TITLE:

GIS-based methodology for Palaeolithic site location preferences analysis. A case study from Late Palaeolithic Cantabria (Northern Iberian Peninsula).

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ABSTRACT:

Factors involved in the selection of a settlement location are key issues in the understanding of hunter-gatherer subsistence strategies and social organization. Site location preferences are the result of a complex decision-making process, in which both economic and cultural needs are involved. This paper presents a specific methodology for site location analysis, based on the definition and calculation of a series of variables. This methodology, applied to Late Palaeolithic sites from the Cantabrian coast, enables an objective comparison between archaeological sites, and consequently the analysis of settlement patterns of Palaeolithic societies.

KEYWORDS:

GIS, settlement, site-location preferences, territory, Late Palaeolithic, Cantabrian coast

1. Introduction

The spatial analysis of prehistoric sites location is one of the main issues in Palaeolithic Archaeology, since it allows providing an approach to the settlement dynamics and mobility strategies of foraging societies. This subject has been approached from different disciplines and perspectives, although most of them focus on the spatial relation between sites, more than on the sites' own location and characteristics. However, the precise site location corresponds to a conscious choice by hunter-gatherer groups (Fano Martínez, 1998a; Jones, 2010; Kellogg, 1994), aimed at meeting their subsistence and social needs; this choice is based on a set of conditioning factors that a given location has to have in order to be chosen as a human settlement, which can be broadly defined as site location preferences.

In many cases, these preferences have been intuitively related to diverse factors, such as strategic location, defensibility, favourable orientation, wide visibility, etc., but they have been seldom analyzed in a systematic way. However, in order to achieve a precise approach to past settlement patterns, a concrete methodology for site location analysis is needed, based on the definition of a series of quantifiable characteristics (Eriksen, 1997; García Moreno and Fano Martinez, 2011). The definition of the factors influencing settlement location, and its precise calculation, makes it possible to study a large dataset, contrasting the characteristics of one site with others, and consequently provides an approach to the preferences in the selection of specific locations as settlements. Once site location preferences are defined, differences in site distribution, derived from their function, can be highlighted, as well as variability through regions or time.

This paper presents such a methodology, based on the calculation of a set of factors influencing Palaeolithic site location, some of them calculated using GIS. As stated above, the objective of this analysis is to define site location preferences, with the aim of providing an approach to the economic, social and cultural-symbolic factors which influenced those preferences, as well as to changes in site location preferences, in relation with changes in subsistence strategies and social organization observed in Cantabrian Late Palaeolithic foraging communities.

2. Material and methods

The study area of this work, the Western Cantabrian region (Fig. 1), is a narrow, west-east oriented strip enclosed by the Cantabrian Sea to the north and the Cantabrian mountain chain to the south. Its steep relief originates from the proximity of the mountain range (rising up to more than 2000 m.a.s.l.) to the coast, which is about 30-40 km from the watershed. Cantabrian rivers are therefore short and wide, shaping geographically enclosed valleys separated from each other by mountain ranges perpendicular to the coast. The shoreline is mainly dominated by cliffs and steep reliefs, with some large bays and estuaries in the main river mouths.

FIGURE 1

This region is a classics area for Palaeolithic research, especially for the Magdalenian period, since research has been carried out here since the mid 19th Century (González Morales and Estévez Escalera, 2004). This long academic tradition, together with its associated fieldwork and excavations, has yielded great knowledge about Magdalenian communities inhabiting Cantabria at the end of the Last Glaciation, regarding different aspects such as their environmental context, chronology, subsistence strategies, technological evolution, art expressions, social organization and settlement patterns (Corchón Rodríguez, 2005; González Morales and Straus, 2005; González Sainz, 2005).

In addition to the large body of research in the subsequent period, the Azilian (Fernández-Tresguerres Velasco, 2004), the historical dynamics of Late Palaeolithic societies can be inferred, with some works proposing major social transformations during this period (González Sainz and González Urquijo, 2004): diversification in subsistence, local resources and raw materials provisioning, simplification of the toolkit or the disappearance of figurative art. Regarding mobility and settlement, some works have proposed a reduction in residential mobility and group territories (Terradas Batlle, et al., 2007), an intensification in open-air occupations, as well as a more dispersed and permeable distribution of population (García Moreno, *in press*).

2.1 Archaeological data set

In order to evaluate Late Palaeolithic communities' site location preferences, as well as the evolution of these preferences in relation with the other economic and cultural transformations, the location of 28 Recent Magdalenian and/or Azilian sites from the Western Cantabrian region is analyzed. Of those sites, 19 were inhabited from these periods on, some of them for the first time, but not during the Older Magdalenian, while the other 9 were already occupied during the preceding period. The larger number of Recent Magdalenian sites in contrast with those from the Older Magdalenian has been correlated with a population increase at the end of the Upper Palaeolithic (González Sainz, 1995) or the appearance of new populations (Arribas Pastor, 2004), although it could be due to a more dispersed settlement pattern (García Moreno, *in press*). Consequently, the chronological framework of this work expands from about 16.200 cal BP to 10.700 cal BP (13.300-9.500 BP), in spite of the existence of sites with older occupation.

This archaeological data set was first divided into two main clusters: Group A, which corresponds to those sites occupied from the Older Magdalenian on, and Group B, for those sites used only during the Recent Magdalenian and/or the Azilian. This division was intended to evaluate a possible change in site location preferences during the Late Palaeolithic, by analysing whether new sites were placed at similar locations to the older ones, or if different kinds of locations were sought.

2.2 Methodology

The methodology presented herein is based on the definition of two different kinds of factors used in the study of every site's location analysis, differentiated by the method used to obtain them. First, those factors regarding site characteristics which could be calculated by direct observation were defined as parameters. The parameters considered were:

- Classification: differentiating between caves and rock shelters (there were no open air sites among the dates set).
- Absolute Altitude: the altitude of the site above modern sea level. In this case, the difference between modern and Pleistocene sea levels is irrelevant, since all the sites would be equally affected.

- Relative Altitude: a measurement of the vertical distance between the site and the lowest part of its close environment, usually valley floors. This parameter gives an idea of the location of the site in relation to its close landscape, better than the altitude above sea level.
- Topography: defines the vertical position of every site, and differentiates between Mid-Slope sites, if they are located high above the lower point of their surroundings, and Valley Floor sites, when they have a direct and easy access to valley floors; in this case, Relative Altitude has to be lower than or about 10 metres. Although related with the Relative Altitude, this variable makes this factor more easily understandable.
- Landscape: refers to the part of the river basin where the site is located: main valley, subsidiary valley, high mountain and coastal plain.
- Aspect: the cardinal direction to which the cave mouth or rock shelter faced.

As stated above, all of these parameters could be calculated by visiting each site, from direct observation, except those relating to the altitude, in which case GPS or references in literature were used.

The second kind of factors analysed were those defined as variables, for calculating which a Geographical Information System (GIS) was used. The variables calculated were:

- Insolation: the mean number of hours of sunlight received monthly by each site (cave mouth or rock shelter), and its seasonal and annual means.
- Viewshed: the amount of surface viewed from each site, and the dominant direction of visibility.
- Terrain: a classification of the environment in a 10 km radius from every site, based on terrain slope.
- Accessibility: a calculation of a cumulative cost when crossing the site’s surroundings, as far as 10 km from every site.
- Distance to coast: the minimum distance to a series of hypothetical shorelines (from -70 to -40 metres from modern sea level), and the least cost path, based on the accessibility variable previously calculated.

For the GIS calculations, a Digital Elevation Model (DEM) was created (Fig. 2), based on the Topographic digital cartography provided by the Centro Nacional de Información Geográfica (1:25.000 series), as well as on the bathymetric cartography provided by the Instituto Hidrogeográfico de la Marina (1:100.000 series), and digitized by the Institute for Environmental Hydraulics of the University of Cantabria. The combination of topographical and bathymetrical cartography enabled the reconstruction of both mainland and submerged surface, thereby making it possible to approximate the Pleistocene coastal plain topography, by placing shoreline at -70 metres below actual sea level (as an estimated sea level for the Late Glacial), and considering the surface between modern shoreline and the -70 m surface as land emerged during the Pleistocene. In this way, all the analyses made were based on a reconstruction of Pleistocene environments; moreover, analyses based on modern topography were made too, in order to evaluate differences between both territories, as well as to have a more solid basis for interpretations.

The DEM was generated using the Inverse Distance Weight (IDW) algorithm, with a cell size of 25x25m. Its Mean Square Error is 2.27m, which places this DEM into the highest level (Level III) of US Geological Survey's quality scale (Felicísimo Pérez, 1994). The software used for its creation, as well as for all the analyses, was ESRI's ArcGIS 9.

FIGURE 2

2.2.1. Insolation

Sunlight and sun heating are usually considered desirable factors for good habitability conditions for any given site (Fano Martínez, 1998b), even for Palaeolithic settlements located in caves, since it is usually assumed that most daily activities were carried out outside or at the entrance.

In order to calculate the potential number of sunlight hours received by each site, twelve insolation models were created for the whole region, one for every month. This calculation was based on the astronomical position of the Sun with regard to the Earth for one day every month, on which insolation was closest to the monthly mean. Once this position was known, a line-of-sight like analysis was carried in order to evaluate whether a virtual line could be established between the "sun" and every cell in the model, in which case it would be "illuminated", or not, because of topographic shading. This analysis was carried out in one-hour intervals from sunrise to sunset for each day, with the sum of them being the total amount of mean potential sunlight hours every cell would receive on that day/month (García Moreno, 2008a). Finally, the monthly potential insolation for every site was obtained by summarizing the number of sunlight hours received by cells where sites where located. Once the monthly potential insolation was obtained, the seasonal and annual means could easily be calculated.

2.2.2 Viewshed

Visibility is a classic issue in archaeological site location analyses, and has been regularly proposed as the main influencing factor for the understanding of sites and/or specific features distribution, such as megaliths (Llobera, 2007). The application of GIS has enabled the improvement and generalisation of visibility analyses, although its limitations have also been highlighted (Gillings and Wheatley, 2001).

Visibility analyses were based on the idea of site viewshed, i.e. on the calculation of the surface viewed from every site. This calculation, which can easily be made using most GIS (Wheatley and Gillings, 2002), was limited to a 10 km radius from every site, in order to simulate human eye perception limitations. Once the viewshed had been calculated, each site radius was divided into eight sectors, each one corresponding to a 45º azimuth arc (337.5 – 22.5= North; 22.5 – 67.4= North-East; etc.), and then the visible surface falling into each sector was calculated. In this way, the main orientation of every site viewshed could be also established.

2.2.3. Terrain

In the Cantabrian region, the site landscape has been related with the site function and game consumption, since a direct relationship between sites located on steep landscapes and ibex hunting has been proposed, as opposed to sites placed on open or hilly environments, where red deer was the main ungulate hunted (González Sainz, 1992). Besides resource availability, the topography impacts on other factors, such as habitability conditions, mobility and accessibility, or even on how a landscape is perceived.

However, it is difficult to quantitatively evaluate the steepness of a given territory without using appropriate tools. In this case, a slope model was generated for the study region from the DEM, which showed the slope of every cell, including those cells corresponding to site locations.

However, the mean slope does not provide an exact idea of territory steepness, and consequently a classification into four terrain categories was applied for every site's 10 km radius. These categories were:

- Category 1 (Level terrain): slope between 0% and 5%.
- Category 2 (Hilly terrain): slope between 5% and 15%.
- Category 3 (Abrupt terrain): slope between 15% and 30%
- Category 4 (Steep terrain): slope over 30%.

This classification presents the data in a more easily understood form, by calculating the proportion of cells coming under every category.

2.2.4. Accessibility

From the early work of Higgs and Vita-Finzi (1967), the analysis of the accessibility to resources and site territory has been a key issue within Spatial Archaeology. Although the idea underlying this approach has been criticized, mainly because of the social factors influencing human beings' movement (Coward, 2005; Whallon, 2006), the concept of a site's foraging territory (Morgan, 2008) can be useful in the sense that it provides a quantitative estimate of the surface accessible from a site, which can be related with some of the factors influencing its location.

The measurement of sites' accessibility to territory was based on the creation of accumulated cost surfaces which estimated the "effort" incurred when crossing a given territory (Howey, 2007). In order to avoid direct anthropological interpretations, which would commit errors derived from the "sociality" of movement, cost of movement was considered as an abstract value, and therefore was neither calculated nor expressed in terms of time or energy investment. Isotropic accumulated cost models, where the direction of the movement is not relevant, were created, since it was considered that return-to-site trips would balance direction effects.

Two kinds of friction surfaces, where the cost of crossing each DEM cell was assigned, were created. In the first one, only topography was considered; in this case, cost was derived from the tangent of slope, which represents more accurately the exponential increase of movement cost according to lineal slope increase (Bell and Lock, 2000). In the second friction surface, the influence of river crossings was added to topography, by giving river cells a cost value equivalent to a 45º slope. There is no evidence for Palaeolithic river navigation in Cantabria, so rivers were considered as barriers and not as waterways. Once these friction surfaces were created, the accumulated cost within a 10 km radius from each site was created.

Once created, cells from both accumulated cost models were reclassified into ten categories, with cells with the lowest values classified as Category 1, and those with the highest as Category 10. Finally, a Cost of Movement Weighted Index (CMWI) was calculated, according to the formula:

$$CMWI = \frac{(\text{No. of Category 1 cells} * 1) + (\text{No. of Category 2 cells} * 2) + \ldots}{\text{Total No. of cells in the model}}$$

As a result of the classification into ten categories and the calculation of the CMWI, it was possible to quantitatively evaluate the accessibility of every site to its surroundings, not in the sense of site catchment territory (*sensu* Higgs, et al., 1967), but as an estimate of how easily could people move across a site's landscape.

2.2.5. Distance to coast

Coastal environments are considered of great interest for prehistoric foraging societies, since they offer a wide range of resources to be exploited (Bailey and Milner, 2002); actually, for the Cantabrian region, there has been a suggestion of an intensification in marine resource exploitation from the Late Palaeolithic onwards (Gutiérrez Zugasti, 2011), and even a major population concentration along the coastal plain, mainly during the Mesolithic (González Morales, et al., 2004). Consequently, access to the coast could likely have been an influencing factor when considering the location for a settlement.

In order to evaluate how accessible the coast was from every site considered, a least accumulated cost path (Bell and Lock, 2000) from sites to their nearest shoreline point was generated. This calculation was based on the first friction surface generated to the analysis of site accessibility, without considering river crossings, since it was assumed that rivers could be followed instead of crossed to easily reach the coast. The Euclidean distance from sites to the shoreline was also calculated, to evaluate the effect of topography when accessing the coast.

3. Results

The classification of Late Palaeolithic sites into a series of specific previously defined parameters (Table 1) highlighted some interesting aspects regarding site location preferences. Among the considered sites, all of them are located in caves, with the exception of only two located on rock shelters. The predominance of caves can not be explained by conservation problems, as should be considered for open-air sites, and in consequence it can be proposed that there is a clear preference for caves in front of rock shelters during the Late Palaeolithic. Sites located on rock shelters will be more important during the Mesolithic.

TABLE 1

Almost half of the sites (13) are located less than 100 metres above sea level, while only one of them is higher than 400 metres (Fig. 3). According to the Kolmogorov-Smirnov test, this distribution seems to follow a uniform random distribution, and in consequence the concentration of sites under 100 meters is not statistically significant, neither for the whole sample (Z = 0.769, p = 0.595) nor for Groups A or B (A: Z = 0.517, p = 0.952; B: Z = 0.708, p = 0.697). The same situation can be observed regarding Relative Altitude (Sample: Z = 0.951, p = 0.327; Group A: Z = 0.532, p = 0.940; Group B: Z = 0.965, p = 0.310). However, when comparing the *Topography* of Group A sites in front of Group B ones (Table 2), it appears that the frequency of valley floor sites during the Late Magdalenian is higher than expected ($X^2 = 6.28$, $p = 0.012$). Despite the small sample size, it would still be interpreted as a preference for sites located on valley bottoms.

FIGURE 3

TABLE 2

Most of the sites located in subsidiary valleys belong to Group B (10 out of 13, 76.92%), which could indicate an increasing interest from the Late Palaeolithic onward for these environments, but in this case there is no significant relationship between *Landscape* and chronology of occupations. For the aspect, the situation is quite heterogeneous, and no significant distribution can be observed.

Considering those variables calculated using GIS, insolation seems to have been an influencing factor when considering a new settlement site during the Recent Magdalenian and the Azilian. The sample mean number of sunlight hours (Table 3) is 6.73 hours per day (± 2.23), while considering the chronology of sites occupation, Group A sites give 5.99 hours per day (h/d) (± 2.66), and Group B sites 7.08 h/d (± 1.98). It can thus be observed that Recent Magdalenian and/or Azilian sites tend to be located in places with higher insolation; however, the one-way ANOVA test shows that difference between Group A and B means is not significant ($F = 1.484$; $p = 0.234$), probably due to sample size limitations.

TABLE 3

Seasonal averages show variability in the potential insolation received by these sites, from sites with a high (about 10 hours per day: La Garma A, El Otero, La Chora, La Fragua, El Perro and Santimamiñe) or intermediate (with 7 or 8 hours per day: El Pendo, Cullalvera, El Mirón, El Horno, Arenaza, Goikolau, Atxeta, Abbitaga and Urtiaga) insolation through the year, to sites with marked contrasts between seasons (Morín, El Valle and Santa Catalina), and even sites with low insolation all year round (El Castillo, El Piélago II, El Rascaño, El Salitre, Cubera, Lumentxa, Ermittia, Ekain and Erralla). The K-S test shows that Group B sites summer insolation does not follow a normal distribution (Table 4), which indicates that sites receive an insolation different (higher) than expected; 78.94% of sites used from the Recent Magdalenian onwards have a summer potential insolation higher than the mean, as opposed to only 22% of sites that had been already inhabited. In fact, the ANOVA analysis shows that the different between Group A and Group B sites summer insolation is *almost* significant at 95% ($F = 4.067$; $p = 0.054$).

TABLE 4

Regarding sites visibility (Fig. 4), there is a large variability in settlements viewshed (Table 5), as indicated by the high standard deviation: 10.85% out of a mean value of 6.01% of visible surface within a 10 km radius. Sites viewshed ranges from six sites with less than 1% of their territory, up to 47.21% (Table 5). This variability is mainly due to the presence of four sites with viewsheds higher than 20%, all of them located along the modern coastline: Lumentxa from Group A and La Fragua, El Perro and Santa Catalina from Group B. Excluding these four extreme values, the situation becomes more homogenous, although a high variability can be also observed (mean = 2.04±1.61%). Despite there being no statistically significant difference between sites from both groups, a differential pattern can be inferred; if sites are classified in two clusters (viewshed > 4% *vs.* viewshed < 4%), 41.6% of sites from the first cluster belong to Group A, while 75% from the second cluster belong to Group B.

FIGURE 3

Considering the dominant direction (Table 4), in 11 cases more than 50% of viewsheds are focused in a single direction. In contrast, the other 17 sites have a wider range of view over the horizon, with several adjacent sectors including more than 10% of viewsheds. 76.4% of these latter sites belong to Group B. Therefore it seems that from the Recent Magdalenian onward there is an increasing interest in sites with a wider visibility of their close environment, in some cases by sacrificing their visual control over a larger territory.

According to the relief of their surrounding territory (Table 3), three clusters can be observed: those sites located in a plain of levelled landscapes, mainly from the coastal plain and lower valleys; those from areas with a moderate relief located usually at mid-valley sections; and finally those located in areas with steep relief (Fig. 5). However, apparently there is no significant difference between Group A and Group B sites, and so it seems that the landscape steepness was not an influencing factor when choosing new locations for Late Palaeolithic settlements.

FIGURE 5

The same can be said for the accessibility to site territories and for their distance to coast (Table 5). Regarding accessibility, the average values are quite similar for both groups, whether or not we consider river crossings (Fig. 6). On the other hand, 53% of sites are located within less than 10 km from the modern shoreline, while a high correlation between distance to modern coast, distance to Pleistocene coast and least accumulated paths can be observed, with the exception of a few sites, where consideration of the topography drastically increases the shoreline distance. Considering the chronology of the sites, it could be argued that Group B sites tend to be closer to the coast and to have more accessible territories; however, this impression could be due only to the higher number of Recent Magdalenian/Azilian sites documented to date, and actually there is no significant differences between both groups for these variables.

FIGURE 6

TABLE 5

Finally, a discriminant analysis was performed in order to evaluate the confidence of those variables for describing Late Palaeolithic settlement preferences, in contrast to the previous period. The inclusion of all the variables yielded a result in which 93% of the cases were correctly predicted in their group; however, Wilks' lambda ($p = 0.120$) shows that the resulting function is not better than any other created by chance. Therefore the discriminant analysis was limited to those variables for which Chi-square showed significant differences between groups: Topography, Summer Insolation, Terrain categories 2 and 3, Viewshed and Distance to Coast. In this case, the analysis correctly classified 85.7% of cases ($p = 0.026$), showing that these variables were relevant when choosing a settlement location.

4. Discussion

At the end of the Palaeolithic, foraging communities registered several changes in their subsistence strategies, technology, social organization and cultural expression, as well as in their settlement patterns and land use strategies, such as a reduction of catchment territories and mobility (Terradas Batlle, et al., 2007) or the generalization of functionally specialized sites (Ibáñez Estévez and González Urquijo, 1997). As a consequence, the site location preferences of Late Palaeolithic (Recent Magdalenian and Azilian) societies were supposed to have also changed; the increasing importance of local resources, together with a new land use strategy and a changing social organization, would lead to the necessity of a different kind of settlement to those inhabited before, sites better suited to the new subsistence strategies and needs.

In this sense, the analysis of some Western Cantabria Late Palaeolithic sites showed that several significant differences can be highlighted between sites already being used during the Older Magdalenian and those occupied for the first time during the Recent Magdalenian or the Azilian. Older Magdalenian sites are preferentially located on the middle basin of river valleys, in a strategic position to reach both the upper and the lower parts of the valleys. They are usually situated next to the first foothills of the Cantabrian range, sometimes close to major pathways: El Castillo, El Mirón or Ekain are good examples. All the Older Magdalenian sites considered here are located on mid-slope, in some cases more than 100 metres above valley floors. This location gives them a good, long-range visibility of their surrounding territory.

In contrast, and despite those sites also being used during the Recent Magdalenian and/or the Azilian, many of the settlements inhabited for the first time in these periods are located on valley floors, some of them even at river level. Those sites tend to have a short-range, wide viewshed, offering their occupants a better visual control of their adjoining territory, to the detriment of the large viewshed enjoyed by mid-slope sites. Regarding their position through river valleys, there is apparently a greater concentration of sites on both upper and lower basins, as well as on subsidiary valleys; Recent Magdalenian and Azilian sites tend to be located closer to the coastline or to valley heads. Finally, it seems that settlements occupied from the Recent Magdalenian on have higher insolation during summer than those used before.

Therefore, it can be suggested that a significant change in site location preferences took place between the Older and the Recent Magdalenian; in other words, the factors considered in the decision-making process involved in settlement location changed at this time.

Some of the limitations of this approach are evident, and derived mainly from the difference between modern topography and environment, which are usually the geographical basis for the analyses, and Pleistocene ones. In this sense, the most important transformations were those due to sea level rise and changes in the vegetation cover, with the substitution of conifer forest by deciduous ones (Iriarte and Hernández, 2009; Ramil, et al., 2001). In order to overcome these limitations, the position of the Pleistocene shoreline was calculated, together with the reconstruction of the emerged coastal plain; however, because of the low resolution of bathymetric cartography, this reconstruction is still quite general, although it is able to identify several features, such as ancient islands, estuaries and river mouths (González Morales and García Moreno, 2011). It can be argued that the disappearance of Pleistocene coastal sites because of coastal plain flooding prevents this kind of study; however, since this process would affect equally Older and Recent Magdalenian sites, a comparison between both periods is possible. On the other hand, although it has not been included in this approach, the consideration of predicted potential distribution of tree vegetation (García Moreno, 2007; García Moreno, 2008b) will improve future site location analyses.

Despite these limitations, the results obtained here are consistent with the archaeological evidence. Among other transformations, for the Recent Magdalenian some works have proposed a broader spectrum in subsistence strategies, with a major focus on local resources, as well as a reduction in site territories and a compartmentalization of space (González Sainz and González Urquijo, 2004; Terradas Batlle, et al., 2007). In this context, the new site location preferences aimed to provide foraging communities with settlements more suited to their changing subsistence strategies and social organization.

The interest in settlements placed on valley bottoms, with a wider visual control of their immediate territory, can be related with the increasing exploitation of local resources,

which can be monitored, accessed and cached in a more direct way from these sites than from mid-slope sites (García Moreno and Fano Martinez, 2011).
The distribution of sites through the upper and the lower parts of the basins and subsidiary valleys could be also related with the adoption of a broad spectrum economy and a reduction of long-range movements, since it would entail the "enhancement" and exploitation of peripheral areas sporadically visited before. The apparent intensification of the occupation of the coastal plain, together with the preferential location of sites on valley floors next to rivers, would be also a consequence of the intensification in marine resource catchment and fishing (Adán Álvarez, et al., 2009; Gutiérrez Zugasti, 2011).

The exploitation of local resources in a more direct way through a set of smaller, dispersed sites, located on valley floors and subsidiary basins, is consistent with the archaeological evidence suggesting an increase of logistical, specialized sites, with fewer activities, usually associated with game processing (Ibáñez Estévez and González Urquijo, 1997). As the analysis of site potential insolation shows, Recent Magdalenian/Azilian sites tend to have a summer insolation significantly higher than sites already used from the Older Magdalenian, which is consistent with a seasonal coast-inland mobility model as proposed for Late Palaeolithic Cantabria (Marín Arroyo, 2008; Straus, et al., 2002). In this sense, a clear relation between seasonal variation in insolation and distance to coast has been highlighted for the Asón river basin (García Moreno, 2008a).

Different site location preferences between the Older Magdalenian and Recent Magdalenian and Azilian also reflect changes in social organization of the foraging communities. The dispersal of sites along basins and their logistical character probably involved a transformation of the demographic structure of human groups, changing in size and composition at different times of year to better adapt to seasonal resource availability, as suggested by archaeological seasonality data (García Moreno, in press).

Finally, these new site location preferences suggest the loss of importance of large residential settlements, which in preceding periods could have acted as aggregation places (sensu Conkey, 1980) where different groups met, as has been proposed for El Mirón cave (Straus, 2006). In a context of dispersed population and mobility reduction, these large sites would lose their social and symbolic role, being replaced by small logistical settlements. As a consequence, large visual control of territory and a significant presence on the landscape were not crucial factors when choosing a settlement location any more; whereas places with direct access to local resources, such as those located on valley floors, were preferred for settlement. Without a need for aggregation sites, settlements probably lost their role as symbolic elements contributing to the construction of social landscapes, and were replaced by logistical sites with more practical, immediate functions.

5. Conclusions

The use of a specific, *ad-hoc* developed methodology for site location analysis enabled important information about Palaeolithic site location preferences and settlement patterns to be inferred. Thanks to the definition of a series of factors which could have participated in the decision-making process of site location choice, and their calculation using objective and quantifiable criteria, the specific properties of archaeological site locations can be highlighted, and put in relation with their function and role within a complex land use strategy. On the other hand, the comparison between sites used through the Late Glacial period with those inhabited for the first time in the Late Palaeolithic makes it possible to follow changes in settlement location preferences, and to put these changes in relation with the transformation and historical dynamics of Late Palaeolithic societies.

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Table 1

Site characteristics as indicated by the defined parameters.

Site	Group	Abs. Alt.	Rel. Alt.	Classif.	Landscape	Topography	Aspect
El Castillo	A	195	175	Cave	Main valley	Mid-slope	NE
Morín	B	57	22	Cave	Coastal plain	Mid-slope	NW
El Pendo	B	90	0	Cave	Coastal plain	Valley floor	S
La Garma A	A	84	53	Cave	Coastal plain	Mid-slope	S
El Piélago I	B	175	20	Cave	Main valley	Mid-slope	S
Rascaño	A	275	30	Cave	Main valley	Mid-slope	SW
El Salitre	B	450	160	Cave	Main valley	Mid-slope	W
El Otero	B	60	10	Cave	Subsidiary valley	Valley floor	W
La Chora	B	40	0	Cave	Subsidiary valley	Valley floor	SE
El Perro	B	70	70	Rock shelter	Coastal plain	Mid-slope	SE
La Fragua	B	130	130	Cave	Coastal plain	Mid-slope	SE
El Valle	B	58	0	Cave	Subsidiary valley	Valley floor	SE
Cullalvera	B	100	0	Cave	Subsidiary valley	Valley floor	NW
El Mirón	A	260	95	Cave	Subsidiary valley	Mid-slope	W
El Horno	B	200	0	Cave	Subsidiary valley	Valley floor	W
Cubera	B	200	8	Rock shelter	Main valley	Valley floor	E
Arenaza	B	195	50	Cave	Subsidiary valley	Mid-slope	SW
Atxeta	B	20	10	Cave	Subsidiary valley	Valley floor	N
Santimamiñe	A	138	120	Cave	Main valley	Mid-slope	S
Lumentxa	A	70	70	Cave	Coastal plain	Mid-slope	SE
Santa Catalina	B	35	35	Cave	Coastal plain	Mid-slope	NE
Abbitaga	B	65	40	Cave	Subsidiary valley	Mid-slope	SE
Goikolau	B	150	100	Cave	Subsidiary valley	Mid-slope	E
Laminak II	B	40	4	Cave	Subsidiary valley	Valley floor	NW
Ermittia	B	130	100	Cave	Main valley	Mid-slope	W
Urtiaga	A	160	20	Cave	Subsidiary valley	Mid-slope	SW
Ekain	A	90	20	Cave	Main valley	Mid-slope	NE
Erralla	A	230	40	Cave	Subsidiary valley	Mid-slope	N

Table 2

Contingency table displaying the frequency distribution of sites according to their *Topography*.

Topography	Group A	Group B
Valley floor	0	9
Mid-slope	9	19

Table 3
Mean hours of sunlight potentially received monthly by each site.

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
El Castillo	0	1	6	7	7	7	7	6	4	1	1	0	3.92
Morín	0	5	8	11	11	11	11	9	7	5	1	0	6.58
El Pendo	4	7	7	10	9	11	9	9	7	7	4	4	7.33
La Garma A	9	9	10	11	9	9	9	10	9	9	9	8	9.25
El Piélago II	0	2	4	5	5	5	5	5	4	2	0	0	3.08
Rascaño	3	3	6	8	8	7	7	8	6	4	3	2	5.42
El Salitre	2	4	5	6	6	7	6	5	5	4	3	2	4.58
El Otero	6	8	10	12	13	14	13	13	11	9	5	4	9.83
La Chora	8	9	10	12	13	14	14	12	12	9	6	7	10.50
El Perro	8	9	9	10	10	10	10	10	10	9	7	8	9.17
La Fragua	8	8	10	10	10	10	10	10	11	9	6	7	9.08
El Valle	0	4	8	11	12	13	13	11	9	6	0	0	7.25
Cullalvera	3	5	8	10	12	12	12	10	8	6	3	3	7.67
El Mirón	6	7	7	10	11	11	11	10	9	8	5	6	8.42
El Horno	5	7	9	10	11	12	11	10	9	8	3	4	8.25
Cubera	3	5	6	7	8	9	8	7	7	5	3	3	5.92
Arenaza	7	7	9	10	11	10	11	10	9	7	7	7	8.75
Atxeta	4	5	7	10	10	10	10	9	8	5	5	3	7.17
Santimamiñe	9	9	10	11	9	10	9	9	9	10	9	8	9.33
Lumentxa	0	0	1	11	6	8	5	4	0	0	0	0	2.92
Santa Catalina	0	5	9	12	13	13	13	11	9	7	1	0	7.75
Abbitaga	7	7	8	10	10	10	10	9	8	7	7	6	8.25
Goikolau	5	7	8	11	10	12	10	10	8	7	5	5	8.17
Laminak II	2	4	6	8	10	10	10	9	6	4	2	2	6.08
Ermittia	0	0	3	5	6	6	5	5	4	0	0	0	2.83
Urtiaga	6	7	9	10	10	10	10	9	8	7	6	5	8.08
Ekain	0	0	6	7	7	7	6	7	4	0	0	0	3.67
Erralla	0	1	5	6	5	6	6	5	4	2	0	0	3.33

Table 4
Kolmogorov-Smirnov test results for seasonal insolation.

Group	Spring	Summer	Autumn	Winter
Sample (N=28)				
Kolmogorov-Smirnov's Z	1.211	1.469	0.698	0.746
p	0.106	**0.027**	0.715	0.634
Group A (N=9)				
Kolmogorov-Smirnov's Z	.707	0.793	0.635	0.812
p	0.7	0.555	0.815	0.525
Group B (N=19)				
Kolmogorov-Smirnov's Z	1.081	1.586	0.558	0.724
p	0.193	**0.013**	0.914	0.671

Table 5

Variables for the sites analysed in this work. *Viewshed* expressed as % of visible surface within a 10 km radius. *Direction* = dominant direction of viewshed; * indicates more than 50% of viewshed in that direction. *Terrain* = coastal plain and hilly landscape (A), steep relief (B), abrupt relief (C). *CMWI* = Cost of Movement Weighted Index, without considering (1) and considering (2) rivers. *Coast* = distance (metres) to modern (1) and Pleistocene (-70 m) (2) shoreline. *Coast 3* = least accumulated cost paths to modern coast longitude.

Site	Viewshed	Direction	Terrain	CMWI 1	CMWI 2	Coast 1	Coast 2	Coast 3
El Castillo	4,54	SE	A	381.84	478.45	13852.50	21332.70	31814
Morín	4,54	SE*	A	277.17	281.87	2432.33	8280.44	3648
El Pendo	0,09	SE-S	A	543.13	583.11	5014.04	12681.40	19043
La Garma A	4,23	SW*	A	390.70	391.01	5292.03	12028.60	15150
El Piélago II	0,38	N	B	389.60	449.69	11898.30	25332.10	27458
Rascaño	1,03	W	C	499.51	537.19	14018.50	27263.30	31624
El Salitre	2,07	SW	C	570.64	521.82	16759.80	30935.00	37472
El Otero	4,02	E	A	371.87	405.12	8825.57	19509.70	12320
La Chora	3,89	S	A	366.45	386.26	8640.38	19182.20	11755
El Perro	23,11	E	A	351.36	370.91	0.00	7885.19	0
La Fragua	18,73	E	A	337.21	359.51	0.00	7020.02	0
El Valle	1,80	W*	B	460.74	459.76	12725.20	20281.20	15718
Cullalvera	3,26	W*	B	512.83	537.35	17694.00	25952.00	24539
El Mirón	3,75	W-NW*	B	551.54	545.55	18744.80	26755.00	24805
El Horno	1,46	W*	B	553.16	573.06	18941.80	26859.10	24990
Cubera	1,20	N	C	485.74	548.05	21703.30	31775.60	28532
Arenaza	1,74	S, NW	C	558.13	565.88	8329.35	18370.80	15111
Atxeta	2,54	E*	B	442.57	482.09	4889.40	12335.00	8688
Santimamiñe	4,39	SW	B	401.05	453.80	4614.72	9517.68	8673
Lumentxa	30,36	N-NE	B	403.93	339.36	213.60	4365.35	276
Santa Catalina	47,21	NW-E	A	308.75	332.86	0.00	3043.85	0
Abbitaga	1,20	S	B	492.04	512.12	2475.50	6775.18	3286
Goikolau	0,14	E*	B	488.64	501.21	2573.18	7178.09	4556
Laminak II	0,04	SE	B	443.03	556.84	2853.18	7192.79	3959
Ermittia	1,21	W	B	498.01	521.37	1750.18	8612.56	2362
Urtiaga	0,25	SW*	B	408.46	426.33	1684.12	7637.29	2931
Ekain	0,85	E*	C	488.92	542.87	6549.05	12041.30	10933
Erralla	0,46	SE*	C	554.17	564.16	8781.02	13813.30	17985

Figure 1

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Figure 2
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Figure 3
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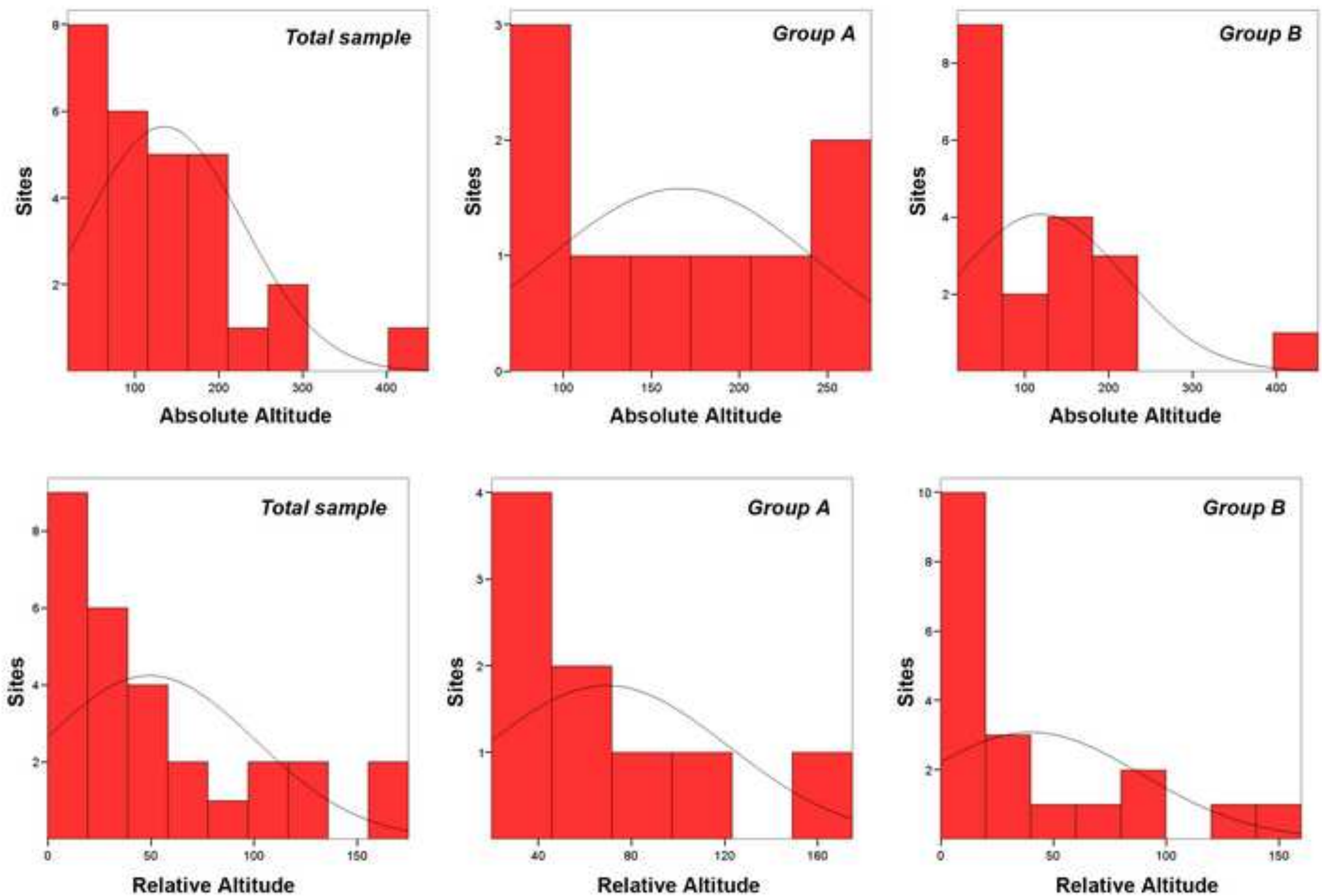

Figure 4
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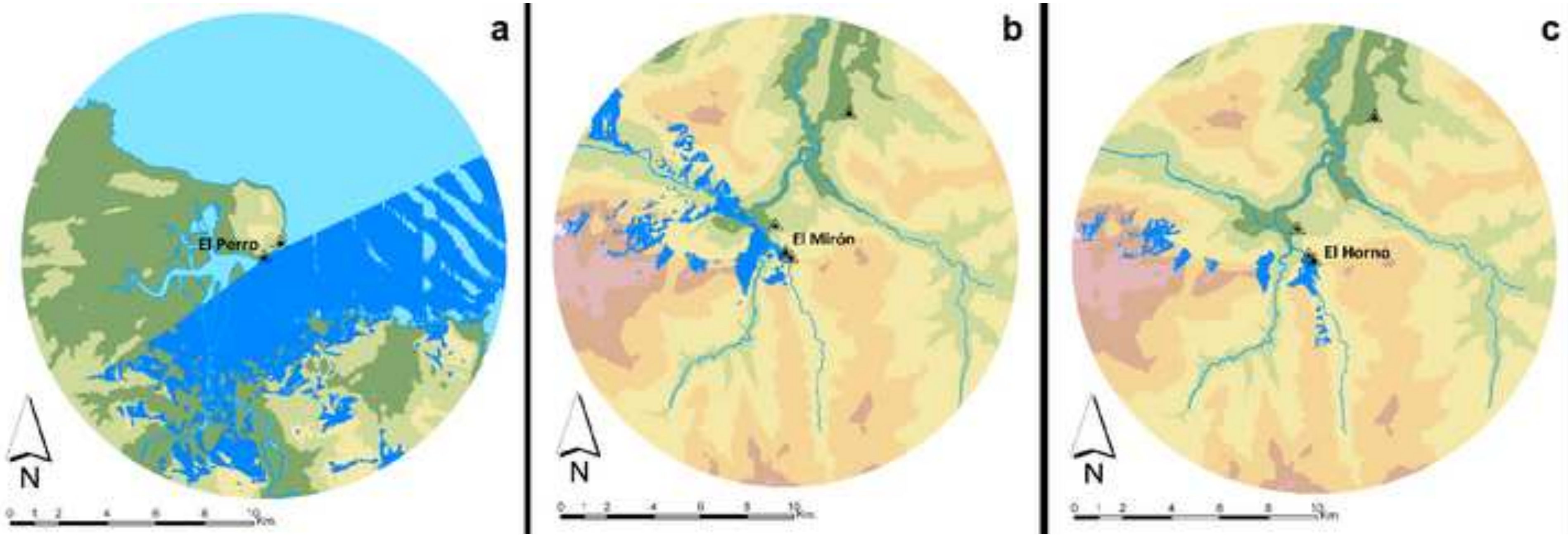

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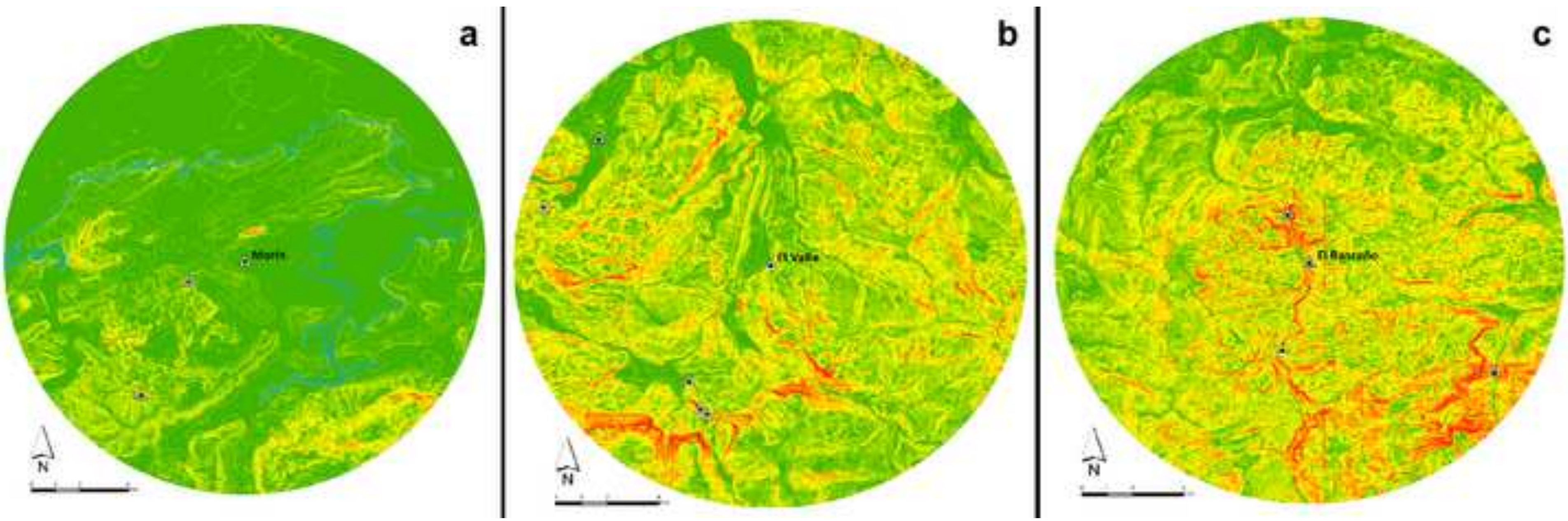

Figure 6

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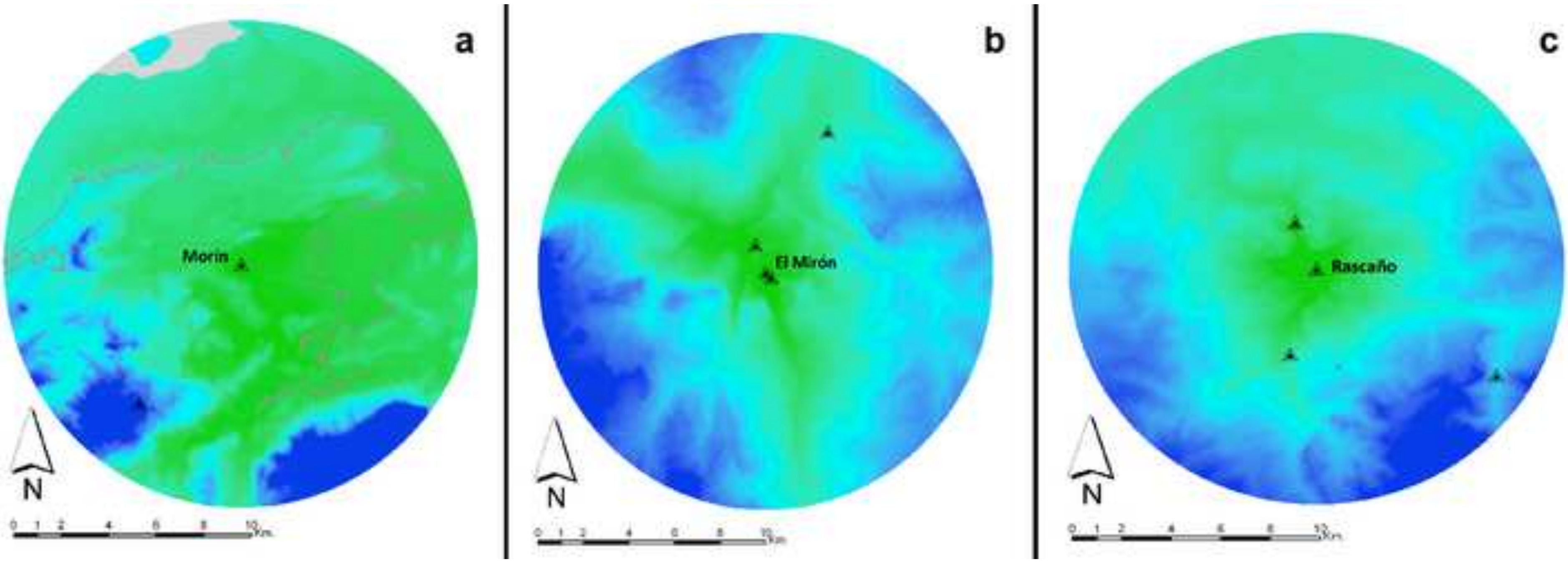

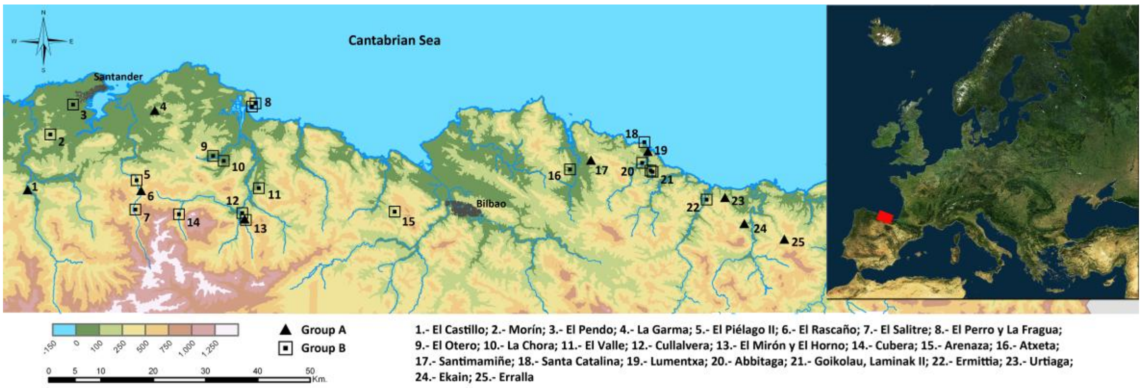

FIGURE 1: Map of the Cantabrian region and location of the sites considered in this work.

FIGURE 2: detail of the Digital Terrain Model (DTM) created from the Digital Elevation Model (DEM) generated for GIS analyses.

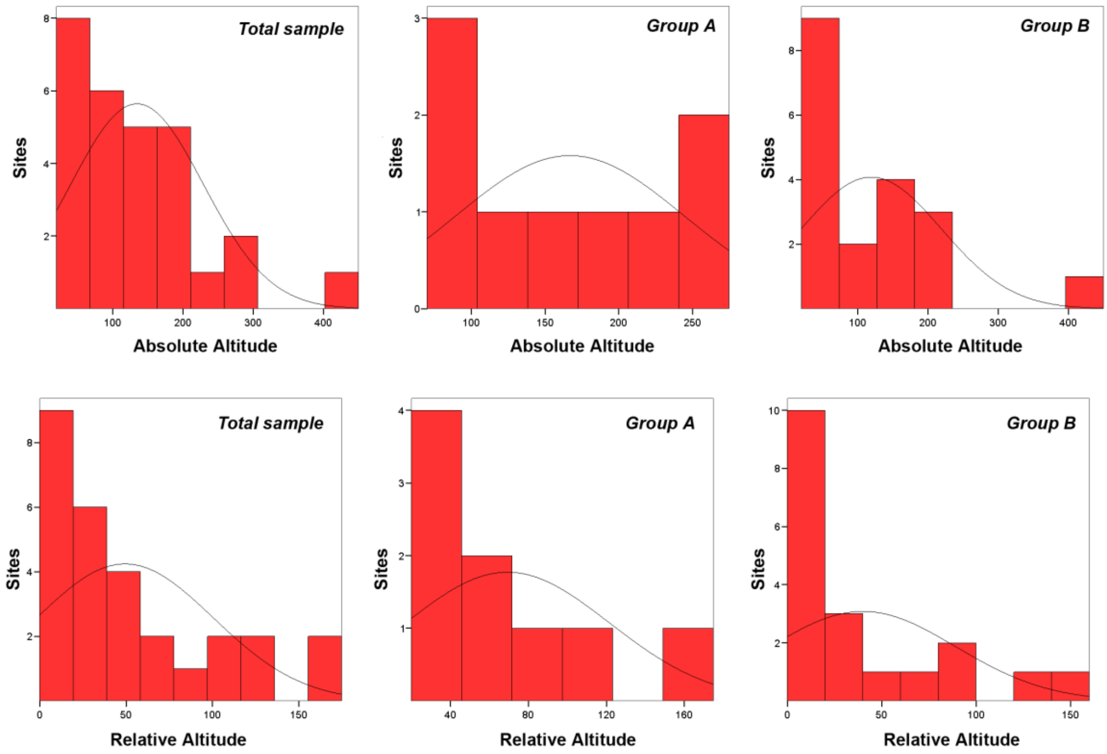

FIGURE 3: Distribution of sites according to their Absolute and Relative altitude.

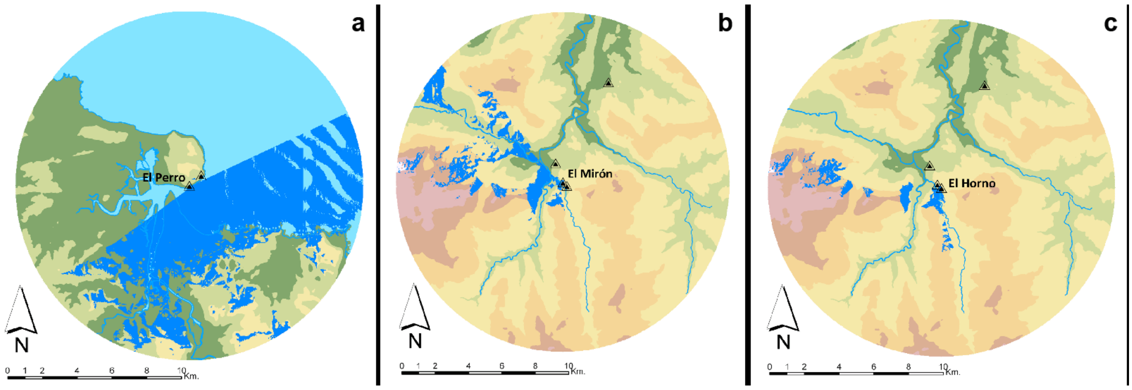

FIGURE 4: Viewshed analyses from a coastal site (a), a mid-slope located site (b) and a valley-floor site (c).

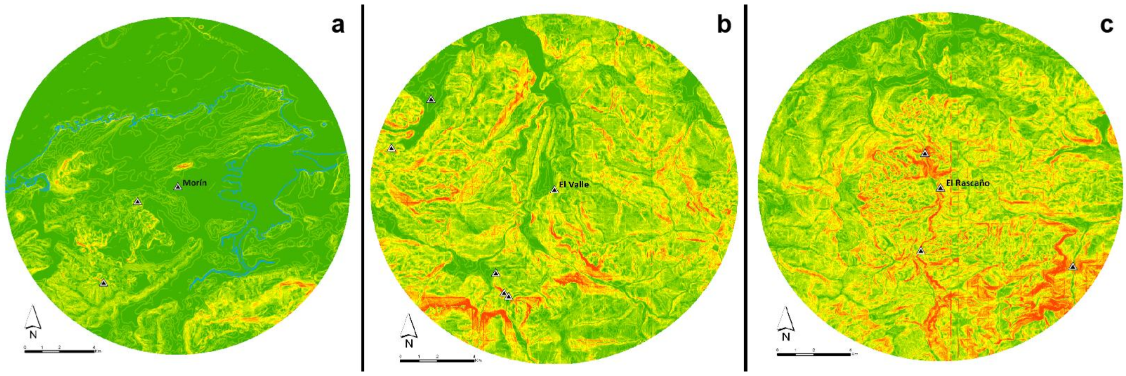

FIGURE 5: Slope analyses from a site in the coastal plain (a), a site in a hilly-steep landscape (b) and a site located in a steep landscape (c).

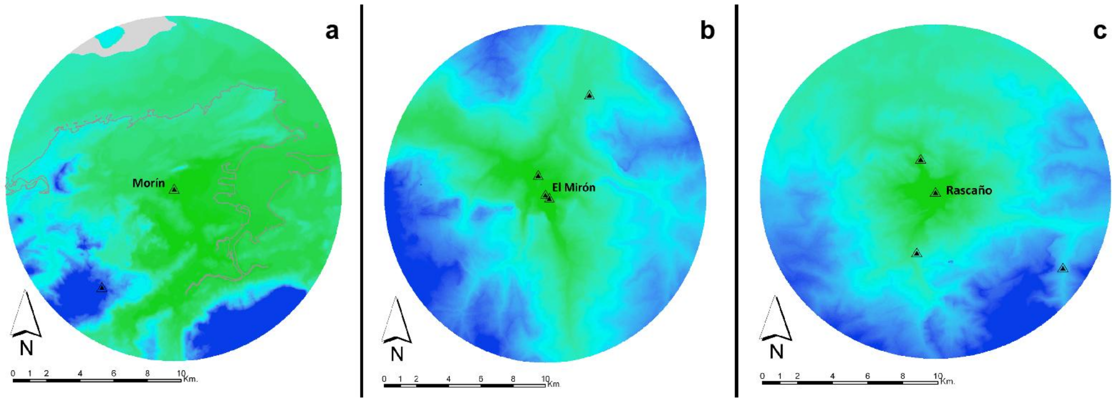

FIGURE 6: Accessibility analyses from a coastal site (a), a middle-valley located site (b) and a mountainous site (c).