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Locational Preferences and Spatial Arrangement in the Barrow Landscape of Serra de Barbanza (North-western Iberia)

Miguel Carrero-Pazos, corresponding author, miguel.carrero.pazos@gmail.com
University of Santiago de Compostela, Department of History, GEPN-AAT
Praza da Universidade 1, 15782 Santiago de Compostela, Spain
Julián Bustelo Abuín, julianbustelo17@gmail.com
University of Santiago de Compostela, Department of History, GEPN-AAT
Praza da Universidade 1, 15782 Santiago de Compostela, Spain
Víctor Barbeito Pose, victor@centroarqueoloxicodobarbanza.org
Centro Arqueolóxico do Barbanza
Neixón, Nine s/n.15991 Cespón, Boiro
Carlos Rodríguez-Rellán, carlos.rellan@fulbrightmail.org
University of Seville, Department of Prehistory and Archaeology, ATLAS
Doña María de Padilla, 41004 Seville, Spain

Abstract

As anywhere else, GIS is an essential tool in Galician archaeological research for examining and analysing spatial data. This is something quite clear in megalithic studies where in the last years these methods have been used for contrasting hypotheses regarding locational preferences drawn from fieldwork. As such, in this paper, a study of locational patterns of the megalithic sites located in the flattened top territories of A Serra do Barbanza (Galicia, NW Spain) is carried out. Using a site-predictive modelling approach, several environmental covariates were analysed to see their role in the distribution of mounds. Next, we study the clustering of megaliths via second-order modelling. The results obtained led us to conclude that the distribution of sites shows an aggregation at very local scales, a trend that can only be explained by intended site spacing dynamics that may have taken place over millennia. Using significance testing via Monte Carlo Simulation, the outcomes of this research allowed us to identify possible preferences regarding the selection of particular landscapes for the location of

Galician megaliths but also modelling the potential impact of tradition, a tendency by which mounds fostered the subsequent construction of megaliths in the nearby areas.

Keywords

Galicia, mound, site predictive modelling, Monte Carlo Simulation, point pattern analysis, GRASS GIS, R Statistics

1. Introduction

Galicia is one of the areas of the Atlantic façade of Western Europe with the highest density of megalithic constructions, their number surpassing the 3,000 mounds in a territory of 29 thousand km^2 (slightly larger than Wales). This number can be increased until more than 7,000 if we use the data from the Official Catalogue from Galician government, although this catalogue which departed from the 1980s has problems that were already pointed out elsewhere (Carrero-Pazos 2017). This intensity of occupation has been emphasized by researchers since the classic work of G. Leisner (1938), who presented one of the first distribution map of the Galician megaliths, although focusing on the coastal areas, or F. López Cuevillas (1973: 54), who pointed out how Galicia has a density of megalithic sites higher than other territories in Spain.

These pioneering approaches prompted an incipient interest on the spatial dimension of megaliths. Thus, A.A. Rodríguez Casal proposed new distribution maps in 1978 and 1990, paying special attention to inland Galicia, which remained virtually unexplored at that time. Proper locational studies started to appear then, leading to the development of an interpretative model of the Galician megalithic phenomenon (Bello Diéguez et al. 1982a, 1987; Criado Boado 1988a, 1988b). These works were based on prospection surveys carried out by F. Criado Boado in the Curtis-Sobrado area (eastern A Coruña) (Criado Boado et al. 1980, 1984a, 1984b) and in the Serra do Barbanza, in the western coast of Galicia (Criado Boado et al. 1986, 1988). The research will reach a full swing during 1990s and early 2000s, thanks to further surveys on the Barbanza Peninsula (Villoch 2000) and in many other areas of the Galician territory (Rodríguez Casal 1997; Rodríguez Casal et al. 1998; Eguileta Franco, 1999; Fábregas Valcarce & Vilaseco Vázquez 2002; Fábregas Valcarce et al. 2003, 2004) that helped to complete the distribution map of the Galician megaliths.

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These efforts, together with that of countless individual researchers, have led to a research inventory that –in 2017– comprised 3,305 megalithic sites,[1] a catalogue which is being improved with new findings (**Fig. 1**).

[Caption]. Figure 1. Current distribution of megalithic monuments in Galicia, NW Spain (University of Santiago de Compostela, GEPN-AAT).

Concerning GIS methods, their introduction in Galician archaeological research was mainly after the 2000s, and specifically in other historical periods, such as Iron Age (see e. g. Parcero-Oubiña 2000; Fábrega-Álvarez 2004; Parcero-Oubiña, Fábrega-Álvarez 2006; Fábrega-Álvarez & Parcero-Oubiña 2007) or Bronze Age rock art (e. g. Rodríguez Álvarez 2012; Rodríguez Rellán & Fábregas Valcarce 2015). Concerning the megalithic studies, we had to wait until recent times where new researches are appearing, specifically in locational patterns and quantitative modelling (e. g. Llobera 2015; Rodríguez Rellán & Fábregas Valcarce 2015, 2019; Carrero-Pazos 2018a,b; Fábregas Valcarce et al. 2018; Carrero-Pazos & Rodríguez Casal 2019;).

2. Serra do Barbanza, a core area of research in Galician megaliths

The Galician megalithic phenomenon, and especially the Barbanza peninsula, has been scientifically researched since late nineteenth century, although genuine spatial approaches came to light in late 1980s and mostly in 1990s. As stated by Fábregas-Valcarce et al. (2018), the most up-to-date inventory for the Peninsula comprises a total of 209 mounds. The upland valleys ("Chans do Barbanza"), a small 7 km^2 flattened top mountain range, concentrated a significant attention by research for long time, although it only holds 20% of the mounds in the region (Bustelo Abuín 2017). In this context, several works from Landscape Archaeology analysed the spatial arrangement of the megaliths linking them to the movement to/from/across the plateau (Criado Boado et al. 1994) and placing them within a network of natural transit which structured the movement across all the peninsula (Criado Boado & Villoch Vázquez 2000: 199-200).

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[1] Data gathered from our megalithic study group at the University of Santiago de Compostela, GEPN-AAT, based on the results of 3 projects directed by prof. Antón A. Rodríguez Casal and funded by Galician Government: "Megalitismo e xeoloxía. Arqueoloxía e ecoloxía da cultura dolménica na provincia de Lugo" (1994-1996)"; "Arqueoloxía e ecoloxía do fenómeno tumular e megalítico no Sur de Galicia (1998-2000)"; Arqueoloxía e ecoloxía do fenómeno tumular e megalítico na Galicia noroccidental (2004-2007)".

These former approaches were carried out in a pre GIS era, so were built from intensive field survey projects, proposing locational patterns out of common-sense interpretations (Lake, Woodman 2003: 690). A second group of studies concerning Serra do Barbanza are those that used GIS and spatial statistics for the analysis and quantification of these locational patterns, all of them in recent times. The proposal of M. Llobera (2015) concerning the mobility and visibility dynamics in the whole peninsula of Barbanza is the main starting basis. This was subsequently followed by works which examined the role of pathways and other variates in the location of megaliths and petroglyphs in this very same area (Rodríguez Rellán & Fábregas Valcarce 2015, 2019; Bustelo Abuín, et al. 2017; Fábregas Valcarce et al. 2018).

Despite all of the tradition of research, there were no dating programs in the area which allow us to reconstruct a timescale of the structures. Some proposals have recently pointed out the existence of two moments in the cluster of sites (early/recent), although based on theoretical assumptions rather than on contrasted archaeological research (see e.g. Criado-Boado, Senín-Vuelta 2017).

A representative dating program is truly a big challenge for the megalithic research in North-western Iberia. Future research in the Barbanza region has to face this problem to allow the reconstruction of the biography of the whole necropolis, to decide whether the barrows are contemporary or not, related, similar to each other, or even discard them if they are not prehistoric barrows, in the case of earthen barrows. This is a classic issue in mound research (see e.g. Hewitt et al. 2011), and there are very well known cases of "false positives" in Galicia already known, specially under rescue archaeology (see Carrero-Pazos 2017).

The lack of radiocarbon dates is, generally, a big question in the megalithic research of North-western Iberia, something common other Iberian and European areas (see e.g. Bourgeois 2013). In the case of Galicia, we currently have 56 radiocarbon dates for a database of more than 3,000 sites, a number which is being under improvement considering rescue excavations and ongoing university projects (Barbeito Pose et al. 2018). The lack of dating is enhanced by another problematic issue: the poor state of preservation of the archaeological structures, mainly affected by ancient destructions and violations. This further difficult the introduction of the time variable in our research, as currently the majority part of the sites are barrows with no rock structures. This way, we have to assume that our sites are contemporary, as it is traditionally done

(Villoch Vázquez, Criado Boado, 2000; Llobera 2015). Consequently, assuming stationarity in the group of sites is accepted when temporal uncertainty arises, at least until we have a very detailed dating scheme for the area (see e.g. Bevan et al. 2013; Bourgeois 2013 for similar cases).

3. Study area and archaeological dataset

The Barbanza Peninsula is the northernmost of the peninsulas located in the Western Coast of Galicia. Following a NE-SW orientation, its main geographical feature is the Serra do Barbanza, a horst structure conformed in the late Tertiary that splits the peninsula in half: the slopes and coastal platforms located to its North and South-East (Nonn 1966; Guitián Rivera 1978). The Serra do Barbanza has an average altitude of 500 m.a.s.l., its upper part being dominated by small plateaus (the aforementioned "Chans do Barbanza") separated by ridges and hills of gentle slopes and crossed by several river valleys that provide water and fresh grazing almost all year round. For this paper, however, we have defined a study area of 82.38 km^2, circumscribed to those upland sectors within the Sierra -above 200 meters high- (**Fig. 2**). Current research in this area is showing that if we take the whole peninsula there are more mounds (66% of the data) on the coastal platform (0-200 m.a.s.l.) than on uplands (Bustelo et al. 2017), although in this paper we wanted to keep our attention in the area that traditionally concentrated the focus of research, as we have seen before. These points out a revision of the traditional hypothesis which considers the megaliths being located eminently in upland landscapes (as stated by Fábregas et al. 2018). Also, it should be noted that there are other factors which certainly have influenced the current distribution of mounds, such as the intensity of lowland occupation, which has probably removed or flattened a high number of monuments (Taylor 1984). The analysis of the influence of historical human occupation, such as farming, is a pending study for the future.

[Caption]. Figure 2. Above: Selected study area, the highlands of Sierra de Barbanza (above 200 meters high). Below: the megalith of Arca da Barbanza, and a view from the Sierra towards the Ría de Muros-Noia (NW).

The archaeological data used in this research comprises a total of 62 megaliths (of the total 209 currently known in the whole peninsula). Such inventory is the result of decades of fieldwork carried out by different researchers and subsequently expanded and revised with further fieldwork and ground-truthing (LiDAR) by some of us (V. B. in the framework of the project OzoNO - HAR2015-67435-P). From the selected 62 megaliths, just a few preserve some kind of structure (not just earthen mounds), ranging from individual slabs, chambers with corridor or cists. Based on fieldwork and comparative analyses with dated monuments, the researchers have developed a typological classification of monuments which allow us to reconstruct a general chronological framework for Galician megalithism. An early phenomenon composed by single chambers (4500-3500 BC); a phase of explosion by 3500-2500 BC, characterised by corridor dolmens, and a late megalithism (2500-1800 BC) with small cists or burials without above-ground structures.

4. Locational model and definition of covariates

In this paper, site predictive modelling is the method used to analyse the role of several locational variables in the distribution of megaliths in Serra do Barbanza. Site predictive modelling is normally understood as the method which allows the prediction of a value of one dependent variable (probability of presence) in a non-sampled location, using one or more independent variables. In Archaeology, this method has been traditionally used to know new archaeological sites, based on a quantitative estimation of the locational preferences of the sites in a defined area (Kvamme 1983, 1990; Kohler, Parker, 1986; Jude, Sebastian 1988; Westcott, Brandon 2000; Conolly, Lake, 2006. See Fernández Cacho, Rodrigo Cámara 2003 for the Spanish pioneer project *MAPA*).

To that vein, ten covariates were selected from previous works and modelled thanks to GIS methods, as summarised in **Table 1.**[2]

[Caption]. Table 1. Variables of the locational model of the megalithic culture in Galicia managed by literature, and setup in a GIS environment.

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[2] Pedological characteristics were not considered in this paper as the analysis of this variable needs reliable data obtained through paleoenvironmental analyses conducted on a local scale, which we do not currently have. The relationship between mounds and other natural features –such as rock outcrops– and archaeological remains –petroglyphs– was not analysed in this work neither (For such an approach see Rodríguez Rellán & Fábregas Valcarce 2015, 2019).

As former approaches (Rodríguez Rellán & Fábregas Valcarce 2015; Carrero-Pazos 2017), the geology was studied through a reclassification of the official MAGNA geological map developed by the Geological and Mining Institute of Spain (IGME). The altitude and slope were derived from a 5 m resolution DEM built from LiDAR data, obtained from the Spanish National Geographic Institute (IGN) (**Fig. 3: A**). The topographic prominence (understood here in the sense of Llobera 2001) was modelled via the topographic position index algorithm in SAGA GIS (Guisan et al. 1999; Weiss 2001; Wilson & Gallant 2000). Since this analysis is scale-dependant, it is recommended to conduct a comparative approach where several radii are considered (Knitter & Nakoinz 2018: 54). For this paper, both local (100 m) and larger scales (500 m) have been used (see De Reu et al. 2011 for an extensive work on this variable) (**Fig. 3: B**).

The watershed map was calculated in GRASS GIS 7.0.4 (*r.watershed*) with a comparative approach between local and global basins, selecting an 8000 cell threshold (minimum size of exterior watershed basin) which provided the theoretical edges of the main watershed basins in this area **(see Fig. 3: A)**. The results match fairly well the main watersheds that drain to the coast (see Fábregas Valcarce & Rodríguez Rellán 2012). Then, the relationship of megaliths, watershed edges and rivers was estimated via Euclidean distance (*r.distance*), generating a raster map of distances from both rasters (**Fig. 3: C**).

[Caption] Figure 3. Some of the first order covariates modelled in this paper. **A:** Elevation, with watershed edges. **B:** Topographic prominence at larger scale (500 m). **C:** Distance to watershed edges (meters). **D:** Total viewshed.

On the other hand, the relation of mounds with flooding areas was modelled, using the topographic wetness index in SAGA GIS (Boehner et al. 2002). Regarding the visibility, we wanted to see if mounds were systematically erected in the most visible parts of the landscape. To know that we followed the total viewshed approach proposed by M. Llobera (2003; Llobera et al. 2010) –although we are aware that this variable needs further development (see e. g. García Sanjuán et al. 2006; Wright et al. 2014; Brughmans et al. 2018; Carrero-Pazos 2018b; Fábrega-Álvarez & Parcero-Oubiña

2019). The total viewshed analysis was done over the total number of cells in the 5 m DTM (3.295.323 of points), using GRASS GIS 7.0.4. (**Fig. 3: D**).

A crucial aspect regarding visibility is whether we can assume that the current landscape properties are similar to the Neolithic period. As stated by Criado Boado and Villoch Vázquez (2000: 196), the reconstruction of the prehistoric plant cover based upon pollen analysis indicates that the area was less degraded in the megalithic period than today, although there was an equal prominence of open vegetation. So, although sparingly, we can assume that current visual conditions between mounds, in a context of open and small vegetation, would fairly match to those in the Neolithic period.

Finally, based also in the work by M. Llobera (2015), who analysed the dynamics of mobility and visibility in this area, a study of the natural transit network was carried out by generating a density map of least cost paths. This approach, developed as well by C. Rodríguez Rellán and Fábregas Valcarce (2015, 2018), allows to get a network of least cost paths displaying areas of special concentration of pathways (White & Barber 2012) that may be interpreted as sectors with a higher potential transit intensity. In this case, we modelled a final network comprising 5.800 routes that were converted into a raster map through kernel density estimation.

5. First-order dynamics

The distribution map shows a clustered pattern over the study area (**see Fig. 2**). This means that the intensity of sites (the expected number of points per unit area) reflects spatial variation so we can use statistical methods to estimate how this spatial variation is (Baddeley et al. 2016). This is interesting as will show if the megalith's distribution depends on the values of specific covariates, for instance, whether sites prefer a particular altitude or not. Thus, the approximation chosen in this paper for analysing the monovariate pattern is the study of the intensity through a non-parametric summary of each univariate relationship between the dependent variable (presence of sites) and the different covariates. This was done in *R Statistics* (RStudio version 1.1.463) (R Development Core Team 2008) using the function *rhohat* from the *spatstat* package (Baddeley et al. 2016: 180) (**Figure 4**).

[Caption] Figure 4. Intensity as an estimated function giving mound density as a function of the different covariates (solid lines show function estimate while grey shading is pointwise 95% confidence band).

The study of the intensity allows us to get a rough idea of the characteristics of megalithic landscapes in the study area. We can compare these results with the percentage of the study area per elevation (in m.a.s.l.) (**Figure 5**): 300 – 17.38%; 400 – 24.39%; 500 – 22.87%; 600 – 29.48%; 700 – 5.88%. The results indicate that megaliths are more likely to be found in elevations ranging from 500 to 600 m ASL and in areas of gentle slopes, zones which represent a 22.87% of the total study area.

[Caption]. Figure 5. Altitudinal distribution of mounds (line) compared to that of the terrain in the study area (bars).

Also, mounds are close to watershed edges and in areas with topographic significance at large scales, which suggests that visibility played an important role in explaining their location, as former approaches have already suggested (Llobera 2015; Fábregas Valcarce et al. 2017; Fábregas Valcarce & Rodríguez Rellán 2019).

To assess these informal conclusions about preferences regarding site-location, we conducted a multivariate regression model (as done by Bevan et al. 2013). Prior to that, a Pearson correlation's test was carried out over the set of variables in order to avoid overparameterization. The results pointed out the pertinence of removing the topographic prominence index (100 m) from the model (**Figure 6**).

[Caption] Figure 6. Pearson correlation's test for the covariates modelled.

The multivariate regression model was then carried out selecting the best combination of the remaining nine variables via stepwise comparison –minimising an Akaike Information Criterion– which allows the evaluation of the relative merit of different models built from the combination of the covariates (Baddeley *et al.*, 2016: 335-336) (**Table 2**).

[Caption] Table 2. Results of the multivariate regression model.

The results of the multivariate regression model rule out the distance to rivers and the topographic prominence index (500 m) as explanatory variates, as opposed to what could be deduced from the simple observation of the intensity maps. On the contrary, elevation, distance to watershed edges, slope, least cost path density (routes), total viewshed and geology are good predictors (p<=0.05). Although significant, geology and least cost path density have lower values than the rest of the variables (see Table 2).

With this six-variable environmental model, we created in *R Statistics* a predicted first-order intensity surface (**Figure 6**), which can be used to analyse the second-order interactions in the distribution of mounds.

[Caption] Figure 7. Predicted first-order intensity surface.

6. Second-order dynamics

The study of the second-order properties of a point distribution involves considering whether the location of points depends on other points, in what has been called interaction (Nakoinz & Knitter 2016: 135). When there is no interaction between points, then the point pattern is random (Complete Spatial Randomness).

Following former works (Bevan et al. 2013; Carrero-Pazos et al. 2019), to approach the second order properties of the mounds located in the highlands of Serra do Barbanza, we can consider –in the first instance– a pair correlation function of the megaliths with an envelope of wholly random Monte Carlo Simulations (**Figure 8: A**).

The observed function shows spatial clustering at local scales up to approximately 1000 m, when the observed pattern may become regular, although the random envelope suggests that such clustering is not significant from 400 m onwards. Therefore, clustering at local scales (up to 400 m., as shown in figure 8A) is not coincidental, and it may be the result of external or internal variables influencing the distribution of points. The most likely explanation could be the effect of some environmental variables not taken into account in this paper and/or of interaction between sites, such as aggregation processes, which caused tumuli to be built near pre-existing ones –second-order trend– (e.g. “tradition”, in terms of Villoch Vázquez 2000).

To examine whether this pattern is the result of the preference for a specific landscape or it is a consequence of attraction or repulsion between megalithic monuments, the intensity of first-order factors in the calculation of the pair correlation function was considered. This was done by forcing the random simulations to take into account the spatially inhomogeneous intensities modelled by the predicted intensity surface (shown in **figure 7**) (Bevan et al. 2013). The results (**Figure 8: B**) show how the observed data matches fairly well the resulting random envelope suggesting that the point process can be explained by environmental affordances. Therefore, the clustered pattern shown by the mounds in our study area may be the result of a selection of specific types of landscapes. This can be further inspected by comparing the AIC of the random model (1874.368) with that of the environmental one (1692.412). Since the latter is lower, it suggests that the first-order surface is rightly accounting for the spatial pattern of the sites. However, it is still remarkable that the observed function gets close to the upper edge of the envelope at smaller distances, suggesting that there might be some borderline propensity for the sites to be clustered up to distances ca. 150-300 m, a possible lurking trend that cannot be accounted by the influence of environmental variables.

[Caption] Figure 8. Point process models for the study of second-order effects. **A:** Pair correlation function with a 95% envelope from wholly random Poisson process. **B:** Pair correlation function of the observed sites with a 95% envelope conditioned on the first-order covariates model. **C:** Pair correlation function with a 95% envelope also conditioned on both the first-order covariates and a second-order, area-interaction model (r = 150 m).

In order to examine this very local -further- clustering, we can explore the comparison of our empirical model with a known theoretical point process model. Following previous works (Bevan et al. 2013), Gibbs point process is perhaps the best choice for our case, since it involves the influence of other points given by an interaction function (Baddeley et al. 2016). As we did in former works (Carrero-Pazos et al. 2019), we use the area-interaction model (Baddeley & Lieshout 1995), which generates inhibition and clustering patterns with reference to a buffer created for all the points of the distribution. The results (**Figure 8: C**) suggest that only when considering a strong interaction between the points the observed data fall entirely well over the envelope, being now accounted by first and second-order trends (AIC=1359.799). The results point out that the resulted environmental variables (elevation, distance to watershed edges, slope, least cost path density (routes), visual prominence and geology) and a very local attraction between points can be used to draw a quite accurate scheme of the distribution of sites in our study area.

7. Discussion and conclusions

The analysis of the first-order dynamics has allowed us to ascertain which environmental covariates can predict the current distribution of mounds in the Chans of Barbanza. The defined pattern confirms initial suspicions regarding elevation and slope cut-off as parameters that can define the megalithic distribution in this area (not in the whole Sierra, just in this study area; see Bustelo Abuín 2017 for an extensive work on that sense). This does not mean that elevation, for example, is the unique important variable, as the relation of mounds with watershed borders is clear in this area, something already defended for other areas in Galicia (Carrero-Pazos et al. 2019) and in other European regions, such as south-west England (Bradley 1991b) and Wales (Roese 1980). This is an evidence that megalith builders made quite explicit use of natural features of the landscape (Bradley 1991a: 78) for further functional purposes than the ceremonial use.

From a general point of view, barrows were located, in our study area, in flattened top places, specific locations where mounds can be highly seen from local and long distances, and these areas frequently match the basin edges and natural transit paths. Simultaneously, it is clear that lowlands are not the preferential locations for these sites, mainly for two reasons. The first one is that people probably lived in coastal regions, as research is currently finding evidence of domestic occupation in these areas (Barbeito Pose 2015). Also, behind the decision of choosing upland territories there could be a more functional sense, as the terrain in low areas uses to be less rough for building a megalithic structure.

The location of mounds in areas of wide visibility seems to be an essential factor on the decision to locate the monuments in the landscape, something which is generally accepted for the whole phenomenon (García Sanjuán et al. 2006). However, from a GIS point of view, the question of visibility is more complex, as it is necessary to further conclude if it was the view from the mound, the visibility to the mound or the intervisibility between monuments the locational criteria which determined the spatial value of the architecture (De Reu 2012: 227; Wright et al. 2014).

This is something that happens as well with the relation of megaliths and the movement through the landscape. Pioneering approaches (namely Criado Boado & Villoch Vázquez 1998, 2000) in Serra do Barbanza defined paths and routes through the Sierra in an *ad hoc* manner (Fábregas-Valcarce et al. 2018: 89), based on field observations conducted only in the proximity of the sites subjected to analysis. As Fábregas-Valcarce et al. (2018: 89) continue, the resulting path networks connected different clusters of monuments and not parts of the landscape, artificially overestimating the spatial relationship between mounds or other sites (such as petroglyphs) and transit routes. Thus, GIS approaches changed the perspective when analysing the movement through the landscape (e.g. Llobera 2015; Rodríguez Rellan & Fábregas Valcarce 2019) without take into consideration the sites into the calculus, to check if mounds are truly located at areas of natural transit. And the results are quite convincing. There is a clear relation between mounds and pathways, however, when we analyse the degree of this relation things become less conclusive. Comparatively, the research presented in this paper show that the relation with natural transit seems to be an important locational factor although subordinated to the influence of proximity to watershed edges. This matches, in fact, the research carried out by one of the authors (M.C.) in areas of the South of Galicia where the relation of megaliths and transit routes is not strong as supposed, as there are a high number of mounds that clearly do not relate with potential pathways. On the other hand, in this area megaliths tend to be (more accurately) located in proximity to watershed edges, places that can coincide with natural pathways or not (Carrero-Pazos et al. 2019). As resulted from our work, the proximity to watershed edges accounts for the spatial pattern of mounds (sites located very closed to water basin edges) better than the density of least cost paths (sites located in nodes of natural pathways), which let us to think about the spatial arrangement of sites in terms of some kind of territoriality (Carrero-Pazos et al. 2019).

To sum up, the spatial and visual relation of mounds with pathways is something already noted by former works in this and other areas (Murrieta-Flores 2012; Llobera 2015; Carrero-Pazos 2017; Carrero-Pazos & Rodríguez Casal 2018a, 2019; Rodríguez Rellán & Fábregas Valcarce 2019). Further approaches in other areas suggest that a visual relation of megaliths with natural pathways may explain specific visual trends (Murrieta-Flores 2010; Wheatley et al. 2010; Carrero-Pazos 2018b).

As pointed out before, all of this has been also approached for Serra do Barbanza but from a more interpretative sense, through the lens of landscape archaeology, which propose that mounds were specifically located dominating agricultural areas (e.g. Criado Boado et al. 1986: 169), getting as well a territorial meaning by orienting the human movement through the Sierra (Criado Boado & Villoch Vázquez 2000). Although both explanations are really interesting, the spatial arrangement of the necropoli should be considered on the basis of a wide contrasted dating program, as they probably comprise monuments from different periods (see e. g. the case of Cotogrande – Abad Gallego 1996– or Serra da Aboboreira –Jorge 1982–). Related to that, we have rigorously demonstrated through spatial statistics that there is some influence of pre-existing mounds in the construction of new ones. Although in a context of temporal uncertainty, this means that the presence of monuments in specific areas of the Serra do Barbanza could have "fostered" encourage the erection new ones in the vicinity, something already suggested in the framework of landscape archaeology (Wheatley 1996; Villoch Vázquez 2000) or for other archaeological phenomena, such as Galician rock art (see Rodríguez Rellán & Fábregas Valcarce 2015).

All that has been said allow us to conclude that the barrow landscape of Serra do Barbanza analysed here should be considered as a landscape of dynamic perceptions (Carrero-Pazos 2017), involving the use and re-use of the same place for constructing cemeteries during several millennia. As stated by Fábregas-Valcarce (et al. 2018: 96), such diversity calls for a qualification of the automatic consideration of these monuments as landmarks intended to been seen, being this true for some barrows but maybe others intended to remain unnoticed.

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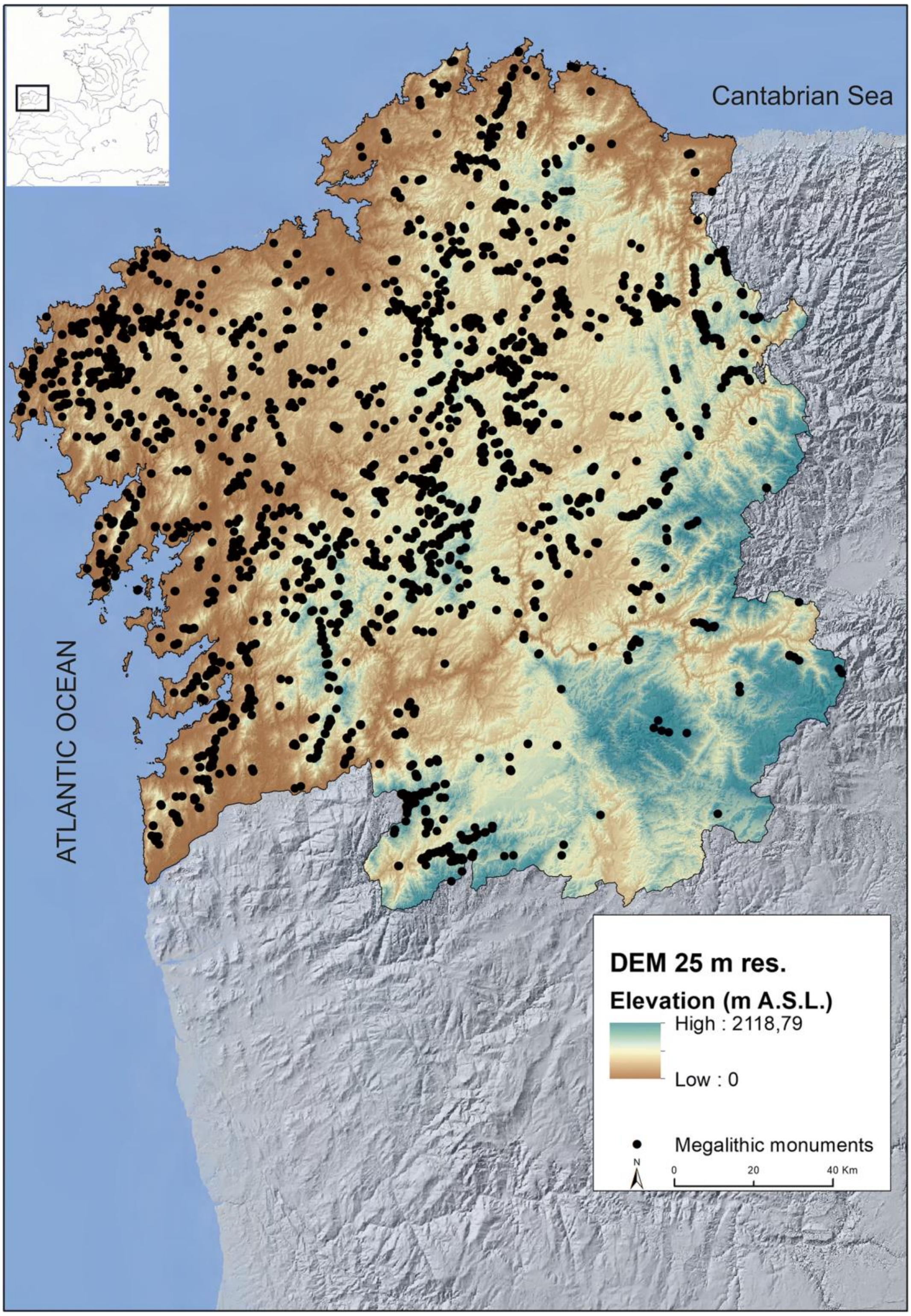

Figure 1. Current distribution of megalithic monuments in Galicia, NW Spain (University of Santiago de Compostela, GEPN-AAT).

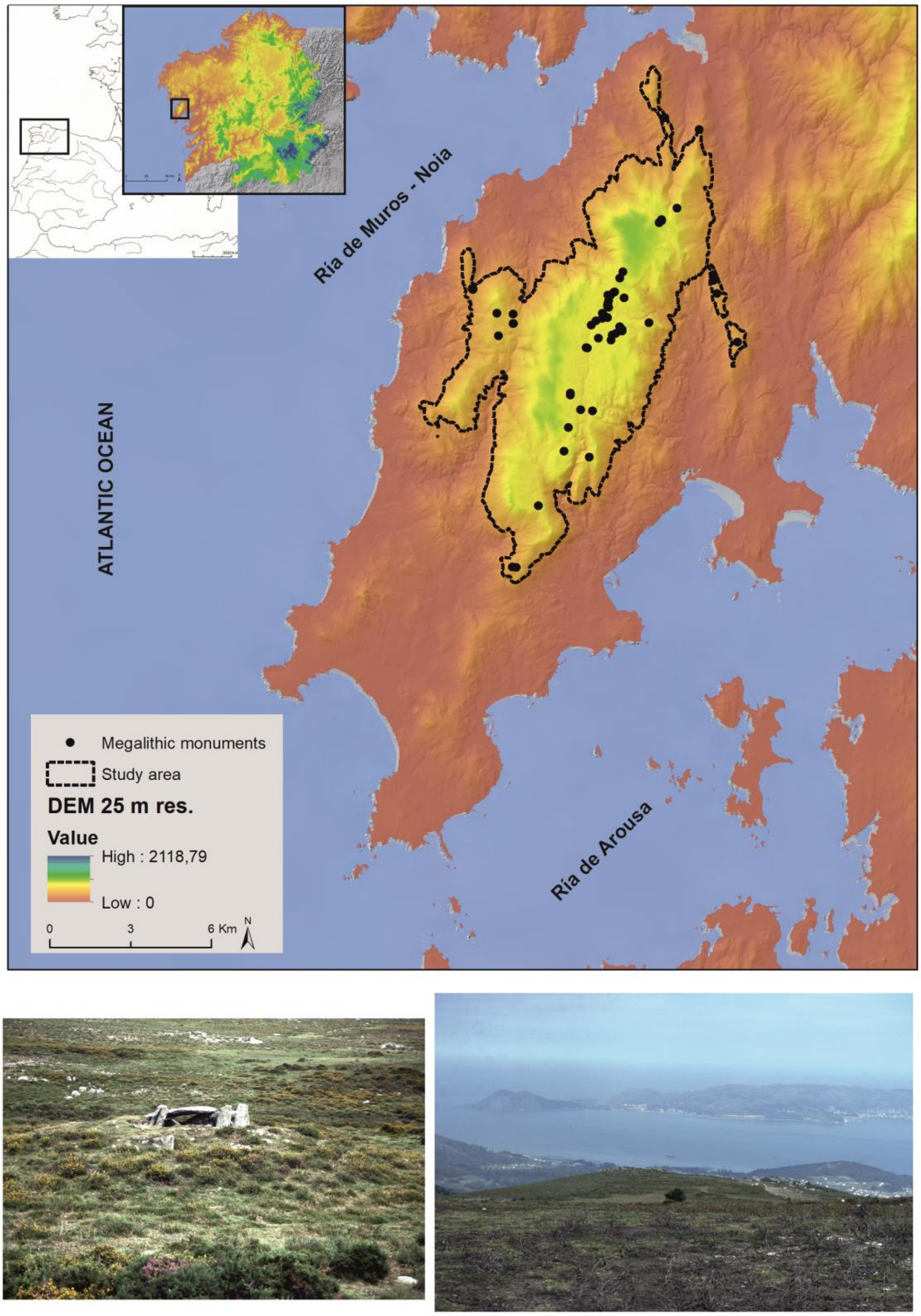

Figure 2. Above: Selected study area, the highlands of Sierra de Barbanza (above 200 meters high). Below: the megalith of Arca da Barbanza, and a view from the Sierra towards the Ría de Muros-Noia (NW).

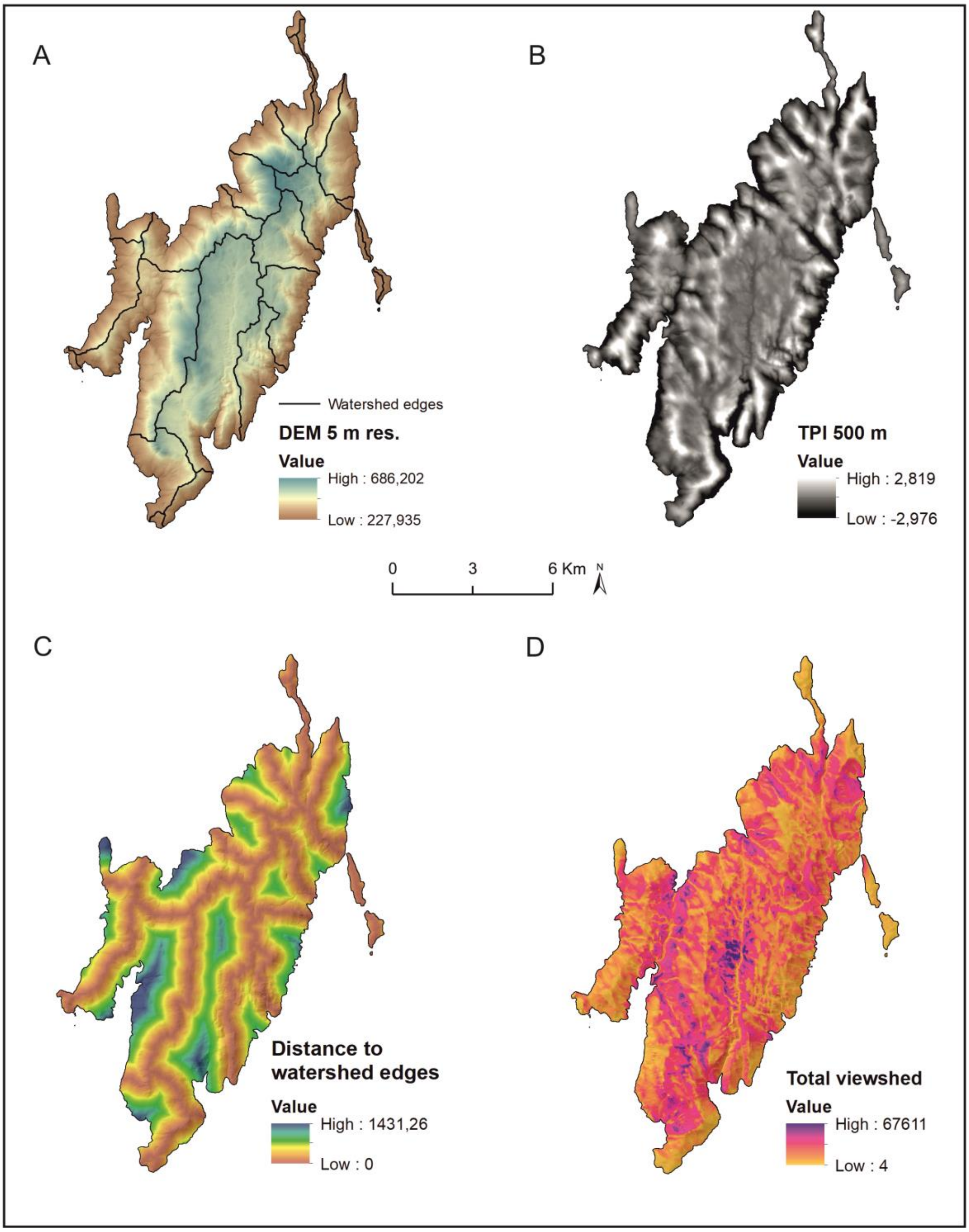

Figure 3. Some of the covariates used in first-order locational modelling. **A:** Elevation, with watershed edges. **B:** Topographic prominence at large scale (500 m). **C:** Distance to watershed edges (meters). **D:** Total viewshed.

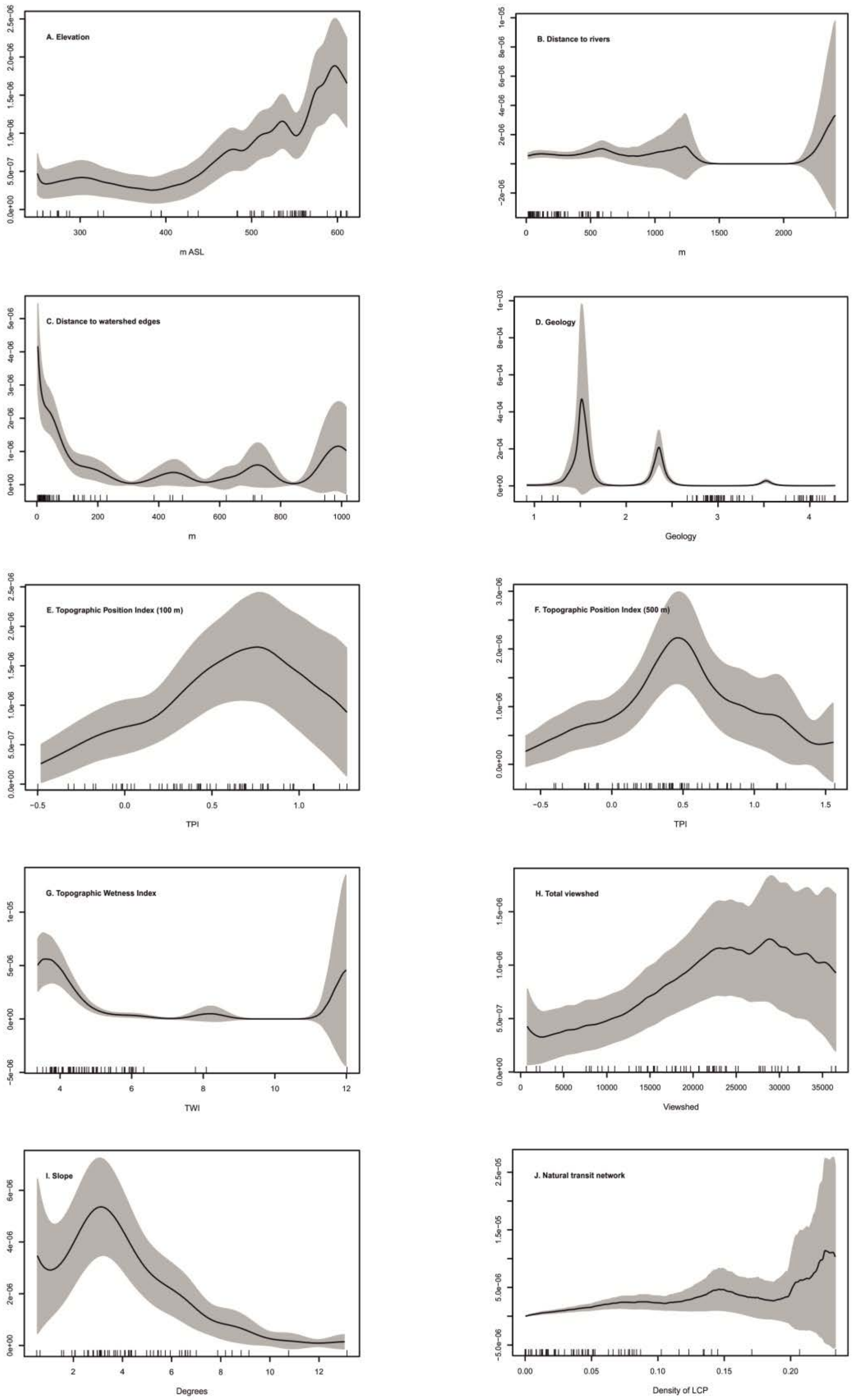

Figure 4. Intensity as an estimated function giving mound density as a function of the different covariates (solid lines show function estimate while grey shading is pointwise 95% confidence band).

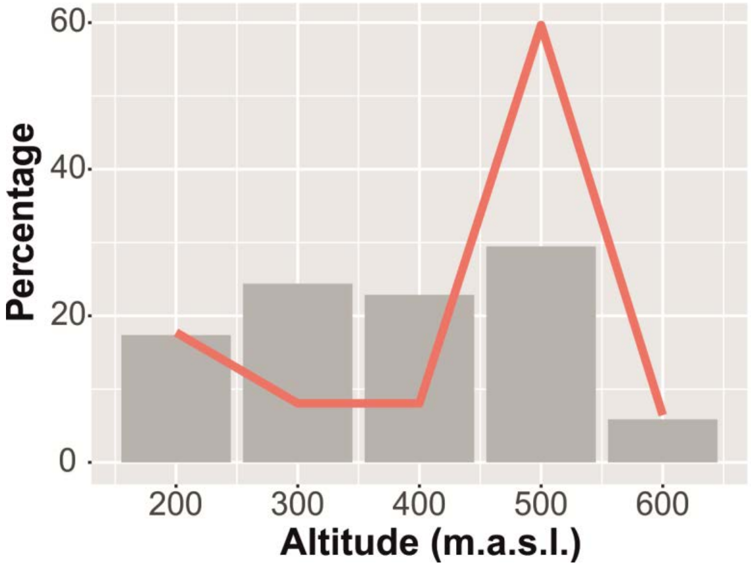

Figure 5. Altitudinal distribution of mounds (line) compared to that of the terrain in the study area (bars).

Figure 6. Pearson correlation's test for the covariates modelled.

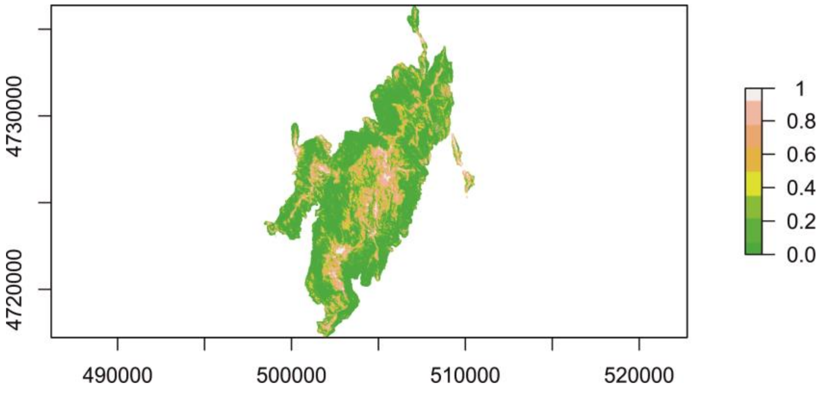

Figure 7. Predicted first-order intensity surface.

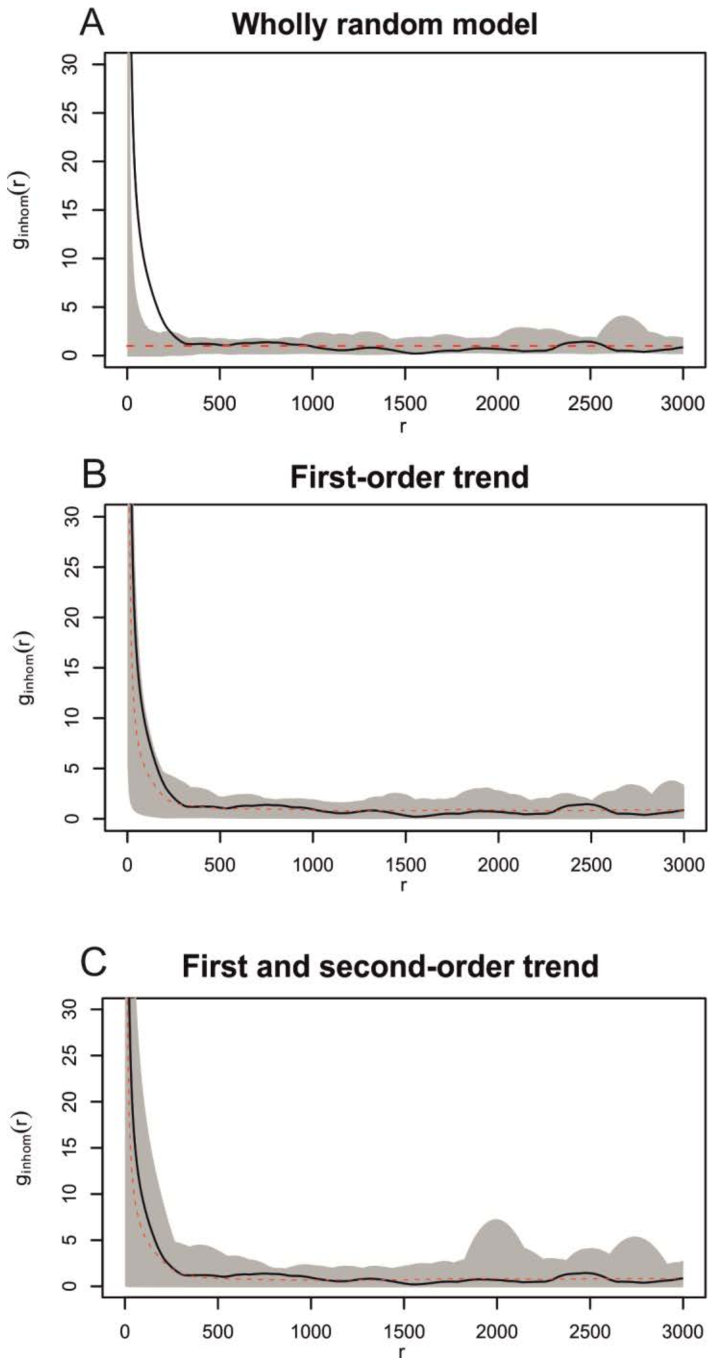

Figure 8. Point process models for the study of second-order effects. **A:** Pair correlation function with a 95% envelope from wholly random Poisson process. **B:** Pair correlation function of the observed sites with a 95% envelope conditioned on the first-order covariates model. **C:** Pair correlation function with a 95% envelope also conditioned on both the first-order covariates and a second-order, area-interaction model (r = 150 m).

TABLES

Locational factor	Reference	Covariable setup
Geology (granite areas)	Leisner 1938; Bello Diéguez et al. 1982, 1987; Criado Boado, Vaquero Lastres 1991; Gómez Vila 2005	Rasterisation of official MAGNA map from National Geographic Institute
Edaphology (sites close to tillage areas)	Criado Boado, Grajal Blanco 1981	Not modelled in this work
Altitude and slope (high elevation areas)	López Cuevillas 1973; Criado Boado 1988	DEM 5 m. built from LiDAR data
Topographic prominence and visual impact	Criado Boado 1984a; Criado Boado 1988	Topographic prominence index (local-large scale) and total viewshed
Relation with transit network	Díaz Sanjurjo 1903; Castillo López 1927; López Cuevillas 1925, 1933; Maciñeira 1935, 1943-1944; Bello Diéguez et al. 1982a, 1982b; Criado Boado, Vaquero Lastres 1991; Vaquero Lastres 1991-1992, 1993-1994; Eguileta Franco 1999	Least cost path density
Relation with water areas	Vaquero Lastres 1990; Méndez Fernández 1998; Villoch Vázquez, 2000; Santos Estévez 2008	Distance to rivers and topographic wetness index
Relation with other natural features and archaeological remains (petroglyphs)	Filgueiras Rey, Rodríguez Fernández 1994; Villoch Vázquez 1995, 1998; Santos Estévez et al. 1997	Not modelled in this work
Relation with watershed edges	Bradley 1991a, 1991b	Distance to watershed edges

Table 1. Variables of the locational model of the megalithic culture in Galicia managed by literature, and setup in a GIS environment.

<table>
<tr><th colspan="6">Multivariate regression model</th></tr>
<tr><td colspan="6">Initial Model: site ~ elevation + slope + distance to rivers + distance to watershed edges + geology + routes + topographic prominence index (500) + total viewshed</td></tr>
<tr><td colspan="6">Final Model: site ~ elevation + slope + distance to watershed edges + geology + routes + total viewshed</td></tr>
<tr><th>Coefficients</th><th>Estimate</th><th>Std. Error</th><th>z value</th><th>p value</th><th>Significance values</th></tr>
<tr><td>(Intercept)</td><td>6.495e+00</td><td>1.005e+00</td><td>6.463</td><td>1.03e-10</td><td>***</td></tr>
<tr><td>elevation</td><td>-5.953e-03</td><td>1.282e-03</td><td>-4.642</td><td>3.44e-06</td><td>***</td></tr>
<tr><td>slope</td><td>-3.225e-01</td><td>3.083e-02</td><td>-10.461</td><td>< 2e-16</td><td>***</td></tr>
<tr><td>distance to watershed edges</td><td>-2.309e-03</td><td>4.748e-04</td><td>-4.863</td><td>1.15e-06</td><td>***</td></tr>
<tr><td>geology</td><td>-5.364e-01</td><td>1.781e-01</td><td>-3.012</td><td>0.002595</td><td>**</td></tr>
<tr><td>routes</td><td>7.115e+00</td><td>2.744e+00</td><td>2.592</td><td>0.009531</td><td>**</td></tr>
<tr><td>total viewshed</td><td>5.196e-05</td><td>1.389e-05</td><td>3.740</td><td>0.000184</td><td>***</td></tr>
<tr><td colspan="6">Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1</td></tr>
<tr><td colspan="6">(Dispersion parameter for binomial family taken to be 1)
Null deviance: 892.34 on 123 degrees of freedom
Residual deviance: 462.05 on 117 degrees of freedom
AIC: 473.48
Number of Fisher Scoring iterations: 5</td></tr>
</table>

Table 2. Results of the multivariate regression model.