the *saltus* of the city. With this approach, we take into account all *Hasta Regia* territory, but it is not a problem since we use these parameters to induce the model and extrapolate this information with the maximum wine production. Some of these parcels could be enough, too large or small, given us a deductive way to know if this way to model the potential *fundus* may correspond to reality.

[9] ANGULO, PORRES 2006; TRAPERO 2020.

[10] PONSICH, 1991; LAGOSTENA, in press.

[11] MARTÍN ET AL. 2017; REVILLA 2012, 2018.

[12] FERNANDEZ et al. 2014

[13] DILKE 1971; CAMPBELL, 2000

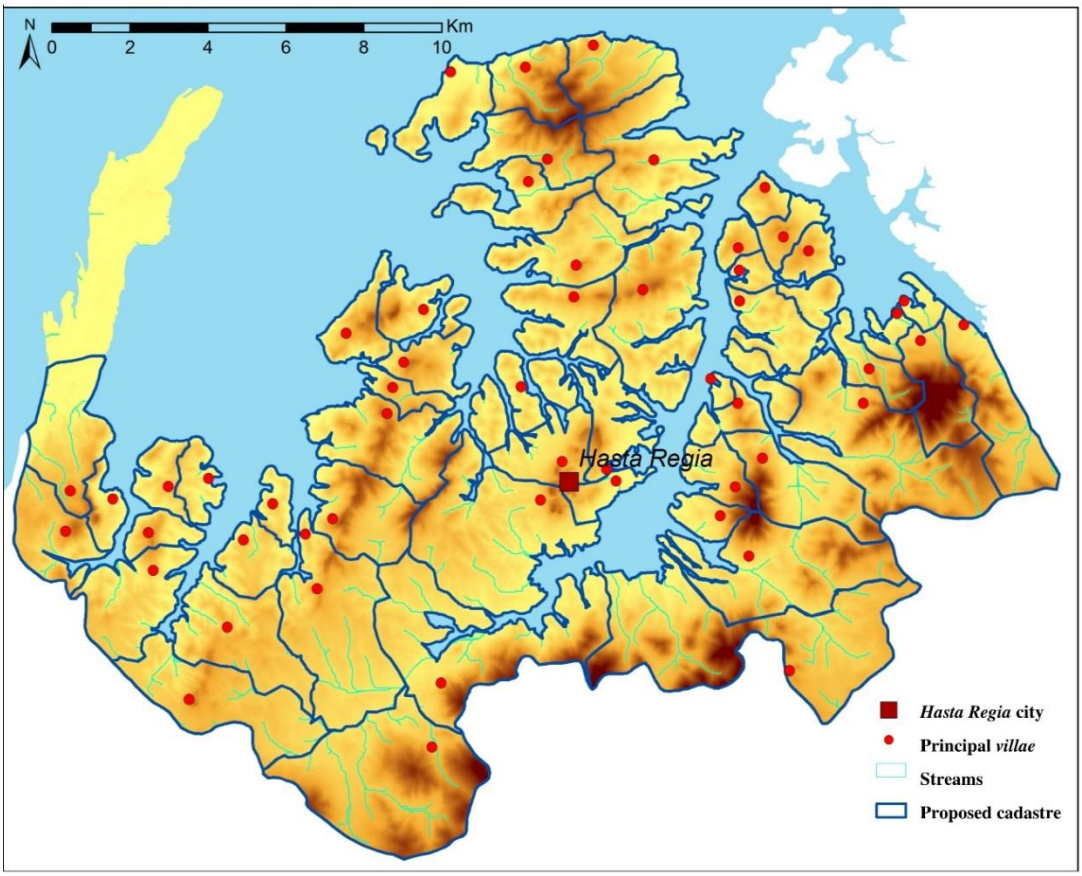


Fig. 1: Proposed cadastre and the main framework for the model.

***Model "Riparian" conditions***

After defining the plot of land, we are interested in analysing those determining factors directly related to viticulture. The use of a cane, esparto and chestnut or other tutors, is necessary for the correct planting of a Roman vineyard and need to be cultivated or harvested on the same farm.[14] Most of this type of plant products are closely related to "riparian" spaces,[15] that have water needs and for our study framework can only be achieved in the immediate area of the ancient coast (salt water) or streams and springs (freshwater).

[14] Columella, *Rust*. 4.30.1

[15] HERMON, 2010

Relevant is the case of the areas of the stream for the canes, as well as the ancient coast for the esparto grass. The tutors as tree species would not need this condition.

Because of this, the potential areas of having these conditions can be modelled. We used a 10 meters buffer on each side of streams, which means a very small area. This has been compared with the maximum width of most of the streams in the area. The hole territory has 26,400 ha and the analysis with a 10-meter buffer for the streams giving us a total of 479.9 ha of the territory that may have this potential for freshwater "riparian" spaces. In the case of the ancient coast, we consider also 10 meters giving us very similar values to the previous ones of 490.9.

This means that approximately 0.4 % of the territory can be left in good conditions for the cultivation of plant species such as esparto grass in the paleo-river and another 0.4 % of freshwater species in the vicinity of streams. Therefore, the total potential of the territory for these species would be 0.8%, a really low percentage, if we consider above all the entrances and exits that the paleo-mouth of the Guadalquivir has.

***Modelling viticulture***

The main criteria are modelled according to Latin agronomists to establish the best conditions for Roman vineyards, taking into account the types of soil, slope and orientation.[16] This method has been already published in previous papers.[17]

The following text can give an idea of what the negative agents are for the vineyards: "Furthermore, they are defects of the place, which generally lead to the ruin of the vineyards, the weakness and sterility of the soil, salty or bitter humidity, sloping and steep position, a valley that is too shady and without sun"[18].

First, we analyse the soil type for viticulture use. In our territory the best will be calcareous regosols, followed by vertisols and luvisols or sandy soils, which the recommendations are made by Columella and also the best current soils for viticulture.[19] In (Table 1) is expressed the values used for ponderate each soil type.[20] Some others could be usefull for wheat or being pooper for crops. This assignment of values does not reflect the best or worst disposition of the different soils; in fact, we consider as good all those that are associated with values of five, eight and ten. The differentiation here is in being able to distinguish which types of soils appear next when combined with other types of criteria. In

[16] OLSON 1943.

[17] TRAPERO 2016A; 2016B; LAGÓSTENA, TRAPERO 2019.

[18] Proper translation. Columella, Rust. 4.22.8. Loci porro vitia sunt, quae fere ad internecionem vineta perducunt, macies et sterilitas terrae, salsa vel amara uligo, praeceps et praerupta positio, nimium opaca et soli aversa vallis.

[19] TERESO 2012; CORZO 1977.

[20] SÁEZ, 1995.

this way, the simple mathematical calculation that adds up the values will give a different composition, if it is a question of one type of soil or another.

Second, about the slopes of the terrain, we have to consider at this point, the reality that much of the territory is optimal from this point of view, for the gentle hills that mark the area of study.[21] We considered slope as an average slope of 7 degrees, as the limit of the flat areas, and up to 11 as an ideal hill area, values given by considering the elevations of the territory itself. With all this, the highest values of this gradient cannot be considered as optimal, since they will be too steep.[22]

These values are reclassified in GIS so that a value of 10 is applied for slopes of less than 7 degrees; 20 between 7 and 11; and finally 30 for more than 11 degrees. The application of these values is thus made to be able to differentiate, with a simple mathematical sum, the values of the different combinations. In this case, for example, the value of 26 would correspond, to the soils of calcareous regosols in a gradient of between 7 and 11, while 25 would be the same gradient, but another type of soil.

Third, we add the orientation of the land. We originally only need to consider an average orientation of the best areas towards where there is more light, that is, to the south. The East is usually well-considered, but, given that for the area due to the influence of the east wind is not recommended, we should consider its use.[23]

The reality is that, for the area of study at present, the Levante or East wind does not affect with the same intensity as for the case of the current coast of the Bay of Cadiz. Therefore, it is considered for this analysis that the East of the hills can be a good position, as well as that of the West. The North orientation is not usually recommended because of its lower luminosity and we continue to consider the South as bad, because, although it does not affect the Levant, the warm winds coming from the Strait have a special incidence in the area and can cause serious problems for this type of delicate crop.

| Value | Edaphic Unit |
|---|---|
| 0 | Takiric Solonchaks and Gleic Solonchaks |
| 2 | Calcium Fluvisols |
| 1 | Verticals, Chromic Vertisols and Calcium Cambisols with Calcium Regosols |
| 1 | Calcium Cambisols, Calcium Luvisols and Chromic Luvisols with Lithosols and Calcium |

[21] Columella, *Rust.* 3.1.8.

[22] Varro *R.R.* 1.6.5.

[23] Columella, *Rust.* 3.12.6.

| | |
|---|---|
| | Fluvisols |
| 3 | Albic sands, humic cambisols and dystric gleysols |
| 0 | Nutritional Planosols, Gleic Luvisols and Plastic Luvisols |
| 6 | Calcium Regosols and Calcium Cambisols with Lithosols, Calcium Fluvisols and Rendsins |
| 4 | Calcium Luvisols, Calcium Cambisols and Chromic Luvisols with Calcium Regosols |
| 5 | Calcareous Vertisols, Rendsins and Regosols |
| 5 | Chromic Vertisols and Verticals with Calcium Cambisols, Calcium Regosols and Pelic Vertisols |
| 6 | Nutritional Regosols, Dystrictive Regosols and Albic Aerosols |
| 5 | Pelvic Vertisols and Chromic Vertisols |
| 6 | Nutritional Regosols, Capillary Xerosols and Lithosols |
| 1 | Vertical Cambisols, Calcium Regosols and Chromic Vertisols with Calcium Cambisols |
| 4 | Calcium luvisols, chromic luvisols and gleic luvisols |
| 4 | Chromic Luvisols Calcium Cambisols and Lithosols |
| 1 | Calcium Cambisols and Calcium Regosols with Lithosols, Calcium Fluvisols and Vertical Cambisols |
| 0 | Molecular Planosols, Pelic Vertisols, Calcareous Phaleozems with Sandy Rankers |

Table 1: values assigned for the model to the different types of soil.

We will consider the different general orientations, where we will consider as optimal the areas to the E and W, as intermediate those immediately in connection SE, SO, NE and NO and finally as worse the N and S. This will be done with values of hundreds to combine them in a sum of the different GIS processes with the others. In this sense, the values 100 will be associated to N and S, 200 to the intermediate ones and 300 to E and W. In the case of flat land areas, we consider them as if they were intermediate. The values obtained from this analysis require another treatment, which consists of unifying the resulting polygons.

The model takes out pixels that are dispersed but very close together, giving spots of optimal locations for the vineyard. However, when calculating the total areas, this is a problem, so a 5-meter buffer is made around these polygons to unify them, since the planting of the vineyard, where chosen, would be extensive.

The territory has a total of 26,409 ha, of which a total of 1,492 ha corresponds to high-quality soils for viticulture based on the above data. This represents approximately 5.6% of the total land. Currently, the specific weight in the territory of the viticulture is higher, over the 4,000 ha dedicated to the cultivation of vineyards. This analysis, however, is only partial, since it is taking the unit measurements from the data pixel that is analysed, of 5x5 meters. Without doubt, there would be no holes in the area of production, so if the potential of continuous farms is considered, these results could be greater (Fig. 2).

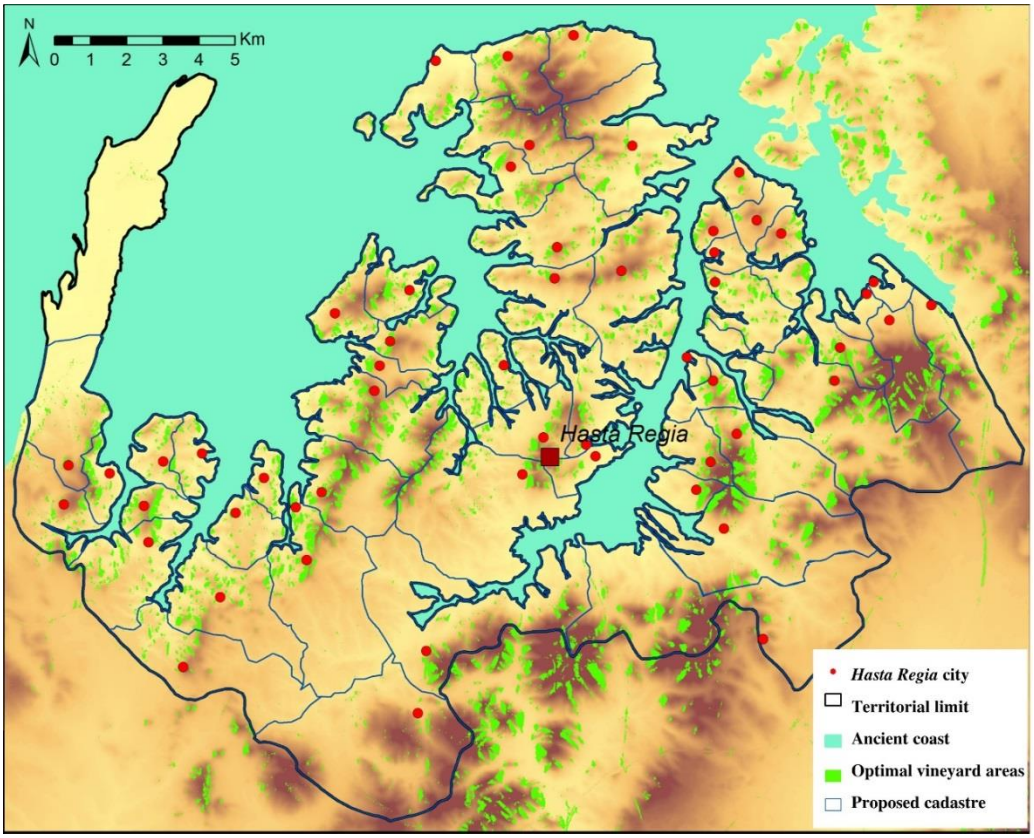


Fig. 2: Optimal vineyard areas in each proposed cadastre.

***Wine production parameters***

With all the spatial components, we only need to analyse the wine production parameters to apply. We can propose some values of wine production of about 3 cups per *iugera*. This average is achieved in the information provided by Columella regarding the minimum yield he considers. Speaking specifically of these calculations, we have several examples that show the possible productivity of the vineyards for Roman times[24]. All the following references are based in Columella (*Rust.* 3.3.2-3):

[24] For the analysis of these values, we use the following reference table, for the transcription of the different measures of weight, volume and area. Columela, *De los trabajos.* p. 317 *iugera*: 2518,21 m$^2$ / Amphora: approx. 26,26 L / Culeo: 20 Amphoras 527,27 L / Urn: ½ Amphora 13,132 L.

- In the texts of Cato and Varro, there is a yield of six hundred urns per hectare of land.
- In the case of the fields of Seneca, each hectare produces eight cupolas.
- For Ceretan fields of Silvino, one vine produces more than two thousand bunches.
- For Columella, eight hundred plants could be crop after two years of grafting reach two thousand bunches, together with the new vines that produce one hundred amphorae per hectare.

A minimum of three hundred or at least two hundred amphorae per yard is proposed as the average value for this management, although for Grecino it very low, says that even if it were 20 amphorae, it would be equally profitable.[25] The minimum profitability of these productions would be one cube per yard.[26] Finally, Columella ends up recommending remove vines that produce less than 3 culeos per *iugera*.[27] The value of 3 culeos comes precisely from this last value provided by Columella as a recommendation. (Table 2).

| | Urn / *Iugera* | Amphora / *Iugera* | Culeos / *Iugera* | Litres / *Iugera* | Litres / $m^2$ | Litres / Ha |
|---|---|---|---|---|---|---|
| Cato and Varon's maxims | 600 | 300 | 15 | 7.879,200 | 3,129 | 31.288 |
| Farms in Seneca | 320 | 180 | 8 | 4.202,240 | 1,669 | 16.687 |
| Columella's new vineyards | 200 | 100 | 5 | 2.626,400 | 1,043 | 10.429 |
| Grecino's profitable minimum | 40 | 20 | 1 | 525,280 | 0,209 | 2.085 |
| Columella's recommendation | 120 | 60 | 3 | 1.575,840 | 0,626 | 6.257 |

Table 2: Different vine yields according to Columella's text

We think that the least recommended to add to the analysis is vineyards at *Ceret*, since it only gives us the productivity by the number of plants, eight hundred vines that

[25] Columella, *Rust.* 3.3.7.
[26] Columella, *Rust.* 3.3.10.
[27] Columella, *Rust.* 3.3.11

produce 7 culeos, a value impossible to take to the previous calculation, since there are many models of distributing the vines.[28]

In the same way, Silvino's case is paradigmatic, but should not be interpreted as representative of production. Columella also criticizes the maximum values expressed by Cato and Varro, precisely because they are too high. In general, we could say that we would be between the great productivity of Seneca's farms and the minimum expressed by Grecino, putting values such as Columella's 3 culeos, as an approximate average.[29]

If we compare these values with the current ones, we can sense if these production would be very far from reality. In the case of "Marco del Jerez" region, the actual territory of the ancient *Hasta Regia* colony, in the 2002 campaign, to give an example of production, it is estimated that the cultivated area is around 10,000 hectares with an average yield of 10,000 kg per hectare, which means approximately 100 million kilos of grapes, which proportionally can be more than 70 million litres of wine produced in the year.[30]

**Results**

***Estimated wine production***

With these productive values and the combination of the modelled areas of vineyard, we can estimate the wine production of Hasta Regia at 9,336,135 litres per year, from an ideal vineyard extension of 1,492 ha and a yield of three cupolas, approximately 6,257.778 L/ha. This means if we compare it with the calculation of the actual "Marco del Jerez", production up to five times less.

About the vine consumption in Roman Times, several theoretical and generalist estimates have been made, which usually coincide around 250 litres per person per year.[31] In any case, it can be used as a maximum parameter, especially if it is calculated for the total possible population, as a representative average.[32] With these values, the territory's production would be sufficient to supply a population of approximately 45,000 people.

This theoretical value give us two main clues. The first one is that the value is much lower than actual wine production. This could be by the better actual techniques or management, but, also that we do not have in this analysis the near cities, like *Gades* or *Nabrissa Veneria*, which also were important winegrowing cities. The second issue is that the

[28] Columella, *Rust.* 5.3.5

[29] INDELICATO 2017.

[30] AA.VV. 2002.

[31] PURCELL 1985.

[32] BRUN 2003; MARTÍN 2015.

production would be very large for the substance of the specific city, even for the region. This is an indirect proof of the commercialization of wine out of the province.

***Needs of other conditions***

This analysis is a generic and theoretical approximation of the territory's production. However, we must completed it by adding not only viticulture but also other activities within the same farm.

We based in the model of Martín-Arroyo[33], who shows us the analysis of these agricultural activities, mainly based on the "riparian" areas necessary to cultivate the vineyard. These basic parameters are based on Columella's quote about the need for one winegrower for every 7 yards of vineyards.[34] It assumes per capita wheat consumption for this person, which is estimated to be about 51 *modii* of wheat per year.[35] Seeing the total yield that wheat can have in the Roman world, which is usually three to one and based on the area of production of this amount per Columella (*Rust.* 2.9.1) 4.25 yards of wheatland would be needed for the winegrower's consumption. This value is increased by adding the seed that is necessary for the next harvest and a three-year system of rotation of the same, which would amount to 18,414 *iugerum* for the maintenance of the same.

We must add the proportion the land that has to be set aside to be able to put the vineyard into operation, namely, osier bed, cane and chestnut groves. The ratio is that each yoke of brick is worth twenty-five of vine, twenty of cane and twenty of chestnut to stake as well as the cane[36].

This means a proportion of 0.63 i*ugerum* of "riparia" (chestnut trees, which do not have these water needs, are removed from the model) and is put about the total non "riparia" land required. It is 7 *iugerum* of vines, the 18,414 of wheat for the winegrower and the part reserved for chestnut trees, which amounts to 0.35, giving a value of approximately 25.764 of non "riparia" for every 0.63 of "riparia". Besides, a correction is added if cane is considered as non-riparian, the proportion being 26.114 as against 0.28.

The application of this model is an attempt to understand the potential of this type of crop, relating it to the potential of "riparian", as a preferential and not marginal place within Roman agriculture. This type of analysis, however, does not achieve great results in our area of study, since only five of the 54 villages under study do not have access to the paleo-river, the ideal place for the cultivation of some of these "riparian" products.

[33] Martín-Arroyo, Trapero Fernández 2015; Martín-Arroyo 2016; Martín-Arroyo, Remesal 2018; Martín-Arroyo, Castro 2019.

[34] Columella, *Rust.* 3.3.8.

[35] Cato. *Agr.* 56; Duncan 1974, 147.

[36] Martín, Remesal 2018, 217.

***Wine management and production***

Following these ideas, a calculation has been made of the proportion of land dedicated to cereals based on the need to supply one person, a winegrower, who will work 7 i*ugerum* of land. However, if we consider a different scale, specifically the one we have modelled for the territory of *Hasta*, we can get an idea of the workforce needed to put these vineyards into operation, the amount of land, in wheat, needed to supply food and the conditions of other associated crops for the vineyards.

We start from a series of previous historical conditions, such as Cato's model, which involves 13 slaves for 100 iugera of wine and 15 slaves for 240 iugera of olives.[37] We are talking about the management measures of a property, not so much the minimum extension itself,[38] so it could be used in Columella chronology as well. Varro makes some very interesting assessments regarding the number of workers commented on by Cato for each of these activities. Through Varro, we also know Saserna's opinion in which he generically refers to the need for one person for every eight *iugerum*.[39]

We have already commented that proportionally the work values of Cato can be assimilated, concerning what Columella recommends, with the difference that, for this second, the work of the winegrower is specialised. But to see the minimum number of workers needed in the cereal lands, we must undoubtedly consider Columella again. He gives a proportion of eight people and two pairs of oxen for every two hundred *iugerum*[40] "a field of two hundred *iugerum* can be cultivated with two pairs of cattle, an equal number of teamsters and six labourers, provided it has no trees"[41]. These values can serve as a basis for working on a potential model in which to integrate the different agricultural management activities, necessary for understanding Roman viticulture.

If we compare with medieval times, we can have an average of approximately 1.5 ploughs of vines, which is what is usually leased to a peasant family. This means approximately 6,708 m2,[42] which, if we compare it with the 7 *iugerum* that a slave winegrower can carry, would be 17,627.47 m2.

We should establish these basic parameters, considering also the potential of the analysis to these other eight people who would be entirely dedicated to the cultivation of

[37] El Boudizi 2003.

[38] Lo Cascio 2009, 33.

[39] Varro *R.R.* 1.18.1-2.

[40] Columella, *Rust.* 2.12.7.

[41] Proper translation. Hac consummatione operarum colligitur posse agrum ducentorum iugerum subigi duobus iugis bovum totidemque bubulcis et sex mediastinis, si tamen vacet arboribus.

[42] Borrero 2003.

wheat. We understand that they do not have to dedicate all their time to the cultivation of wheat, which is much more seasonal than the vine and, therefore, these people could be in other activities, in the case of livestock or the care of the vegetable gardens. Besides, if we consider the existence of olive groves, Cato gives us an average of the people we may have associated, with which we can weigh the workers needed to put into operation an area of cereal, olive groves and vineyards.

We consider that for the feeding of a slave, starting from the model expressed above, it is necessary to have 6,138 *iugerum* of wheat.[43] In the same way, that the Roman system of a plantation would be biannual, so the total area needed would be 12,276.[44] If we also add an ideal farm of 200 *iugerum* of farmland dedicated to wheat, we would sum up the consumption of the eight people needed to make this system work, which would be 98,208 *iugerum* of land, plus the winegrower, 110,484 *iugerum*. This means an approximate extension of the land of almost 28 hectares, dedicated to cereal production for own consumption.

In (Table 3) we present the data and results of this model, under the following criteria:

- The potential areas of vineyard previously analysed have been used in comparison with the total of the territory, identifying the theoretical fundus that has been assigned with the cadastral model.
- In the same way, the values of "riparian" potential, in section 3.2.5. Associated crops were used to add in this table the estimated values of possible area for these uses.
- After this, an analysis was made of the minimum areas of cane and wicker that corresponded to the minimum "riparian" necessary to be self-sufficient. Also, we considered other crops such as chestnuts, which would not be strictly riparian.
- Finally, we propose the number of people that might be necessary, an average of one vinedresser for 7 *iugerum* and eight workers for two hundred *iugerum* of cereal, to which we add their possible wives and children, doubling this value and also adding the foreman and his wife.

| *Villae* | *Fundus* ha | Optimal vineyard ha | Vineyard % | Modelled marshland and streams in ha | Min.cereal cultivation in ha | Min. total área needed ha | Min. riparian area in ha | Min. other crops área in ha | Min. vineyard workers require | Total workers (Manager, slaves, families) |
|---|---|---|---|---|---|---|---|---|---|---|

[43] MARTÍN-ARROYO, REMESAL 2018, 217.

[44] GARCÍA 1979.

| | | | | | | | | | d | |
|---|---|---|---|---|---|---|---|---|---|---|
| Alamedinilla III | 590,8 | 62,9 | 10,7 | 19,1 | 465,9 | 537,6 | 5,7 | 3,1 | 9,0 | 37,9 |
| Alventus | 373,7 | 19,1 | 5,1 | 19,8 | 158,5 | 180,3 | 1,7 | 1,0 | 2,7 | 12,9 |
| Berango | 172,0 | 14,5 | 8,4 | 7,3 | 125,9 | 142,4 | 1,3 | 0,7 | 2,1 | 10,3 |
| Carranza | 607,8 | 16,4 | 2,7 | 19,5 | 139,6 | 158,3 | 1,5 | 0,8 | 2,3 | 11,4 |
| Casa de la Gallarda | 1.355,2 | 39,2 | 2,9 | 54,7 | 299,2 | 343,8 | 3,5 | 2,0 | 5,6 | 24,4 |
| casa del Águila | 163,9 | 28,6 | 17,4 | 6,6 | 225,1 | 257,8 | 2,6 | 1,4 | 4,1 | 18,3 |
| Casa del Águila | 443,0 | 23,2 | 5,2 | 13,3 | 187,1 | 213,5 | 2,1 | 1,2 | 3,3 | 15,2 |
| Casarejo 3 | 547,7 | 25,9 | 4,7 | 20,6 | 206,3 | 235,8 | 2,3 | 1,3 | 3,7 | 16,8 |
| Caserón de Evorilla | 206,0 | 10,3 | 5,0 | 6,6 | 96,6 | 108,3 | 0,9 | 0,5 | 1,5 | 7,9 |
| Casit | 44 | 18,5 | 4, | 13,2 | 154,5 | 175,6 | 1,7 | 0,9 | 2,6 | 12,6 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| a Palomares | 2,1 | | 2 | | | | | | | |
| Cerro Capita | 294,3 | 24,9 | 8,5 | 15,1 | 199,1 | 227,5 | 2,2 | 1,2 | 3,6 | 16,2 |
| Cerro de las Vacas | 460,5 | 4,0 | 0,9 | 16,3 | 52,8 | 57,4 | 0,4 | 0,2 | 0,6 | 4,3 |
| Cerro de los Castillejos | 387,4 | 35,9 | 9,3 | 18,3 | 276,4 | 317,3 | 3,2 | 1,8 | 5,1 | 22,5 |
| Cerro Gibraltar | 96,4 | 0,3 | 0,4 | 3,4 | 26,9 | 27,3 | 0,1 | 0,1 | 0,1 | 2,2 |
| Corchitos 2 | 111,2 | 0,1 | 0,1 | 10,2 | 24,7 | 24,7 | 0,1 | 0,1 | 0,1 | 2,0 |
| Corchitos 3 | 99,6 | 0,2 | 0,2 | 8,6 | 25,6 | 25,8 | 0,1 | 0,1 | 0,1 | 2,1 |
| Cortijo de Alijar | 829,8 | 16,0 | 1,9 | 21,4 | 136,9 | 155,2 | 1,4 | 0,8 | 2,3 | 11,2 |
| Cortijo de Cestelo | 1.122,7 | 24,9 | 2,2 | 33 | 199,1 | 227,5 | 2,2 | 1,2 | 3,6 | 16,2 |
| Cortijo de Évora 5 | 187,6 | 12,3 | 6,6 | 9,7 | 111,1 | 125,2 | 1,1 | 0,6 | 1,8 | 9,1 |
| Cortijo de | 285, | 38,1 | 13,4 | 15 | 291,9 | 335,4 | 3,4 | 1,9 | 5,4 | 23,8 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Monteagudo | 1 | | | | | | | | | |
| Crespellina | 915,6 | 38,4 | 4,2 | 39,6 | 293,6 | 337,3 | 3,5 | 1,9 | 5,5 | 23,9 |
| El Cementerio | 47,6 | 2,7 | 5,7 | 3,9 | 43,7 | 46,8 | 0,2 | 0,1 | 0,4 | 3,6 |
| El Olivar Casarejo | 474,3 | 20,4 | 4,3 | 19,3 | 167,8 | 191,1 | 1,8 | 1,0 | 2,9 | 13,7 |
| El Pastor | 109,7 | 15,6 | 14,2 | 4,7 | 134,0 | 151,8 | 1,4 | 0,8 | 2,2 | 10,9 |
| El Peñón | 358,9 | 30,6 | 8,5 | 13,3 | 238,8 | 273,6 | 2,7 | 1,5 | 4,4 | 19,5 |
| El Pino 1 | 1.771,1 | 72,6 | 4,1 | 51,9 | 533,8 | 616,6 | 6,5 | 3,6 | 10,4 | 43,5 |
| Espartina | 240,5 | 12,7 | 5,3 | 8,7 | 113,9 | 128,4 | 1,1 | 0,6 | 1,8 | 9,3 |
| Finca el Olivillo | 105,6 | 29,6 | 28,0 | 5,8 | 232,3 | 266,1 | 2,7 | 1,5 | 4,2 | 18,9 |
| Haza de la Torre 2 | 628,4 | 40,9 | 6,5 | 17,7 | 311,1 | 357,7 | 3,7 | 2,0 | 5,8 | 25,3 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| La Galguera | 1.320,0 | 71,8 | 5,4 | 46 | 528,3 | 610,2 | 6,5 | 3,6 | 10,3 | 43,0 |
| Loma de Alijar | 720,6 | 37,8 | 5,2 | 21,1 | 289,5 | 332,5 | 3,4 | 1,9 | 5,4 | 23,6 |
| Loma de Cartuja 3 | 560,5 | 52,2 | 9,3 | 12,3 | 390,7 | 450,3 | 4,7 | 2,6 | 7,5 | 31,8 |
| Loma de Espartina VII | 348,3 | 40,8 | 11,7 | 14,7 | 310,5 | 356,9 | 3,7 | 2,0 | 5,8 | 25,3 |
| Loma de Maina | 584,8 | 32,7 | 5,6 | 20,8 | 253,8 | 291,1 | 2,9 | 1,6 | 4,7 | 20,7 |
| Loma de Ventosilla | 142,4 | 11,4 | 8,0 | 8,5 | 104,5 | 117,5 | 1,0 | 0,6 | 1,6 | 8,5 |
| Los Villares | 865,9 | 27,6 | 3,2 | 37 | 218,1 | 249,5 | 2,5 | 1,4 | 3,9 | 17,8 |
| Mojón Blanco | 177,3 | 1,3 | 0,7 | 4,6 | 33,5 | 35,0 | 0,1 | 0,1 | 0,2 | 2,7 |
| Mojón Blanco 2 | 122,0 | 2,5 | 2,1 | 4,6 | 42,4 | 45,3 | 0,2 | 0,1 | 0,4 | 3,5 |
| Molino de Mont | 266,6 | 28,4 | 10,6 | 11,8 | 223,5 | 255,8 | 2,6 | 1,4 | 4,1 | 18,2 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| eagudo | | | | | | | | | | |
| Monjas | 265,9 | 20,3 | 7,6 | 12,2 | 166,6 | 189,7 | 1,8 | 1,0 | 2,9 | 13,6 |
| Montegil de Buenavista | 432,5 | 36,3 | 8,4 | 7 | 278,9 | 320,2 | 3,3 | 1,8 | 5,2 | 22,7 |
| Norieta Grande | 162,9 | 32,4 | 19,9 | 6,3 | 251,4 | 288,3 | 2,9 | 1,6 | 4,6 | 20,5 |
| Olivillo Alto | 291,3 | 11,9 | 4,1 | 10 | 108,1 | 121,7 | 1,1 | 0,6 | 1,7 | 8,8 |
| Painobo | 721,0 | 72,3 | 10,0 | 26 | 531,5 | 614,0 | 6,5 | 3,6 | 10,3 | 43,3 |
| Portugalejo | 1.314,3 | 114,4 | 8,7 | 38,2 | 826,8 | 957,2 | 10,3 | 5,7 | 16,3 | 67,3 |
| Portugalejo II | 262,5 | 30,2 | 11,5 | 13,4 | 236,0 | 270,4 | 2,7 | 1,5 | 4,3 | 19,2 |
| Pozos del Rosario | 381,0 | 25,6 | 6,7 | 15,2 | 204,2 | 233,4 | 2,3 | 1,3 | 3,7 | 16,6 |
| Redondón | 380,7 | 21,6 | 5,7 | 11,6 | 175,8 | 200,4 | 1,9 | 1,1 | 3,1 | 14,3 |
| Regaj | 15 | 7,6 | 4, | 9,2 | 78,1 | 86,8 | 0,7 | 0,4 | 1,1 | 6,4 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| o 1 | 6,7 | | 9 | | | | | | | |
| Regajo 3 | 359,9 | 17,9 | 5,0 | 26,4 | 150,3 | 170,7 | 1,6 | 0,9 | 2,6 | 12,2 |
| Viña Cabeza Alcaide | 142,0 | 7,9 | 5,6 | 7 | 80,1 | 89,1 | 0,7 | 0,4 | 1,1 | 6,5 |
| Viña de Arcade | 1504 | 13,0 | 0,9 | 41,8 | 115,5 | 130,3 | 1,2 | 0,6 | 1,9 | 9,4 |
| Viña Rosario | 410,3 | 27,1 | 6,6 | 26,6 | 214,5 | 245,3 | 2,4 | 1,4 | 3,9 | 17,5 |
| Zarpa 2 | 1.087 | 68,3 | 6,3 | 42,2 | 503,3 | 581,2 | 6,1 | 3,4 | 9,8 | 41,0 |
| **Average** | **489,1** | **27,6** | **4,4** | 9 | **218,3** | **249,8** | **2,5** | **1,4** | **3,9** | **17,8** |
| **Totals** | **26.409** | **1.492** | **100** | 970,8 | **1.1788** | **13.488** | **134** | **74,6** | **213,1** | **854,2** |

Table 33: Farm areas analysed concerning optimal vineyards, riparian areas, workers and other criteria.

**Discussion**

***General issues***

With this analysis, we can debate some minor issues about the winegrowing production.

First, the question about of higher yield or higher quality comes in. Without a doubt, the study area does not occupy a quarter of what is currently the Marco del Jerez, although it

does take in a large part of the particularly good areas, such as the north of the actual cities Jerez, all of Trebujena and a good part of Sanlúcar. These maximum production values are reasonable, considering the average production for the territory, which is these three cubic metres of wine.

In addition, not all wine production would be dedicated to wine. Probably, the areas closest to cities, such as the outlying villages of *Hasta Regia*, could not only be used for wine production but also fresh grapes or even raisins. In the same way, knowing the export of products such as *defrutum*, no doubt part of these productions would be destined to these uses or products such as vinegar. The relevant question here is if for this type of production, which is not so main, it would be necessary to use the best croplands or it would be enough to use more normal lands.

Second, about the "riparian" needed, we see the importance of this economical activity that need to be part of farm management. Although, given the small amount of land required and the potential of the territory to have wells, there could be the possibility of watering these certain resources if necessary.[45] In this case, the need of those spaces would not be so relevant for this analysis.

Third, about the labour, it is difficult for all the agricultural activities we have in a vineyard to be carried out by a single person. The vine grower is strictly dedicated to the constant tasks required by the vineyard, such as digging, pruning, plucking, etc. However, to cultivate the vine and especially in the harvest, other people would be needed, either other slaves from the same farm or hired workers for these seasons.[46] Those people could be the ones we analyse in our model.

***Management and feedback***

With this model, we propose a theoretical model that would give us the minimum real extension necessary to be able to cultivate some areas of vines, which have been modelled as optimum, in the context of a certain fundus that corresponds in turn to the average distances between sites analysed and historical criteria for their delimitation.

This analysis must be understood with caution, especially when considering the small and medium property that would surely exist between the large wine estates. That is why the main parameter is the optimal areas of the vineyard, which simply answers the question of, if these areas were planted with vines, how much of other resources would be

[45] BOWMAN 2013; FRANK 2004; WILSON 2014.

[46] MEIGGS 1989.

necessary.[47] Under this premise, the model addresses the theoretical potential put into practice, since the parameters used are entirely based on classical agronomy.

The values that can be observed in Table 3 are not strange for a product area such as Jerez, where current viticulture surpasses these values in area and productivity. The number of people that we consider, approximately eight hundred and fifty for all the main towns in the area, does stand out at first sight.

We should also mention Cerro Gibraltar or Corchitos 2 and 3, where the model has barely registered optimal areas for vineyards, despite being areas with important archaeological remains that show us potential villae in the area. Perhaps the effect of the data chosen, especially the soil typology, is the explanation for these values since all these sites are very close to the ancient coast.

It is also important to highlight in (Table 3) the maximum areas needed for the vineyard, adding up the area of the vine itself, with those of "Riparia" and other crops, and finally the estimated area of cereal to maintain the members of the estate itself. There are *fundi* that are smaller than the areas that have been proposed, especially in the case of the smallest ones. This contradiction is a value in itself of the model itself, as it can serve to correct and contemplate the viability of a given theoretical wine farm. Probably the *finia* defined among these *fundi* do not fit the existing reality in the background. The cases of *villae* such as Lomas de Espartinas VIII, Portugalejo 2 or Cortijo de Monteagudo, whose suitability for vine cultivation is very high, are interesting, but the potential area of the same would not be sufficient in our theoretical model to produce the own food consumption and requirements of the vine for that estate. This surely confirms that not all the optimal area would be used for vine cultivation since even in a case of specialization of the vine; other crops would not be abandoned secondarily.

If we assume, for a moment, that the farm was only dedicated to wine production, this would be the minimum land that a slave-run farm should have, in the conditions described by Columella. Evidently, on this matter, there can be controversy, since the feeding of the people in the village would not be only of wheat, as the cultivation of other vegetable species in the fallow land or the own cattle raising that could have in the property. However, we find this an interesting methodological approach, since be based our study entirely on values expressed by agronomy.

Along with this, we must consider whether the need of eight people for every two hundred yards of cereal land. We are probably dealing here with a type of work that would involve salaried workers, possible peasants or free settlers who could carry out certain support tasks. In any case, if these parameters are possible for the village described by

[47] Carandini 1987.

Columella, these workers would occupy other tasks once the sowing and harvesting are finished, such as helping in the maintenance of the vineyard itself or other activities. That is why we believe that the analysis is quite logical and exportable to other areas.

Finally, we should highlight the potential of implementing this same model with oil production, which undoubtedly should have existed in the background in our territory, but is mainly in other areas of the Betica or outside it.

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