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# Studies

## ARCHAEOLOGY

### STATISTICAL PATTERN ANALYSIS OF ROMAN *VILLAE* IN ANDALUSIA FROM QUALITATIVE MULTISTATE VARIABLES

**Abstract:** The political and cultural domination of Rome over the Iberian Peninsula and, more specifically, over its southern half (later the province of *Baetica* (Andalusia, Spain) produced a prolonged process of Romanisation in all areas between the 1st century BC and the 5th century AD. During these years a large number of *villae* were erected in Andalusia, mainly in the region near the Guadalquivir river valley. However, the archaeological information available is very scattered and sometimes quite heterogeneous.

This work has been carried out based on a recently published compilation, in collaboration with researchers from Andalusian universities, which contains the state of art of the Roman *villae* in Andalusia. This article focuses exclusively on the *villae* that show evidence of the production of pottery. The pottery associated with these *villae* provide geographical information, chronological information about the period of use, typology of material found, and functionality of material. With this information, a database has been developed containing only the *villae* with associated pottery factories. Subsequently, different statistical analyses have been carried out, including both univariate and bivariate as well as multivariate analyses applied to qualitative multistate variables. The results obtained have allowed us to characterize the *villae* that show evidence of pottery production, to quantify the information in order to highlight the underlying trends in the data, to obtain a statistical classification in several groups, and to characterize the resulting patterns.

**Keywords:** *correspondence analysis, cluster analysis, qualitative, Roman villae.*

#### INTRODUCTION

The Roman occupation of *Baetica*, current day Andalusia, led to an important development of the pottery workshops associated in antiquity with the *villae Baeticae*. This relationship between the ceramic production of the *villa* and its *fundus* is already referred to in classical sources (Varrón *Res Rusticae* I) with regard to the use of a clay quarry as an important economic resource for self-sufficiency of the *fundus*<sup>1,2</sup>. Therefore, the production of pottery in the *villae* ensures the self-consumption of the dominus and also the production of vessels to market the surplus of consumer goods, thus achieving an added benefit. This hypothesis fits an articulation of pre-industrial economies in two sectors, i.e. a natural/domestic

<sup>1</sup> CATO 2009.

<sup>2</sup> VARRÓN 2023.

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sector for subsistence and a monetary/acquisitive sector for commercialization<sup>3</sup> For some years now, archaeological excavations have highlighted the frequency of pottery workshops in *villae* throughout the Western Mediterranean, reaffirming this relationship between agricultural ownership and pottery production. In Italy, many works have studied this relationship and the problems of production in *villae*. These works include those of Pliny the Younger in San Giustino (Umbria), San Pietro di Tolve, San Gilio and Masseria Ciccotti in *Basilicata* or the *Ager Cosanus* and the amphorae production of the *Sestii*. Several collections have been made of Hispanic potteries located in *villae* of the Iberian Peninsula and the relationship between *figlinae* and *fundi* has been analysed.<sup>4</sup>

In the *Baetica*, a complete and systematic catalogue of the finds had not been carried out until 2016. This delay resulted in the absence of analysis of the recorded data<sup>5</sup>, but this work has some limitations. Thus, the locations of pottery factories from the Roman period can be classified as urban, suburban, and rural, though it is sometimes difficult to link a rural pottery factory to a *villa* or to other categories of rural space such as *vicus* or *mansio* since in *Baetica* most of the pottery factories located in the countryside are known via superficial surveys and thus it is difficult to link them to any of these spatial categories of the rural environment. Therefore, in this work we only included the pottery factories that could be classified as *villaticus*.

Further, the factories producing oil amphorae, mainly of the Dressel 20 type, raise several questions regarding management structure, rentals, and *locatio-conductio* contracts among other issues. In addition, the ownership of the pottery factories and their situation on private land, that is, whether or not they belong to *fundi* or public land, is another question that has not yet been completely resolved. The study of these issues has been carried out on the basis of amphorae epigraphy and the analysis of archaeological data. The results have made it possible to establish the heterogeneity of the *figlinae* with regard to their management and ownership, without being able to propose a single model. The governments of Caesar and, above all, of Augustus, produced a very important colonising impulse based on a new form of exploitation and organisation of the territory in *fundi* directed from the *villa*. This new way of exploiting the land led to a significant increase in the production of olive oil, which was transported in amphorae produced in the workshops located along the navigable course of the rivers *Baetis* and *Singilis* to the sea, there to be redistributed throughout the Empire. Another equally complex aspect is the identification of a piece of pottery from the material remains on the surface because there are many cases where firing failures have been linked to pottery without any other indicator of production. In addition, during an excavation or survey, it is common for productivity indicators to appear that may not be identified or that do not appear in the archaeological record.

<sup>3</sup> KULA 1972.

<sup>4</sup> FERNÁNDEZ-GARCÍA/RUIZ/PEINADO 2016.

<sup>5</sup> Hidalgo 2016

These problems have led us to analyze only the workshops unequivocally identified, discarding doubtful locations.

## MATERIALS AND METHODS

Until very recently, research on the potteries of Roman villas has lacked systematization of the data collected in the various excavations. Furthermore, the materials found are not studied from a metric point of view. Rather, the existence of different types of ceramic material found is listed on the basis of binary variables of the presence or absence of the type. A compendium of Roman villas found in Andalusia was published in 1999<sup>6</sup> and, subsequently, an updated compilation was published.<sup>7</sup> We have used the chapter dedicated to the *villa* pottery as it is the most recent complete catalogue. The variables are of an identifying nature (name of each *villae*, locality, and province) together with three archaeological variables (period covered by the remains found, type of material, and the function of the *villae*) (Fig. 1).

The total number of pottery factories associated with *villae* in Andalusia is 184, but there are no data for 61 of these, so the total number having complete data is 123 *villae* workshops. This data set has been used to carry out the analyses. The methodology used was based on multivariate statistical analyses of qualitative variables, mainly on correspondence analysis developed by J.P. Benzècri,<sup>8,9</sup> which is based on the percentages of each modality as calculated by statistical software developed in R programming language by one of authors of this article (José Antonio Esquivel) using the supplementary packages ‘ca’, ‘FactoMineR’, ‘factoextra’ and ‘gplots’.<sup>10</sup> In the Iberian Peninsula, some pioneering works focused on the analysis of anthracological data from archaeological excavations.<sup>11,12</sup> Cluster analysis had been computed using the SSPP statistical software.

## PRELIMINARY REMARKS

Data on the pottery factories of Roman *villae* in Andalusia have traditionally been scattered in different publications and consist, at best, of a small number of qualitative variables with various modalities. In general, the variables available are the occupation period of the *villae* and the typology of the material produced in its pottery factories only. The basis of the work is a very complete catalogue of Andalusian *villae*,<sup>13</sup> focusing only on those with a pottery factory producing various types of pottery.<sup>14</sup> These *villae* have been defined by means of three archaeological variables corresponding to the period of occupation of each villa (I-bC to VaC), the type of ceramic production of their pottery, which is made explicit as A=amphora, CC=common

<sup>6</sup> FORNELL 1999.

<sup>7</sup> HIDALGO 2016.

<sup>8</sup> BENZÈCRI 1973.

<sup>9</sup> GREENACRE 2017.

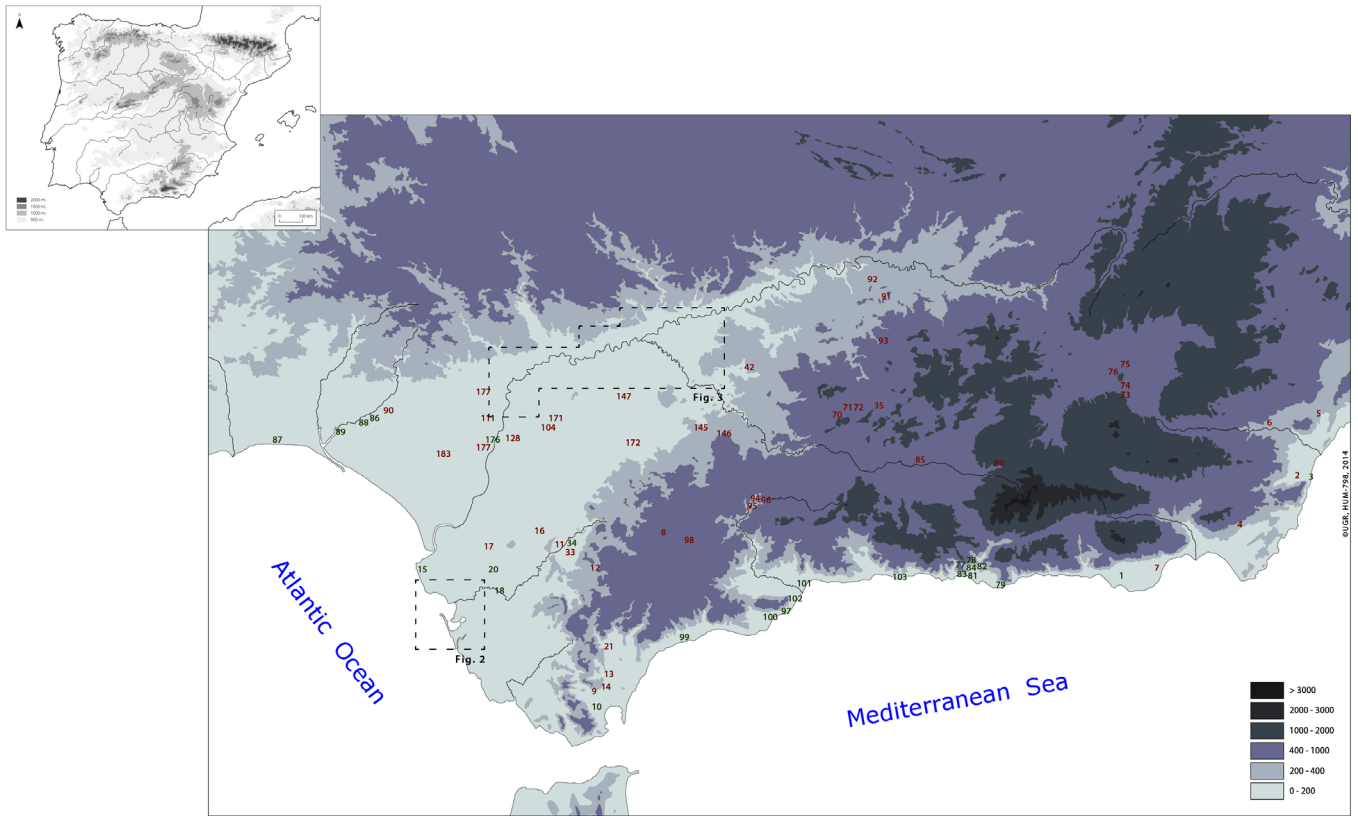
<sup>10</sup> CARLSON 2017.

<sup>11</sup> RODRÍGUEZ-ARIZA/ESQUIVEL 1989-90.

<sup>12</sup> RODRÍGUEZ-ARIZA/VALLE/ESQUIVEL 1996.

<sup>13</sup> HIDALGO 2016.

<sup>14</sup> FERNÁNDEZ-GARCÍA/RUIZ/PEINADO 2016.



**Fig. 1.** Location of *villae* in the *Baetica* region.

ceramics, OC=other ceramics (lucernas, dolia, pondera, etc.) and MC=material construction (bricks, tegulas, etc.). Other variables are the purpose for which the production was destined with the modalities AC=ceramics for self-consumption and CO=ceramics destined fundamentally for trade (see their breakdown by provinces in the annex.<sup>15</sup>

This catalogue is a compilation of different excavations published with extremely varied information, so it is necessary to reclassify the modalities of each variable. The fundamental modalities are the period and the typology of the material. Firstly, the chronological periods are very heterogeneous and were described in a diffuse way due to the different systematic approach of field interventions carried out by the different teams working at the *villae*. In this case, the authors of this work propose a complete and univocal classification of the data in six modalities based on the existing knowledge about periodisation in Roman Andalusia. These modalities were established by means of periods spanning a century or an interval between centuries that characterise the different moments (Table Ia). Secondly, there is a great variety of ceramic production and, in addition, each villa may have produced objects of more than one type (a common case). The classification has been carried out taking into account the most common associations (Table Ib). The purpose of the materials has very little variability as it only has the states ‘trade’ (CO) and ‘for self-consumption in the village’ (AC).

**Table I.** Frequency of variables a) period, and b) material.

Period	n	%	Material	n	%
I-aC	9	7.76	A	44	38.60
I-dC	6	5.17	A_CC	12	10.52
I-II dC	25	21.60	A_CC_MC	20	17.54
II-dC	10	8.62	A_CC_MC_OC	5	4.39
II-III dC	50	43.10	A_MC	18	17.78
IV-V dC	16	13.79	A_MC_OC	2	1.75
a.			A_OC	1	.08
			CC	1	.08
			CC_MC	6	5.26
			CC_MC_OC	4	3.51
			MC	11	9.65

b.

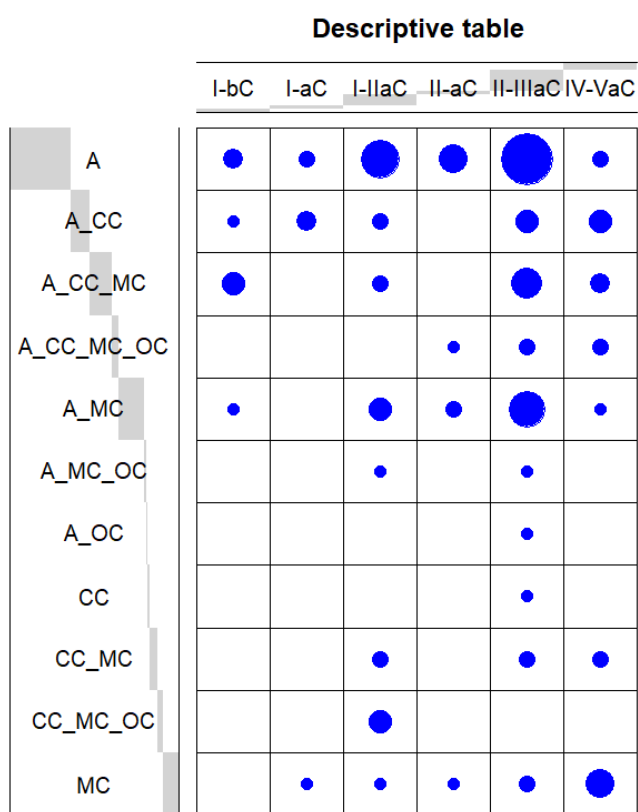
**DESCRIPTIVE ANALYSIS**

Based on this reclassification of the variables ‘period’ and ‘typology,’ a database has been constructed including the two previous variables and the location data ‘name of the *villa*’ ‘municipality to which it belongs’ and ‘province’. Pottery factories in *villa* without chronological or material data have been excluded from the analysis.

The data are shown in a contingency table (Fig. 2), highlighting the production of amphorae in the I-IIaC which increases in II-IIIaC, probably associated with the promotion

<sup>15</sup> FERNÁNDEZ-GARCÍA/RÚÍZ/PEINADO 2016.

of trade in basic necessities supported by the Roman State. The association (A\_MC) of amphorae with building material and also with common ceramics (A\_CC\_MC) also stands out. This result indicates that an increase in amphorae favours the flourishing of the economy both in construction and in the production of common ceramics, although the products themselves packed in the amphorae are the protagonists in the development of the economy. It is clearly observed that economic development begins in I-IIaC and follows an upward trend in the trade flows in basic necessities (foodstuffs) in the period II-IIIaC. However, it should be noted that pottery other than amphorae that appears in I-IIaC does not appear in II-IIIaC, perhaps because they are objects with little added value and/or commercial significance. Finally, in IV-VaC, construction materials dominate the rest of the ceramic production (Fig. 2) as a result of the socio-economic transformations of the period and the fall, by then, of the annony trade.



**Fig. 2.** Chronological periods vs materials in the villae.

The application of the  $\chi^2$  test to the two-by-two archaeological variables indicates that, in all cases, the null hypothesis  $H_0$  of independence between the variables is rejected and, therefore, it is concluded that there is a statistically significant association between the variables at significance level  $\alpha < 0.05$ <sup>16</sup> (Table II).

This result provides that the materials and their intended use are associated with the temporal periods

<sup>16</sup> ZAR 2010.

**Table II.** Association  $\chi^2$  test between the archaeological variables.

	$\chi^2$	df	p-value
period v.s. material	71.279	50	0.02566
period v.s. utility	13.716	5	0.01751
material v.s. utility	63.008	10	9.728e-10

of occupation of the villae and, therefore, more complex analyses of these three variables (only available for the whole of Andalusia) will allow us to obtain relevant archaeological information.

**CORRESPONDENCE ANALYSIS. PERIOD VS MATERIAL**

Correspondence analysis is a technique developed in the 1970s by the French mathematician Jean Paul Benzécri for analysing multivariate distributions of data defined by multistate qualitative variables. It has usually been applied to the analysis of contingency tables and is conceptually similar to principal component analysis (PCA), but since qualitative variables are involved, the data are scaled so that rows and columns are treated equivalently.

This technique is based on Pearson's  $\chi^2$  statistic applied to the contingency table obtained from two qualitative variables.<sup>17,18,19</sup>

The application of correspondence analysis to the three pairs of variables has made it possible to establish the underlying trends in the data, to obtain a factorial structure of few dimensions, and to provide the importance of each variable. In addition, like PCA, the analysis produces a factor-type graph showing graphically the relationships between the modalities of the variables.

This analysis has been applied to the pottery factories with the villae in the Baetica. Firstly, the Period vs Material analysis indicates that a factorial structure based on the first two dimensions carries almost 70% of the variance (or total inertia). This value allows us to establish that the dimensional structure based on two dimensions (dim-1 and dim-2) explains the distribution of the data quite well, especially since there are some cells with very small frequency values. Moreover, adding the dim-3 dimension only increases the percentage of inertia it explains by 15% (Table III):

The first factor (Fig. 3) determines a dichotomy between the potteries of the villae, showing at one extreme

**Table III.** Summary of eigenvalues in correspondence analysis for each dimension.

	dim-1	dim-2	dim-3	dim-4	dim-5
$\lambda_1$	0.24	0.14	0.086	0.065	0.02
% inertia	43.59	25.17	15.24	11.66	4.33
% cum inertia	43.59	68.76	84.00	95.67	100.00

<sup>17</sup> BENZÉCRI 1973.

<sup>18</sup> BAXTER 1983.

<sup>19</sup> GREENACRE 2017.

the periods between the I-IIIaC as opposed to the *villae* in IV-VaC and I-aC corresponding, respectively, to the Low Empire and the High Empire. This bipolar factor determines a classification that reflects the definitive consolidation of the Romanization process (I-aC), a period of expansion in the production of ceramic materials (I-IIIaC) and finally, a period (IV-VaC) of reduced activity marked by the gradual loss of political control of the Roman State in the region, the transformations in the provincial ruling bodies, and the decline of the large-scale trade in basic goods until then sponsored by the Roman State.

With respect to the materials found, at one extreme, a factor dominated by amphorae (A) stands out, together with other materials (MC, OC, etc.) except for common ceramics (CC). This result indicates that, in this period (I-IIIaC), there was a flourishing of the pottery factories in the *villae* and the manufacture of amphorae (perhaps associated with trade), construction activities, and the manufacture of everyday objects such as oil lamps or even ponderae. At the other extreme are located the pottery factory at *villae* determined by construction activities (MC), together with amphorae, although this time associated with common ceramics (A\_CC) or, simultaneously, with all materials (A\_CC\_MC\_OC) (Fig. 3):

together with amphorae (A) and common ceramics (CC). The 2nd dimension (dim-2) is at the opposite pole and is dominated by intervals I-IIaC and II-IIIaC, mainly due to the large amount of amphorae and building materials found. This result is associated with the flourishing interval of the *villae* in Andalusia (Table IV a). With respect to the materials found, building materials (MC) dominate quite intensely in dim-1, which doubles the next most important modality (A\_CC). This indicates that the manufacture of construction materials leads the productive effort and equals the sum of the categories of ceramics plus everyday pottery (Table IV b).

**Table IV.** Contribution of each dimension to the total inertia in the two-dimensional space a) rows, and b) columns.

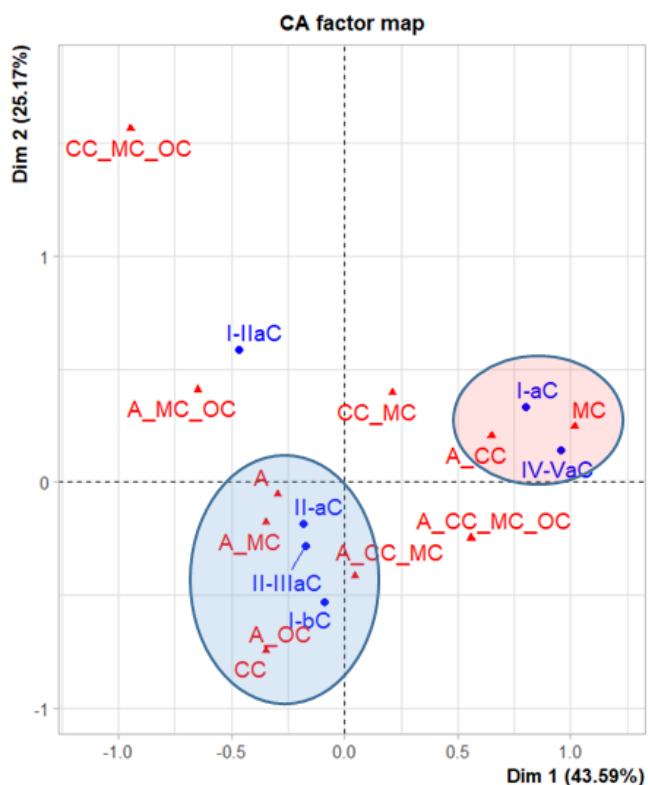
	dim-1	dim-2		dim-1	dim-2
I-aC	0.25	14.85	A	12.93	0.75
I-dC	12.87	3.85	A_CC	19.81	3.39
I-II dC	19.85	<b>53.23</b>	A_CC_MC	0.11	16.09
II-dC	1.10	1.94	A_CC_MC-OC	5.24	1.18
II-III dC	4.95	22.88	A_MC	7.28	3.37
IV-V dC	<b>60.98</b>	2.26	A_MC_OC	2.81	1.94
a.			A_OC	0.40	3.24
			CC	0.40	3.23
			CC_MC	0.90	5.47
			CC_MC_OC	12.02	<b>56.88</b>
			MC	<b>38.84</b>	3.83

b.

The row contributions to the total inertia show that the modality with the highest contribution in dim-1 is in the IV-VaC period (60.98%), while that in dim-2 is associated with the I-IIaC period (53.23%). These row contributions indicate that the modality with the highest contribution is construction ceramics (CM), while the rest of the modalities have a much lower contribution. This fact possibly indicates that this is a time of low activity in the overall ceramic production and that only the production of construction materials is maintained, albeit at a lesser rate. The contribution of dim-2 is focused on the production of ceramics not used for economic purposes, perhaps indicating abandonment of the production activity.

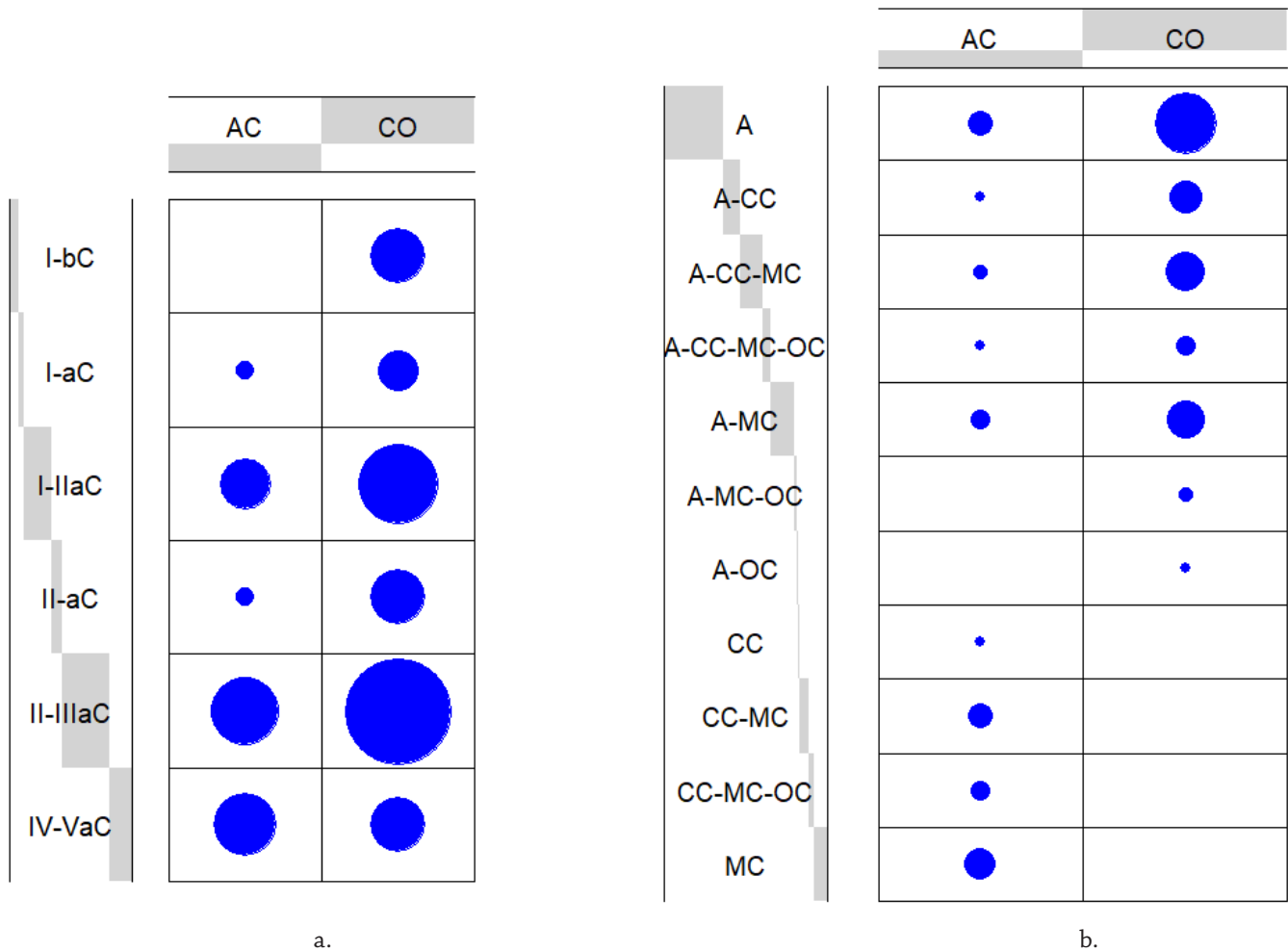
**STATISTICAL ANALYSIS. PERIOD VS FUNCTION AND MATERIAL VS FUNCTION**

The variables Period and Material are the ones that have the greatest influence on the data distribution, showing a greater variability in each modality. On the other hand, the function variable is of great importance since it allows us to analyse very important archaeological information as it focuses to characterize the most important activity of the potteries of the *villae*. Only the data recorded about consumption (AC) and commercial activity (CO) are available for this information.



**Fig. 3.** Biplot two-dimensional from Correspondence Analysis.

The contribution to the inertia of each variable shows that, as far as chronology is concerned, the data have a bipolar structure with the chronology dominated by the IV-V aC period in dim-1, and this is the time when the pottery factories in *villae* seem to show great building activity with a predominance of building material (MC)



**Fig. 4.** Descriptive statistic including the *function* variable.

From the descriptive statistical analysis of the relation Period vs Function it is clear that in I-bC commercial activity has begun and trade is increasing, stabilising in the periods I-IIaC and II-IIIaC. However, the consumption shows an increasing trend beginning in the period I-aC, continuing in I-IIaC, and reaching a maximum in II-IIIaC. Subsequently, it shows a very large drop to the starting levels in the Lower Empire, probably as a result of the phenomena of concentration of agrarian property (Fig. 4a).

On the other hand, the statistical analysis of the relation Material vs Function highlights some important results. Firstly, with regard to commercial activity (CO), the production of construction material (MC), amphorae (A) and common ceramics (CC) stands out while the other modalities have a marginal character. However, with regard to self-consumption (AC), the production of amphorae, although it is produced in the potteries of practically all the *villae*, stands out because there is a large number of potteries in *villae* (44.7%) in which amphorae have been produced exclusively. In addition, it appears in combination with other products, but no pottery factories dedicated to the production of ceramics other than amphorae have been found (Fig. 4b).

Since the variable function has only two modes, the hypothesis that requires the number of modes of each

variable to be greater than 2 is not verified, so it is not possible to apply correspondence analysis.

### CLUSTER ANALYSIS

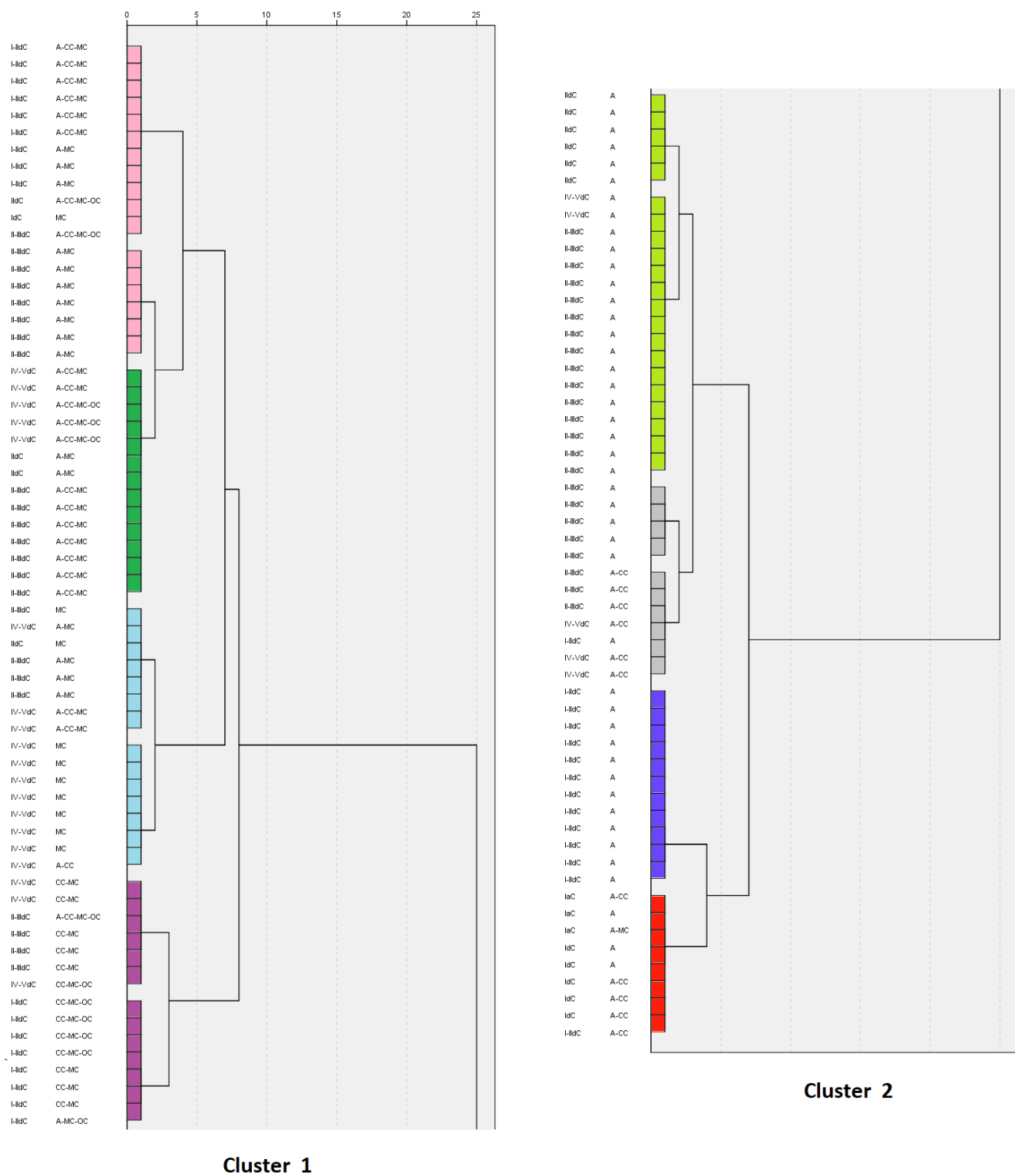
Finally, the multivariate technique of cluster analysis was applied to the archaeological data (Period, Material, and Function) to classify the potsherds attached to the *villae* into groups. In this work, as these are multistate qualitative variables, the similarity measure used is based on the counts of the modalities of the variables using Pearson's  $\chi^2$  statistic.<sup>20</sup> On the other hand, the agglomeration method used is Ward's method, which is based on the fact that in the agglomeration process the variance of the union of two groups is greater than the variance of the original groups.<sup>21,22</sup> At each step of the process the similarity is calculated and the method merges the clusters that minimise the variance of the resulting group. This procedure is SHAN (Sequential, Hierarchical, Agglomerative, and Non-Overlapping), creating homogeneous groups with similar size.<sup>23</sup> The result is displayed by means of the dendrogram plot (Fig. 5).

<sup>20</sup> ZAR 2010.

<sup>21</sup> EVERITT/LANDAU/LEESE 2001.

<sup>22</sup> BOUVEYRON/CELLEAUX/MURPHY/RAFERTY 2023.

<sup>23</sup> KRIEGER/MUTZEL/SCHÄFER 2014.



**Fig. 5.** Dendrogram using period, typology and function

Dendrogram shows the existence of two large groups of pottery production in the *villae*. The *villae* on 'Cluster 1' are characterized by the fact that they contain a great diversity of materials, among which amphorae also appear, but they are mainly associated with construction materials together with other materials. It should be noted that in several pottery factories in *villae* of this group only construction materials and common ceramics appear. This is possibly due to these being larger *villae* or that they had greater

continuity over time. However, among the *villae* of 'Cluster 2,' only amphorae, or amphorae together common ceramics, have been and, in only one case, with construction material.

The two large groups are subdivided into smaller clusters that form specific patterns. Cluster 1 is divided into the subgroups:

- 1A, composed by the *villae* that have a majority A-CC-MC kernel belonging to I-IIaC period. One *villa*

stands out as containing only MC, perhaps because its construction was abandoned or never occupied.

- 1B, formed by the *villae* with an A-MC centre and belong to I-IIaC, with a small sub-group from the IV-VaC.
- 1C, mainly composed of MC from IV-VaC, together with other *villae* that have A-MC and A-CC-MC.
- 1D, composed of *villae* that mostly do not contain amphorae and belong to different chronologies.

Cluster 2 is more homogeneous, having the following subgroups:

- 2A. All the *villae* in this subgroup contain exclusively amphorae A belonging to I-IIaC period.
- 2B. This subgroup is constituted for amphorae A or A-CC, with a chronology mostly from the I-IIaC period.
- 2C. This subgroup consists exclusively of amphorae from the I-IIaC period.
- 2D. The pottery of these *villae* belong to the period I-IIaC and contain mostly amphorae together with common pottery and building materials (Fig. 5).

## CONCLUSIONS

The raw data sets are defined by means of the values of qualitative variables with a large number of modalities, so a prior reduction is necessary. In this sense we have considered time periods and groups of materials on the basis of archaeological significance.

Preliminary analyses have highlighted the importance of amphorae in the ceramic production of the *villae* potteries, both individually (38.60 %) and in association with other products (81.50 %), thus indicating their importance for the economy. This apogee begins in 1-aC, develops until the end of 3<sup>rd</sup> aC and begins its decline in the period IV-VaC.

As these are qualitative multi-state data, a correspondence analysis was carried out to extract the associations between chronological periods and the materials found in the *villae*. The results obtained show a strong association between the IIaC and II-IIIaC periods on the one hand, and the groups formed by *villae* with production of amphorae only, amphorae and common pottery, and of this pottery with building materials on the other. In the I-IIaC period, although dominated by the production of amphorae, there is an increase in the production of building materials. On the other hand, I-aC and IV-VaC periods constitute a group. Additionally, the I-aC and IV-VaC periods are grouped together showing similar characteristics because they both stand out in A\_CC and MC, with small or absent values in the rest.

Finally, the application of a SHAN cluster analysis on each individual *villa* has provided a classification in two large clusters. Cluster 1 is mainly determined by the *villae* with only amphorae remains and, to a lesser extent, by the A\_CC association, and they appear in practically all periods. One possible explanation is that these are the most fragmented remains, or also that they are areas where they have been

used for pottery production but are not associated with any habitat. The Cluster is composed of the data belonging fundamentally to the interval I-IIIaC, which corresponds to the great apogee of Romanisation in Andalusia and, to a lesser extent, to the final period of the IV-VaC period. Perhaps due to this circumstance, the ceramic remains show great variability and it is difficult to find a defined pattern.

The analyses have provided very important information to establish patterns in the pottery factories of Roman *villae* in *Baetica*, although it is necessary to continue obtaining more data regarding other relevant variables.

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