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A larger-scale study of the visual dominance at the Gor River megalithic landscape (Granada, Spain)

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ABSTRACT

This paper presents the results of various analyses conducted on the megalithic complex of the Gor River valley (Granada, Spain) with the aim of exploring the visual landscape of this area on a larger scale during the Late Prehistoric period. The analyses performed include clustering of burial mounds using DBSCAN, calculation of Relative Topographic Position, calculation of fuzzy viewsheds, and statistical analysis of the existence or non-existence of relationships between dimensions, topographic prominence, and visibility. Fuzzy viewshed analysis is implemented to refine other visibility analyses that had previously been conducted on the complex, without considering the fuzziness variable, which is obtained by taking into account distance and size. The results are consistent with previous analyses that indicate no relationship between the size of the megaliths, topographic position, and visibility. It reveals the importance of the entire complex to define the related territory although the existence of possible particularities associated to various ecological niches in the study area can be also suggested.

1. Introduction

The megalithic group of the Gor River Valley (Granada, Andalusia, Spain) (Fig. 1) is one of the primary clusters forming the so-called Megalithic Phenomenon of the Southeastern Iberian Peninsula (García Sanjuán 2009),being one of its main characteristics the high density of megaliths per km^2. Initially, 238 dolmens were recorded along 17 km of the valley during early surveys (Siret 2001). However, only 151 megalithic monuments have been found in the most recent systematic survey, which is explained by the mechanisation of the agricultural lands since the mid XX century and the lack of legal and practical protection of the monuments till the 10 s (Cabrero et al. 2021). Other specific characteristics of this ensemble include varied chamber typologies, primarily small in size, and the use of the tombs over a wide temporal range—from the late Neolithic to the Chalcolithic period—with frequent reuses in the Late Bronze Age (Dorado et al. 2023). This aspect has been widely registered by the study of the objects found in the chambers (Lorrio 2008) and by the 11 radiocarbon dates obtained till the present, with data between 4307 ± 33 and 2690 ± 30 cal. BP (Cabrero et al. 2023a: 4). This characteristic is shared by many megaliths located in Hoya de Guadix (Aranda et al. 2022) and other Southeastern Iberian areas (Lorrio 2008; Dorado et al. 2023).

Given the scarcity of data for sites related to settlement, megalithic monuments are virtually the only evidence we have to analyse the occupation and settlement patterns in this area during Late Prehistory. Megaliths are considered to never be placed outside the space exploited by the community that built them (Cámara 2001; Furholt and Müller 2011; Schmitt et al. 2019). Besides their primary funerary use, they served as markers of routes and territories of exploitation (García Sanjuán et al. 2009; Scarre 2011), although the type of exploitation (extensive or intensive, pastoral, agrarian, or other) may vary. The territory is understood as the space modified and appropriated by human social activity (Hägerstrand 1973, 1975; Carlstein 1983; Tuan 2001, 2004). Thus, the distribution of megaliths forming necropolises would not be random but would have a specific configuration related to land ownership, anthropization, and sacralization of the terrain by Late Prehistoric farming communities through the burial of their ancestors (Criado 1984; Godelier 1989; Augé 1992; Fabietti and Matera 2000; Lèvi-Strauss 2000; Cámara 2001; Shaffer 2005; Littleton 2002, 2007; Chénier 2009).

If we accept that the landscape is a space modified by human experience and activity, and that it conditions human life (Ingold 1993;

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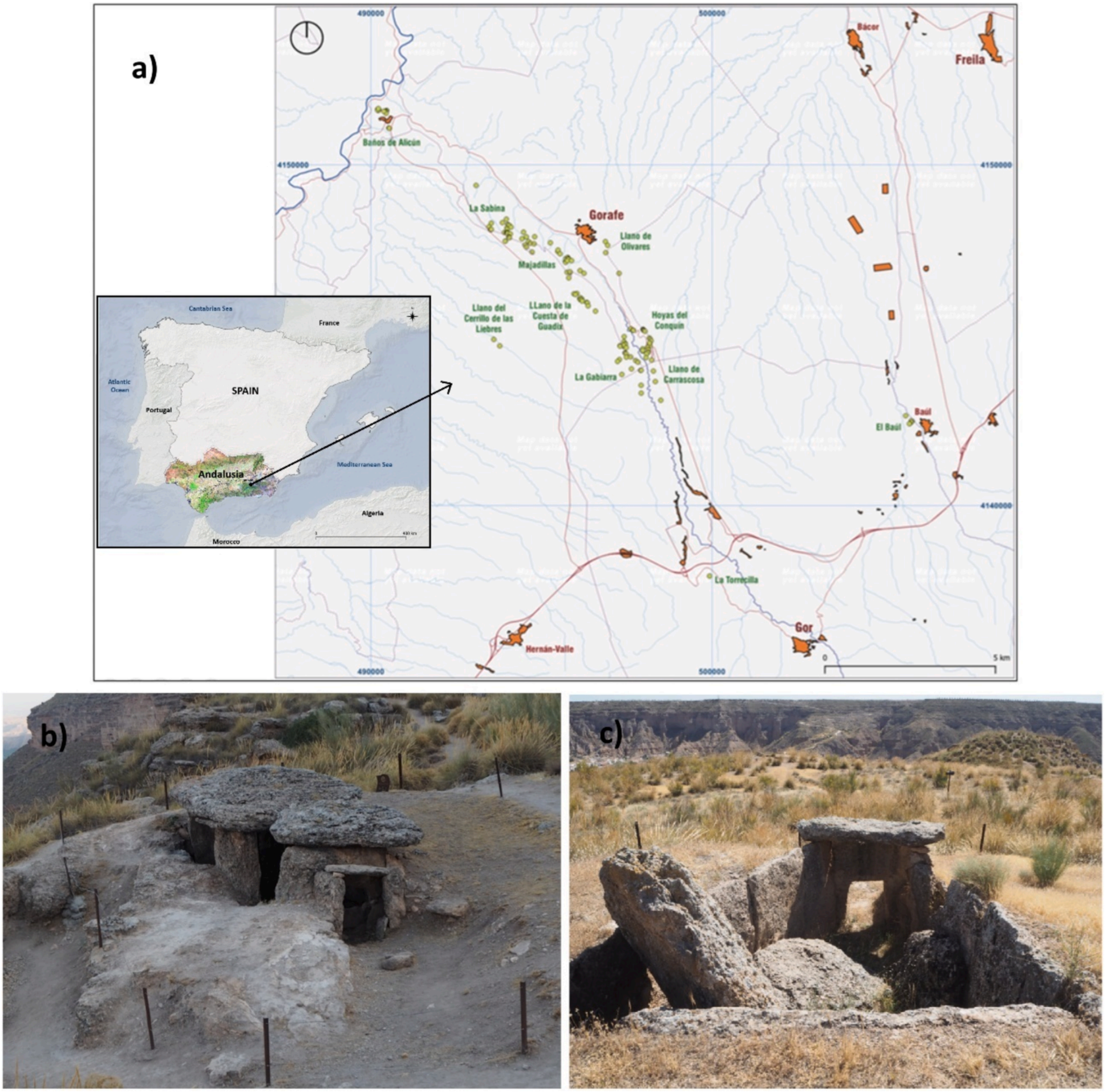

Fig. 1. A) location of the Gor River in the region of Andalusia (South of Spain). b and c, Hoyas del Conquín 134 and Majadillas 69, two of the most known monuments of the area.

Tilley 1994; Ashmore and Knapp 1999; Bongers et al. 2012; Cruz et al. 2024; Grier et al. 2017; Šprajc et al. 2022), the study of the distribution of megaliths and their relationship with the environment, space, and geography can be one of the best approaches to understanding the communities that built the tombs (Schiffer 1987; Hodder 1990; Criado 1997; Lock and Molineaux 2006; Gillings and Pollard 2016; Whittle 2017; Lock and Puncett 2017; Cámara et al. 2021), especially considering the absence of other evidence related to these communities in our study area.

This substantial quantity of megaliths and their proximity to one another have traditionally been interpreted as a manifestation of an intense degree of appropriation and demarcation of the territory by Late Prehistoric communities. Therefore, studying the distribution of megaliths and their relationship with the environment is key to understanding these past communities, especially in light of the scarcity of other archaeological data (Renfrew 1976; Sherratt 1990; Binford 1999).

In this paper, we present a new approach to understanding the experience and perception of these communities on the territory, mainly through the analysis of fuzzy visual basins applied to the preserved megaliths. Although visibility analysis has a long history in this region (Cabrero et al. 2024), this research aims to refine previous results and extend the study radius to analyse the territory on a larger scale.

2. Background. Approaches to the visual landscape of the Gor River

One of the best ways to analyse the relationship between megaliths and the territory is through visibility analyses (Čučković 2016). Visibility is a broad aspect that allows exploration of the relationship between an archaeological item and its surroundings, the existence or absence of interrelation between various archaeological structures, the prominence of a site over its surroundings, or the perceptibility of a particular element, among many other aspects (Wheatley and Gillings 2000; Llobera 2003, 2012). These different issues help us approach the visual landscape from a specific site or set of sites (Llobera 2007), closely related to the perception and significance of the sites for past communities (Criado 1984, 1999; Gillings and Wheatley 2001; Scarre 2010; Rodríguez-Rellán and Fábregas 2023).

In the case of the Gor River area, early 21st-century studies were conducted by a team from the University of Granada focused on aspects related to the domain of burial mounds over the landscape (Afonso et al. 2006, 2008, 2010; Spanedda et al. 2014). Although these publications did not analyse the entire cluster or use GIS techniques, they established interesting hypotheses about the visual landscape. Their conclusions suggested the existence of a single visual network where the megaliths were strategically positioned to control the entire territory, emphasizing routes from the steep-sided valley to the surrounding plateau. However, individual differences related to construction typologies or the specific topographic positions of individual megaliths were noted within each necropolis.

The first studies using GIS techniques on the entire cluster were recently conducted as part of a PhD thesis focused on the Gor River dolmenic complex and their spatial dimension (Cabrero 2023). This research considered the 151 preserved megaliths and other Chalcolithic archaeological structures related to valley access defence (Cabrero et al. 2024). Visibility was analysed from each megalith, the megaliths as a whole, and the visual relationship between the megaliths and other archaeological sites. The results reinforced initial research conclusions, showing a well-planned network with no flaws in the intervisibility of the main dolmenic group. Differences appeared in more distant necropolises like Baños de Alicún and El Baúl, which seemed to form separate groups based on visibility and distance, with differences in constructive and topographical patterns (Cabrero et al. 2021). Also in the frame of the cited PhD work, a research focused on the comparison of the architectonic features between the megaliths and the necropolises (typology, presence or lack of corridor, measures of the chambers and corridors) was carried out (Esquivel et al. 2022). This approach served to emphasize these particularities. These differences have been interpreted as cultural boundaries related to the exploitation of different ecological niches, with megaliths near other riverbeds apart from the Gor River. However, establishing peripheral and resistance areas in Hoya de Guadix has been challenging due to the scarcity of settlement data (Leisner and Leisner 1943).

Despite consistent visibility results, these studies had limitations due to partial data regarding variables like grave goods, shape, and size, and methodological issues, as they used simple binary visibility analyses without considering distance gradation. This is particularly relevant for intervisibility studies where megaliths are far apart, potentially yielding different results with added distance variables. Previous analyses were limited to a 3 km radius, excluding distant geographical elements (e.g., mountain peaks) despite their visibility above the horizon line due to size, as it has been already pointed out by other studies (Wheatley 1996; Parcero et al. 1998; Van Leusen 1999).

This paper aims to improve upon previous research through a refined visibility analysis using fuzzy viewsheds from each megalith, considering a larger scale and expanded visibility radius to study the relationship between megaliths and the entire landscape. This will allow to nuance and to refine the results of the cited previous works, as long as to contrast them.

3. Materials and methods

Probability in viewshed analysis was introduced to address issues in simple viewshed analysis, that considered only if a given point is completely visible or completely invisible, which can hardly be adjusted to the reality of human experience. P.F. Fisher added the statistical probability range of visibility between two points, taking into account that vision decays exponentially and not constantly as a function of distance (Fisher 1992). D. Ogburn (2006) later refined this by adding the size component, acknowledging that larger objects remain visible over greater distances before becoming blurry. Although more realistic for visibility and human perception, this complex analysis is rarely used in archaeology (Cerrillo Cuenca and Liceras 2016), contrasting with the success of simplified analyses (see Criado 1988; Criado and Fábregas 1989; Wheatley 1995, 1996; Villoch 2000; Ericson 2002; López-Romero 2007; Scarre 2010; Nash 2013; Llobera 2016; Carrero-Pazos 2018, 2022), which is mostly explained due to the technical complexity or the frequent difficulty in clearly defining the boundaries of archaeological sites and structures (Davis et al., 2019). In other words, in this case, the combination of fuzzy logic and viewsheds allows for the representation of degrees of visibility, instead of the usual viewsheds that present information in a dichotomous "all or nothing" manner. This procedure more adequately captures the continuous and ambiguous nature of human perception.

The data for these analyses were obtained during the last survey campaign in the Gor River area in summer 2019 (available at https://zenodo.org/doi/https://doi.org/10.5281/zenodo.8351123). We primarily used the geographical location of the tumuli in UTM ETRS89 coordinates. The base cartography is provided by the National Aerial Orthophotography Plan by the National Geographic Institute of Spain, mainly DTMs based on LiDAR data, publicly available at https://pnoa.ign.es/web/portal/pnoa-lidar/presentacion. These DTM's were created during the second coverage of the national territory (between 2015 and 2021), and provide a minimum point density between 0.2 and 2/m^2, an altimetric accuracy of $\leq$ 30 and a RMSE Z $\leq$ 20.[1]

As noted in section 2, isolating a specific moment in the landscape is difficult due to continuous changes and the changing perception and significance by past communities (Tuan 2001, 2004). This challenge is compounded by the scarcity of radiocarbon dates, with only 11 dates available between the Early Copper Age and Final Bronze Age (4300–2700 BP) (Cabrero et al. 2023a). Thus, following previous research, we consider all megaliths as contemporary at a certain moment, assuming all were built by the end of the 3rd millennium and served as visible territorial markers, although their use for new burials at concrete periods and building date could be uncertain.

The specific methodology used is as follows:

3.1. Vectorization of burial mounds

Firstly, the burial mounds were digitized using the data from the second LiDAR coverage of the National Aerial Orthophotography Plan by the National Geographic Institute of Spain as a reference. For processing, all non-ground classified points were filtered out. The remaining terrain points were interpolated with a mesh step of 0.5 m using the Inverse Distance Weighting (IDW) algorithm, implemented in the WhiteboxTools toolkit for Python. The digitization was performed considering the visible footprint of the construction on the ground, which may introduce some inaccuracies due to the preservation state of the mounds.

[1] All technical specifications are available at https://pnoa.ign.es/web/portal/pnoa-lidar/especificaciones-tecnicas.

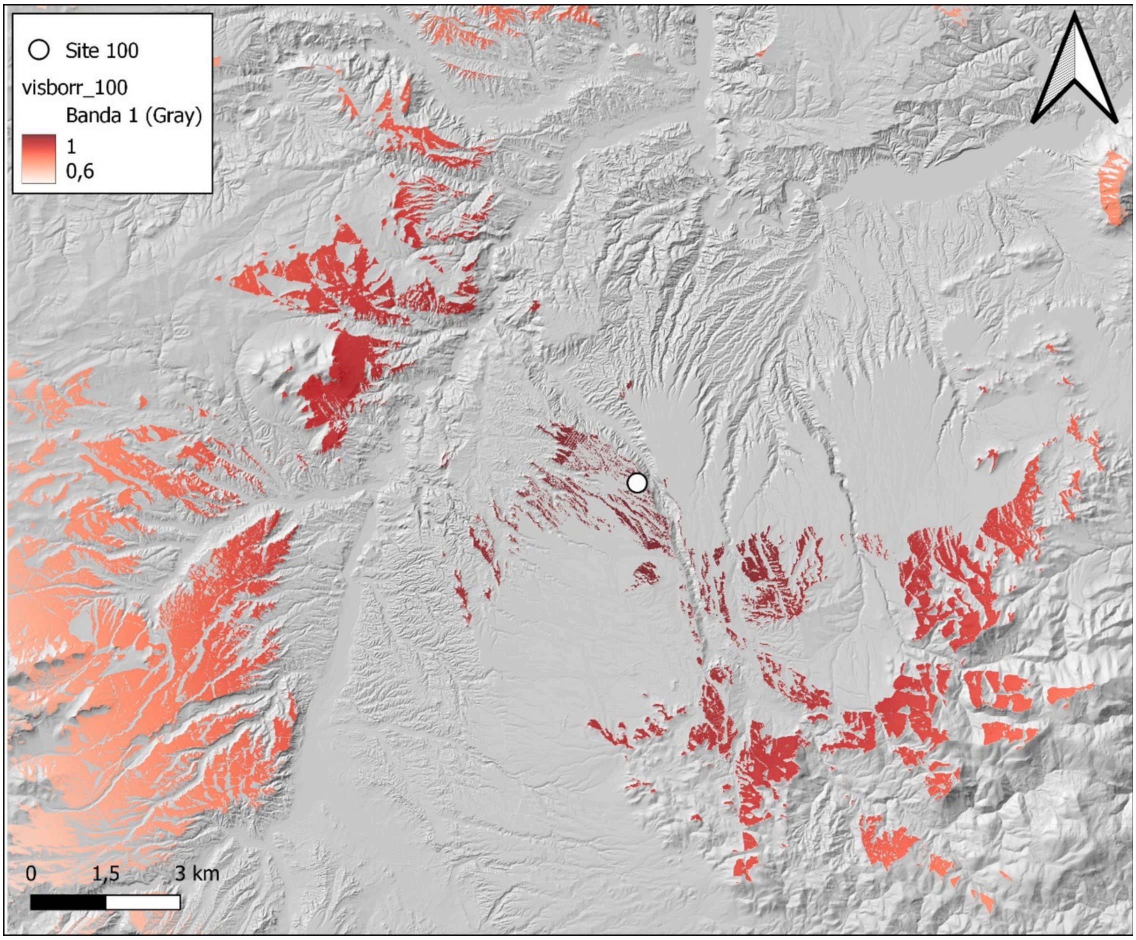

Fig. 2. Fuzzy viewshed of site number 100. The colour scale represents the visibility value attributed to the pixel in the range [0,1].

3.2. Clustering of burial mounds using DBSCAN

For a better statistical analysis, the sites were grouped into natural clusters to evaluate trends. The archaeological data does not allow distinguishing specific groups of tombs within the necropolis; thus, the purpose of this analysis is merely to make comparisons within the extensive group of mounds we have. These clusters were created using the DBSCAN algorithm from Scipy, configured to ensure clusters contained at least three elements with a maximum dispersion of 200 m between them. DBSCAN has been used, for example, by Carrero-Pazos (2019) in the study of Galician megaliths. These distances can be challenging to establish, especially to objectify in cultural terms, but they help to characterize the spatial properties of the necropolises and should be understood only from this perspective. Of all the metrics available in the DBSCAN implementation in Scipy, we have chosen the Euclidean distance, as it is closest to the intuitive distance of human space, which ultimately could have determined the grouping of the tombs. However, it should be noted that this metric does not consider topographic features such as terrain slope or accessibility to certain topographic positions. It is important to note that the sample is initially biased as not all the mounds catalogued by G. and V. Leisner (1943) could be recognized by recent surveys (Cabrero et al. 2021) and as many mounds are not visible in surface and partially destroyed (Cabrero et al. 2023b). The groupings, therefore, may be coherent, but it is necessary to keep in mind that these combined factors can influence the clustering of the monuments.

3.3. Implementation of fuzzy visibility

To analyse the fuzzy visibility of the ensemble, the distance decay function implemented by Ogburn (2006) was applied. The function was programmed in Python using various scientific libraries such as Scipy, Geopandas, Rasterio, and WhiteboxTools, among others. The code is available at https://github.com/ecerrillo/fuzzyviewshed. All calculations were performed on the 5-meter resolution Digital Terrain Model provided openly by the National Geographic Institute of Spain (publicly available at https://pnoa.ign.es/web/portal/pnoa-lidar/modelo-digital-del-terreno). The process considered a surface of 45 by 39 km, covering the entire study area and its surroundings.

The process started by considering the morphology of the digitized mounds. The centroids of all mounds were automatically found, and the maximum distance between nodes was calculated, allowing estimation of the maximum preserved mound size. The Euclidean distance from each centroid to the rest of the raster cells was calculated. Visibility was calculated using the "viewshed" command of WhiteboxTools, using the centroid of each mound as the observation point with an observer height of 1.65 m, which is the medium high identified by the most complete anthropological study upon the buried individuals found in past archaeological campaign in the Gor River valley (García Sánchez, 1961). Using the visible area returned by this algorithm as a mask, the fuzzy visibility map was calculated using the formulae established by Ogburn (2016, 410):

$$\mu\left(x_{ij}\right) = 1 for d_{vp\rightarrow ij} \leq b1$$

where $\mu\left(x_{ij}\right)$ represents the fuzzy membership value for a cell at position

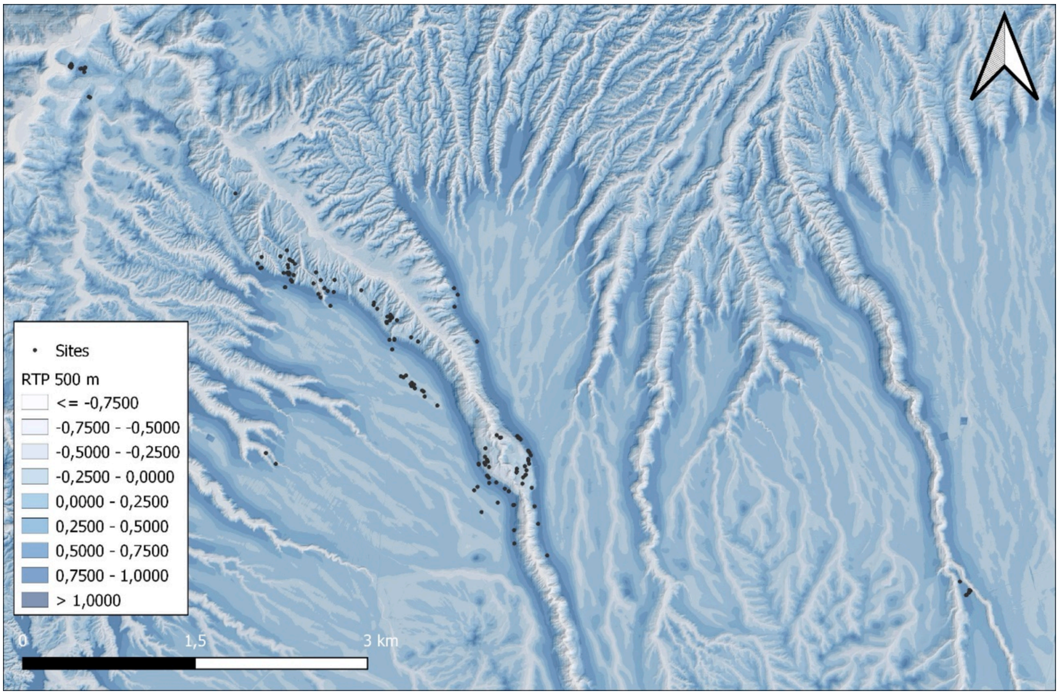

Fig. 3. Map representing the RTP values in the study area for a calculation radius of 500 m.

x_{ij}. $d_{vp\rightarrow ij}$ is the distance in meters from the viewpoint to a given cell. $b1$ represents the limit of the foreground zone where visibility is considered perfect, meaning that any object within this distance is assumed to be fully visible. $b1$ was set to 1 km, as suggested by Ogburn (2006). This distance is chosen because it represents a foreground zone of high visual clarity, where object details are still sharp to the human eye, in addition to being consistent with previous research on visual ranges.

For pixels beyond the foreground limit the modified formula proposed by Ogburn (2006) was used.

$$\mu(x_{ij}) = \frac{1}{1+2\left(\frac{d-b1}{b2}\right)^2} for d_{vp\rightarrow ij} > b1$$

This formula adjusts the decay function to account for the size of the target object, using a visual arc of 1′. Thus, $b2$ is the distance from $b1$ to the point where an object subtends a visual arc of 1′. The factor of 2 in the denominator ensures that the drop-off in visibility is appropriately gradual.

For each of the studied sites, the resulting (x_{ij}) values from both

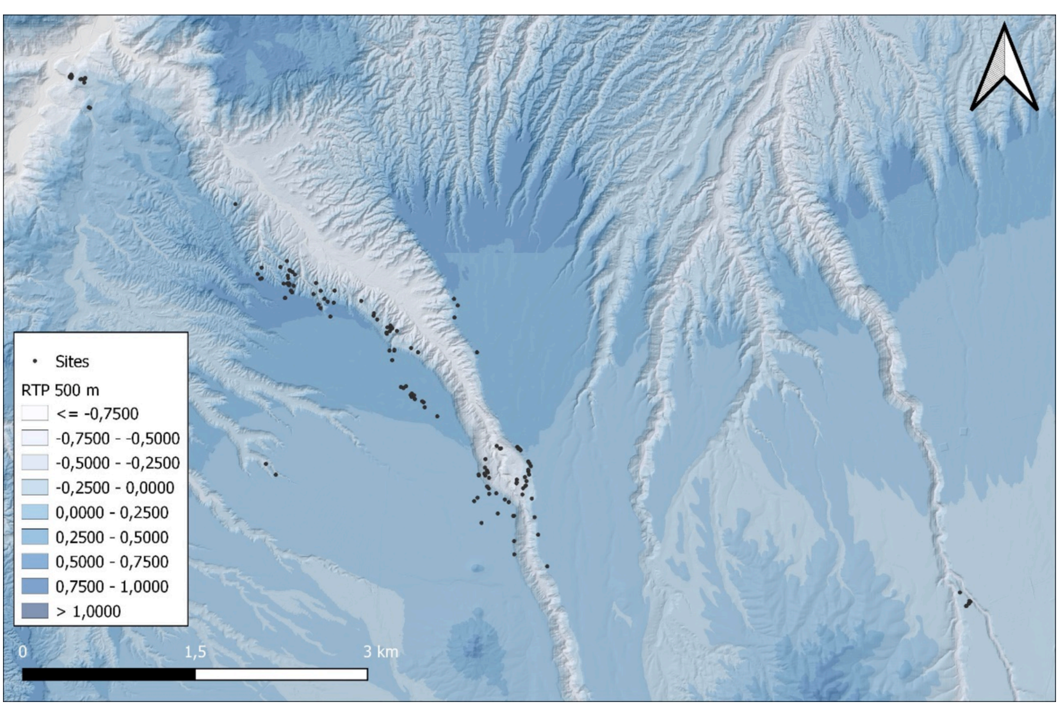

Fig. 4. Map representing the RTP values in the study area for a calculation radius of 5000 m.

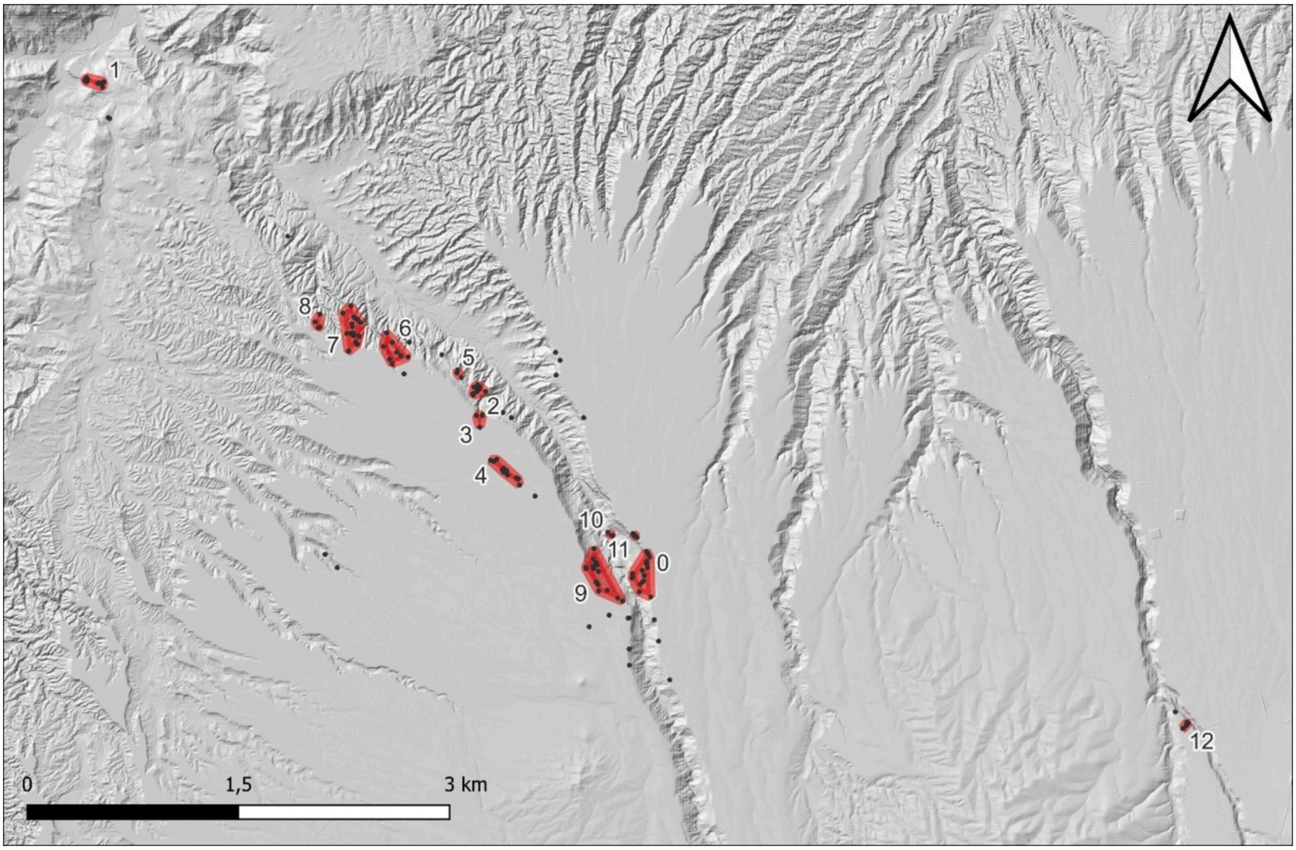

Fig. 5. Distribution of clusters generated by DBSCAN in the study area.

formulas were combined into a single raster, which was then reclassified using the conventional binary visibility raster as a mask, forming the fuzzy visibility map. Each of these rasters presents probability μ values in the range 0–1, where 0 generally corresponds to non-visible areas —those excluded from conventional viewshed analysis— and 1 to the highest fuzzy membership value. It is essential to remember that each pixel in this raster should be understood as expressing the likelihood of belonging to the "visible" category. An example of a fuzzy viewshed is represented at Fig. 2.

3.4. Calculation of relative topographic position

Topography plays a fundamental role in relation to the visibility of cultural elements in the landscape, which is why it is advisable to analyse prominence. The use of this variable is already described in Llobera (2001). To put in a wider perspective the results, an analysis of relative topographic prominence (RTP) was performed using the RelativeTopographicPosition command from WhiteboxTools. This function (Newman et al. 2018) considers a neighbourhood with a given buffer size and establishes the relative position of cells based on the maximum and minimum values in the vicinity. If a given pixel is lower than the neighbourhood mean, the prominence value is calculated by subtracting the pixel value from the mean, divided by the mean minus the minimum value of the vicinity. If the value is equal to or greater than the mean, the last term in the division is replaced by the maximum value of the vicinity minus the mean. The resulting value ranges from [-1,1], where −1 indicates a depressed value in the surrounding topography and 1 indicates a high prominence. For this calculation, the 5-meter resolution DEM was used, and values were obtained with the centroids of the mounds. Although in previous papers we have used the calculation of topographic prominence in comparison with fuzzy visibility (Cerrillo Cuenca and Liceras 2016), in this work we opt for a function already implemented in a Python library due mainly to its higher degree of optimization in the calculation of the variable. The differences between the topographic prominence (Llobera 2001) and the formula used in this article essentially lie in the fact that the prominence proposed by Llobera calculates the percentage of points that, within a given radius, are located lower than the observed position, while the described approach compares the elevation of a point with the mean and its extreme values. In itself, the prominence calculation has the advantage of being intuitively interpretable, while the RTP, as presented in this article, is more sensible to extreme values and can provide positive or negative values, potentially offering more nuanced information about a location in the landscape.

The neighbourhood was set with radii of 100, 500, 1000, 2000, 4000, and 5000 m, as recommended by other authors (Llobera 2001). This allows for understanding different behaviors of topographic prominence at various radii, enabling a more detailed exploration of the relationship between monuments and topography. An example of an RTP raster is shown in Figs. 3 and 4.

The analysis of "visualscapes" certainly encompasses other possibilities. The ability to explore the relationship between the most prominent positions and those most visually exposed is something that has been previously tested, for example through the analysis of total and cumulative visibilities (Llobera 2006b, 2007). These approaches are certainly an appropriate way to contrast the impact of cultural sites on the landscape, combined with the analysis of topographic features. In this work, we have chosen to make the contrast with fuzzy visibility, as it contemplates certain granularity in the analysis of individual tombs and groups, allowing the introduction of gradual nuances of clarity in observation. By integrating RTP with fuzzy viewsheds, we can explore the visual and topographic landscape of the monuments based on their positions (Cerrillo Cuenca and Liceras 2016), allowing an approach to hypothetical symbolic logics of megalith location.

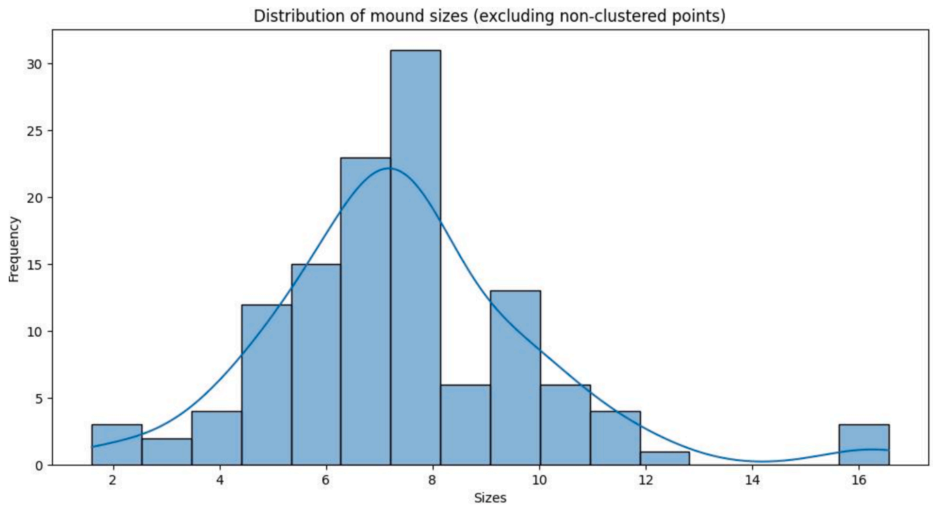

Fig. 6. Histogram representing the mound sizes in the study area.

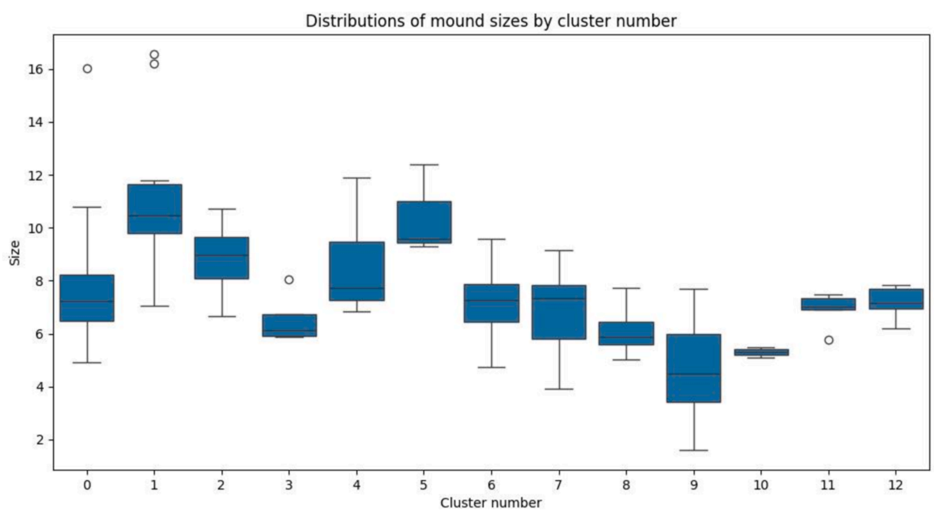

Fig. 7. Boxplot of the distribution of mound sizes by cluster number.

4. Results

4.1. Clustering of burial mounds using DBSCAN

The DBSCAN analysis identified 13 spatially significant mound clusters, ranging from 21 monuments to 3. This information is summarized in Fig. 5 and Tab. 1. Of a total of 151 recognized mounds, 28 remained isolated from the clusters proposed by DBSCAN. This means they correspond to groups of at most two tombs are far from the main distributions and not integrated into these. This lack of integration may also be due to preservation issues because many tombs, especially at the plateau area, have disappeared or cannot be identified (Spanedda

Table 1
Results of the DBSCAN analyses clustering in relationship to the size of the mounds.

Cluster	Number of mounds	Mean size (m)	Standard Deviation	Mound Minimum Size (m)	Mound maximum size (m)	Significant mean differences regarding other clusters (Turkey HSD)
0	17	7.9	2,61	4,9	16	1, 9
1	11	11	3,05	7,1	16,6	0, 3, 4, 6, 7, 8, 9, 10, 11,12
2	11	8.9	1,31	6,8	10,8	9
3	4	6,5	1,02	5,9	8	1
4	12	8,4	1,57	6,8	11,9	1, 9
5	3	10,4	1,58	9,3	12,4	9, 10
6	8	7,2	1,71	4,7	9,6	1
7	21	6,9	1,43	3,9	9,2	1, 9
8	4	6,1	1,47	5	7,7	1
9	17	4,6	1,46	1,6	7,7	0, 1, 2, 4, 5, 7
10	3	5,3	1,81	5,1	5,5	1
11	6	6,9	0,62	5,8	7,5	1
12	6	7,2	0,62	6,2	7,8	1

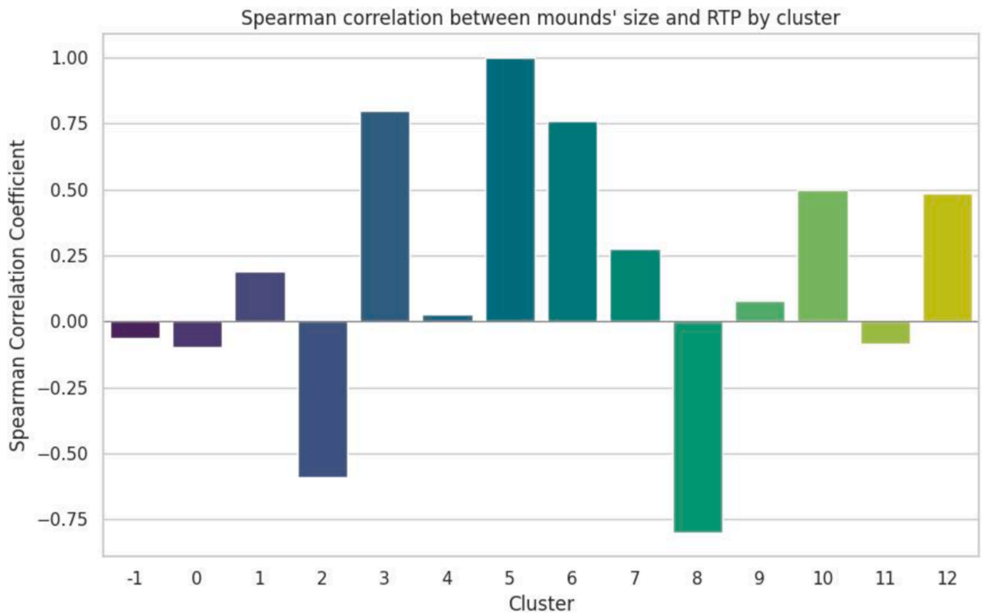

Fig. 8. Barplot representing Spearman's r values for the intra-group relationship between RTP and mounds' size in clusters.

et al., 2014; Cabrero et al., 2023b), because of recent alterations, mainly by farming activities. The resulting separation of some little clusters in peripheral areas might have influenced the spatial analysis.

4.2. Characterization of mound size and its Relevance to visibility

The documented mound widths range from 1.6 to 16.6 m (Figs. 6 and 7), with an average maximum width of 7 m (standard deviation of 2.5). An ANOVA test was performed to evaluate if there were significant differences in the size of the mounds between the clusters determined by DBSCAN, resulting in $F(12, N-13) = 9.447$, $p < 0.001$. This rejects the null hypothesis, which states that the mean mound sizes are equal for the different clusters. Given the significant differences, a post-hoc Turkey HSD (Honest Significant Difference) test was conducted to identify clusters with significant differences in their mean sizes. Significant differences between clusters can be found in Table 1. The mounds in cluster 1 stand out for their larger sizes, while clusters 9 and 10 have smaller mean sizes. Clusters 0 and 1 returned higher standard deviation values, indicating greater variability in mound sizes compared to other clusters. Conversely, clusters 11 and 12 appear more regular, with sizes ranging from 5.8 to 7.8 m.

Although recorded mound sizes are influenced by alteration processes, it can be thought that the majority of graves could experience in a similar way these reductions by erosion and farming activities. Consequently, results can be thought as significant and can be explained by social factors (differences between areas and/or social differences inside every necropolis). In fact, mound sizes also vary in clusters located in relatively plain areas as shown by cluster one standard deviations and a social explanation can be searched for these differences.

In addition, mounds are greater in this northern necropolis (cluster 1), whose distance to the central clusters and typological differences had already been used to referred possible boundaries reflected on those architectural differences (Esquivel et al., 2022).

4.3. Characterization of relative topographic position (RTP)

In absolute terms, the RTP behavior does not show expressive results. In smaller buffers of 100 m, the value is 0.51, with a standard deviation of 0.32, indicating a tendency to locate mounds in moderately elevated positions, though with some variability. In larger RTP calculation scales, the mean significantly decreases (1000 m: 0.37, 2000 m: 0.31, 5000 m: 0.12), with more or less homogeneous standard deviations.

The relationship between mound size and relative topographic position (RTP) was analysed, as these are the two most direct resources that can increase tomb visibility in the landscape. A Spearman correlation analysis (Fig. 8) for all megaliths ($n = 123$) indicates no relationship between mound size and their topographic prominence within a 1000-meter radius of the analysed area ($rs(98) = -0.037$, $p = 0.651$). Among the clusters, only cluster 8 shows a perfect negative relationship between tomb size and topographic prominence ($rs(2) = -1$, $p = 0$), but due to the limited sample size ($n = 4$), this result should not be considered significant. Significant results were obtained only for cluster 2 ($n = 11$), showing a moderately strong positive relationship between size and RTP in 2000-meter ($rs(9) = 0.7$, $p = 0.01$) and 4000-meter buffers ($rs(9) = 0.75$, $p = 0.008$). This relationship suggests an increase in mound size as they occupy more prominent positions in the environment. Among the 13 clusters analysed, this is the only significant association, based on a slightly larger number of monuments, making it a noteworthy correlation.

4.4. Evaluation of fuzzy visibility

Considering the total values of fuzzy viewsheds, the average probability of visibility for all analysed locations is 0.53 (standard deviation 0.27). Excluding the b2 areas, the majority of probabilities are around 0.3. This suggests that neither the site choice nor the mound size aimed to enhance the visibility of tombs in the distant landscape. Within clusters, the common trend is consistent: the probability rapidly declines inside the b2 areas, especially evident in cluster 1 ($n = 11$), which has the largest mounds. This indicates no clear relationship between mound size and their perceptibility in the landscape.

As suggested above, differences in mound size exist, but if graves were not necessarily designed to be seen from long distances, other social factors should be taken into account to explain their differences in size, probably related to increasing hierarchy.

Fuzzy visibility was evaluated considering two levels: intra-group analysis, visibility among tombs within each cluster, and inter-group analysis, evaluates the quality of intervisibility among the megaliths within and between clusters.

For inter-group fuzzy visibility, partial dissimilarity matrices were obtained, and averages below the diagonal were calculated. Clusters 3 ($n = 4$), 4 ($n = 12$), and 11 ($n = 6$) have a mean value of 1, indicating full

Table 2
Dissimilarity matrix representing the means of fuzzy viewshed values between clusters (inter-group).

	c0	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12
c0		0	0	0	0	0	0	0,07	0,01	0,73	0,02	0,19	0
c1	0		0	0	0	0	0	0	0	0	0	0	0
c2	0	0		0,18	0	0,73	0	0	0	0	0	0	0
c3	0	0	0,18		0,96	0,33	0,37	0,38	0,25	0,32	0	0	0
c4	0	0	0	0,96		0	0,37	0,42	0,16	0,23	0	0,01	0
c5	0	0	0,73	0,33	0		0	0	0	0	0	0	0
c6	0	0	0	0,37	0,37	0		0,41	0,09	0,09	0	0	0
c7	0,07	0	0	0,38	0,42	0	0,41		0,2	0,1	0	0	0
c8	0,01	0	0	0,25	0,16	0	0,09	0,2		0,1	0	0	0
c9	0,73	0	0	0,32	0,23	0	0,09	0,1	0,1		0,57	0,59	0
c10	0,02	0	0	0	0	0	0	0	0	0,57		0	0
c11	0,19	0	0	0	0,01	0	0	0	0	0,59	0		0
c12	0	0	0	0	0	0	0	0	0	0	0	0	

visibility among tombs within these clusters. Cluster 5 (n = 3) showed no visibility among its tombs (μ = 0). The general trend shows an average between 0.7 and 0.3, indicating potential visibility loss among the necropolis tombs.

To analyze inter-group relationships, we extracted submatrices from the general dissimilarity matrix comparing each pair of clusters and excluding intra-group comparisons. The mean value was calculated for each submatrix, resulting in the average probabilities of inter-group visibility presented in Table 2. Generally, inter-group studies show low visibility probability among groups. Clusters 3 (n = 4) and 4 (n = 12) have the highest visibility probability (0.96), possibly due to their proximity. Clusters 2 (n = 11) and 5 (n = 3) show a medium–high visibility probability (0.73), also likely due to proximity. These data should be interpreted cautiously, considering the potential artificial division by DBSCAN, which might have split originally coherent groups.

In fact, as previously referred according to intervisibility analysis, cumulative and total viewshed (Cabrero et al., 2024), the design of a dense network of connected graves could play an important role in territorial control, but the results of this analysis suggest that system was thought for short distances and not for long ones. It can be asserted that graves lines served more as inner markers, maybe related to different groups that boundary ones.

Medium-high visibility probability (0.73) between clusters 0 (n = 17) and 9 (n = 17) can be explained by their location at the valley's edge, highlighting them in the landscape. Other clusters show probabilities close to 0.5 or very low, suggesting that tomb intervisibility was not a sought-after visual pattern.

5. Conclusions

The results of the cluster analysis using DBSCAN show considerable heterogeneity, which corresponds to the diversity in the size of the burial mounds, ranging from 1.6 m to 16.6 m. This reality is undoubtedly the result of a constructive evolution linked to the wide temporal frame during which the tombs were constructed (and, of course, used and remodelled). This architectural variability was alsoanalysed in a previous work by taking into account the measurements of the orthostats, rather than the mound size (Esquivel et al. 2022). This study show also a great variability and size dispersion. In this case, apart from the grouping based on architectonic features, another one based on locational factors such as distance to the Gor River, altitude, and UTM X and Y coordinates was carried out, revealing 13 groups. In this way, it is

Fig. 9. Several burial mounds in the Llano de Olivares necropolis. All of them are very small in size and have a wide visibility index due to their position at the edge of the high plateau.

Fig. 10. On the top, Llano de la Ermita 5 (left) and 9 (right), in Baños de Alicún, hypogeic and presenting a large size. At the bottom, El Baúl 193 and 194, with small dimensions and presenting a square typology without a corridor.

important to note that the DBSCAN cluster serves as a basis for the analyses presented here, and are not aimed to present a new internal division of the complex (Cabrero et al. 2023).

The lack of a relationship between tomb size and topographic location had also been suggested in larger studies aiming to find possible correlations explaining visibility, specifically considering tomb size and their position in prominent areas as key factors (Cabrero 2023). The absence of a positive relationship between these variables suggests that there was no intent to achieve broad visibility for individual megaliths. This idea had already been proposed, emphasizing the concept of the complex as a network of intervisibility over the terrain, creating a sort of landscape scenography or monumentality through the appropriation of the territory with an extensive and dense network of monuments throughout the area (Cabrero, 2023). In this regard, we cannot overlook the positive statistical relationship between large size and elevated positions in cluster 2 (corresponding to the Majadillas necropolis). However, it should be noted that this cannot be generalized, as other necropolises in high plateau areas have particularly small sizes, such as the Llano de Olivares necropolis (Fig. 9), making this an isolated result, not extensible to the entire complex. In any case, it must be highlighted that Majadillas is also the only necropolis where a certain relationship between situation, size and abundant grave goods can be found (Spanedda et al. 2014). For this reason, as referred above regarding mound sizes at cluster 1 – Baños de Alicún, we can suggest that social differences were also marked at Las Majadillas necropolis through graves situation.

An exception that seems particularly interesting appears in the relationship between tomb size and geography for clusters 1, 11, and 12. Cluster 1 refers to the Baños de Alicún necropolis, the northernmost in the complex, cluster 11 to three closely located tombs in Hoyas del Conquín, in the Umbría del Conquín subgroup, and cluster 12 to the easternmost necropolis, El Baúl. The particularity lies in the fact that the Baños de Alicún and El Baúl necropolises have been identified in other studies as groups with evident anomalies in their geographical position and constructive characteristics (dimensions and typology, hypogeic nature in the case of Baños de Alicún) (Fig. 10). Considering the analysis that regrouped the megaliths into necropolises based on topographic variables such as distance to the Gor River, altitude, and UTM X and Y coordinates, these groups appear as distinct zones not belonging to the megalithic complex of the Gor River area (Esquivel et al. 2022). An interesting hypothesis was developed, suggesting that these groups are slightly closer to other watercourses, the Fardes and Baúl rivers, respectively. Thus, the differences in location and architecture might reflect neighbour communities with some cultural differences, probably exploiting different ecological niches. These differences or particularities might be subtle, explaining the difficulty in tracing them in other aspects of the archaeological record (generally summarized in the scarce grave goods found) (Cabrero, 2023).

Finally, regarding the results of the fuzzy viewshed analysis, although it had previously been noted that there was significant visibility among the tombs of each group and in relation to neighbour groups with few differences between the tombs regarding the area visually controlled from them (Cabrero et al., 2023a, 2024), the results of the analysis conducted here show that, largely, this pattern derives from the proximity of the tombs and their multiplication, given that the perceptibility of the mounds decreases considerably with distance. This aspect largely depends on the fact that neither size nor prominence was emphasized when the tombs were erected. The difficulty in perceiving monuments from certain distances has already been identified in other cases (Rodríguez-Rellán and Fábregas 2022). This can be interpreted in cultural terms, since megaliths are only recognizable if the observer is placed at a short distance and, above all, if they already know their position or appearance. In this way, megaliths would be an identifying element of the same community, not identifiable by outside and unaware groups. This hypothesis goes along the lines already mentioned of the existence of different groups, probably linked to different ecological niches or riverbeds. Anyway, this is more related to the perceptibility (the visibility to the megaliths) than to the visibility from the megaliths, so specific researches would be needed to explore this line.

It is evident that some of these aspects depend on the preservation state of the mounds, which in many cases, due to erosive or anthropic processes, have lost part of their original perimeter or even the tombs themselves were almost levelled, leading to clear problems of identification and interpretation (Cabrero et al., 2023b). However, the multiplication of tombs that must have existed in the Gor River area during the Late Prehistoric period, from the 151 now clearly defined (Cabrero et al. 2021) to the approximately 240 estimated as the minimum number actually constructed in the area (Spanedda et al., 2014; Cabrero et al., 2023b), would only facilitate visibility among the closest mounds without modifying long-distance visibility, visually controlling specific areas of their immediate surroundings, especially those not favoured by the inherent visibility of the area, as a way to ensure the "sacralized" domination of the entire exploitation/circulation territory (Cabrero et al. 2024).

The results presented here suggest that the Gor River megalithic group was designed in order to mark the territory owned by one (or several communities). In any case, it would be interesting to extend surveys and studies to other areas also identified within the Megalithic Phenomenon of the Southeast of the Iberian Peninsula, such as the nearby Fardes River area, so that cultural and constructive differences, as well as placement or visibility patterns, could be contrasted on a larger scale.

CRediT authorship contribution statement

Carolina Cabrero González: Writing – original draft, Investigation, Data curation. **Juan Antonio Cámara Serrano:** Writing – review & editing, Supervision. **Enrique Cerrillo Cuenca:** Validation, Methodology, Formal analysis.

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.

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Data availability

The link to the repository of the data used is in the manuscript.

References

Afonso, J.A., Cámara, J.A., Molina, F., 2010. La organización interna de las necrópolis del Río Gor (Granada) a partir de la ubicación de sus tumbas. MUNIBE Extra 32, 270–284.
Afonso, J.A., Cámara, J.A., Haro, M., Molina, F., Montufo, A.M., Sánchez Jiménez, I. and Spanedda, L. (2006). Organización territorial en el valle del Río Gor en la Prehistoria Reciente. In N. Bicho and M.S. Corchón (Coords.), Simbolismo, arte e espaços sagrados na Pré-historia da península ibérica: Actas do IV Congresso de Arqueología Peninsular (pp. 39-53). Faro: Centro de Estudos em Arqueologia, Artes e Ciências do Patrimonio.
Afonso, J.A., Cámara, J.A., Haro, M., Molina, F., Montufo, A.M., Salas, F.E., Sánchez Jiménez, I. and Spanedda, L. (2008). Tipología y seriación en el megalitismo granadino. El caso de Gorafe. In M. Hernández, J. Soler and J.A. López (Coords.), IV Congreso del Neolítico peninsular (pp. 64-76). Alicante: Museo Arqueológico de Alicante.
Aranda, G., Milesi, L., Hamilton, D., Díaz-Zorita, M., Vílchez, M., Robles, S., Sánchez, M., Benavides, J.A., 2022. The tempo of the Iberian megalithic rituals in the European context: The cemetery of Panoría. J. Archaeol. Sci. 140, 105579. https://doi.org/10.1016/j.jas.2022.105579.
Ashmore, W., Knapp, B. (Eds.), 1999. Archaeologies of Landscapes: Contemporary Perspectives. Blackwell Publishers, Oxford.
Augé, M., 1992. Non-Lieux. Introduction á une anthropologie de la surmodernité. Le Seuil, París.
Binford, L., 1999. Forces that shaped the past origins of the new archaeology. Archaeology 52 (1), 54.
Bongers, J., Arkush, E., Harrower, M., 2012. Landscapes of death: GIS-based analyses of chullpas in the western Lake Titicaca basin. J. Archaeol. Sci. 39 (6), 1687–1693. https://doi.org/10.1016/j.jas.2011.11.018.
Cabrero, C., Bueno, J.A., Esquivel, F.J., Garrido, A., 2021. Una revisión del megalitismo del valle del Río Gor desde los GIS y el análisis estadístico. Nuevos datos y nuevas preguntas. Cuadernos De Prehistoria y Arqueología De La Universidad De Granada 31, 75–94. https://doi.org/10.30827/CPAG.v31i0.17010.
Cabrero, C., Cámara, J.A., Esquivel, F.J., Spanedda, L., Garrido, A., 2023a. A geographical dataset describing the complexity of the Gor River megalithic landscape. J. Open Archaeol. Data. https://doi.org/10.5334/joad.117.
Cabrero, C., Garrrido, A., Esquivel, F.J., Cámara, J.A., 2023b. A model of spatial location. New data for the Gor River megalithic landscape (Spain) from LiDAR technology and field survey. Archaeol. Prospect. 30 (2), 89–103. https://doi.org/10.1002/arp.1879.
Cabrero, C., Cámara, J.A., Garrido, A., 2024. Approach to the visual landscape of the Gor River megalithic necropolises (Granada, Spain). Digital Appl. Archaeol. Cult. Heritage 33, e00335.
Cabrero, C. (2023). El fenómeno megalítico del Sudeste de la Península Ibérica a partir de su dimensión espacial. El caso del paisaje megalítico del valle del Río Gor. Doctoral Dissertation. Granada: University of Granada. https://hdl.handle.net/10481/84744.
Cámara, J.A., Dorado, A., Spanedda, L., Fernández, M., Martínez, J., Haro, M., Martínez, G., Carrión, F., Molina, F., 2021. La demarcación de los espacios de tránsito en Los Millares (Santa Fe de Mondujar, Almería) y su relación con el simbolismo megalítico. Zephyrus 88, 65–86. https://doi.org/10.14201/zephyrus2021886586.
Cámara, J.A. (2001). El ritual funerario en la Prehistoria Reciente en el sur de la península ibérica. British Archaeological Reports, International Series, 913. Oxford: Archaeopress. DOI: 10.30861/9781841711669.
Carlstein, T., 1983. Time Resources, Society and Ecology. Pre-Industrial Societies. Allen & Unwin, Londres.
Carrero-Pazos, M., 2018. Modelando dinámicas de movilidad y visibilidad en los paisajes megalíticos gallegos. El caso del Monte de Santa Mariña y su entorno (Comarca de Sarria, Lugo). Trab. Prehist. 75 (2), 287–306. https://doi.org/10.3989/tp.2018.12216.
Carrero-Pazos, M., 2019. Density, intensity and clustering patterns in the spatial distribution of Galician megaliths (NW Iberian Peninsula). Archaeol. Anthropol. Sci. 11 (5), 2097–2108. https://doi.org/10.1007/s12520-018-0662-2.
Chénier, A., 2009. Bones, people and communities: tensions between individual and corporate identities in secondary burial ritual. Nexus: the Canadian Student. J. Anthropol. 21, 27–40.
Criado, F., 1984. El tercer factor o la lógica oculta del emplazamiento de los túmulos megalíticos gallegos. Cuadernos De Estudios Gallegos 35, 7–18.
Criado, F., 1988. Arqueología del Paisaje y espacio megalítico en Galicia. Arqueología Espacial 12, 61–117.
Criado, F., 1997. Introduction: Combining the different dimensions of cultural landscape: is a total archaeology of landscape possible? Trabajos En Arqueología Del Paisaje 2, 5–9.
Criado, F., 1999. Del terreno al espacio: planteamientos y perspectivas para la Arqueología del Paisaje. University of Santiago de Compostela, Santiago de Compostela.
Criado, F., Fábregas, R., 1989. Aspectos generales del megalitismo galaico. Arqueología 19, 48–63.

Čučković, Z., 2016. Advanced viewshed analysis: a Quantum GIS plug-in for the analysis of visual landscapes. J. Open Source Softw. 1 (4), 32. https://doi.org/10.21105/joss.00032.

Davis, D.S., Lipo, C.P., Sanger, M.C., 2019. A comparison of automated object extraction methods for mound and Shell-ring identification in coastal South Carolina. J. Archaeol. Sci. Rep. 23, 166–177. https://doi.org/10.1016/j.jasrep.2018.10.035.

Dorado, A., Rodríguez, C., Spanedda, L., Cabrero, C., Molina, F., Cámara, J.A. (2023): La temporalità dei riusi dei megaliti nel Sud-Est della penisola iberica durante l'età del bronzo e le loro implicazioni sociali. In F. Mercadante (Ed.): Atti del Convegno Internazionale "Il Mediterraneo e il Megalitismo durante il III e II millennio A.C. Architetture megalitiche, strutture cultuali archeo-astronomiche, siti geoarcheologici, contatti, riadattamenti, morfo-facies della architettura megalitica nei territori, nelle Isole e nelle coste del Mediterraneo (27-28-29 settembre 2023. Villa Riso ai Colli, Palermo) Palermo: Edizioni del Mirto, 23-31. https://hdl.handle.net/10481/91455.

Ericson, K., 2002. Visible intentions? Viewshed analysis of Bronze Age burial mounds in Western Scania (Sweden). In: Scarre, C. (Ed.), Monuments and Landscape in Atlantic Europe. Perception and Society during the Neolithic and Early Bronze Age, pp. 179–191.

Esquivel, F.J., Cabrero, C., Cámara, J.A., Esquivel, J.A., 2022. Statistical analysis on metric and geometric features of dolmens in the Gor River megalithic landscape (Granada, Andalusia, Spain). Archaeometry 64 (4), 815–832. https://doi.org/10.1111/arcm.12750.

Fabietti, U., Matera, V., 2000. Memorie e identità. Simboli e strategie del ricordo. Maltemi Editore, Roma.

Fisher, P.F., 1992. First experiments in viewshed uncertainty: simulating fuzzy viewsheds. Photogramm. Eng. Remote Sens. 58, 345.

Furholt, M. and Müller, J. (2011). The earliest monuments in Europe: architecture and social structures (5000-3000 cal b. C.). En M. Furholt, F. Lüth and J. Muller (Eds.), Megaliths and identities (pp. 15-32). Bonn: Dr. Rudolf Habelt GmbH.

García Sánchez, M., 1961. Restos humanos eneolíticos procedentes de los dólmenes de Gorafe (Granada). Archivo De Prehistoria Levantina 9, 49–78.

García Sanjuán, L., 2009. Introducción a los sitios y paisajes megalíticos de Andalucía. In: García Sanjuán, L., Ruiz González, B. (Eds.), Las Grandes Piedras De La Prehistoria. Sitios y Paisajes Megalíticos De Andalucía. Junta de Andalucía, Sevilla, pp. 12–32.

Gillings, M. and Wheatly, D. (2001). Seeing is not Believing. In B. Slapszak (Ed.), On the Good use of gepgraphic Information Systems in Archaeological Landscape studies (pp. 25-36). Bruselas: Office for Official Publications of the European Communities.

Gillings, M., Pollard, J., 2016. Making megaliths: Shifting and unstable stones in the Neolithic of the Avebury landscape. Cambridge Archaeol. J. 26 (4), 537–559. https://doi.org/10.1017/S0959774316000330.

Godelier, M., 1989. Lo ideal y lo material. Pensamiento, economías, sociedades. Taurus, Barcelona.

Grier, C., Angelbeck, B., McLay, E., 2017. Terraforming and monumentality as long-term social practice in the Salish Sea region of the Northwest Coast of North America. Hunter Gatherer Research 3 (1), 107–132. https://doi.org/10.3828/hgr.2017.7.

Hägerstrand, T., 1973. The domain of human geography. In: Chorley, R.J. (Ed.), Directions in Geography. Methuen, Londres, pp. 67–87.

Hägerstrand, T., 1975. Space, Time and Human Conditions. In: Karlqvist, A., Lundquist, L., Snickars, F. (Eds.), Dynamic Allocation of Urban Space. Saxon House Lexington Books, Lexington, pp. 3–14.

Hodder, I., 1990. The domestication of Europe: structure and contingency in Neolithic Societies. Blackwell, Oxford.

Ingold, T., 1993. The temporality of the landscape. World Archaeol. 25, 152–174. https://doi.org/10.1080/00438243.1993.9980235.

Leisner, G. and Leisner, V. (1943). Die Megalithgraber¨der Iberischen Halbinsel. Der Süden Verlag von Walter de Gruyter & Co, Berlin.

Lèvi-Strauss, C., 2000. I churinga degli aborigini australiani. In: Fabietti, U., Matera, V. (Eds.), Memorie e Identità. Simboli e Strategie Del Ricordo. Maltemi Editore, Roma, pp. 70–73.

Littleton, J., 2002. Mortuary behaviour on the Hay Plain: do cemeteries exist? Archaeol. Ocean. 37, 105–122. https://doi.org/10.1002/j.1834-4453.2002.tb00513.x.

Littleton, J., 2007. From the perspective of time: hunter–gatherer burials in southeastern Australia. Antiquity 81, 1013–1028. https://doi.org/10.1017/S0003598X00096083.

Llobera, M., 2001. Building past landscape perception with GIS: Understanding topographic prominence. J. Archaeol. Sci. 28 (9), 1005–1014. https://doi.org/10.1006/jasc.2001.0720.

Llobera, M., 2003. Extending GIS based analysis: the concept of visualscape. Int. J. Geogr. Inf. Sci. 17 (1), 25–49.

Llobera, M., 2007. Reconstructing visual landscapes. World Archaeol. 39 (1), 51–69. https://doi.org/10.1080/00438240601136496.

Llobera, M., 2012. Life on a pixel: challenges in the development of digital methods within an "interpretive" landscape archaeology framework. J. Archaeol. Method Theory 19, 495–509. https://doi.org/10.1007/s10816-012-9139-2.

Lock, G. and Molyneaux, B. (2006). Confronting Scale in Archaeology: Issues of Theory and Practice. Nueva York: Springer.

Lock, G., Puncett, J., 2017. Spatial thinking in Archaeology: is GIS the answer? J. Archaeol. Sci. 84, 129–135. https://doi.org/10.1016/j.jas.2017.06.002.

López-Romero, E., 2007. Factores visuales de localización de los monumentos megalíticos de la Cuenca del Sever (Portugal-España). Trab. Prehist. 64 (2), 73–94.

Lorrio, A.J., 2008. Qurénima: el Bronce Final del sudeste de la Península Ibérica. Real Academia de la Historia, Madrid.

Nash, G., 2013. Megalithic art: A visual repertoire for the dead. In: Smith, C. (Ed.), Encyclopedia of Global Archaeology. Springer, Nueva York, pp. 4758–4769.

Newman, D.R., Lindsay, J.B., Cockburn, J.M.H., 2018. Evaluating metrics of local topographic position for multiscale geomorphometric analysis. Geomorphology 312, 40–50. https://doi.org/10.1016/j.geomorph.2018.04.003.

Ogburn, D.E., 2006. Assessing the level of visibility of cultural objects in past landscapes. J. Archaeol. Sci. 33 (3), 405–413. https://doi.org/10.1016/j.jas.2005.08.005.

Parcero, C., Criado, F., Santos, M., 1998. Rewriting landscape: incorporating sacred landscapes into cultural traditions. In: Bradley, R., Williams, H. (Eds.), The past in the past: the Reuse of Ancient Monuments. Routledge, London, pp. 159–176.

Renfrew, C., 1976. Megaliths, territories and populations. Dissertationes Archaeologicae Gandenses 15, 198–220.

Rodríguez-Rellán, C., Fábregas, R., 2023. Assesing the Perceptibility of Prehistoric Monuments on their Landscape. An Exploratory Approach Using Agent-Based Modelling. Vegueta 1 (23), 115–145. https://doi.org/10.51349/veg.2023.1.05.

Scarre, C., 2011. Stone people: monuments and identities in the Channel Islands. Megaliths and identities. Dr. Rudolf Habelt GmbH, Bonn, pp. 95–104.

Scarre, C. (2010). Megaliths, memory and the power of stones. In D. Brandherm and M. Trachsel (Eds.), Monumental questions: prehistoric megaliths, mounds, and enclosures (pp. 91-96). BAR International Series 2122. Oxford: Archaeopress.

Schiffer, M., 1987. Formation Processes of the Archaeological Record. University of New Mexico Press, Albuquerque.

Schmitt, F., Bueno Ramírez, P., Bartelheim, M., 2019. Just passing by? Investigating in the territory of the megalith builders of the southern european plains. The case of Azután, Toledo. In: Müller, J., Hinz, M., Wunderlich, M. (Eds.), Megaliths Societies Landscapes. Early Monumentality and Social Differentiation in Neolithic Europe. Verlag Dr. Rudolf Habelt, Bonn, pp. 601–619.

Shaffer, G.D., 2005. Nanticoke Indian burial practices: Challenges for archaeological interpretation. Archaeol. East. N. Am. 33, 141–162.

Sherratt, A., 1990. The genesis of megaliths: Monumentality, ethnicity and social complexity in Neolithic North-West Europe. World Archaeol. 2, 147–167. https://doi.org/10.1080/00438243.1990.9980137.

Siret, L., 2001. España prehistórica.1891-2001. Junta de Andalucía, Sevilla.

Spanedda, L., Afonso, J.A., Cámara, J.A., Molina, F., Montufo, A.M., Pau, C., Haro, M., 2014. Tomb location and grave goods: continuous use and destruction in the Río de Gor megalithic necropolis. In: Schulz Paulsson, B., Gaydarska, B. (Eds.), Neolithic and Copper Age Monuments. Emergence, Function and the Social Construction of the Landscape. British Archaeological Reports, International Series 2625, Oxford, pp. 107–124.

Šprajc, I., Marsetič, A., Štajdohar, J., Dzul Góngora, S., Ball, J.W., Esparza Olguín, O., Kokalj, Ž., 2022. Archaeological landscape, settlement dynamics, and sociopolitical organization in the Chactún area of the central Maya Lowlands. PLoS One 17 (1), e0262921.

Tilley, C. (1994). A Phenomenology of Landscape. Places, Paths and Monuments. Oxford: Beg.

Tuan, Y.-F., 2001. Space and place. The perspective of experience. University of Minnesota Press, Minnesota.

Tuan, Y.-F., 2004. Cultural geography: Glances backward and forward. Ann. Assoc. Am. Geogr. 94 (4), 729–733.

Van Leusen, P.M. (1999). Viewshed and cost surface analysis using GIS (cartographic modelling in a cell-based GIS). In J.A. Barcelo, I. Briz and A. Vila (Eds.), New techniques for old times: computer applications and quantitative methods in archaeology (pp. 215-223). Barcelona: Tempus Reparatum.

Villoch, V. (2000). La configuración social del espacio entre las sociedades constructoras de túmulos en Galicia: Estudios de emplazamiento tumular. Doctoral Dissertation. University of Santiago de Compostela: University of Santiago de Compostela.

Wheatley, D., Gillings, M., 2000. Vision, perception and GIS: developing enriched approaches to the study of archaeological visibility. Nato Asi Series a Life Sciences 321, 1–27.

Wheatley, D. (1995). Cumulative viewshed analysis: a GIS-based method for investigating intervisibility, and its archaeological application. In G. Lock, G. and Z. Stancic (Eds.), Archaeology and Geographic Information Systems: a European Perspective (pp. 171-185).

Wheatley, D. (1996) The use of GIS to understand regional variation in earlier Neolithic Wessex. In H.D. Maschner (Ed.), New methods, old problems. Geographic Information Systems in modern archaeological research (pp. 75-103).

Whittle, A., 2017. Places of special virtue: Megaliths in the Neolithic landscapes of Wales. Oxbow Books, Oxford. Recuperado de: http://digital.casalini.it/9781785705441.