Journal of Archaeological Science: Reports 51 (2023) 104124

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Sampling with transects inside archaeological sites. A rapid action protocol based on statistical analysis of diagnostic collections and quantitative records

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ARTICLE INFO

Keywords:
Field archaeology
Surface survey
Ploughsoil archaeology
Non-invasive method
Statistical control
Landscape archaeology

ABSTRACT

The paper proposes a two stage-sampling strategy for surface surveys. The suggested approach has two stages. First, an intensive survey is undertaken across linear transects, georeferencing the position of each item, and then supplementary diagnostic artefacts between the linear transects are collected. The main objective of the paper is to save time in the first stage of fieldwork. The key claim is that this approach would provide a representative sample of the surface scatter using just one selected transect. The proposed method is applied to the examination of two sites in the *Municipium Flavium Baesuccitanum*, a Roman municipality from the 1st century CE, located in the upper Guadalquivir valley, in the south of Spain, where a total survey was previously carried out. To assess the reliability of this approach, a simulation study was conducted at these two sites, selected by intensive sampling. These sites were chosen because they are real cases with different singularities, which facilitates analysis of how the proposed protocol would behave in different scenarios. In both cases, the statistical results confirm the plausibility of the hypothesis of similarity between the distributions of the whole site and the candidate transect.

1. Introduction

Unified working protocols and universally agreed standards have still not been established across the practice of on-site archaeological survey campaigns intended to enhance our understanding of the protohistoric Mediterranean cultures such as the Greek, Etruscan, Iberian, etc. This makes historical comparisons across different case studies very difficult. In order to address this problem, some coordinators and regular participants in the scientific meetings of the International Mediterranean Survey recently published a guide for best practice in non-destructive archaeological fieldwork (Attema et al., 2020).

1.1. The Mediterranean long-term intensive survey projects

Only a few long-term projects have so far contributed to the development of a regional archaeology based on intensive archaeological survey analysis, following the experience of the Boeotia Project (Bintliff, 2013). But the unification and coordination of these projects, mostly conducted by university academics, is beginning to configure a historic large-scale map of the ancient Mediterranean (Koninklijk Nederlands Instituut Rome, 2021). This unified methodology, focused on non-destructive strategies, should be implemented in any archaeological survey campaign.

The challenge is not a lack of resources but the need to define objectives that guarantee the spatial control of the scatter distribution; hence the importance of designing a correct methodology. Arguably, scientific practice in archaeological surveys is inextricably linked with knowledge of the horizontal stratigraphic contexts. But one of the main criticisms of the classical works is that surveys have long been evaluated by the methods used and not by the number of sites discovered or the

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https://doi.org/10.1016/j.jasrep.2023.104124
Received 5 November 2022; Received in revised form 27 June 2023; Accepted 15 July 2023
Available online 31 July 2023

number of findings collected (Shennan, 1985). The study presented here aims to propose a rapid intervention model for archaeological sites that combines statistically compatible qualitative and quantitative sampling methods.

The model offers a way of standardising the information based on a set of precise, parallel data based on the material culture registered on the surface of each area of land surveyed. Archaeological sites should be characterised according to the distribution of artefact densities on a regional scale, defined variously according to the part of the world we are dealing with, and we must be able to apply meaningful statistical comparisons to discussions of material culture (Plog et al., 1978).

1.2. Our archaeological survey experience

The province of Jaén (Fig. 1) is considered a benchmark for surveying practice in Spain (Ruiz, 2004). Extensive archaeological survey campaigns were carried out over a long period in order to characterise settlement patterns on a regional scale (Ruiz et al., 1987). Nowadays, we use on-site sampling to get the internal characterisation of complete settlements and battlefields (Gutiérrez and Bellón, 2001; Bellón et al., 2015). We regard the territory as a 'continuum of evidence', reformulating the pioneering objective proposed by Binford (1964) for working with taxonomies of functionally characterised settlements. Binford's statement should now be updated to consider the interpretation of settlement patterns as complex palimpsests composed of various types of complementary evidence.

The present authors' experiences in survey campaigns at Jaén have facilitated the planning of an effective strategy that follows international standards. The next step must be to raise the quality of the intensive sampling in order to improve the statistical interpretation of the scatter distributions. The objective is to establish a useful work protocol to improve the characterisation of the settlement patterns in the territory. These territories are clearly identified by epigraphic documentation, and we work with a group of individual on-site sampling cases. The aim of the procedure described here is to manage the information available to us as effectively as possible and as quickly as possible.

Our survey programme focuses on investigating settlement patterns in protohistoric and Roman times across a very extensive territory. The survey design, though, is adapted to the conditions of the archaeological sites under study, which, in most cases, are isolated rural buildings that provide limited evidence of material culture. The main objective of the planned action is to develop a common working method that can save time in the intensive archaeological surveys of all the settlements while guaranteeing the quality of the record. To achieve this, we had to reduce the quantitative sampling to a single transect for each archaeological site, applying a statistical method that allows us to select a representative survey line. The reproduction of the same sampling conditions in all the archaeological sites guarantees the reliability of the statistical inference in each case.

2. Method

2.1. The opportunity. Local case study: Roman territories of Baessuci and Ilugo

This paper outlines a recent case study in the Andalusian region, in the Guadalquivir valley, province of Jaén. The project area has now been extended from the economic territory linked to the Iberian Culture protohistoric town of Giribaile (Gutiérrez, 2011) to the boundaries shared by two Roman territorial entities attributed to the end of the 1st century CE or the beginning of the 2nd century CE (Fig. 2). The only evidence of the existence of *Baesucci* and *Ilugo* is stone epigraphs (González and Mangas, 1991).

2.1.1. Survey area 1. Field archaeology in the Municipium Flavium Baesuccitanum

We carried out a survey campaign in 2015 to the north of Giribaile, in the hypothetical territory of the ancient Roman *Municipium Flavium Baesuccitanum*. The experimental sampling area covered just the central part. We located a group of seven archaeological sites, including El Raso y Juan Clavero (Fig. 3), and we developed the same sampling protocol in all of them. These are very small Roman-period rural sites with a high prevalence of tiles and very durable diagnostic pieces of pottery. Also, the majority of these archaeological contexts define monophasic sites, easy to recognise.

Some important aspects of depositional and post-depositional

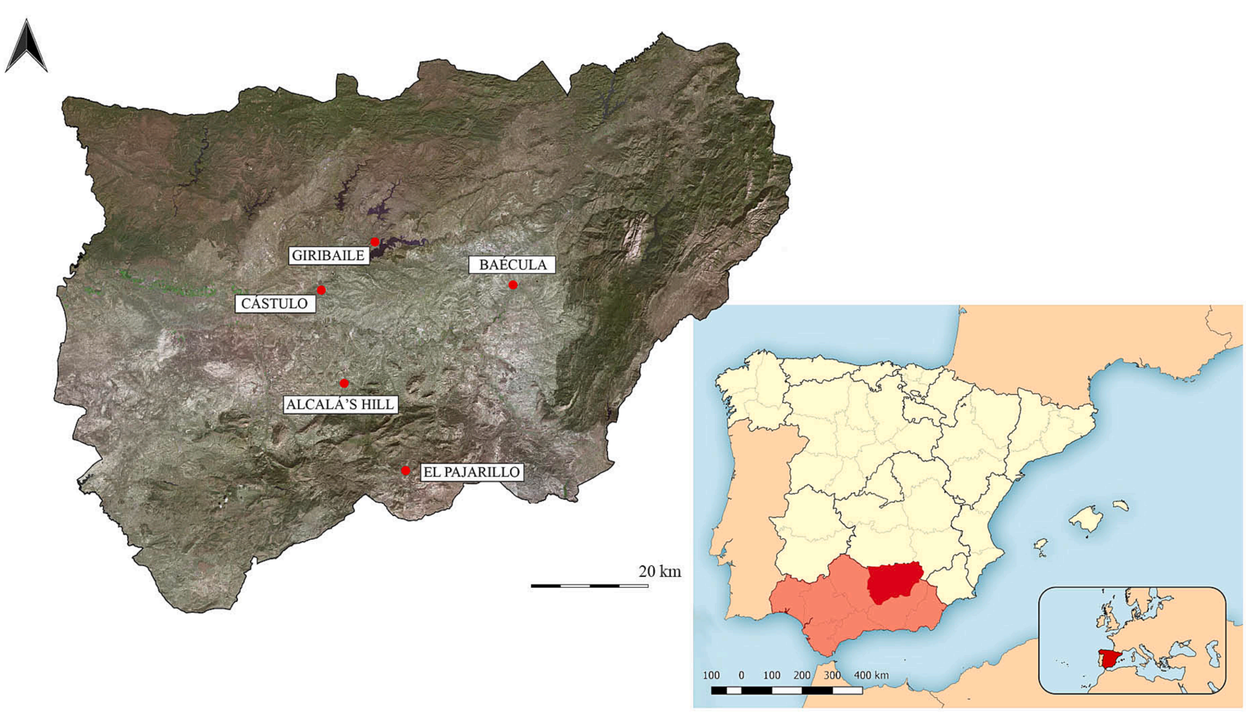

Fig. 1. Locations of the different surveying areas mentioned in the province of Jaén (Spain).

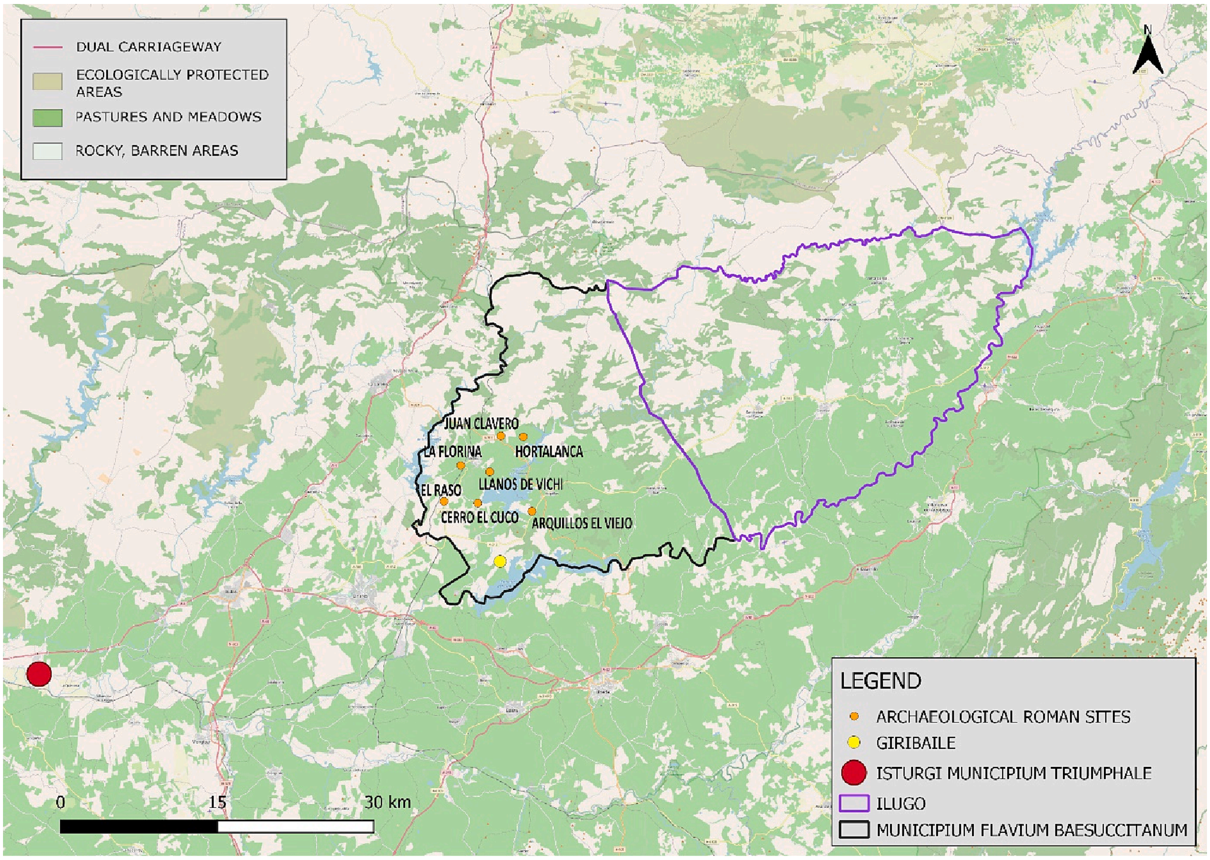

Fig. 2. Survey area with the hypothetical boundaries of the two Roman municipalities.

registration conditions must be considered in this paper. Most of the remains of Roman settlements have been altered by recent farmhouse construction. Besides, as the region was sparsely populated in the mediaeval period, there is little evidence of large-scale alteration of the landscape prior to the farmhouse construction and plantation activities. In the last few decades, the olive groves have been ploughed less to prevent erosion, which is a serious problem in mountain landscapes with shallow soil cover over the bedrock. The reduction of tractor use, to some extent, deters the post-depositional alteration of sites and limits the movement of overall scatter.

The preferred land use is olive groves. We used the rows of trees as an ideal checkerboard for undertaking systematic samplings. The olive groves were systematically surveyed. The basic idea was to take linear transect-type samples across the spaces between the rows of olive trees (Phase 1). The width of the transect was always 1 m, and the length varied with the distances between the rows of olive trees. Sometimes the machinery used in the field left an easy-to-follow track of the desired width (Fig. 4). In any case, we used a measuring tape on the ground to provide a visual reference of the transect and included in the database only items located less than 50 cm from each side, measured to a tolerance of one centimetre using a Leica GPS device.

Along this corridor, the positions of all found items were georeferenced. They included pottery from all periods with no minimum size and many indeterminate elements such as fragments of coarseware Roman ware or pieces of tile. These transects corresponded to a sampling of 10 % of the total land area.

After the quantitative sampling had been finalised (Phase 1), the work was completed with a systematic collection of diagnostic pieces (Phase 2). The objective of the qualitative sample was to identify elements of material culture that could improve the functional or chronological references. This collection took in the remaining 90 % of the olive grove fields, i.e. the area unaffected by the linear sampling.

2.1.2. *Survey area 2. Sampling in the Roman municipality of Ilugo*

As of 2019, the archaeological survey was expanded from the territory of the *Municipium Flavium Baesuccitanum* to the territory of *Ilugo* (Fig. 2), which may also have had the status of a Roman municipality. This survey affects all of the present-day county of El Condado Jaén, an area of 1.488 km^2.

The potential number of archaeological sites in this vast territory made it impossible for our research team to replicate the sampling procedure described above (survey area 1). On the other hand, it was necessary to continue characterising archaeological sites under comparable conditions. The statistical analysis was essential in developing an effective strategy while retaining the established objective of a sample that combines qualitative and quantitative-based records. It is clear that the qualitative sample is also quantitative because the final balance includes the diagnostic artefacts.

Therefore, we hypothesise that, for the purposes of basic archaeological characterisation, the quantitative result of surveying just one survey line could be similar to one obtained by systematically surveying the complete set of survey lines. The fieldwork would be significantly optimised by using this collection from a single transect-type linear. The aim was to determine statistically whether it was possible to reduce the number of linear samplings per settlement to just one in the new archaeological survey project in the *Ilugo* territory.

2.2. *Statistical proposal*

In this section, we describe the main aspects of the statistical analysis of the adequacy of this proposal. The protocol of the scientific experiment had three simple steps:

- Phase 1. Definition of qualitative and quantitative variables and evaluation of the site, collecting the diagnostic pieces (qualitative

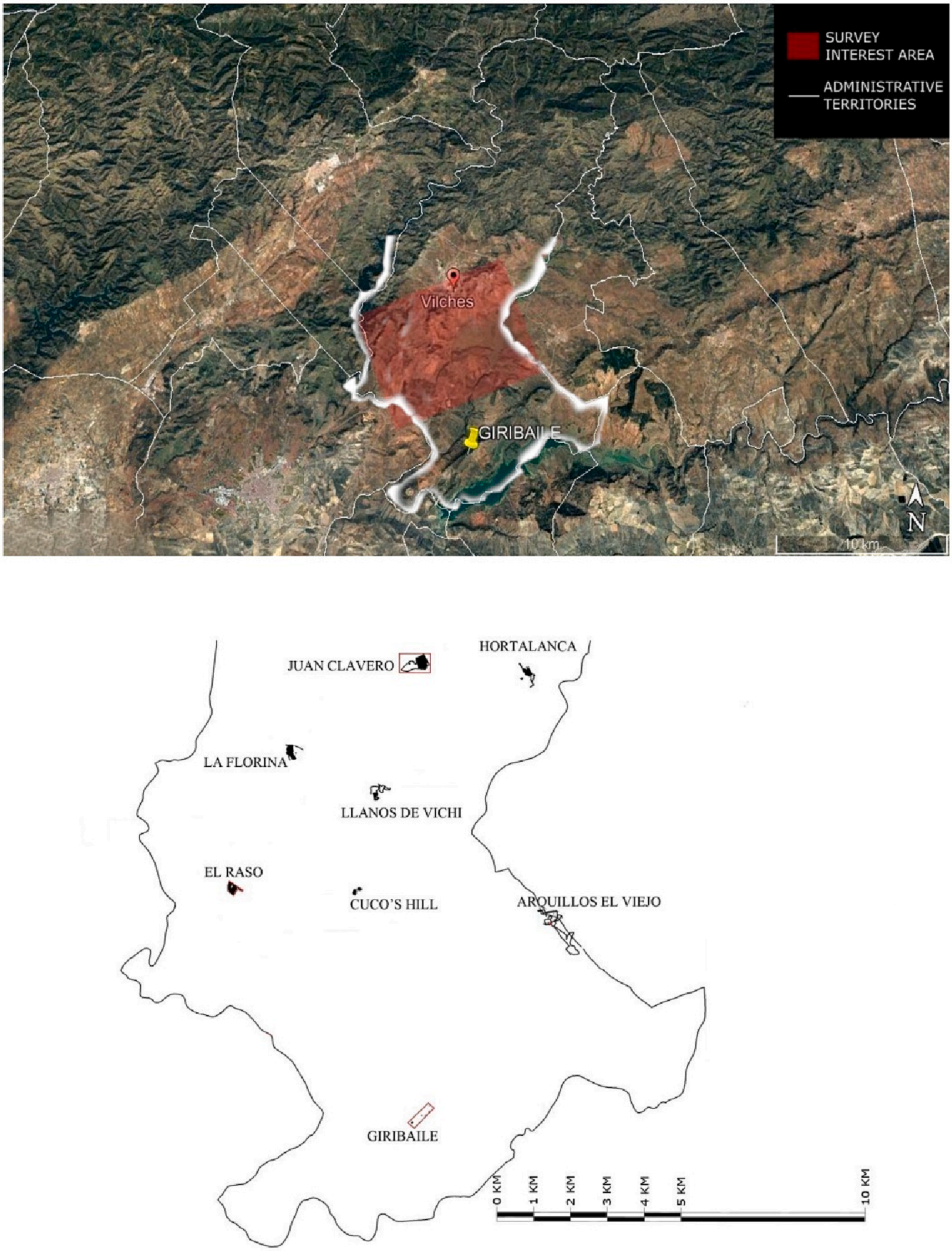

Fig. 3. Survey area in the territory of the *Municipium Flavium Baesuccitanum* at the municipality of Vilches (Spain). Location of the archaeological sites.

Fig. 4. La Florina. Aluminium range rod on the impressions made by a tractor (left part). Llanos de Vichi. Surveying a transect with GPS and measuring tape (right part).

sample). In this phase we used the GPS device to plot find-locations across the whole survey area, identifying and picking up diagnostic pieces (fineware).
- Phase 2. Generation of a 2D contour map.
- Phase 3. Choosing the final transect as the survey line crossing the centre of the kernel and then returning and doing a complete quantitative georeferencing GPS of building materials (tile/brick) and coarseware.

To evaluate the reliability of this proposal, a simulation study was carried out in 2015 by means of intensive sampling at two sites, El Raso and Juan Clavero. Both sites were intensively sampled in two phases, as described in Section 2.1.1. In Phase 1, the quantitative sampling followed the olive grove lines, and in Phase 2 the diagnostic pieces were systematically collected. The main considerations in implementing the collection were as follows. These deposits are real cases influenced by post-depositional factors; in this way, it is possible to analyse how the proposed protocol would behave in different scenarios. Specifically, the Juan Clavero site has a very small number of diagnostic pieces and the area with the highest density of these pieces is limited by a wire fence around a farmhouse. At the El Raso site, the main problem is that another farmhouse is located in the central part of the site, which is assumed to have the highest density of diagnostic pieces.

2.2.1. Phase 1. Definition of qualitative and quantitative variables and evaluation of the site, collecting the diagnostic pieces (qualitative sample)

To undertake this statistical evaluation, it was necessary to determine the most relevant archaeological diagnostic pottery categories belonging to the Roman period (Fig. 5). These are the intense red-varnished terra sigillata pieces from early Imperial times made in *Isturgi, Municipium Triumphale*, located at the present-day village of Los Villares de Andújar (Fernández, 1998; Fernández et al., 2015), 50 km from the territory of the *Municipium Flavium Baesuccitanum* (Fig. 2). The Isturgís pottery workshop was one of the most relevant ceramic production areas of the whole Iberian Peninsula during Roman Imperial period (Ruiz, 2013). These categories are, in part, contemporaneous to the terra sigillata coming from the southern Gaul. On the other hand, African red slipware and other indigenous Roman slip wares such as "terra sigillata hispánica tardía meridional" (Orfila, 1993, 2008) are abundant in the region. Both show its characteristic orange varnish, which continued into late antiquity.

In the quantitative approach, fragments of bricks/tiles and unidentified sherds of coarseware Roman ware are relevant, as they correspond to the most representative categories of find in surface collections, as confirmed by the survey in Ammaia (Mlekuz and Taelman, 2012). Normally, little attention is paid to such findings, but they are decisive in establishing the occupation density throughout the sequence. In fact, most of the items recorded within the transect-type samples that run through the centre of the olive grove lines were sherds that are difficult to identify due to a lack of characteristic features. They would be coarseware, the most frequent category in Roman archaeological records, or building materials, categories that are often confused with each other. This quantitative sample complements the qualitative sample focused on collecting diagnostic pieces and indicates the intensity of occupation and the density of the built spaces. Tiles and tegulae can be considered the diagnostic pieces of ancient Roman buildings, and the method used in this survey campaign can help to identify the main building spaces of the archaeological sites.

Once the qualitative and quantitative variables had been selected back at the office, we began the fieldwork with the qualitative analysis, collecting a systematic register of diagnostic pieces across the whole archaeological site.

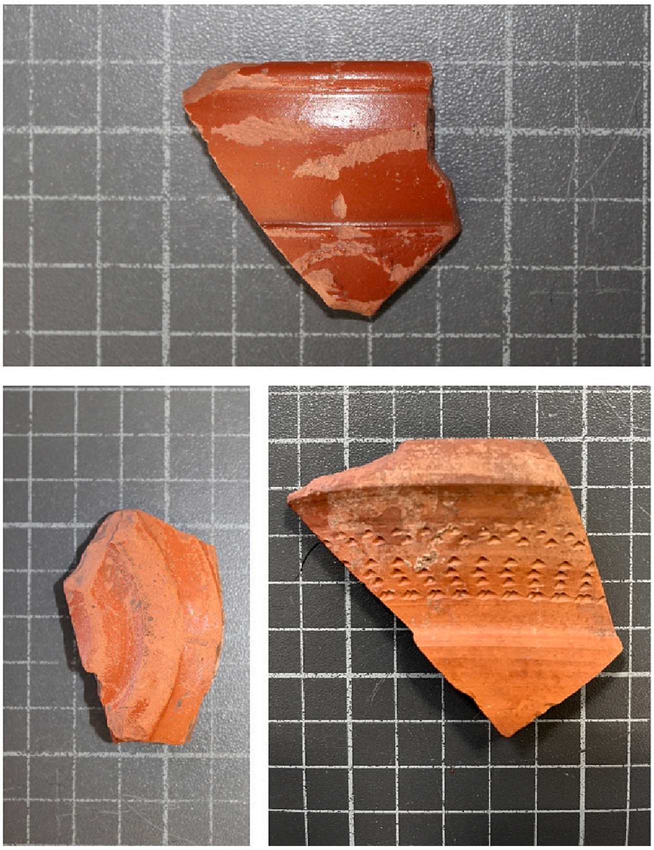

Fig. 5. Some examples of diagnostic pottery categories: sigillata from Isturgi, African red slip ware and terra sigillata hispánica tardía meridional. The reference scale shows 1 cm square units. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2.2.2. Generation of a 2D contour map

The contour maps are based on the evaluation of the results of two selected archaeological sites sampled in 2015, Juan Clavero and El Raso (Figs. 6 and 7), taking into consideration the distribution of diagnostic pieces from the Roman period, mainly fragments of different categories of terra sigillata from Early Imperial times to Late Antiquity. We assume that the scatter patterns of different archaeological sites in the study area show similar depositional and post-depositional conditions, because they share common natural and historical contexts.

For simulation purposes, we cannot identify any phase of these surveys with from the collection of diagnostic pieces in the proposed protocol. The equivalent of the protocol collection would be the set of diagnostic pieces found in Phase 2 and some that would have been found from in Phase 1. Therefore, for the simulation, the contour lines of both the full survey and Phase 2 are considered for both sites. The contour density plots were created using the geom_density_2d function of the R package ggplot, considering the 28 diagnostic pieces shown in Fig. 6a and the seven diagnostic pieces from Phase 2 (Fig. 6b) for Juan Clavero and the 131 diagnostic pieces shown in Fig. 7a and the 52 diagnostic pieces from Phase 2 (Fig. 7b) for El Raso. At both sites, the contour maps of the full survey and Phase 2 point to the same candidate transects.

The linear transect-type sample proposed here is intended to compare archaeological sites from documented records under similar conditions in the areas with the highest concentrations of diagnostic pieces. Contour mapping follows the concept of multistage surveys (Wilkinson, 2010). This technique analyses the highest concentrations of items on the surface and returns to the archaeological site in order to delimit and characterise the site's centre and its periphery.

Once the contour map has been topographically delimited, a compatibility analysis of the terra sigillata records is performed in the selected survey lines. We anticipate that the statistical results confirm that, in the two cases analysed, either of these survey lines would have served to establish a useful map of material densities.

2.2.3. Choosing the final or golden transect as the survey line crossing the centre of the kernel

Once the candidate survey line has been obtained, selected by means of an estimated kernel, the next phase is to study whether there are significant statistical differences between the distribution of the pieces collected in these golden transects and that of the whole site. For this purpose, a study is carried out of the frequency distribution of the pieces whose typology is considered of interest for the characterisation of each site. Specifically, the selected typologies are Roman coarseware, diagnostic pottery items and construction pieces. In order to show the results most completely, a table is constructed that compares the distribution of pieces in the whole site and in each of the different transects. In each case, we include the number of pieces of each typology, their relative frequency, the multinomial confidence interval (using the MultinomCI function of the R package DescTools) and the goodness-of-fit test (using the M chisq. test function of the R package stats) of their distribution with that of the whole site (Snedecor and Cochran, 1989) including the experimental chi-square value, the P-value and the conclusion of the test.

3. Results

The results from Juan Clavero (Table 1) show how the multinomial intervals of the pieces for the candidate transects 19 and 20 show the highest level of coincidence with the interval of the whole site while the other candidate transect, 18, differs slightly due to the lack of pieces of coarseware (Fig. 6). This is also supported by the goodness-of-fit test on transects 19 and 20. Therefore, we can conclude that the statistical results confirm the plausibility of the similarity hypothesis between the distributions of the whole site and the candidate transects. It can also be seen that many survey lines show multinomial CIs with almost no coincidences with those of the whole site. This underlines the importance of transect selection.

The results for the El Raso site (Table 2) show that there are more transects crossing regions with high representations of diagnostic pieces, and the central part is destroyed by a farmhouse. According to the multinomial intervals, the candidate transects, 12 and 13, show concordance with the whole site (Fig. 7). Moreover, the point estimate of diagnostic pieces for these transects is contained in the multinomial interval of the whole site. Transects 10, 11 and 14 also show similarities. As for the goodness-of-fit test, where it can be calculated, the hypothesis of significant differences in transects crossing areas of high diagnostic piece representation is not rejected.

4. Discussion

This paper discusses sampling strategies intended to obtain representative archaeological surface collections, combining quality and quantitative phases. This is a very important discussion in the context of needing to design a plan to accelerate the characterisation of large numbers of archaeological sites. The discussion focuses on two main aspects of the plan. First, the statistical evidence seems to validate the initial hypothesis of comparing limited quantitative registers between archaeological sites. On the other hand, questions remain around the quantitative analysis methods used to define the density of the nucleus of the archaeological sites. It is clear that our main target is to compare archaeological sites with a quick protocol focused on a limited sample. We can try to improve the precise spatial control of the collection of surface items with a more detailed methodology, but this is not the most important output of this contribution. We need to explain briefly some arguments on how to sample inside archaeological areas to get a basic

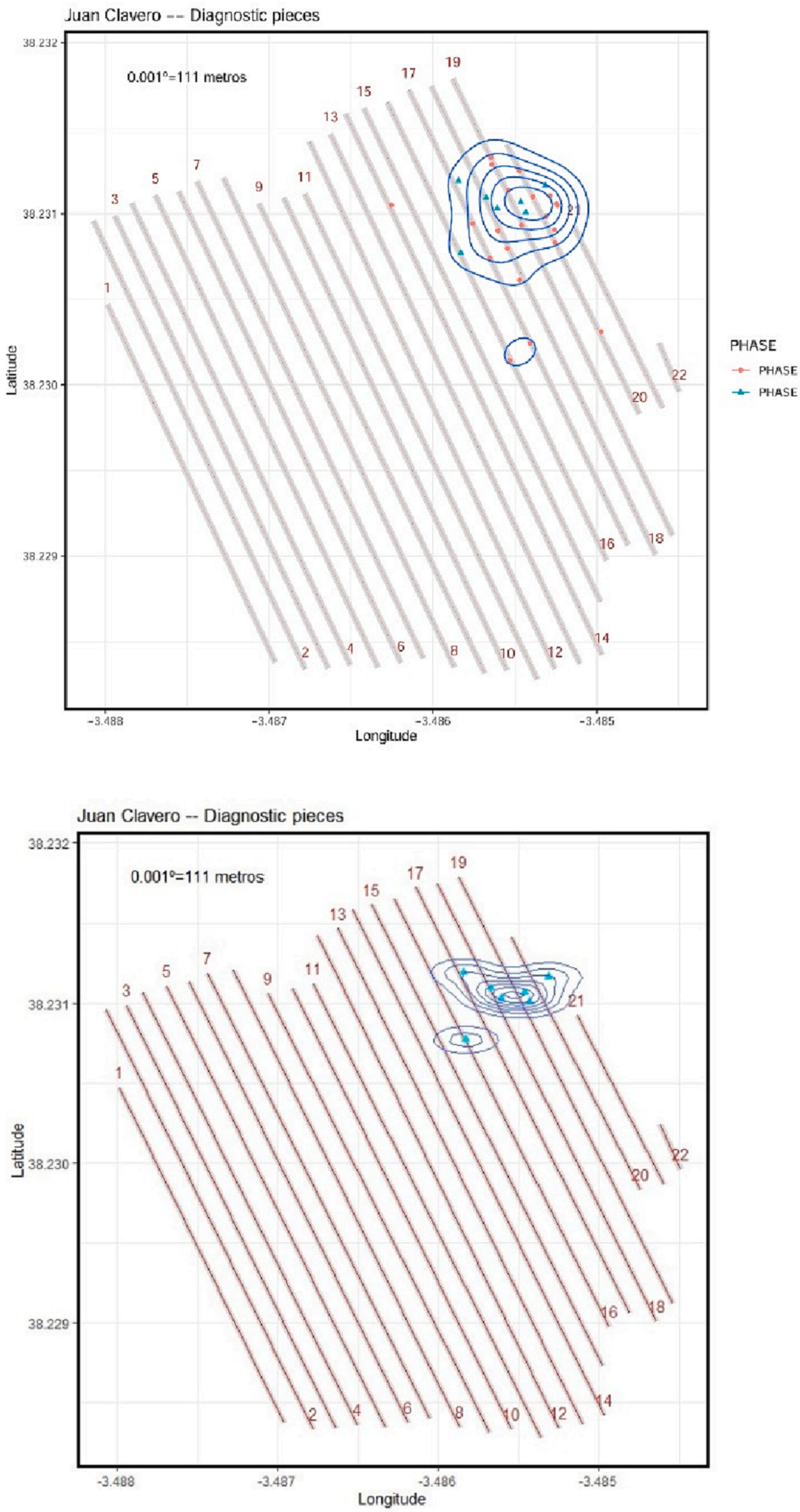

Fig. 6. Juan Clavero. Contour map based on the presence of diagnostic pottery pieces in transects (Phase 1) and the rest of the site (Phase 2). 6a. Phase 1 and Phase 2. 6b. Phase 2. The blue contour line shows the area with the highest concentration of diagnostic pieces. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

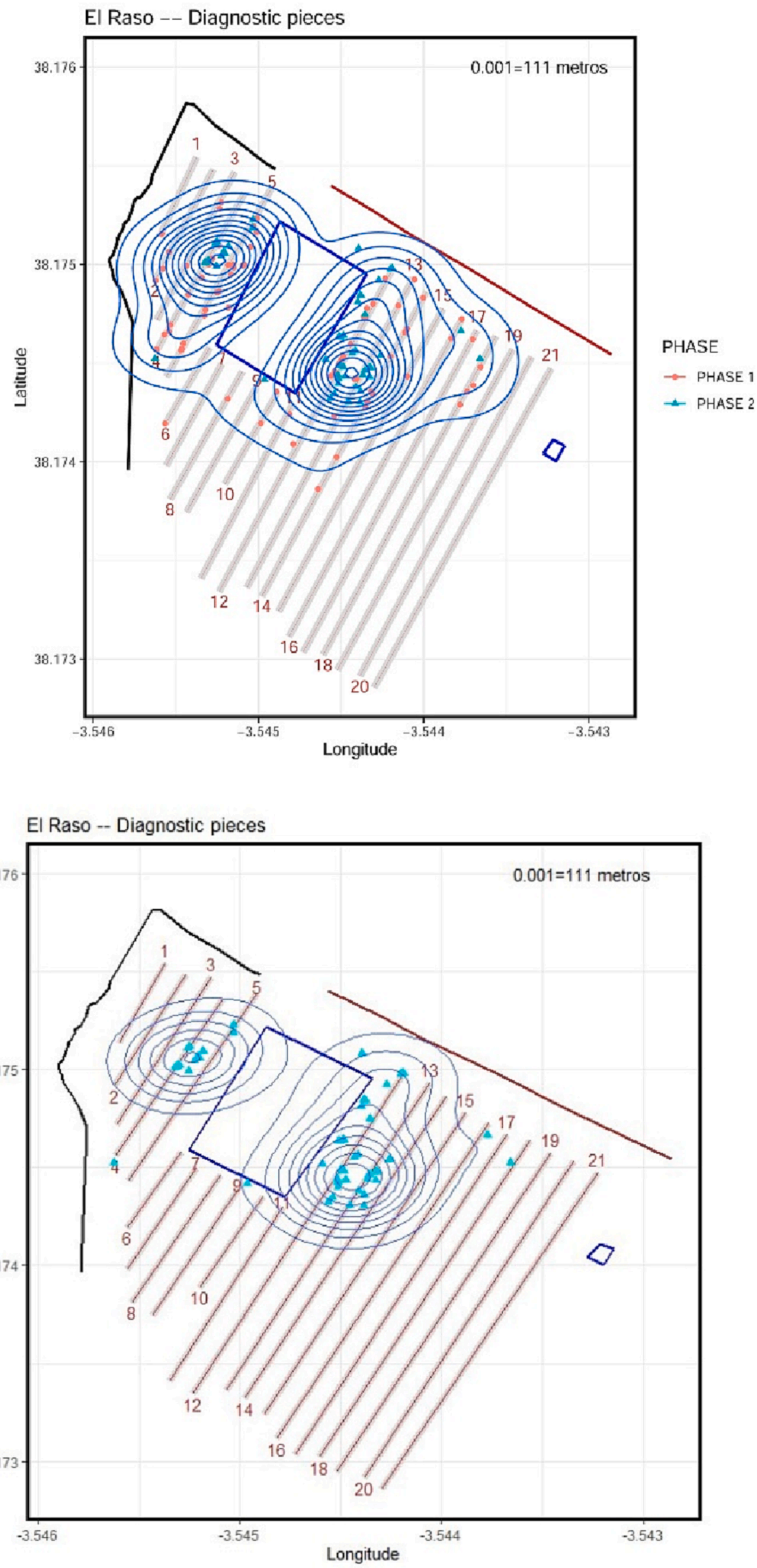

Fig. 7. El Raso. Contour map based on the presence of diagnostic pottery pieces in transects (Phase 1) and the rest of the site (Phase 2). 7a. Phase 1 and Phase 2. 7b. Phase 2. The blue contour lines show the area with the highest concentration of diagnostic pieces. The red line shows the boundary of the parcel. The black line shows the trace of the presence of a wire fence. The rectangles marked in blue show two isolated rural buildings. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Frequency distribution of the pieces of interest for the whole site of Juan Clavero and different transects (candidate transects are marked in bold) and the goodness-of-fit test resulting from comparing the different transects with the whole site.

		Count	Estimate	Multinomial CI		Test		
				Lower	Upper	Chi-square	P-value	Conclusion
Whole data set	Coarseware	32	0.0087	0.0051	0.0125	–	–	–
	Diagnostic	28	0.0076	0.0041	0.0115			
	Building	3605	0.9836	0.9801	0.9875			
Transect 1	Coarseware	1	0.01923	0	0.0517	–	–	–
	Diagnostic	0	0	0	0			
	Building	51	0.9808	0.9615	1			
Transect 2	Coarseware	0	0	0	0	–	–	–
	Diagnostic	0	0	0	0			
	Building	73	1	1	1			
Transect 3	Coarseware	0	0	0	0	–	–	–
	Diagnostic	0	0	0	0			
	Building	64	1	1	1			
Transect 4	Coarseware	0	0	0	0	–	–	–
	Diagnostic	0	0	0	0			
	Building	83	1	1	1			
Transect 5	Coarseware	1	0.0256	0	0.06889	–	–	–
	Diagnostic	0	0	0	0			
	Building	38	0.9743	0.9481	1			
Transect 6	Coarseware	0	0	0	0	–	–	–
	Diagnostic	0	0	0	0			
	Building	32	1	1	1			
Transect 7	Coarseware	1	0.0256	0.0385	0.1919	–	–	–
	Diagnostic	0	0	0	0			
	Building	24	0.9231	0.8846	1			
Transect 8	Coarseware	3	0.1304	0.0435	0.2750	–	–	–
	Diagnostic	0	0	0	0			
	Building	20	0.8696	0.7826	1			
Transect 9	Coarseware	0	0	0	0	–	–	–
	Diagnostic	0	0	0	0			
	Building	15	1	1	1			
Transect 10	Coarseware	0	0	0	0	–	–	–
	Diagnostic	0	0	0	0			
	Building	10	1	1	1			
Transect 11	Coarseware	0	0	0	0	–	–	–
	Diagnostic	0	0	0	0			
	Building	9	1	1	1			
Transect 12	Coarseware	0	0	0	0	–	–	–
	Diagnostic	0	0	0	0			
	Building	13	1	1	1			
Transect 13	Coarseware	0	0	0	0	–	–	–
	Diagnostic	0	0	0	0			
	Building	21	1	1	1			
Transect 14	Coarseware	1	0.0137	0	0.0412	0.0046	0.9977	Not reject H_0
	Diagnostic	1	0.0137	0	0.0412			
	Building	71	0.9726	0.9452	1			
Transect 15	Coarseware	1	0.0040	0	0.0109	–	–	–
	Diagnostic	0	0	0	0			
	Building	71	0.9959	0.9919	1			
Transect 16	Coarseware	1	0.0137	0	0.0070	0.0307	0.9848	Not reject H_0
	Diagnostic	1	0.0137	0	0.0070			
	Building	71	0.9726	0.9452	1			
Transect 17	Coarseware	4	0.0083	0	0.0179	0.0003	0.9998	Not reject H_0
	Diagnostic	3	0.0062	0	0.0158			
	Building	475	0.9856	0.9772	0.9951			
Transect 18	Coarseware	0	0	0	0	–	–	–
	Diagnostic	3	0.0046	0.0015	0.0099			
	Building	647	0.9954	0.9923	1			
Transect 19	**Coarseware**	**8**	**0.0187**	**0.0070**	**0.0350**	**0.0069**	**0.9966**	**Not reject H_0**
	Diagnostic	**5**	**0.0117**	**0**	**0.0280**			
	Building	**415**	**0.9696**	**0.9579**	**0.9951**			
Transect 20	**Coarseware**	**3**	**0.0061**	**0**	**0.0198**	**0.0075**	**0.9963**	**Not reject H_0**
	Diagnostic	**9**	**0.0184**	**0.0082**	**0.0320**			
	Building	**476**	**0.9754**	**0.9652**	**0.9890**			
Transect 21	Coarseware	2	0.0055	0	0.0113	–	–	–
	Diagnostic	0	0	0	0			
	Building	359	0.9944	0.9889	1			
Transect 22	Coarseware	0	0	0	0	–	–	–
	Diagnostic	0	0	0	0			
	Building	25	1	1	1			

Table 2
Frequency distribution of the interest pieces for the whole site of El Raso and different transects (candidate transects are marked in bold) and the goodness-of-fit test resulting from comparing the different transects with the whole site.

				Multinomial CI		Test		
		Count	Estimate proportion	Lower	Upper	Chi-square	P-value	Conclusion
Whole data set	Coarseware	36	0.0172	0.0067	0.0286	–	–	–
	Diagnostic	131	0.0628	0.0522	0.0741			
	Building	1919	0.9199	0.9094	0.9313			
Transect 1	Coarseware	0	0	0	0	–	–	–
	Diagnostic	1	0.0476	0	0.1275			
	Building	20	0.9524	0.9048	1			
Transect 2	Coarseware	2	0.0303	0	0.0922	0.0122	0.9939	Not reject H_0
	Diagnostic	3	0.0454	0	0.1074			
	Building	61	1	0.8788	0.9861			
Transect 3	Coarseware	0	0	0	0	–	–	–
	Diagnostic	3	0.0183	0.0062	0.0400			
	Building	158	0.9814	0.9689	1			
Transect 4	Coarseware	3	0.0064	0	0.0219	0.0738	0.9678	Not reject H_0
	Diagnostic	12	0.02575	0.0129	0.0412			
	Building	451	0.9678	0.9549	0.9833			
Transect 5	Coarseware	0	0	0	0	–	–	–
	Diagnostic	19	0.0387	0.0244	0.0556			
	Building	471	0.9612	0.9469	0.9780			
Transect 6	Coarseware	0	0	0	0	–	–	–
	Diagnostic	1	0.0263	0	0.0707			
	Building	37	0.9737	0.9474	1			
Transect 7	Coarseware	0	0	0	0	–	–	–
	Diagnostic	0	0	0	0			
	Building	7	1	1	1			
Transect 8	Coarseware	0	0	0	0	–	–	–
	Diagnostic	1	0.0196	0	0.0527			
	Building	50	0.9804	0.9608	1			
Transect 9	Coarseware	0	0	0	0	–	–	–
	Diagnostic	0	0	0	0			
	Building	17	1	1	1			
Transect 10	Coarseware	0	0	0	0	–	–	–
	Diagnostic	2	0.0513	0	0.1032			
	Building	37	0.9487	0.8974	1			
Transect 11	Coarseware	2	0.0408	0	0.1087	0.1020	0.9503	Not reject H_0
	Diagnostic	1	0.0454	0	0.0882			
	Building	46	0.9388	0.8979	1			
Transect 12	**Coarseware**	**0**	**0**	**0**	**0**	–	–	–
	Diagnostic	**13**	**0.0710**	**0.0382**	**0.1054**			
	Building	**170**	**0.9289**	**0.8962**	**0.9634**			
Transect 13	**Coarseware**	**1**	**0.0123**	**0**	**0.0721**	**0.0020**	**0.999**	**Not reject H_0**
	Diagnostic	**5**	**0.0618**	**0.0251**	**0.1215**			
	Building	**75**	**0.9259**	**0.8889**	**0.9857**			
Transect 14	Coarseware	1	0.0125	0	0.0862	0.0366	0.9819	Not reject H_0
	Diagnostic	10	0.0618	0.0625	0.1996			
	Building	79	0.8625	0.8000	0.9371			
Transect 15	Coarseware	0	0	0	0	–	–	–
	Diagnostic	1	0.0175	0	0.0471			
	Building	56	0.9824	0.9649	1			
Transect 16	Coarseware	1	0.02	0	0.0864	0.0138	0.9931	Not reject H_0
	Diagnostic	2	0.04	0	0.1064			
	Building	47	0.94	0.9	1			
Transect 17	Coarseware	5	0.1020	0.0482	0.1990	0.1605	0.9229	Not reject H_0
	Diagnostic	1	0.0204	0	0.1174			
	Building	43	0.8775	0.8163	0.9746			
Transect 18	Coarseware	6	0.1538	0.0513	0.3003	0.1785	0.9146	Not reject H_0
	Diagnostic	4	0.1026	0	0.2491			
	Building	29	0.7436	0.6410	0.8901			
Transect 19	Coarseware	1	0.0385	0	0.1032	–	–	–
	Diagnostic	0	0	0	0			
	Building	25	0.9615	0.9231	1			
Transect 20	Coarseware	2	0.0689	0.0345	0.1723	–	–	–
	Diagnostic	0	0	0	0			
	Building	27	0.9310	0.8965	1			
Transect 21	Coarseware	2	0.1538	0.0769	0.3786	–	–	–
	Diagnostic	0	0	0	0			
	Building	11	0.8461	0.7692	1			

characterisation.

4.1. Sampling with quadrats and transects

The use of square sample units offers a more effective realisation of full coverage surveys than simple linear transect-type samples. They are especially recommended for the characterisation of large settlements. In fact, from the beginning of the 1990s we have used a mobile aluminium grid designed by ourselves that could be transported easily. It consists of 16 one-metre-long spars and four corners of 0.5 m on each side. The grid can be subdivided internally into units of 1 m^2 by hooking elastic straps into holes arranged in the central part of the aluminium spars. We have developed several Roman and protohistoric case studies, such as *Ossigi Latonium* (Lozano and Gutiérrez, 2006) and El Pajarillo (Gutiérrez et al., 1998). Giribaile, a fortified town with an area of more than 14 ha, was the greatest challenge up to 2004–05 in the experimental practice of intensive archaeological surveying in the province of Jaén. As a result, a specific work protocol was published in 2010 to deal with systematic random characterisations (Gutiérrez, 2010). The project at Giribaile, in which a total of 45 days of fieldwork was invested (Fig. 8), recorded 1 % of the total area in sample units of 1 m^2.

This project was a success, but we needed to design a new operative plan in order to reduce the time spent on the basic internal characterisation of archaeological sites of the *Municipium Flavium Baesuccitanum*. In order to define the main concentrations of items, we substituted transects for quadrats and sampled the olive plantations systematically, based on the recording and documentation of the diagnostic pieces.

The aim is to arrive at a reasonable estimate of the density of findings by sampling a limited collection picked up from the site surface. We also opted to record all items by using points in the GPS device, including diagnostic pieces and shapeless fragments of pottery. Various limited pick-up practices are followed when find densities are very high, but this is not what we did. It is true that grid sampling systems are the best models for obtaining grouped statistical estimations (Richards, 2010; Mayoral and Sevillano, 2013), and are usually reserved for characterising extensive sites.

A survey strategy in successive phases is usually recommended, beginning with an initial assessment of the find assemblage dispersion. After this preliminary study had been carried out, we determined one or more linear suitable sampling axes that cross the archaeological site from side to side, including both the core and part of the periphery. The statistical analysis permits us to choose the most convenient survey line. The objective of statistical comparison is to obtain a significant sample from the smallest collection volume. A single linear sampling for each archaeological site can provide relevant quantitative information about their occupation densities. Any orientation of the transect line could be valid.

Fig. 8. Mobile grid used in two case studies: El Pajarillo and Giribaile.

The significance of the samples is based on the repetition of comparable conditions at all archaeological sites, in our current case study a corridor of 1 m wide by 100 m long. The length of the transect is an *ad hoc* adaptation to the settlement pattern of this project.

4.2. Sample limits

The supervisors of surveying teams generally impose time limits on the observation of each grid. Thus, for example, in the 2002 campaign in Potenza, the reconnaissance of square units of land measuring 40 × 40 m was limited to 20 min (Vermeulen and Verhoeven, 2006). In the 2005 Ricina campaign, 4 min were allocated to the collection of diagnostic pieces in a 10 × 10 m square (Van Limbergen et al., 2017). In 2008–2009, the Belgian-Maltese survey project required two people to collect as much pottery as possible in 5 min within a 10 × 10 m grid (Vella et al., 2019). Finally, in the Thorikos survey, groups of students were given 20 min to inspect each quarter subdivision of an area of 50 × 50 m (Van den Eijnde et al., 2018).

Likewise, a minimum size of 1 cm has been established to document a piece. Among many other cases, we can cite the 2010 survey campaign in Trea and that undertaken in the central Italian Adriatic area in 2012 (Van Limbergen et al., 2017). The summer 2010 campaign in Ammaia is a paradigmatic case, since the land was divided into 10 × 10 m squares, with all the finds over 1 cm in size being collected in 10 min (Mlekuz and Taelman, 2012).

On the other hand, transects are associated with extensive surveying actions, which often cover distances of kilometres through cultivated fields. In the cases of Thespiae and Tanagra, the surveyors were separated by 15 m intervals in 100 × 100 m, and the finds were recorded by chronological periods (Bes et al., 2006). In the Belgian-Maltese surveying project, all the archaeological findings were collected (21,000 fragments in 2008 and 13,000 in 2009), and a form was completed for each section; some twenty people covered an area of less than 2 km^2 (Vella et al., 2019). In Potenza, the distance between surveyors was 15 m. Where the amount of pottery varied significantly, that area was marked with flags. Nothing was collected immediately in the marked areas until the territory had been fully surveyed. Finally, all the finds were re-bagged, and their position was recorded using GPS (Vermeulen and Boullart, 2001).

There is a reference case study in northern Spain (García and Cisneros, 2013). In the first phase, it concentrated on the distribution of the dispersions, determining a first count with manual GPS, and differentiating between pre-Roman or Roman sherds and the rest. The second phase used the GIS application in the GPS devices to perform a chronological discrimination of the highest concentrations of findings by chronological horizons. During the third phase, the findings to which a significant functionality or chronology was assigned were collected.

The examples cited represent nearby and current cases of intensive archaeological surveys, carried out mainly on Mediterranean landscapes. They share the same methodology, adapted to the particular needs of each research project (Table 3). In general, archaeological sites are characterised by the analysis of significant concentrations of findings and the collection of diagnostic pieces in relation to previously established chronological horizons. There are usually time constraints in field inspection, especially in areas with high densities of surface findings. Although all these systems are useful and serve as references for new projects, we need to set up new procedures to speed up the recording of documentation in the field.

Table 3
Some examples of sampling methodology in ancient Mediterranean landscapes.

Survey campaign	Measure unit (meters)	Spent time (minutes)	Number of prospectors	Size of pottery (centimeters)	Distance between prospectors (meters)	Time of collection
Potenza, 2002	40 × 40	20			15	not immediately
Ricina, 2005	10 × 10	4	individual			
Belgian-Maltese, 2008–2009	10 × 10	5	two people	all items		
Thorikos	50 × 50	20	group			
Ammaia, 2010	10 × 10	10		>1		
Thespiae and Tanagra	100 × 100				15	

4.3. Statistical analysis

Finally, the simulation study concludes that statistically significant data can be obtained by carrying out a single linear sample at an archaeological site. It is, though, important to note that there is a very strong predominance of construction pieces, which shows that the minimum of 5 % representation is reached neither in the whole site nor in any of the survey lines. Taking this limitation into account, and assuming that the test results cannot be conclusive, the test is carried out for the cases in which the three categories considered are represented, in order to provide extra contextual support.

It is also important to note that the test confirms the hypothesis “H_0: There is no significant difference between the observed and the expected value”. Therefore, when the test does not reject this hypothesis, it cannot

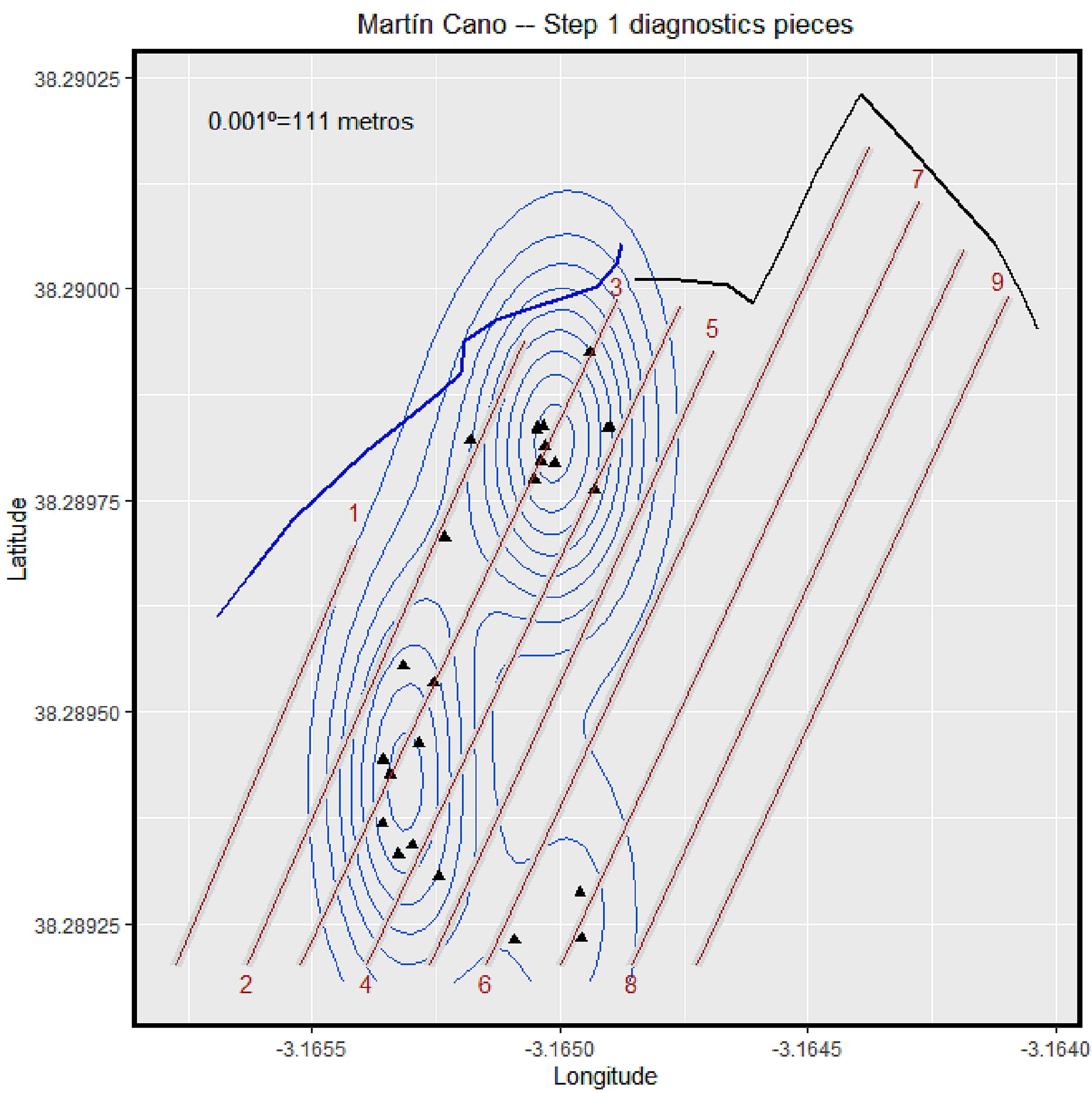

Fig. 9. Contour density plot of the Martín Cano site generated from the diagnostic pieces collected in phase 1 of the protocol. The barriers of the study area are a blue line indicating the existence of a rural road and a black line indicating the existence of a fence that delimits the olive grove. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

be concluded that the observed frequency distribution is equal to the given one, but rather that it cannot be rejected that they are similar. This means that the similarity between the two distributions is statistically plausible and, therefore, can be regarded as statistical support for this hypothesis.

5. The operationalisation of trials as proof-of-concept

As a final verification of the method, the archaeological site known as Martín Cano, a Roman settlement belonging to the territory of Ilugo, was surveyed. The objective was to present a real case that serves as an example of the proposed method. The protocol was followed strictly, in three phases.

5.1. Phase one

The three sets of materials that comprise the previously selected variables (diagnostic pieces, coarseware and building materials) were loaded into the GPS database. Next, the archaeological area was qualitatively surveyed, with georeferencing of all the diagnostic pieces that were recognizable on the surface of the terrain.

5.2. Phase two

Generation of a 2D contour map from the distribution cloud of the diagnostic pieces located, all of them terra sigillata from Early Imperial times. This analysis facilitated the selection of a better-defined survey line to be sampled.

The Martín Cano site, not previously surveyed, was studied following the proposed protocol. Fig. 9 shows the contour density plot generated from the diagnostic pieces collected in phase 1 of the protocol, indicating that transect number 3 is the candidate.

5.3. Phase three

The survey team returned to the field to carry out the sampling (qualitative and quantitative) of the selected transect. Finally, the results for the Martín Cano site (Table 4) show that the distributions of pieces from the golden transect (3), the adjacent transects (2 and 4), and transects 5 and 6 show concordance with the distribution of pieces from the whole site.

6. Conclusions

Surveys of large territories require the design of effective surveying strategies. The effectiveness of the intensive archaeological surveying proposal depends on relating what to do and how to do it. Thus, surveying one transect per archaeological site may be important from a statistical point of view. Statistical analysis makes it possible to set up a combined qualitative and quantitative sampling system, which allows meaningful comparisons between settlements.

This paper will help to increase the effectiveness of comparisons of quantitative samplings, which are reduced to a single linear transect-type sampling 1 × 100 m. This kind of sampling can be undertaken by just two well-trained archaeological surveyors. The current proposal is based on the need to establish spatial control over the context and to obtain representative samples.

The main consequence of this statistical analysis has been that, since 2019, the order in which the fieldwork phases are executed has changed: archaeological site surveys have begun to include collecting diagnostic pieces. This qualitative sampling indicates the most appropriate survey line for a single linear quantitative sampling.

The best procedure will be the one that combines the optimum use of available resources and adherence to research objectives. In any event, the statistical contribution to the samplings discussed in this work is part

Table 4
Frequency distribution of the pieces of interest for the whole of Martín Cano site, the various transects (candidate transects are marked in bold), and the goodness-of-fit test comparing the different transects with the whole site.

				Multinomial CI		Test		
		Count	Estimate proportion	Lower	Upper	Chi-square	P-value	Conclusion
Whole data set	Coarseware	18	0.0155	0.0043	0.0273	–	–	–
	Diagnostic	41	0.0352	0.0240	0.0471			
	Building	1105	0.9493	0.93814	0.9612			
Transect 1	Coarseware	0	0	0	0	–	–	–
	Diagnostic	0	0	0	0			
	Building	35	1	1	1			
Transect 2	Coarseware	3	0.0191	0	0.04816	0.0044	0.9978	Not reject H_0
	Diagnostic	4	0.0255	0	0.05453			
	Building	150	0.9554	0.9299	0.9845			
Transect 3	**Coarseware**	**1**	**0.0062**	**0**	**0.0264**	**0.02873**	**0.9857**	**Not reject H_0**
	Diagnostic	**3**	**0.0187**	**0**	**0.0389**			
	Building	**156**	**0.9750**	**0.9562**	**0.9951**			
Transect 4	Coarseware	2	0.0139	0	0.0427	0.0103	0.9948	Not reject H_0
	Diagnostic	3	0.0208	0	0.0497			
	Building	139	0.9653	0.9444	0.9941			
Transect 5	Coarseware	4	0.0213	0	0.0456	0.0250	0.9876	Not reject H_0
	Diagnostic	3	0.0159	0	0.0403			
	Building	181	0.9628	0.9415	0.9871			
Transect 6	Coarseware	2	0.0171	0	0.0457	0.0841	0.9588	Not reject H_0
	Diagnostic	1	0.0085	0	0.0372			
	Building	114	0.9743	0.9573	1			
Transect 7	Coarseware	3	0.0428	0.0143	0.09177	–	–	–
	Diagnostic	0	0	0	0			
	Building	67	0.9571	0.9286	1			
Transect 8	Coarseware	0	0	0	0	–	–	–
	Diagnostic	2	0.05	0	0.1007			
	Building	38	0.95	0.9	1			
Transect 9	Coarseware	0	0	0	0	–	–	–
	Diagnostic	0	0	0	0			
	Building	16	1	1	1			
	Diagnostic	0	0	0	0			
	Building	11	0.8461	0.7692	1			

of a comprehensive research methodology based on non-destructive analysis techniques. Experience in the olive groves of Jaén has facilitated the planning of an effective strategy that meets international standards. However, one potential limit to the application of our method to other Mediterranean landscapes must be considered. In the site studied here, olive cultivation means that disruption by deep ploughing is relatively limited, an there is good soil visibility for morest of the year: not conditions that apply everywhere.

Controlling the statistical quality of intensive samplings improves the interpretation of the find assemblages and makes it possible to evaluate the methods used and the effectiveness of the strategy. The objective is to establish a useful work protocol to improve the characterisation of the settlement patterns in the territory. These arguments open a debate over the accuracy of using intensive non-destructive surveys inside archaeological sites.

Funding

This paper has been grant-funded by the Research Group PAIDI-HUM357 (GIPAJ).

CRediT authorship contribution statement

Luis María Gutiérrez Soler: Conceptualization, Methodology, Validation, Investigation, Writing – original draft, Supervision, Project administration. **Francisco Javier Esquivel Sánchez:** Methodology, Software, Formal analysis, Writing – review & editing. **María Alejo Armijo:** Validation, Investigation, Data curation. **Francisco Pérez Alba:** Validation, Investigation, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2023.104124.

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