

PEASANT SETTLEMENT PATTERNS IN CENTRAL ROMAN IBERIA: A NETWORK ANALYSIS OF MATERIAL ASSEMBLAGES

Patrones de asentamiento campesino en la Iberia central romana:
Análisis de redes de los conjuntos materiales

FERNANDO MORENO-NAVARRO *

ABSTRACT In recent decades, preventive excavations around the city of Madrid (Spain) have provided us with a unique opportunity to study rural non-elite peasant settlements in the Roman period. Based on the systematic analysis of the archaeological record of nine of these sites and the use of tools derived from network science, this work characterises the consumption patterns of these communities. By focusing on the differences between the patterns of each of the settlements, this work offers new data for interpreting the settlement patterns and how peasant communities exploited the territory in Roman times. The results offer a series of differences between the consumption patterns that are compatible with a ‘distributed habitation’ type of landscape exploitation, in which households are distributed in the landscape in different settlements that exploit the territory more efficiently.

Keywords: Roman Spain, Peasant Consumption, Network Analysis, Centrality Measures, Distributed Habitation.

RESUMEN En las últimas décadas disponemos de una oportunidad única para el estudio de los asentamientos rurales de tipo campesino en época romana debido a las excavaciones preventivas del entorno de la ciudad de Madrid. Sobre la base del análisis sistemático de los registros arqueológicos de nueve de estos yacimientos y la utilización de herramientas derivadas de la ciencia de redes, este trabajo caracteriza los patrones de consumo de estas comunidades. Enfocándonos en las diferencias entre los patrones de consumo cada uno de los asentamientos, este trabajo ofrece nuevos datos para interpretar sus patrones de asentamiento y cómo las comunidades campesinas explotaban el territorio en época romana. Los resultados obtenidos ofrecen una serie de diferencias entre los patrones de consumo que son compatibles con un tipo de explotación

* Fernando Moreno-Navarro (Orcid: 0000-0002-7279-5856) Instituto de Cultura y Tecnología ‘Antonio Rodríguez de las Heras’, Universidad Carlos III de Madrid. fermore@hum.uc3m.es

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del paisaje similar al de “hábitat distribuido” en el que los espacios domésticos se distribuyen en el paisaje en diferentes asentamientos que explotan los recursos del territorio de forma más eficiente.

Palabras clave: Hispania romana, Consumo campesino, Análisis de redes, Medidas de centralidad, Hábitat distribuido.

INTRODUCTION

In this paper, we aim to provide new insights into the complexity of peasant communities within the rural areas of the Roman world. We focused on an area located in Central Iberian Peninsula known as the north of the Carpetania region. We seek to contribute to a better understanding of this area by characterising the domestic consumption patterns of nine distinct peasant communities in this region, based on a systematic analysis of their archaeological evidence. Additionally, we intend to investigate the applicability of the ‘distributed habitation’ concept (Bowes, 2020: 462-464) to interpret the settlement patterns observed in this region. Our main hypothesis is that these can indeed be attributed to a distributed type of settlement pattern. Furthermore, we propose that by analysing consumption patterns, we can better understand these settlement patterns.

To test these hypotheses, we employ network science methods, specifically centrality metrics (Freeman, 1977, 1979, 2004; Barabási, 2002; Newman, 2010; Scott and Carrington, 2011; among others). This approach effectively analyses the relationships between different variables in the archaeological record from these settlements. The application of network science in archaeology has been widely developed in recent years (Brughmans, 2010, 2013; Collar *et al.*, 2015; Mills, 2016; Peeples, 2019 Brughmans and Peeples, 2023; among others), and has shown good results in uncovering complex relationships within the archaeological record.

In recent decades, many studies of the rural world in Roman times have sought to better understand and characterise the living conditions in these areas in a much more complete way. Traditionally, the focus of previous research has been mainly on monumental settlements, i.e., those monumental dwellings known as *villae*. In the region where our research takes place, we have several examples such as Valdetorres del Jarama (Madrid) (Arce *et al.*, 1997) or Carranque (Toledo) (Fernández Galiano, 1995; Arce, 2003) among others. The study of this type of settlement has been the basis for the characterisation of the economy of rural areas in the Roman period, especially since the excavation of the Settefinestre *villa* (Italy) (Carandini, 1985). The characteristics of this *villa* are consistent with a slave-like exploitation similar to that described by authors such as Cato (*Agr.* I, 3, 2-6). Traditionally, the emergence of a market economy based on a long-distance commercial exchange of agricultural surpluses has been associated with the spread of this type of settlement (Giardina and Schiavone, 1981; Leveau, 2007). The use of advanced agricultural technologies, a storage capacity capable of supporting agricultural surpluses, and a wide variety of tableware and cooking utensils could defend this type of economy in Roman times (for an opposite example, *vid.* Bermejo, 2022a:32).

Several projects have transformed the object of study used to characterise the way of life and economy in rural areas of the Roman world. This has been possible thanks to systematic studies of the archaeological record generated by preventive archaeology in different areas of the Roman West (Smith *et al.*, 2016; Allen *et al.*, 2017; Reddé, 2017, 2018; Bowes, 2020; Bermejo and Grau, 2022). These recent studies reinterpret the economic models previously described by traditional historiography (Kron, 2008, 2017; Ouzoulias, 2014), as well as a much more precise characterisation of the Roman rural habitat. These preventive excavations have brought to light archaeological sites belonging to settlements quite different from the monumental *villae*, revealing the existence of habitats compatible with settlements characterised in other contexts as peasant type (Chayanov, 1966; Sahlins, 1972; Netting, 1993).

The north of Roman Carpetania is a good example, which coincides with the location of the current Madrid metropolitan area, leading to the emergency excavation of numerous archaeological sites due to the excessive urban expansion of recent decades. Many of these sites correspond to Roman settlements that are quite different from the monumental *villae* known to date, revealing a quite different settlement pattern, especially in the Early Imperial period (Azcárraga, 2015; Baquedano, 2017; Bermejo, 2017). Systematic analysis of the archaeological materials found at these sites has also revealed consumption patterns similar to others characterised as peasant-type (Bermejo, 2022a, 2022b).

This paper takes up the concept of ‘distributed habitation’ as a form of spatial organisation in rural settlements in Roman times (Bowes, 2020:462-464). In contrast to traditional models that describe settlement patterns as mere clusters of individual settlements, the concept of ‘distributed habitation’ envisions a much more complex form of habitation in which settlements are interconnected and used in a variety of ways for different activities. The peasant settlements studied in Bowes’ project (2020) are not simply those settlements where people live statically in one area, but also serve as spaces where many other functions take place, such as production activities, and ceremonial or religious activities that can articulate the space, just like some shrines found in other contexts (Grau, 2017). In this way, these inhabitants can move around the territory to carry out these activities in the places that suit them best. Bowes (2020:464) describes how, within these landscapes, different structures were maintained by the cooperation of diverse groups of people living in the territory. These structures could be elements of symbolic character, but also structures for the processing of raw materials such as wine presses. The concept of ‘distributed habitation’ provides a more holistic view of the distribution of settlements in the rural areas of the Roman world and, additionally helps to understand how different activities were integrated and coordinated within the community through the organisation of space. Based on the concept of ‘distributed habitation’, this paper attempts to provide data that will help to understand whether this concept of habitat and territorial organisation can be used to explain the settlement patterns that exist in the rural areas of the central Iberian Peninsula.

In this study, we employ network science as a primary method of analysis, focused specifically on centrality measures — specifically Page Rank (Bring and Page, 1998). Our data is mapped onto a network where each node represents one of the nine archaeological sites of our case study. Each link between two sites represents shared artefact types. The strength of this link indicates the number of shared artefact types, capturing shared consumption patterns. We hypothesise that the differences in consumption patterns between these sites reflect the ‘distributed habitation’ settlement pattern. By analysing node centrality, we gain information about the prominence of each site within the network as a function of shared consumption patterns. Centrality measures allow us to examine similarities and differences in consumption patterns across the network. Centrality measures (Bonacich, 1972; Freeman, 1977, 1979; Stephenson and Zelen, 1989; Newman, 2010) cannot be used to identify similarities between different nodes in a network, as these measures are designed to assess the importance of a node in relation to the network. Other analyses, such as Brainerd-Robinson coefficient (Peeples, 2011), can assess the similarity between two pairs of nodes, and it was used in other archaeological contexts (Mills *et al.*, 2013, 2015). However, in our case, we used centrality measures to calculate the hierarchy of nodes in the 1-mode network composed of archaeological sites. Hierarchy refers to the degree to which the nodes of the network are organised into levels of importance.

The remainder of this paper is organised as follows: In the next section, we provide an introduction on how we characterise settlement patterns by analysing the consumption patterns. We also discuss how the elements that influence these consumption patterns result in distinctive ‘fingerprints’, unique to each settlement. Following this, in the Materials and Methods section, we present in detail the case study and the archaeological sites that form it. We then present the methods we have used in this paper, detailing the centrality metrics used and explaining why they are important for our study. Subsequently, in the Results section, we present our findings, detailing in different subsections each of the parts analysed. Finally, we discuss and conclude with an exploration of our analyses’ results. We explore how they align with the ‘distributed habitation’ pattern found in other archaeological contexts, and how various aspects, such as length of occupation, activities performed, and the nature of the settlements, influence the archaeological record.

HOW DO WE CHARACTERISE SETTLEMENT PATTERNS THROUGH CONSUMPTION?

The study of consumption in Archaeology has two main threads of focus (Mullins, 2011). One approach is structural, which looks at the material, ideological and other processes that bring goods to consumers and shape how they are received and defined. On the other hand, an approach that focuses on consumers’ conscious symbolic agency and how people actively define the meaning of things, often in opposition to dominant ideologies or interests (Mullins, 2011:134). In

other words, one approach focuses on consumption as symbolic and semiotic, and the other as a creative activity for self-expression (Buchli and Lucas, 2001). However, whether our approach considers goods to determine the consumption of the communities, or whether we consider that communities are consciously defined in a symmetrical way, each household will have unique consumption patterns that are differentiated from others.

How can we use consumption patterns to get to other types of patterns that are, in principle, unrelated? The different activities carried out in the settlements leave a diversity of material culture (Kent, 1999:91). However, there are other elements that determine consumption patterns at a given archaeological site. If we are analysing peasant settlements, the economic component is a fundamental factor in these processes. In principle, the consumption patterns found in a peasant settlement will be quite different from those of an elite settlement. Another feature may be the physical environment of the site, i.e., the climate or the topography. The proximity or remoteness of trade networks can have a significant impact on the consumption patterns of a household. Other cultural and social factors can also have a major impact on the type of objects that communities are consuming. In this sense, social status, age and gender of the inhabitants, and their cultural identity, influence the significance of certain goods, so they can influence these patterns (Bourdieu, 1998; Douglas and Isherwood, 2002; Licerias-Garrido, 2021). Depending on the activity performed in these peasant settlements, their period of habitation may be uneven throughout the year. For example, this seasonality may be due to the relation of some of these settlements with the harvesting season of a particular crop, as in the case of oil or wine presses (Vaccaro *et al.*, 2013). On the contrary, other settlements may have had a more continuous habitation throughout the year due to the performance of different activities or a greater number of them (Ghisleny *et al.*, 2011). However, there are other factors related to post-depositional processes at the sites, although analysis of discard patterns can provide insights into how a settlement was abandoned (Deal, 1985).

Considering all these characteristics, different consumption patterns can be found in each analysed site, which are unique to each settlement. Consumption patterns thus serve as a fingerprint that differentiates them based on the aforementioned features. The advantage that consumption patterns have over other evidence such as production patterns is that in practically all settlements, we can find consumption practices with which to characterise the communities that inhabited them.

MATERIALS AND METHODS

Case study

The case study is geographically framed within the Madrid basin, around the river courses coming from the Sistema Central mountains towards the Tagus River on its right bank. The rivers Guadarrama, Jarama, Henares, Manzanares

and Tajuña, among others, form fertile river terraces that are ideal for agricultural use. In Roman times, this was a very rural area which could be described as an intermediate sector between the *territoria* of three different *municipia*: *Complutum* (Alcalá de Henares, Madrid), *Tituliam* and *Mantua Carpetanorum*. The location of the latter two is still a matter of controversy (Knapp, 1992:185; Stylow and Von Hesberg, 2004). The study area lies mainly within the boundaries of the present-day Comunidad de Madrid, around the metropolitan area of the city of Madrid. The excessive urban growth of cities in recent decades has led to a large number of preventive excavations conducted after the enactment of heritage protection laws¹. These interventions have led to the discovery and documentation of many rural settlements dating from the Roman period. The systematic excavation and stratigraphic documentation of these archaeological sites provide a unique opportunity to analyse the economic structures and living conditions of the humblest communities in the rural provinces of the Roman world.

Our work is based on the sampling of the material contexts of archaeological deposits documented in nine sites located in the study area (fig. 1). The analysis of the archaeological materials took place between 2018 and 2022 within the framework of the project '*Economías domésticas en el norte de la Carpetania romana (100 a.C.-400 d.C.): condiciones de vida, redes y desigualdad*', directed by Dr Jesús Bermejo Tirado². A summary of the settlements analysed can be found in the table below (table 1). The data were sampled and documented using an approach based on two basic procedures (Wilk and Rathje, 1982; Allison, 2009; Parker and Foster, 2012). Firstly, the selection of specific archaeological deposit material contexts according to taphonomic criteria, that is, the analysis of those records that make up archaeological deposits that are comparable to the concept '*de facto* refuse' (Schiffer, 1987:93; LaMotta and Schiffer, 1999) or those strata associated with deposits that have been sealed as landfills or silo fills. This selection implies that we have deliberately excluded all those finds from other strata in order to avoid taphonomic distortions related to the so-called 'Pompeii premise' (Binford, 1981; Schiffer, 1985). Secondly, a systematic analysis of all the finds, including ceramics, metals, bone industry, lithics, glass, etc., has been conducted, considering variables of identification and formal description, traditional chronological and typological variables, use-wear, and context analyses. In our analyses, we have used only the variables chronotype and form. The chronotype variable refers to traditional typologies that provide chronological information. For example, Terra Sigillata Hispana (TSH) Hisp. 37. On the other hand, the form variable refers to the physical form

1. Law 16/1985 regarding the Spanish Historical Heritage and the law 10/1998 on the Historical Heritage of the Autonomous Community of Madrid.

2. Project '*Economías domésticas en el norte de la Carpetania romana (100 a.C.-400 d.C.): condiciones de vida, redes y desigualdad*' Ref. 2017-t1/HUM-5516 and '*Carpetania rustica: arqueología de los asentamientos campesinos en el norte de la Carpetania romana*', Ref. 2021-5A/HUM-20947 (P.I. Jesús Bermejo Tirado).

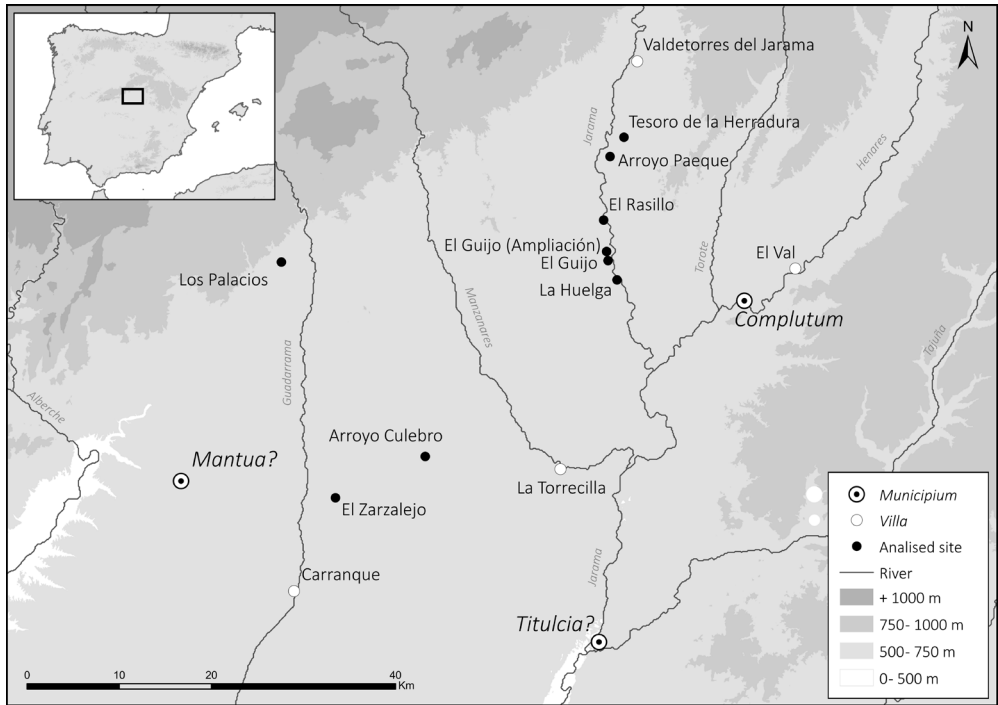


Fig. 1.—Map of the study area showing the distribution of the analysed sites and other reference settlements.

TABLE 1
SUMMARY OF THE ATTRIBUTES PER SITE

Site ID / Name	No. of Stratigraphical Units / Contexts analysed	Total no. of sampled finds	Chronology				References
			1st AD	2nd AD	3rd AD	4th AD	
Arroyo Paeque	14	77					(Pérez, 2007)
El Guijo	16	145					(Dumas and Redondo, 2002)
El Guijo (Ampliación)	5	170					(Domínguez <i>et al.</i> , 2004a)
El Rasillo	10	197					(Vigil-Escalera, 2004)
El Zarzalejo	35	221					(Vigil-Escalera, 2012)
La Huelga	6	111					(Domínguez <i>et al.</i> , 2004b)
Los Palacios	9	341					(Gorostidi <i>et al.</i> , 2016; Major <i>et al.</i> , 2013)
Tesoro de la Herradura	12	209					(Vega <i>et al.</i> , 2017)
Arroyo Culebro	19	89					(Penedo <i>et al.</i> , 2002)

of the object to which the fragment belongs. For example, TSH Hisp. 37 may be a bowl, although the form and chronotype variables are not usually related.

In the following table (table 1), we present a summary with information on the archaeological sites analysed in our case study. The first column refers to the number of deposits analysed in each site. The second column refers to the number of fragments analysed and represents the size of the sample analysed at each site. These fragments belong mainly to ceramic materials due to their preservation. However, they also belong to other types of materials, such as fragments of iron, bronze, bone, etc. Subsequently, we refer to the chronological information for each site according to their presence in time intervals of a century. The archaeological information does not allow us to better determine the chronology of each site. Finally, we refer to the reports and publications where each site can be consulted.

Network analysis: centrality measures

In applying network science methods to our archaeological data, we expect to better understand complex patterns of domestic consumption across the peasant communities in the study area. We choose network science because it efficiently represents relationships between sites and artefact types. We hypothesise that variations in the prominence of the sites, inferred from their centrality measures, will reveal differences in consumption patterns that might correspond to a distributed habitation settlement pattern. Higher-ranking nodes, as measured by PageRank (Brin and Page, 1998), might reflect more stable and durable sites throughout the year as it shows a wider range of shared artefact types. Conversely, lower-ranking nodes might represent peripheral nodes, with fewer shared artefact types and more unique consumption patterns, probably due to a more seasonal stay throughout the year.

In a hierarchical network, some nodes are more central than others, and generally these nodes have a higher hierarchical level, while less important or peripheral nodes have lower levels. Measuring the hierarchy of nodes can be useful to understand the structure of a network, but also the differences between nodes. The centrality measure used is PageRank, expressed in percentage. PageRank was developed by the founders of Google as a way of ranking web pages (Brin and Page, 1998). This measure is based on the premise that a web page is important if it is related to other important web pages. Thus, a node is considered more important if it is related to other equally important nodes. The importance of a node is determined by the number—and hence its importance—of the links that connect it to other nodes. This measure considers the weight of links between nodes. A link coming from a high-ranking node has a higher weight than a link coming from a lower ranking node. This allows the algorithm to rank the nodes more accurately. This tool has been used in other archaeological contexts for different purposes (Dubini and Gattiglia, 2013; Brookes and Huynh, 2018).

The application of PageRank to our dataset begins by assigning each site an initial, evenly distributed score. Each site then contributes a portion of its current

score to all sites to which it is connected through shared artefact types; stronger links represent a greater number of shared artefact types and thus a greater contribution. This process is repeated iteratively until the scores converge, resulting in a ranking that reveals the top sites based on their network connections. In our case, we use PageRank because it takes into account not only a site's immediate connections, but also the wider network of connections. For instance, a site connected to many other sites may seem important at first, but if those connected sites have few connections, its value will be lower than that of a site connected to fewer sites but with more connections. While other centrality measures would give more importance to a site just because of its greater number of links, PageRank would assign a higher score to a site with better overall prominence of its connections.

To analyse the archaeological data, we must represent the archaeological material as network data³. We created similarity networks, represented as 1-mode projections from 2-mode networks, following methods similar to those used in other archaeological contexts (Östborn and Gerding, 2014; Feugnet *et al.*, 2017; Moreno-Navarro *et al.*, 2023). We first created a 2-mode network, where one set of nodes represents sites (mode 1), and the other set of nodes represents the material variable (mode 2), in our case can be chronotypes or forms. In the 2-mode network, links are created between the mode 2 (chronotypes and forms) and a site if the former is present in the archaeological record of the latter. The strength of the link represents the number of times a chrono-type or a form has been found at that site, i.e., the frequency of that variable. Once we have this 2-mode network, we can multiply the matrix by itself to convert it into two different 1-mode projections. Of both 1-mode projections, we will only use the networks in which the nodes represent archaeological sites.

It should be noted that the dataset used in this study is not evenly distributed across all sites in terms of the number of samples collected (table 1). Some sites have a more extensive archaeological record analysed than others, which may reflect differential intensity of past activity, excavation strategies, preservation conditions. This uneven distribution, which is not uncommon in archaeological research, could influence the relative strength of links between nodes in our network in two ways. Although conversion to 1-mode networks and the application of PageRank can help mitigate this problem by focusing on the quality of connections and not just their quantity, they do not eliminate it entirely. Therefore, the interpretation of our network analysis and centrality measures must consider these factors.

The dataset used for this study is provided as a supplementary material, split into four distinct CSV files. 'MATRIX_SITE-CHRONOTYPE_CARPETANIA.csv' records the presence and frequency of an artefact chrono-type at each site; 'MATRIX_SITE-FORMS_CARPETANIA.csv' records the presence and frequency of an artefact form at each site; 'ATTRIB_SITES_CARPETANIA.csv' contains attribute information for each site; and 'ATTRIB_CHRONOTYPES_CARPETANIA.csv' records the presence and frequency of an artefact form at each site.

3. For the network analyses we used Visone software, version 2.17. (Baur *et al.*, 2002).

csv' compiles attribute information for each artefact chrono-type. This dataset is also openly available for public access at <https://doi.org/10.5281/zenodo.8213172>

RESULTS

Analysis sites - chrono-types

The analyses have been conducted based on the 1-mode projections derived from the 2-mode network. However, through visual analysis of the 2-mode network, relevant information can be extracted. In the 2-mode network (fig. 2), most of the chrono-types are located in the outer part of the network. This means that most of them are present in one or two sites at most. In contrast, in the centre of the network are those artefacts that are found in the archaeological records of most of the

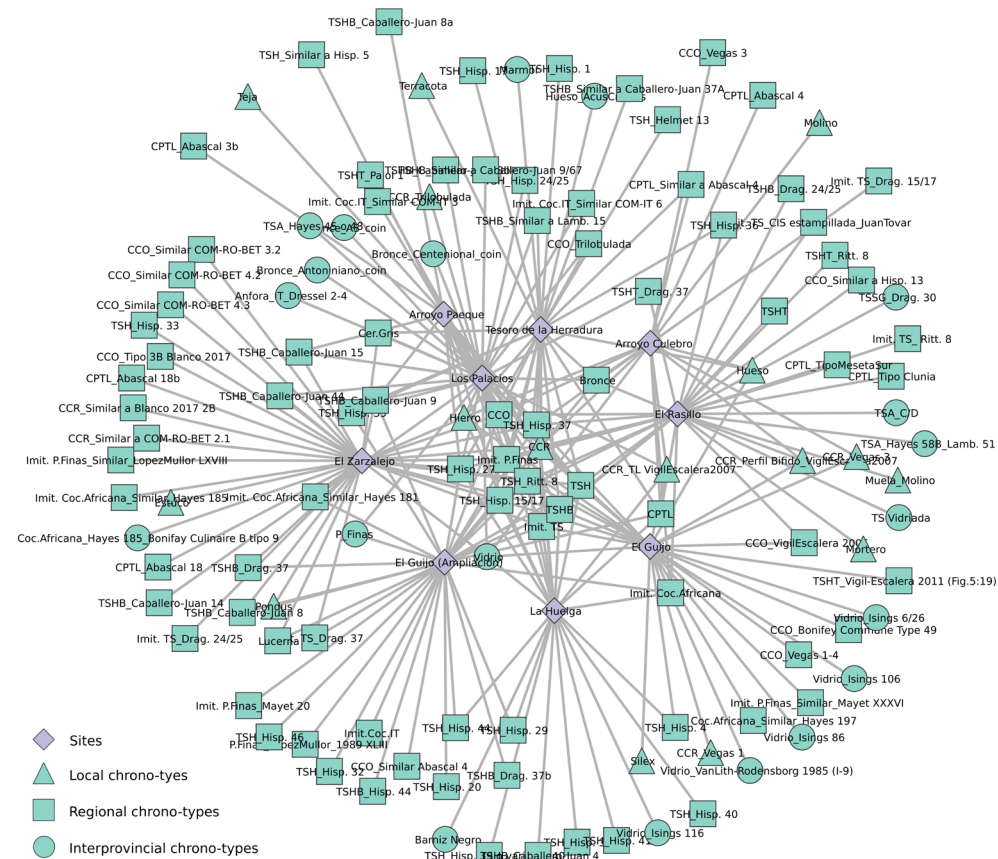


Fig. 2.—2-mode network representing the sites (purple rhombuses) linked to the chrono-types found on them (in green); the provenance scale of the chrono-types is represented by the nodes' shape.

analysed sites. The different types of artefacts found at each site can be checked in the dataset used for this work (an analysis based on the networks generated by the chronotypes in this same case study can be found in Moreno-Navarro *et al.*, 2023)

The following analysis (fig. 3) is based on the 1-mode projection of the archaeological sites resulting from the 2-mode network linking sites and chronotypes. In this case, we analyse the network representing the archaeological sites analysed in our case study. The distribution of the nodes is done according to the PageRank centrality measure expressed in percentages. The chosen distribution places the nodes with the highest centrality value at the centre of the network. The remaining nodes are placed further apart according to this value. In addition, the nodes are moved closer or further apart according to the strength of their links, i.e., the number of types they share. The strength of the links is also represented as the

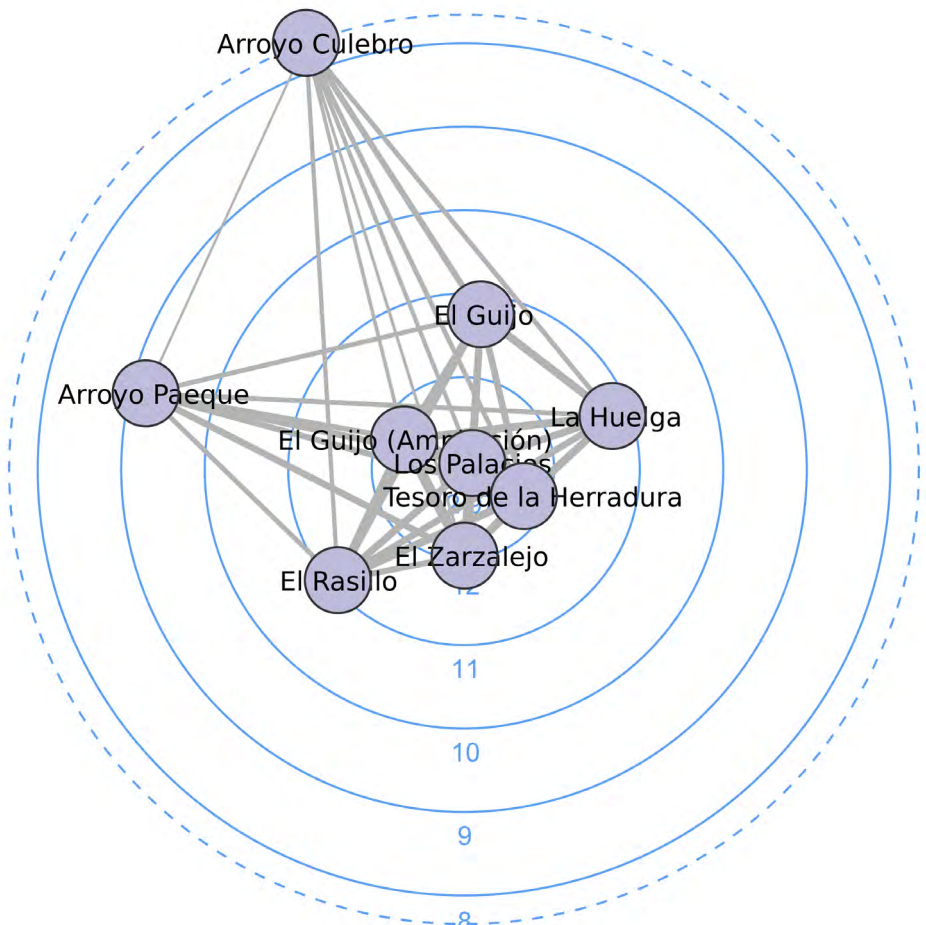


Fig. 3.—1-mode network representing the PageRank centrality of the analysed sites considering all chrono-types found on them; the strength of the links is represented by the line width.

link width. This analysis allows us to visualise very clearly the differences of the settlements analysed by centrality analysis.

The network places the node representing Los Palacios site in the centre of the graph, since it is the node with the highest centrality (12.96%). The following table (table 2) shows the data on the centrality of the sites. Very close to the centre of the network are the nodes representing Tesoro de la Herradura and El Guijo Ampliación sites, followed at a very short distance by El Zarzalejo. These four sites form the core of the network. This core can be interpreted as a grouping of nodes that share several chronotypes and whose distribution patterns are remarkably similar. At a greater distance are the nodes representing the sites of El Guijo, La Huelga and El Rasillo. Despite being in a ring further from the centre of the network, these nodes have a centrality of around 11%, not far from the central node. Finally, the two most distant nodes are those representing Arroyo Paeque and Arroyo Culebro. The latter is the node with the lowest centrality with 7.66%.

TABLE 2
PAGERANK VALUES AND PERCENTAGES OF THE NODES IN THE PREVIOUS ANALYSES

Site	<i>All chrono-types</i>		<i>Non-ubiquitous chrono-types</i>	
	<i>PageRank %</i>	<i>PageRank</i>	<i>PageRank %</i>	<i>PageRank</i>
A. Culebro	7.658	0.69	6.224	0.561
A. Paeque	9.184	0.827	7.452	0.671
El Guijo	11.229	1.011	10.95	0.986
El Guijo Amp.	12.291	1.107	13.822	1.245
El Rasillo	11.087	0.998	11.82	1.064
El Zarzalejo	12.063	1.086	12.284	1.106
La Huelga	11.208	1.009	10.886	0.98
Tesoro de la H.	12.31	1.109	12.731	1.146
Los Palacios	12.969	1.168	13.831	1.246

How does this network evolve when we remove ubiquitous nodes from the analysis? By ubiquitous nodes we mean those chrono-types that are present in overwhelming numbers in all archaeological records. These are, for example, general find types to which archaeological material is attributed when the specific chronotype is unknown: Hispanic *Terra Sigillata*, for example. Such attributions play a significant role in the distortion caused by the so-called ‘researcher fatigue’. To try to reduce this and other biases, we have preferred to repeat the analyses by removing the nodes representing these types of finds. Once removed from the 2-mode network, we generated a new network with sites linked according to the number of chrono-types they shared. As in the previous case, the nodes are distributed according to the PageRank centrality value expressed as a percentage.

The result of this analysis (fig. 4) places the nodes representing the sites of Los Palacios and El Guijo Ampliación in practically the same position. Both have similar PageRank percentages (13.83% and 13.82% respectively) and are therefore the ones located in the centre of the network. This result is remarkable because both sites have very similar distribution patterns once the ubiquitous nodes are removed, despite the difference in size and typology of the two sites. Very close to the centre of the network, but a little further away, are the nodes representing the sites of El Zarzalejo, Tesoro de la Herradura and El Rasillo. These sites, together with the two at the centre of the network, form a group with similar centrality values. This is because all these sites share a large number of chrono-types and have similar distribution patterns. In this analysis, the nodes representing the sites of El Guijo and La Huelga are slightly further away from the core of the network than in the previous case. This is because most of the chrono-types shared with the core of the network are of the ubiquitous type. The nodes representing Arroyo Culebro and Arroyo Paeque are even further away from the core of the network than in the

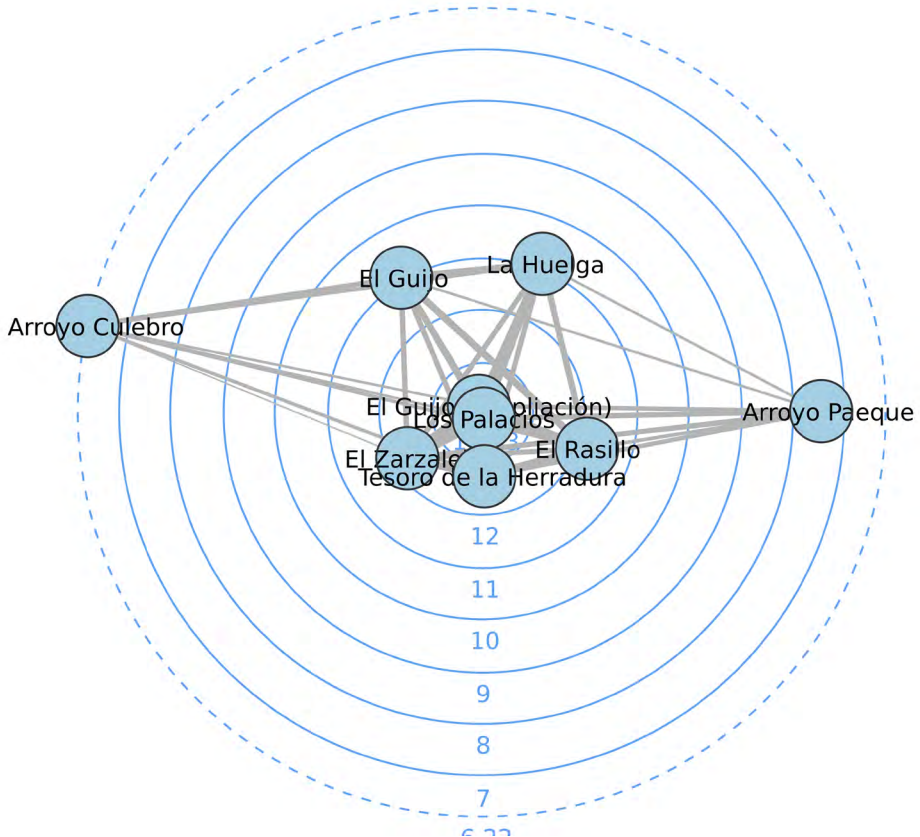


Fig. 4.—1-mode network representing the PageRank centrality of the analysed sites considering non-ubiquitous chrono-types. The strength of the links is represented by the line width.

previous analysis. It is also observed that, due to the weakness of their links, they share very few chrono-types with the rest of the sites. In fact, it is shown that the two sites are very distant from each other since they do not have any common chrono-type in this analysis. In the previous analysis they only shared ubiquitous chrono-types.

TABLE 3
PAGERANK VALUE AND PERCENTAGE OF THE NODES IN THE SITE-SHAPE ANALYSIS, AND THE NUMBER OF SAMPLED FINDS WITH FORM ASCRIPTION FOUND AT EACH SITE

<i>Site</i>	<i>No. of sampled finds</i>	<i>PageRank (%)</i>	<i>PageRank value</i>
A. Culebro	89	5.323	0.479
A. Paeque	77	5.670	0.511
El Guijo	145	12.404	1.117
El Guijo Amp.	169	11.366	1.024
El Rasillo	198	15.242	1.373
El Zarzalejo	218	10.884	0.980
La Huelga	87	9.387	0.845
Los Palacios	337	17.052	1.536
Tesoro de la H.	206	12.671	1.141

Chronological evolution of the site centrality

Using the chronological ascription of the artefacts and archaeological sites, we have been able to analyse the chronological evolution of the site centrality through PageRank measures expressed as percentages (fig. 5).

In the chronological period comprising the 1st century AD, the general trend is very similar to that seen in the networks of the previous analyses, despite the fact that a settlement as important as El Zarzalejo in our case study, is not yet active. The node with the highest degree of centrality in this period is the one representing the site of Tesoro de la Herradura. This node is closely followed by the node representing Los Palacios. Both sites are part of the core of the network, indicating similar chronotype distribution patterns at both sites. The core of the network is followed by a ring of four nodes representing El Guijo, El Guijo Ampliación, El Rasillo and La Huelga. These four nodes have a remarkably similar degree of centrality and are therefore located at a similar distance from the centre of the network. Despite the similar centrality value, the distribution has placed them in opposite positions to each other, indicating significant differences in the distribution patterns of the chrono-types. At the extremes of the network are the nodes of Arroyo Paeque and Arroyo Culebro, the latter being the one with the lowest degree of centrality. Their

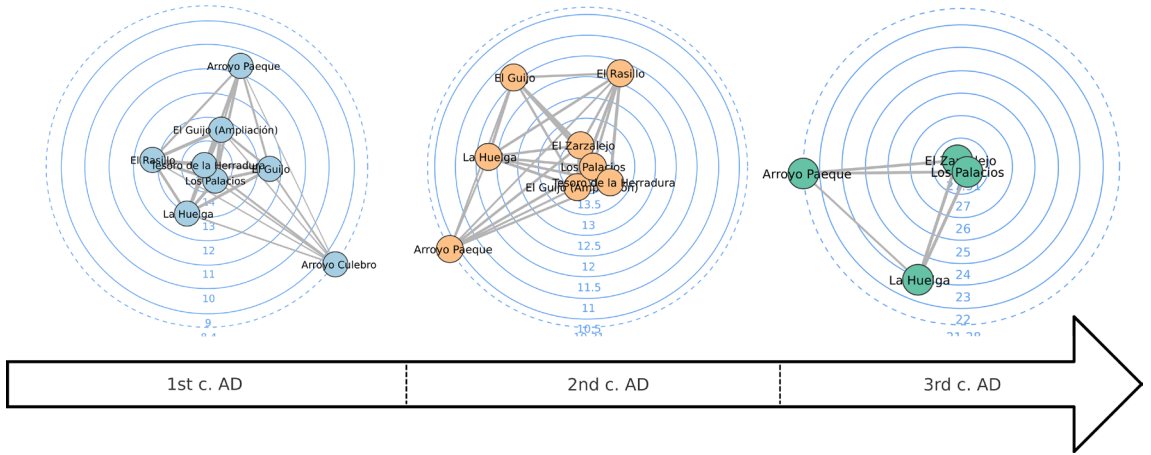


Fig. 5.—Chronological sequence of 1-mode networks representing the PageRank centrality of the analysed sites considering all chrono-types for each century; the strength of the links is represented by the line width.

differences from the rest of the sites can be seen in the weakness of the links that connect them to the rest of the nodes.

In the time range comprising the 2nd century AD we observe a more compact network. The node with the highest degree of centrality this time is the one representing the site of Los Palacios. It is closely followed by the nodes of Tesoro de la Herradura, El Guijo Ampliación and El Zarzalejo, the latter appearing for the first time in this chronological range. The four sites form the core of the network and demonstrate similar behaviour in the distribution patterns. In comparison with the previous chronological period, the node representing El Guijo Ampliación *moves closer* to the core of the network, unlike other nodes such as those representing the sites of El Guijo, El Rasillo and La Huelga whose tendency is to decrease their degree of centrality. The node with the lowest degree of centrality is Arroyo Paeque, although its PageRank does not vary much with respect to the previous century. In general terms, apart from the core of the network, the whole network appears to be more expanded, but this is mainly due to the fact that in this chronological period the Arroyo Culebro site, whose node represented the most atypical value in the previous century, is no longer active.

The 3rd century AD is characterised in our case study mainly by the fact that most of the sites are no longer active. Despite the reduction in the number of sites, the general trend that can be observed in the graph for this period is very similar to the previous periods. The nodes located in the centre of the network are those representing the sites of Los Palacios and El Zarzalejo. As in the previous century, both form part of the core of the network and show similar distribution patterns. On the opposite side are the nodes representing La Huelga and Arroyo Paeque, the latter being the node with the lowest degree of PageRank centrality. Compared to the previous chronological periods, the node representing La Huelga seems to

reduce its centrality in relation to the rest of the nodes in the network, being closer to the Arroyo Paeque node than to the centre of the network.

Considering only ceramics artefacts

We have repeated our analysis of the temporal progression of the centrality measurements of the excavation sites, using exclusively the ceramic artefacts identified within their archaeological records (fig. 6).

For the period covering the 1st century AD, the overall trend appears to be a concentration of nodes in the centre of the graph. There is a core group of four nodes, which represent the sites of Tesoro de la Herradura, El Guijo Ampliación, Los Palacios and El Rasillo. These nodes have centrality values that are approximately 14%. This suggests that, when considering only ceramic materials, these four sites exhibit similar distribution patterns. In a slightly more distant ring, there are the nodes representing the sites of La Huelga, El Guijo and Arroyo Paeque. Comparing previous analyses, this latter node, Arroyo Paeque, appears to be situated closer to the centre of the network. This implies that non-ceramic elements contribute to this node's atypical value. In contrast, the node representing the site of Arroyo Culebro exhibits the opposite pattern. When using solely ceramic elements, this node has a notably atypical value in relation to the other nodes in the network, situated in a highly peripheral location with less than half the centrality value of the centre of the network. However, it should be noted that the sample analysed for this site is smaller compared to the other sites. This fact can generate an important distortion in the analysis that must be considered.

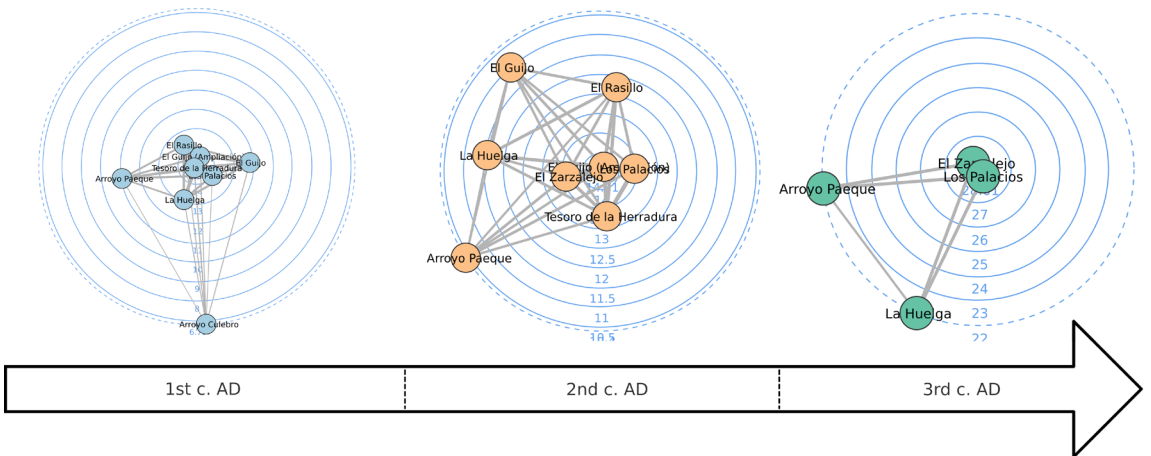


Fig. 6.—Chronological sequence of 1-mode networks representing the PageRank centrality of the analysed sites considering only ceramic chrono-types for each century; the strength of the links is represented by the line width.

There is a shift in the scale of the graph in the chronological period corresponding to the 2nd century AD, since the node of Arroyo Culebro, which had a particularly atypical value in the previous chronological period, is no longer active. In this case, the node with the highest centrality value is the one representing the site of El Guijo Ampliación. This node is followed at some distance by those of Los Palacios and El Zarzalejo. These last two nodes are no longer at the centre of the network, as was the case in previous analyses. This is because many of the common distribution patterns were not those related to ceramic elements. When we removed these non-ceramic elements, their position changed. Something similar happens with the node representing the site of the Tesoro de la Herradura. This node is located in an intermediate ring of the network, so its position varies with respect to the previous chronological period, where it had the highest centrality value. In an outer ring are the nodes belonging to El Rasillo, La Huelga and El Guijo. Close to them is the node representing the site of Arroyo Paeque, which has the lowest PageRank value. As a general trend, it seems that the nodes tend to be more similar.

For the chronological period that covers the 3rd century AD, the overall trend is very similar to that of the analysis that includes non-ceramic elements. The nodes representing the sites of Los Palacios and El Zarzalejo are located in the centre of the network, representing the nodes with the highest centrality. Conversely, the nodes representing the sites of Arroyo Paeque and La Huelga are located on the opposite side of the graph, representing nodes with almost the same level of low centrality.

Analysis sites – forms

In order to determine the differences between the different settlements in our study area, it is necessary to accurately characterise the consumption patterns of the people who inhabit them. Thanks to the level of detail of the databases used for our analyses and the application of network science, it is possible to characterise this consumption by visualising it as a whole. For the analyses conducted in this section, we have used the variable ‘form’. In our study, the concept of ‘form’ refers to the design of a specific object at the time of its conception by its producer, for example a bowl or a jar, or the possible subsequent use as another element. The form of the object is not always evident from the archaeological fragments analysed, so the sample size in this case may vary depending on this fact in all sites.

As in the previous analysis, the archaeological data are first represented in a 2-mode network (fig. 7). In this case, the network will represent the number of times a form is present in a given site. One type of node in the network will represent all the sites analysed, while the other type of node will represent the different forms present in the archaeological record. The strength of the links between the two types of nodes represents the number of times a form has been analysed in a particular site.

Although we do not formally analyse the 2-mode network in our work, some patterns derived from the distribution of nodes based on the strength of the links can

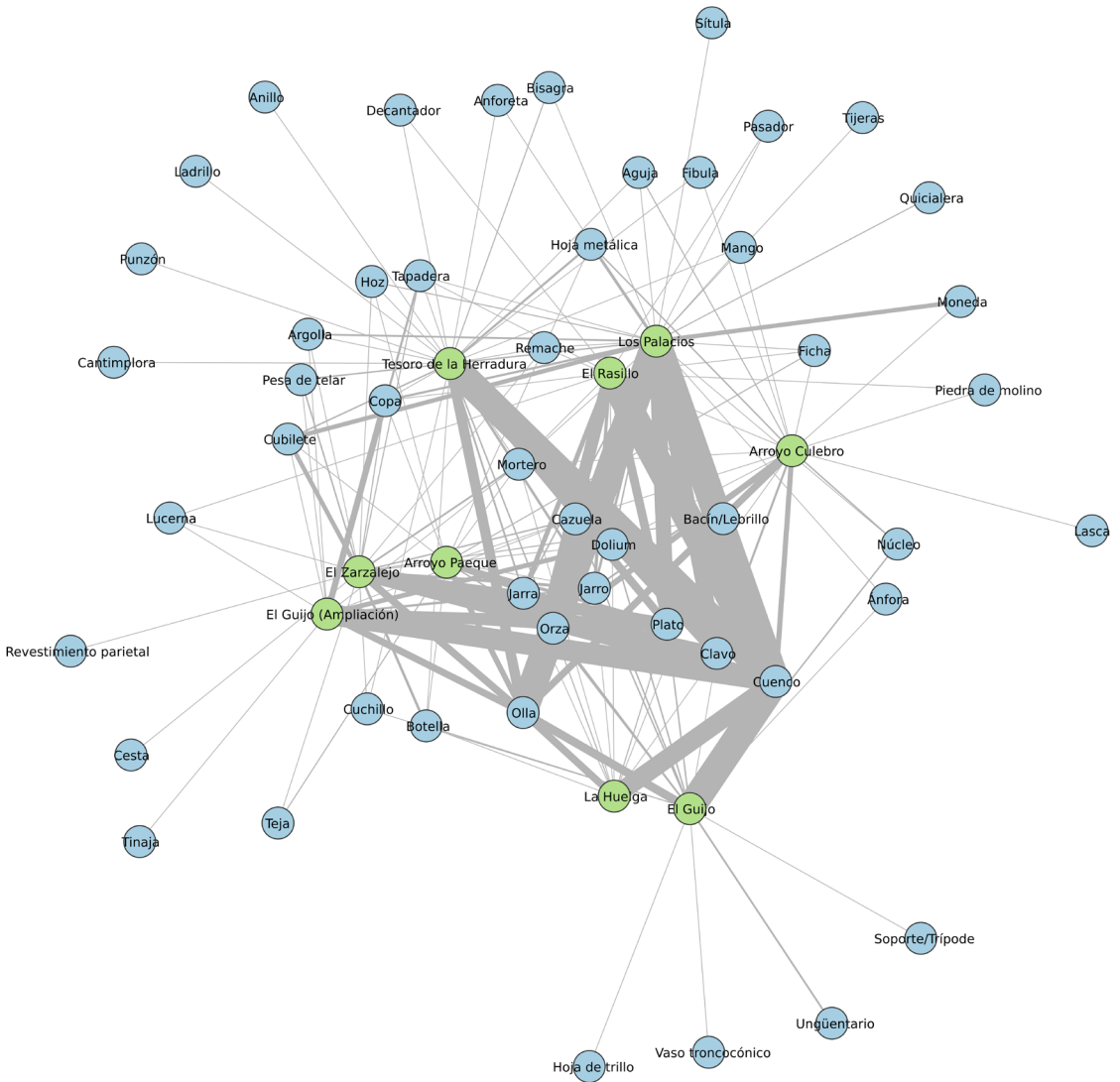


Fig. 7.—2-mode network representing the sites (in green) linked to the material shapes found on them (in blue); the strength of the links is represented by the line width; as the database is in Spanish, a list of translations is provided in the annexes.

be visually identified. The nodes belonging to the forms located in the central zone of the graph are those that are most shared and used in the analysed sites. Among them, there are some with greater strength in their links, such as the bowl or the plate. The opposite pattern is observed with the nodes located at the periphery of the network. These nodes represent little used forms and in most cases are present in only one site. This is the case of the ‘situla’ or ‘ungüentario’ (ointmentary). All categories of shapes used can be found in the dataset provided.

Site centrality through the analysis of the form variable

The next analysis is performed on the network resulting from the multiplication of the matrix of the previous bimodal network (fig. 8). In this case, the chosen distribution of nodes is based on their PageRank centrality value. In this way we can compare the networks and better understand the differences between the analyses.

The general trend is a very widespread network in which the nodes representing the sites of Los Palacios and El Rasillo stand out, as they are the nodes with the highest PageRank value: 17.05% and 15.24% respectively. Around the centre of the network there is a ring made up of the nodes representing most of the other sites: Tesoro de la Herradura, El Guijo, El Guijo Ampliación and El Zarzalejo. These five sites have similar centrality values, around 10 and 12.5%. At the end of the network, we find the nodes representing the sites of Arroyo Paeque and Arroyo Culebro with very low PageRank values in relation to the rest of the nodes, between 5 and 6% of the PageRank centrality value.

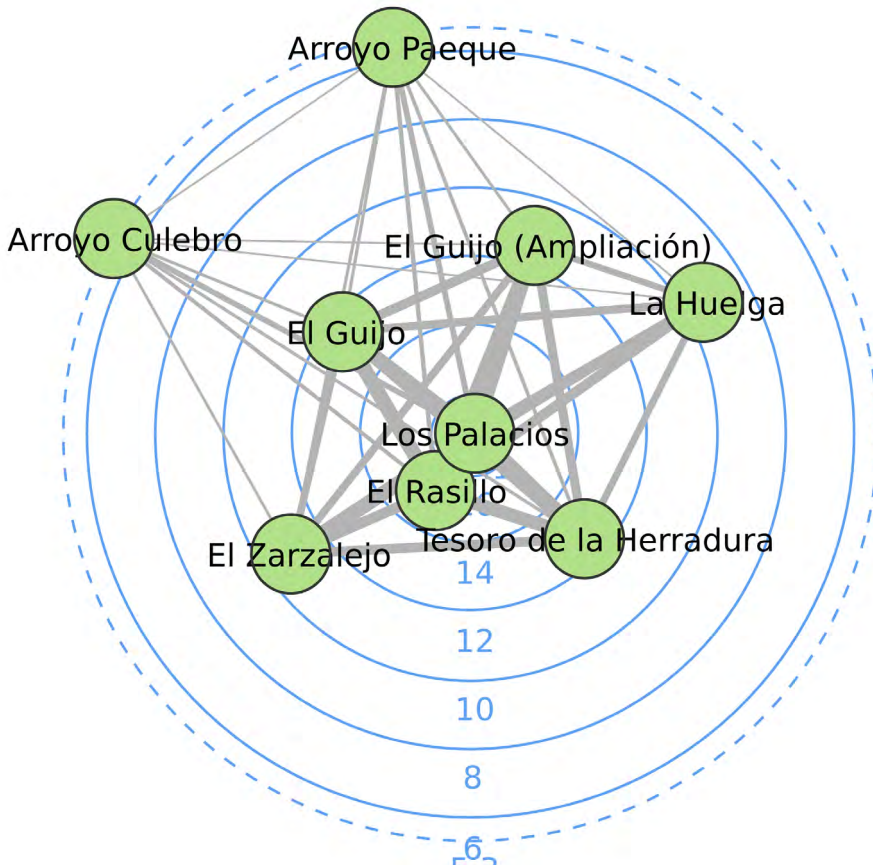


Fig. 8.—1-mode network representing the PageRank centrality of the analysed sites considering all shapes found on them; the strength of the links is represented by the line width.

DISCUSSION AND CONCLUSION

The results of our analyses are consistent with a ‘distributed habitation’ pattern described in other archaeological contexts (Bowes, 2020:463-469). This model suggests that the activities performed by the inhabitants of a household are carried out in a distributed manner across the territory. To this end, these inhabitants establish different settlements throughout the landscape that help these communities to conduct tasks related to agricultural processing, cultivation, craft production or animal husbandry (Bowes, 2020:463). To these settlements, it is necessary to add other important places related to the symbolic aspect of the communities and which could have played a significant role in the articulation of the landscape (Grau, 2017). Some of these structures could have been maintained by members of different households on a communal basis. Depending on the needs of the inhabitants, private and communal properties coexist so that all communities have access to the resources of the territory, allowing for an effective conservation of these resources for the future (Netting, 1976). In other contexts on the Iberian Peninsula, the existence of a type of dispersed settlement pattern has its roots in pre-Roman communities. Roman administrations maintained this type of exploitation of the landscape in the less accessible areas, as the effort to impose a different model would have been much greater (Grau, 2022:102).

In this type of habitation, some settlements are occupied for longer periods than others, depending on the needs of the communities using them. These temporal differences produce different archaeological records, as it is logical to assume that the longer a settlement is occupied, the greater the variety of artefacts we will find at the archaeological site. Furthermore, these differences may be since communities are not static and are in a constant state of negotiation and reconstruction in terms of how they relate to space (Grey, 2011). We also cannot rule out an organisation of space that allows for forms of passive resistance to state power (Scott, 1985). Studies based on the transport network in our case study (Moreno-Navarro, 2022) provide insight into how an effective articulation of the territory could have been conducted by certain secondary settlements in the interstitial areas of the *municipia* present in the territory.

Due to the different nature of the excavated settlements, different patterns of both chrono-types and artefacts forms can be found in their archaeological records. Undoubtedly, the length of time that the inhabitants of a given community inhabit a given settlement influences the formation of the archaeological record of the site. Both in our case study and in analyses conducted in other archaeological contexts (Bowes, 2020), differences are found in the assemblages of the diverse types of peasant settlements excavated. Considering this difference but without losing sight of the relationships between the assemblages found in these sites, we believe it is possible to provide information on the peasant settlement patterns. Our results have many similarities with those of comparable sites in the central Italian context (Bowes, 2020). Sites such as Pievina, especially phase 2, where a greater number of activities are carried out than in other peasant contexts as attested by the existence of

a kiln, a hearth, and other stable structures such as a possible granary, has a smaller number of ceramic forms than the nearby village of Roselle, yet more than twenty different functionally specific pottery types were found just in two stratigraphical units (Ghisleny *et al.*, 2011:table 2). Pievina can be compared with settlements such as Los Palacios, El Zarzalejo or Tesoro de la Herradura, where there may have been a slightly greater desire of permanence than other settlements of the same region. Also, in both regions there are settlements with a single building structure consisting of a single room. This is the case of San Martino (Bowes, 2020:163-181), but also of settlements in our case study such as Arroyo Paeque. In the Central Italian case, San Martino would be related to livestock activities, while Arroyo Paeque seems to be associated with agricultural activities. At the other end, sites without known building structures such as Case Nuove (Vaccaro *et al.* 2013), would have their referent in sites like the 'Área 500' at El Guijo. In both 'open sites', the structures found would have served a specific activity in the landscape: in one case for olive and grape pressing, and in another case for small-scale ceramic production. The relationships and differences between the archaeological records of 'The Roman Peasant Project' have been studied using correspondence analysis (Bowes, 2020: Figs. 12.17 and 12.18). Their analysis detects a complexity that can be broadly related to the size and type of settlement, but more importantly to the sum of the activities carried out in these settlements (Bowes, 2020:460).

Even though centrality measures do not provide a precise assessment of the similarity between nodes in a network, our analysis allows us to draw some conclusions about the similarity of the archaeological records of the settlements studied. Most of the archaeological records have similar PageRank values when analysing the relationship across all chrono-types (fig. 3). These values become much more diverse when non-ubiquitous nodes are removed (fig. 4), although seven of the nine values fall within a range of 10 to 15% (table 2). The fact that most settlements have similar centrality values is due to the fact that these settlements share a large number of chronotypes in their archaeological assemblages. These patterns distance these communities from the possible 'cultural revolution' noted in consumption practices in other strata of the Roman world, which required the use of a wide variety of formal types to fulfil the complex social rituals common to the Roman elite (Wallace-Hadrill, 2008:319-329).

The patterns identified through the application of network science in our study suggest several implications for the interpretation of the settlement patterns of the rural communities studied. Even though all the archaeological records of these sites could be considered similar to those generally considered to be peasant in nature (Bermejo, 2022a; 2022b), our analysis shows that there are significant differences between them. This is evident when considering all the chronological phases of the sites (figs. 3 and 5), as well as when removing those elements that could potentially introduce distortions (figs. 4 and 6). Our analysis reveals the presence of certain sites in prominent hierarchical positions. These archaeological records typically correspond to settlements that have both structures for the transformation of raw materials and structures that could be considered living structures, including the

presence of a hearth. In most cases, these sites are Los Palacios, El Zarzalejo and Tesoro de la Herradura. On the other hand, other sites that were primarily production sites have a lower centrality in relation to the central nodes. This is the case, for instance, of Arroyo Paeque.

The nature of these settlements makes a detailed investigation of inter-settlement trade networks very difficult. Nevertheless, it is important to analyse the integration of these peasant communities into trade networks at different scales. This possible integration is an aspect that we have explored in previous work (Moreno-Navarro *et al.*, 2023). In it, we have found that the peasant communities in our case study were strongly integrated into local and regional trade networks. The analysis of the centrality of settlements in relation to the forms they share (fig. 8) also suggests a diversity in the number of forms in each of the settlements. In general, the nodes with lower centrality in this analysis represent settlements that have a lower variety of forms in the analysed archaeological record. While the variation in the number of findings analysed across different sites could partially contribute to the observed patterns, we assert that the sample size at each site is substantial enough to facilitate valid comparisons between them. The employment of a limited number of forms suggests that these communities used the most versatile forms for everyday use (Moreno-Navarro, in press). This type of consumption pattern is different from the complex patterns found in other elite settlements sampled with the same method (Bermejo and Quevedo, 2014:494-496; Bermejo *et al.*, 2019:243-253). In this case, the difference in the centrality of the nodes in our analysis does not imply that these settlements had a different economic status, but that some of these settlements had the capacity to collect a greater variety of forms, probably due to a longer occupation of their structures.

The heterogeneity documented in our analyses suggests that the structures characterising this type of rural settlement were more complex than some previous studies have tended to describe (for contextualisation of this discussion, see Erdkamp, 2005:55-105; Kron, 2008, 2017). The patterns revealed by our analyses remain relatively stable throughout the chronological period analysed in this case study (figs. 5 and 6). The continuity of these patterns is consistent with the findings of another study (Bermejo, 2022a:fig. 5) on the evolution of inequality in the same nine settlements using Gini coefficients/Lorenz curves on habitat size. In this study, the evolution of inequality remains with little change from the 1st to the 3rd century AD.

In line with our initial hypothesis, the application of network science to our archaeological dataset has uncovered new insights into the complex nature of rural peasant communities during the Roman period. This approach has allowed us to view these settlements not as homogeneous units but as complex entities with their own unique characteristics. We have identified that there are significant differences among the settlements, in terms of both chrono-types and artefact forms. This suggests a dynamic pattern of rural habitation, where settlements were occupied for varying lengths of time, and different communities constantly negotiated and redefined their relationship to the landscape.

In conclusion, this work presents network science as a useful and versatile tool for the study of archaeological records from a relational perspective. This tool allows for the analysis of relationships between different variables and attributes of finds and sites, as well as for comparative studies between different archaeological records. There are many relational factors within archaeological data that can be explored to improve our understanding of the living conditions of rural communities during the Roman period. Therefore, network science is presented as a useful tool for characterising this type of economy. In order to continue this work, it is necessary to establish new studies that start from a holistic perspective, paying attention not only to the ceramic elements of the archaeological record, which are easy to chronologically assign, but also to all the archaeological finds that can be used to characterise domestic economies in all their complexity.

DATA AVAILABILITY

To ensure the reproducibility of this work, the dataset is openly at: <https://doi.org/10.5281/zenodo.8213172>

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