Chapter 4
Not All Everywhere: Understanding Site Patterns and Deciphering Pastoral Territories in a Pyrenean High Mountain Area

Ermengol Gassiot-Ballbè, David Garcia-Casas, Laura Obea-Gómez, and David Rodríguez-Antón

Abstract Archaeology in high mountain areas is uncovering a large number of previously unknown archaeological sites in places that were once unheard of. Generally, these unique archaeological landscapes tend to be linked to the historical use of these areas for livestock farming, primarily as summer pastures. High-altitude sites, alpine and subalpine pastures, snow in winter, and grass in summer come together as factors in an equation that associates these archaeological remains with the consolidation and endurance of livestock farming in high mountain areas. However, many aspects remain to be resolved. What was livestock farming like, and how has it changed over time? And what about the societies that practised it? Are all the sites related to livestock activities? Did all these places make sense for livestock farming? This chapter seeks to answer the last of these questions and evaluate whether the different types of sites located in the high mountain areas of the Pyrenees follow a single pattern. If not, it aims to discern which variables influence the dispersion of sites related to livestock farming. In this sense, it seeks to advance the archaeological understanding of high mountain livestock territories. To do this, it uses the extensive archaeological record gathered from 20 years of research in the Aigüestortes i Estany de Sant Maurici National Park, in the southern central Pyrenees.

Keywords Mountain archaeology · Landscape archaeology · High-mountain livestock · Spatial analysis

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E. Gassiot-Ballbè (✉) · L. Obea-Gómez · D. Rodríguez-Antón
Departament de Prehistòria, Universitat Autònoma de Barcelona, Barcelona, Spain
e-mail: Ermengol.Gassiot@uab.cat

D. Garcia-Casas
Instituto de Ciencias del Patrimonio (INCIPIT), CSIC, Santiago de Compostela, Spain

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4.1 Introduction

The Pyrenees are one of the southern European mountain ranges that has experienced a boom in high-mountain archaeology since the beginning of the twenty-first century. On both slopes and throughout its extent, several research programs have revealed an extensive archaeological record covering at least the entire Holocene, which is gradually coming to light (e.g. Clemente et al. 2020; Garcia Casas 2018; Gassiot 2016; Gragson et al. 2015; Le Couédic 2010; Montes et al. 2019; Palet et al. 2019; Rendu 2003; Rendu et al. 2016).

In general, these studies have focused particularly on the development of livestock practices over time. In this regard, they have explicitly assumed the hypothesis that the use of high-altitude pastures has been one of the key activities in the occupation of the alpine and subalpine belts of the Pyrenees since the beginning of the Neolithic. The results of various fieldwork projects tend to support this premise, as a significant portion of the documented archaeological remains appear to be related to the management of different types of herds. However, archaeological and paleoecological evidence suggests that complementary activities, such as agriculture and, in more recent times, metallurgy, also played a role in the human occupation of the high mountains at certain periods.

One of the areas of the mountain range that has been the focus of the most intensive archaeological research is the Aigüestortes i Estany de Sant Maurici National Park (PNAESM). Located in the northwest of Catalonia, it spans nearly 40,000 hectares at the eastern end of the Maladeta granitic batholith, in the central Pyrenees. Its highest peaks slightly exceed 3,000 meters in elevation, while its main valley bottoms lie around 1,400 meters at their lowest points. This park features the most rugged terrain in the Catalan Pyrenees, shaped by a granitic substrate—a highly resistant rock—and contains the highest concentration of glacial lakes in the entire mountain range. The current climate is characteristic of high mountain areas in southern Europe, with annual precipitation ranging between 1,000 and 1,500 mm, depending on altitude. Average temperatures range from −4°C to 2–3°C in January and from 13°C to 19°C in July. However, throughout the Holocene, temperatures and precipitation levels have undergone constant fluctuations (Catalán et al. 2013, 2019).

Research at PNAESM began in 2004, led by the High Mountain Archaeology Group (GAAM) of the Universitat Autònoma de Barcelona (UAB) and the Milà i Fontanals Institute (IMF-CSIC), and is still ongoing. The research had a dual purpose. On the one hand, the park's management aimed to establish a comprehensive database of archaeological sites for heritage management and preservation. On the other hand, GAAM sought to initiate a research line focused on the patterns of human occupation and land use in high mountain environments over time.

The project was initially based on two main hypotheses: (1) Human presence in the area originated in the Early Holocene, primarily associated with hunting activities, and (2) from the Neolithic onwards, livestock farming became the dominant activity of successive human occupations, which largely took place during the warm season. Additionally, on a methodological level, the research was guided by another

hypothesis: that the scarcity of archaeological data was primarily due to a lack of systematic surveys rather than an actual absence of human presence. In this sense, previous studies, such as those conducted by Rendu (2003) in eastern Cerdanya, had already demonstrated human activity at high altitudes—often above 2,000 m asl—albeit in areas with somewhat gentler topography.

As in other areas of the Pyrenees, archaeological research in PNAESM has uncovered a large number of archaeological remains of different types. Due to their characteristics, most of these remains have been linked to livestock farming practices across different periods (Garcia Casas and Gassiot 2022; Gassiot 2016; Gassiot and Garcia Casas 2014). This paper examines the spatial distribution of the identified archaeological features to refine interpretations of their functionality and, as far as possible, to delineate the patterns that characterize high-altitude pastoral territories. In essence, it seeks to determine which factors and variables influence the location of these remains and whether their impact varies depending on the type of archaeological context. Ultimately, this analysis aims to enhance our understanding of past human occupation and land use in high mountain environments.

4.2 Methods and Materials

4.2.1 The Archaeological Record of PNAESM

The archaeological record of PNAESM derives from several archaeological survey campaigns, complemented by the excavation of some of the documented sites (Gassiot 2016; Gassiot et al. 2016; Gassiot et al. 2014). In all cases, excavations have revealed long occupation sequences, with recurrent human presence during various prehistoric and historic periods (Gassiot et al. 2015; Gassiot Ballbè et al. 2020a; Gassiot et al. 2023). The analysis of archaeological materials and intra-site patterns provide insights into changes in settlement organization, resource exploitation, and the activities carried out at these sites (Mazzucco et al. 2019; Obea, 2024; Obea et al. 2021; Rodríguez Antón, 2020; Tarifa, 2019). These data complement information from surface surveys, underscoring the limitations of surface records, which often conceal the variability and complexity of occupation dynamics at many sites.

However, the majority of the archaeological data from PNAESM comes from successive survey campaigns conducted mainly between 2004 and 2012. These surveys were based on systematic pedestrian inspections using transects, following an extensive methodology aimed at covering as much ground as possible across different zones into which PNAESM was segmented (Gassiot 2016; Gassiot et al. 2016). Only very steep slopes with poor terrain visibility, areas accessible only by climbing, and unstable slopes were excluded. The documentation of archaeological evidence was carried out using a recording system that was progressively refined to

align with parameters shared among different research teams working in the Pyrenees (Le Couédic et al. 2016b). In recent years, remote sensing techniques such as LIDAR, aerial and satellite imagery, as well as photogrammetry and drone-based documentation, have been introduced to enhance site recording.

The chronology of archaeological sites based solely on surface data is very difficult to establish, especially since diagnostic portable objects, such as ceramics, are generally absent. This scarcity of material is attested in archaeological contexts related to pastoral activities (Le Couédic et al. 2019; Vroom 1999). To address this, numerous small test pits have been excavated to identify occupation levels at certain sites and to obtain chronologically diagnostic materials and samples for absolute dating. Currently, 119 AMS dates are available for archaeological contexts from PNAESM, of which 52 come from samples obtained through probing at 41 different sites. The remaining dates are from excavations in extension. Overall, these dates reveal an occupation sequence of nearly 10,000 years at PNAESM, with increasing intensity over time. Additionally, with the progress of the research, it has become possible to propose the temporal framework for some of the architectural elements visible on the surface (Garcia Casas 2018; Garcia Casas and Gassiot 2022; Gassiot and Garcia Casas 2014).

In recent decades, there has been some debate within archaeology regarding the definition of "archaeological site," a concept that in the Spanish-French context is terminologically linked to the word "*yacimiento* / *gisement*". This debate has also arisen within the field of Pyrenean high mountain archaeology, largely driven by the ongoing presence of archaeological elements, more or less dispersed over relatively large areas (Colominas et al. 2023; Gassiot 2023; Le Couédic 2010; Le Couédic et al. 2016a). In short, the question is what qualifies as a "site" and how to define its boundaries, especially when there are no clear features delineating a group of remains. A large proportion of the archaeological remains documented in the high Pyrenees are architectural. On this basis, one alternative in this debate is to consider each "architectural structure" as the fundamental unit for documentation, assimilated to an area such as a hut, an enclosure, or any other individualizable functional element. This approach solves the problem of delimiting a site, but it has the drawback of eroding our overall understanding of the settlements. Specifically, it struggles to identify and characterize settlement units made up of multiple structures, such as a group of enclosures and huts operating synchronously. On the other hand, attempting to assimilate a site to a settlement entails the challenge of grouping different archaeological indicators into the same temporal reality. This is evidenced by the dynamics observed in the excavation of some of these sites, where different chronological phases overlap, each with its specific elements and spatial delimitations.

Acknowledging these limitations and complexities, this paper organizes the surface archaeological evidence from PNAESM into "(archaeological) sites," understood as settlements or places where activities were carried out that have left behind material remains. This classification is based on interpretive hypotheses derived from fieldwork observations and their subsequent analysis (Gassiot 2023), subject to revisions as the research continues. According to these parameters, a total of 378 sites with archaeological elements have been documented in PNAESM to date. Most of these

sites are defined by architectural remains visible from the surface and are primarily linked to livestock practices (Garcia Casas and Gassiot 2022; Gassiot 2016).

4.2.2 Classification of Archaeological Sites

This paper deepens the spatial analysis of the archaeological remains of PNAESM raised in some previous studies (mainly Garcia Casas 2018; Garcia Casas and Gassiot 2022; Gassiot 2016). For this purpose, we consider the full set of documented remains, without regard to their chronology. In other works, we have demonstrated how the relationship between different sites and the network of access roads, as well as their proximity to certain pasture areas, varied over time (Garcia Casas and Gassiot 2023; Gassiot et al. 2020b). However, in this case, the time variable is omitted, despite the risks involved. The purpose of the analysis presented here is twofold: first, it aims to identify the general patterns that influence the location of archaeological remains in PNAESM; and second, it seeks to establish the specific behavior of those sites related to livestock practices, in comparison to those that may be linked to activities other than those directly associated with herd management and the labour force involved.

Given the objectives of this analysis, the archaeological information has been simplified into a table containing summary details of the 378 sites with documented archaeological remains (Table Sites_PNAESM.csv). Their geopositioning has been carried out using x,y coordinates (UTM ETRS89, 31N), a method that simplifies their morphology, reducing it to a point and excluding the variable extension, which may be relevant for other types of analysis. The classification of sites into 11 different categories based on their morphology, as proposed by Garcia Casas (2018), Garcia Casas and Gassiot (2022), and Gassiot (2016), has been simplified into the following five classes to clarify the results:

- **Rock shelter** (Fig. 4.1): This refers to human occupations within small cavities, primarily located in hollows beneath large erratic granite blocks. There are no visible architectural elements on the exterior, although occasionally a small wall may be present to enclose the inner space. Excavated examples, such as the Abric de Les Obagues de Ratera and the Abric de l'Estany de la Coveta I, have shown occupations spanning from the Mesolithic to contemporary times (Gassiot 2016; Gassiot Ballbè et al. 2020; Gassiot et al. 2022). Except for the oldest phases, these are largely linked to livestock activities.
- **Livestock architecture** (Fig. 4.2): This category includes sites with visible architectural elements that are primarily, though not exclusively, associated with livestock activities. It encompasses rock shelters with adjacent enclosures, isolated enclosures, isolated huts, different types of enclosure and hut assemblages, and various herd management structures (Garcia Casas and Gassiot Ballbè 2022). Although isolated huts may be somewhat ambiguous, they are generally related



Fig. 4.1 Abric de Les Obagues de Ratera (top) and Portarró (bottom)

to livestock activities. Except for a few cases, the oldest of which date to the Late Neolithic (Gassiot et al. 2014), their chronology spans from Antiquity onwards.



Fig. 4.2 Examples of livestock-related architecture. Top: In the foreground, a hut from the Port de Rus settlement, excavated and dated to the fourteenth century. Behind it are enclosures from the same phase, and in the background, the remains of an older architectural complex. Bottom: A complex of enclosures and a hut, apparently from the modern/contemporary period, near the lake of Garguilhs de Jos



Fig. 4.3 View of the front wall and platform of charcoal kiln ESP-066 in a forested area

- **Charcoal kilns** (Fig. 4.3): Flat platforms, generally enclosed by a front wall, where charcoal production took place, with abundant residues remaining. In the nearby Vallferrera region, their chronology ranges from Roman times to the twentieth century (Gassiot 2023). These sites are linked to the production of fuel for metallurgical activity.
- **Stone circles** (Fig. 4.4): This category refers to stone circles, possibly cromlechs or tumuli, up to 6 meters in diameter. They have sometimes been linked to protohistoric funerary elements, particularly in the western Pyrenees, though their interpretation is not always clear (Agirre-García et al. 2018).
- **Others**: This category includes a very diverse range of evidence, the frequency of which is limited: occasional surface finds of lithic material, caches of ceramic vessels from the Bronze Age (Gassiot et al. 2014), some cave engravings, mining evidence, isolated walls, etc. These items stand out because they cannot be directly linked to livestock activities.

4.2.3 Spatial Analysis

The spatial analysis was carried out in two phases. The first phase involved creating a matrix of geographic data for the different sites in PNAESM. For this purpose, the following cartographic bases were used: the 5 x 5 m Terrain elevation model



Fig. 4.4 Stone circle at Pleta d'Erdo

(DEM) from the Institut Cartogràfic i Geològic de Catalunya (ICGC), the Ebro and Garonne basins from the EU-Hydro River Network Database 2006–2012 (vector) of Copernicus, the Land cover Map of Catalonia (2019–2022), and the Regional geological map of Catalonia 1:50,000 from the ICGC.

The following variables were derived directly from these maps: altitude, vegetation, distance to water (specifically the geometric distance, which integrates linear distance and altitude difference), and lithology of the geological substrate. The vegetation data are contemporary and do not account for the variability documented in vegetation landscapes throughout the Holocene. However, they provide insight into a scenario where the impact of cattle ranching, through the opening of pastures, is still visible despite the retreat of the past century. To some extent, hydrological information may also vary over time. On one hand, climate may influence the existence of certain sources, which during wetter phases of the middle Holocene may have been more frequent. However, this variation is likely negligible at the scale being used. On the other hand, the variability of watercourses over time may introduce some nuances in specific river sections, noticeable at a detailed level. This same situation can be assumed for the orography resulting from the dynamics of slopes in steep mountain areas. In both cases, this potential variability is disregarded.

Using the DEM, several thematic maps with a 5x5 m grid were generated with the free, multiplatform GIS software QGIS (v3.42) and SAGA, from which the values for the different sites were extracted based on their location. These variables include:

- **Slope Inclination:** Expressed in percentage to highlight steep gradients.
- **Slope Orientation (Aspect):** Initially, the azimuth value in degrees was obtained. To reclassify it into a continuous range from 1 (north orientation) to −1 (south

orientation), the cosine of the azimuth angle was derived using the raster calculator. In mid-latitude mountain areas, the north/south exposure of slopes influences insolation and the persistence of the snowpack.

- **Radiation at the Summer and Winter Solstices:** Accumulated radiation values in watt-hours per square metre (Wh/m^2) for the 24-hour periods of June 21 and December 21, 2024.
- **Visibility Index (VI):** Considered a 3000m radius, showing the visibility of each map cell from and to its surroundings, with a range between 0 and 1. High values indicate greater visibility.
- **Morphometric Protection Index (MPI):** Taking a 2000m radius, it measures the degree of protection from erosive and other geomorphological processes of a point in relation to its immediate surroundings. High values indicate sheltered points, while low values suggest more exposed locations.
- **Wind Exposure Index (WEI):** Considered in a 360º range. High values indicate greater exposure, and low values suggest protection from wind.
- **Topographic Position Index (TPI):** With an inner radius of 0 and an outer radius of 100m, this index evaluates the degree of topographic prominence of a point relative to its nearest surroundings.
- **TPI-based Landform Classification:** With a bandwidth of 75m, this index classifies the map cells into 10 different landform categories.
- **Terrain Ruggedness Index (TRI):** With a bandwidth of 75, it measures terrain ruggedness, indicating areas of greater or lesser topographical variation.

All these calculations have been made without considering the vegetation factor, which is highly variable over time due to both climatic and anthropogenic influences.

To provide a reference for contrasting the data matrix obtained for the 378 archaeological sites, a layer of the same number of random points has been generated, for which the same spatial information has been gathered. This set of points is considered to provide a representative sample of the terrain's characteristics. As such, the scope of dispersion for these random points was limited to the areas effectively prospected in PNAESM, excluding those that were not surveyed. Using QGIS's Nearest Neighbour Analysis, which calculates the quotient between the average observed distance and the average expected distance, a brief evaluation of the dispersion of both sets of points was performed.

The spatial information was processed along two axes. The first comparison contrasts the data matrices of all 378 archaeological sites with the 378 random points, aiming to identify which variables and factors exhibit significantly different behaviours in the locations of the archaeological sites relative to the terrain's configuration. The second comparison assesses the five groups of archaeological sites to determine whether their spatial distribution follows a homogeneous pattern or if certain categories exhibit particularities.

4.2.4 Statistical Analysis

Due to its great versatility, the statistical analysis was conducted using RStudio 4.1. The procedures followed varied depending on the nature of the data. First, the Shapiro-Wilk test from the RStudio 4.1 base library was used to confirm the non-normality of all quantitative variables (all continuous) across the different datasets (sites and random points). This was expected, given that the data are all influenced by highly rugged orography.

Next, the datasets for the sites and random points were compared across the different variables. For the quantitative variables, an initial descriptive analysis was conducted, calculating the mean, standard deviation, and quartiles (using the *numSummary* function from the *RcmdrMisc* library). This was followed by the nonparametric Mann-Whitney-Wilcoxon test (*wilcox.test* function from the *stats* library). When p-values exceeded 0.05, the analysis was repeated with two alternative hypotheses ("greater" and "less") to identify potential differences in parts of the distribution. Based on this test, the extent of discrepancies in the behaviors of the archaeological sites relative to the terrain structures, primarily shaped by the relief, was evaluated.

For the categorical variables (landform and soil cover), contingency tables were created to provide an initial view of the distribution of sites and random points across different categories. The behaviours of the two datasets for each variable was then compared using Pearson's Chi-squared Test for Count Data (*chisq.test* function from the *stats* library). In cases of soil cover, where some categories had fewer than 5 observations, Fisher's Exact Test for Count Data (*fisher.test* function from the same library) was used to analyze sample independence.

Subsequently, an analysis of the subsets of archaeological sites was conducted. As before, an initial descriptive statistical analysis was performed for the different variables and site types. A comparison of the behaviour of each variable was made between the different site categories. The Kruskal-Wallis test (*kruskal.test* function, *stats* library) was employed to compare multiple non-parametric samples. Dunn's post-hoc analysis (*dunnTest* function from the *FSA* library) was then used to compare multiple groups (i.e., the different site categories) based on the Kruskal-Wallis test, applying the Bonferroni correction to adjust p-values. This approach was selected over the Pairwise Wilcoxon Rank Sum Tests due to its increased sensitivity to unequal sample sizes and the presence of low values in some observations. For qualitative variables, which in this case incorporate lithology, similar procedures were followed, including pairwise comparisons and using Fisher's Test where some levels had small numbers of observations.

Table 4.1 Number of archaeological sites for each of the 5 summarized categories considered in this chapter

	Charcoal kiln	Livestock architecture	Rock shelter	Stone circle	Other
Number (%)	11 (291)	250 (66.31)	81 (21.43)	10 (2.65)	26 (6.9)

4.3 Results

4.3.1 The Archaeological Sites of PNAESM

The 378 archaeological sites documented in PNAESM are distributed across the various surveyed basins. A broad majority of these sites are characterized by the presence of architectural remains (Table 4.1 and Table Sites_PNAESM.csv). The second most common category is rock shelters, while the remaining categories are represented much less frequently. As noted in previous sections, inferring the functionality of an archaeological site based solely on surface data is highly challenging. However, the presence of enclosures, often interpreted as corrals, in many sites with architectural remains allows for a preliminary association with activities related to herd management (Garcia Casas and Gassiot 2022; Gassiot 2016). This pattern aligns with similar findings in other high mountain areas in the Pyrenees (Colominas et al. 2023; Le Couédic 2010; Palet et al. 2017 2019; Rendu 1998 2003; Rendu et al. 2016). In the case of rock shelters without visible exterior architecture, this association is more complex, particularly when there is no evidence of livestock stabling. These sites are generally linked to human habitation, potentially associated with the shelter of shepherds, but they may also have been used for other activities. Excavations of some of these shelters reveal evidence compatible with livestock (and possibly agricultural) practices dating back to the Neolithic (Gassiot 2016; Gassiot et al. 2020a; Gassiot et al. 2022; Gassiot et al. 2015; Mazzucco et al. 2019). Therefore, it can be posited that the two most common types of sites—architectural remains and rock shelters—are largely related to pastoral and possibly agricultural activities.

On the other hand, the morphology of the rest of the documented sites suggests some clearly distinguishable specific activities, as in the case of mining traces (inside "Others") or charcoal kilns. The function of the stone circles and burial mounds remains unclear. In some cases, they could have served as markers or possibly as burial sites, although the evidence supporting these interpretations is far from conclusive.

4.3.2 Spatial Distribution of Archaeological Sites

Figure 4.5 shows the distribution of the different types of archaeological sites within PNAESM together with that of the random points that constitute the contrast set. The values of the spatial dispersion analysis on a bidirectional plane of archaeological

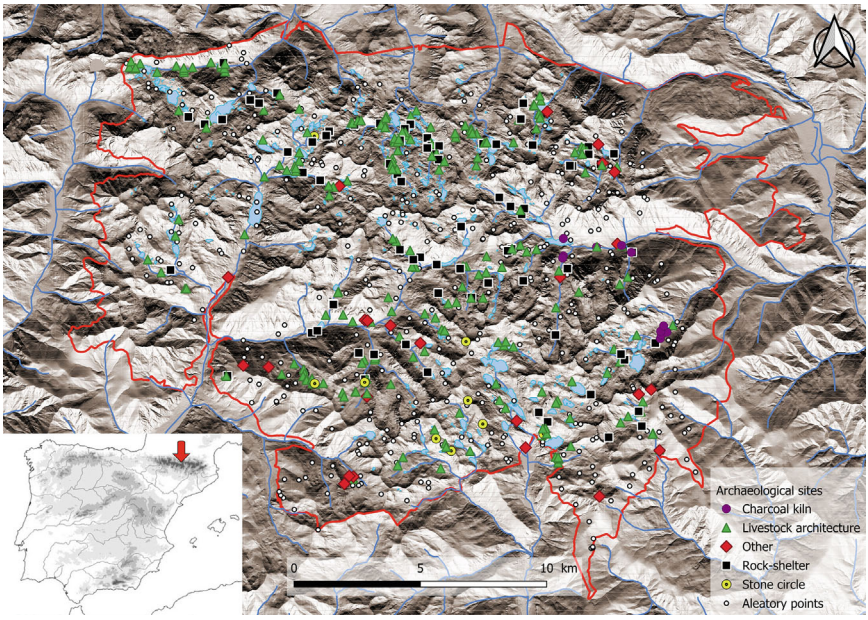


Fig. 4.5 Map of PNAESM with the location of the different types of sites and the random points

sites and random points are presented at supplementary material . Roughly speaking, the sites show a Nearest neighbour index of 0.514 and the points of 0.785, with Z-scores of −18.055 and −7.968. These data indicate that the random points show a greater randomness than the archaeological sites, which show a greater tendency to clustering.

The thematic maps with sites and random point are included in the supplementary material . The data matrices obtained from extracting the map values at the archaeological sites and random points are also provided in the supplementary material (Sites_Random_QUANT and Table Sites_Random_QUAL). Additionally, the supplementary material includes the results of the descriptive statistics for each variable, comparing archaeological sites and random points. Finally, to facilitate the reading of the data, for each quantitative variable its graphical output is presented in the form of boxplots and computing empirical cumulative distribution curves of the two sets of each one (Figure 4.6, all the graphics are in the supplementary material). For the different qualitative variables, the corresponding contingency tables and frequency histograms comparing sites and random points are presented (Figure 4.7, the graphics are in the supplementary material).

Table 4.2 summarizes the p-values from the comparisons of the different quantitative variables between sites and random points using the Mann-Whitney-Wilcoxon test. It is observed that 7 out of the 10 variables show a statistically significant difference ($p < 0.05$) between the archaeological sites and the random points, which are assumed to represent the terrain's distribution. Additionally, for the 3 variables

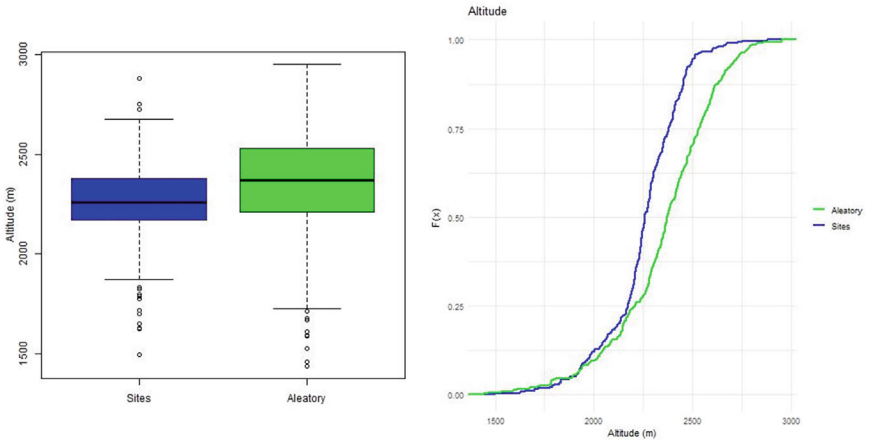


Fig. 4.6 Example of graphical output from the analysis of qualitative variables in the comparison between archaeological sites and random points, in this case of altitude. On the left, boxplot with a range = 1.5 for the plot whiskers. On the right,the empirical cumulative distributions curve of the altitudes of sites and random points. In both cases, the random points show a greater range of values and, especially, a greater proportion of values above 2400 m altitude

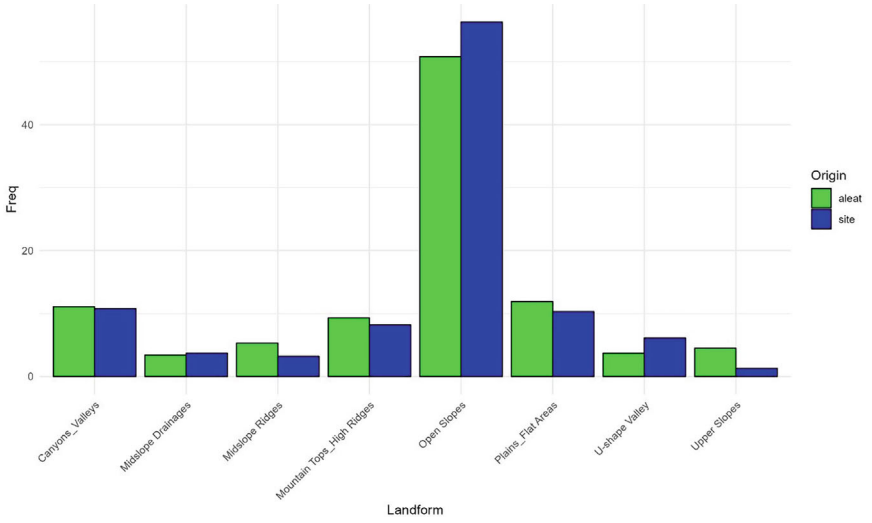


Fig. 4.7 Distribution of archaeological sites and random points in the different landform types

where the two-sided test did not reveal any significant differences, no differences were detected even when considering either a greater or lesser null hypothesis.

In the case of altitudes, the archaeological sites exhibit a lower altitudinal range and a preference for altitudes significantly lower than the overall terrain distribution. Specifically, 70% of the sites are situated below 2350 m, whereas fewer than 45% of

Table 4.2 P-values from the Mann-Whitney-Wilcoxon test comparing quantitative variables between archaeological sites and random points. P-values <0.05 are shaded to indicate significant differences

	Two-sided	One-sided (less)	One-side (more)
Altitude	**1.443e-12**		
Distance to water (Geometric/Euclidean)	**< 2.2e-16**		
Slope (%)	**< 2.2e-16**		
Aspect/Slope orientation	**0.2925**	0.1463	0.8538
Solar radiation (June)	**< 2.2e-16**		
Solar radiation (December)	**0.9919**	0.5042	0.4959
Topographic prominence (TPI)	**0.008319**		
Topographic ruggedness (TRI)	**< 2.2e-16**		
Morphometric protection (MPI)	**0.1966**	0.09829	0.9018
Wind exposure (WEI)	**< 2.2e-16**		
Visibility (VI)	**1,737e-11**		

the random points fall below this threshold. On the higher end, only 20% of the sites are located above 2406 m, while nearly 45% of the random points are positioned above this altitude. In total, 82.2% of the archaeological sites are found between 2000 and 2500 m asl, a range that covers just over 60.5% of the surveyed land in PNAESM.

The difference in the geometric or Euclidian distance to water between the archaeological sites and the random points is even more pronounced. Approximately 41.3% of the sites are located less than 100 m from a water source, such as a river or lake, and almost two-thirds (65.3%) are within 200 m of water. In contrast, only 17.2% and 30.2% of the random points are within these respective distances. To find 41.3% of the random points, one must be more than 286 m from water, and 65.3% are found at distances greater than 460 m. This suggests that the archaeological sites tend to be clustered near water sources, which is notable even within PNAESM, an area rich in lakes, rivers, and streams of various sizes.

Slope gradients also show significant differences between the archaeological sites and the random points. Most of the archaeological sites (62.7%) are situated on slopes of less than 30%, a proportion more than three times higher than that of the random points in the same gradient range. While archaeological material has been found on some ridges, with sites located on slopes exceeding 150%, these are rare occurrences. Overall, 80% of the archaeological sites are found on slopes below 41.4%, while the same percentage of random points are located on much steeper slopes, up to 80.6%. This indicates that archaeological sites are generally located not only near water but also in areas with gentler slopes.

In high mountain areas, slope orientation plays a crucial role, as it influences sunlight exposure and, consequently, the persistence of snow cover. For instance,

medieval villages in the Pyrenees that were permanently occupied are typically situated on south-facing slopes. In the orientation map analysis, we focused on the degree of southward (value −1) or northward (value 1) slope orientation. Values below 0 indicate a predominantly southward orientation, with 0 representing an eastward or westward disposition.

The archaeological sites exhibit a slightly more southerly orientation than the random points: 52% of the sites have values below 0, compared to 48.1% of the random points. Additionally, 35.1% of the sites are located on slopes with values below −0.5, while only 30.3% of the random points are similarly oriented. However, the differences between the two datasets are not statistically significant. On the other hand, 32.4% of the sites have a northward orientation with values ranging from 0.5 to 1, compared to 35.8% of the random points. Overall, the orientation of the slope does not appear to have a significant influence on the presence of archaeological sites, unlike slope inclination.

In mountainous regions, solar radiation on the ground is largely determined by slope orientation, though other factors, such as climatic conditions, latitudinal position, prominence, and exposure, also play a role. The absence of a strong southern orientation in the archaeological sites seems to be reflected in the radiation they receive during the winter solstice. Specifically, 34.9% of the random points are located in poorly insolated areas (receiving less than 0.5 Wh/m^2), while only 24.1% of the archaeological sites fall into this category. At the other extreme, only 15.1% of the sites receive more than 1.2 Wh/m^2 of radiation, compared to 25.1% of the random points. However, the middle range of solar radiation (0.4 to 0.9 Wh/m^2) shows similar frequencies for both the archaeological sites (59.8%) and random points (58.2%), with no significant differences observed.

Regarding solar radiation at the summer solstice, the situation differs. The sun's higher altitude at this season increases the areas receiving more insolation. As a result, the archaeological sites tend to be located in areas that receive notably higher solar radiation. Only 7.7% of the sites have radiation values lower than 6 Wh/m^2, compared to 35.2% of the random points. Conversely, 23.8% of the sites receive more than 7 Wh/m^2 of radiation, compared to just 10.1% of the random points. The differences between these two groups are highly significant. This discrepancy in solar radiation, particularly between the summer and winter solstices, may provide insights into the factors influencing the selection of archaeological sites, as noted in previous studies (Garcia Casas 2018).

Greater topographic prominence could contribute to increased insolation at archaeological sites or provide more defensible locations in times of conflict. However, the Topographic Position Index (TPI) values suggest that archaeological sites tend to be situated at slightly lower elevations relative to their immediate surroundings compared to random points. Specifically, 66.1% of archaeological sites have a TPI < 0, meaning they are positioned in lower-lying areas relative to their surroundings within a 100 m radius. This percentage is lower for random points (59.3%). While random points exhibit a greater number of extreme low TPI values, they also display a higher frequency of elevated values; for instance, 17.5% of random points have a TPI > 7, compared to just 11.1% of archaeological sites. Overall, the

differences between the two datasets are statistically significant, with archaeological sites generally exhibiting lower TPI values and a narrower range.

The Topographic Ruggedness Index (TRI) and Wind Exposure Index (WEI) are two additional orographic variables that show significant differences between archaeological sites and random points. Archaeological sites tend to have lower TRI values, with a smaller range (0 to 6.4) compared to random points (0 to 12.5). Only 42% of the sites have a TRI above 1, and just 8.2% exceed 2, whereas 39.2% of random points have TRI values above 2, and 13.2% surpass 3. Similarly, WEI values, which range from 0 to 1.3, are generally lower at archaeological sites. Only 29% of sites have a WEI above 1.05, compared to 62% of random points, and just 14% of sites exceed 1.1, compared to 38% of random points. This suggests that archaeological sites tend to be located in areas with lower wind exposure compared to the general terrain. In contrast, no significant differences are observed between archaeological sites and random points in the Morphometric Protection Index (MPI).

The Visibility Index (VI) indicates that archaeological sites are not typically established in highly visible locations. On the contrary, most sites exhibit significantly lower VI values compared to random points. Only 31.5% of sites have a VI > 0.07, and just 5.5% exceed 0.15, whereas these figures are substantially higher for random points (56.3% and 16.7%, respectively). However, there is one notable exception: site VB-107, which has a VI of 0.43—far higher than the next most visible site and also exceeding the highest random point values. This site is likely the only small fortified structure or tower identified in the area, strategically positioned to provide extensive visibility over the Taüll valley and a large section of the Boí valley.

Regarding landform types, 56.3% of archaeological sites and 50.8% of random points are located on "open slopes", indicating a slight overrepresentation of sites in this category. A similar pattern is observed in "U-shaped valleys" (6.1% vs. 3.7%). In contrast, random points are more prevalent in other terrain units, with the largest overrepresentations in "upper slopes" (4.5% vs. 1.3%) and "midslope ridges" (5.3% vs. 3.2%), both of which are elevated locations. The Chi-squared test ($p = 0.084$) suggests that these differences are not highly significant. Nevertheless, the underrepresentation of archaeological sites on peaks and ridges is notable, despite the occasional presence of lithic materials or stone circles in these areas.

The comparison of land cover types reveals distinct patterns. Archaeological sites are strongly overrepresented in current "meadows and grasslands" (61.9% vs. 34.1%) and in "peat bogs" (3.7% vs. 0.5%). In contrast, their presence is significantly lower in other land cover types, particularly in forested areas, rocky terrain, and lakes. The latter discrepancy may be influenced by sampling issues in dammed water bodies, where artificially raised water levels obscure potential sites. The overpresence of archaeological sites in current grasslands areas is both evident and statistically significant. Due to low counts in some categories, Fisher's Exact Test was performed, yielding a highly significant p-value (1.898e–13), confirming the strong divergence between site and random point distributions.

4.3.3 *Differences and Similarities in the Spatial Distribution of Site Types*

Archaeological sites are not a homogeneous group. While the data—primarily derived from surface surveys—require careful interpretation, most sites appear to be associated with activities directly related to livestock management. In previous studies, we have noted how even within settlements linked to habitation and livestock practices, distinct spatial patterns emerge across different chronological periods in relation to specific variables (Garcia Casas and Gassiot 2023; Gassiot Ballbè et al. 2017; Gassiot et al. 2020b). In this analysis, we set aside the temporal variable to examine whether settlements related to livestock practices exhibit distinct characteristics compared to other types of archaeological sites.

A multiple comparison of the five types of archaeological sites across eleven quantitative variables using the Kruskal-Wallis test yielded p-values below 0.05 for all variables except distance to water ($p = 0.0586$). We then conducted Dunn's Kruskal-Wallis Multiple Comparisons to assess differences between specific groups for each variable. Table 4.3 presents the resulting p-values. Significant differences were found in all but two variables: slope orientation and visibility. The lack of significance in slope orientation aligns with our earlier observation that no clear pattern exists in relation to the predominant orientations of the terrain. Meanwhile, although visibility values did not differ significantly between site types, they were consistently lower than those observed for the random points.

Overall, archaeological sites are located near water. Among them, only Stone Circles have more than 12% of their cases situated over 500 meters from a river or lake, while at the opposite extreme, all Charcoal Kilns are found within this distance. However, differences in this variable are not statistically significant among site types, except in the comparison between Charcoal Kilns and Stone Circles, which have the shortest and longest distances to water, respectively.

Archaeological sites also follow a distinct pattern compared to the surrounding terrain in terms of ruggedness, favouring less irregular surfaces. However, no significant differences in Topographic Ruggedness Index (TRI) were observed among site types, except between Rock shelters and Others with Livestock Architecture. Rock shelters tend to be in rougher terrain, sometimes in like-scree areas, while Livestock Architecture is found in smoother areas, except for site VB-016, which consists of an enclosure next to a rock shelter in a scree area.

In terms of slope inclination, archaeological sites are generally located on moderate slopes. However, significant differences emerge when comparing Rock shelters and Livestock Architecture. Notably, Rockshelters are absent from slopes below 10%, whereas 12.7% of Livestock Architecture sites are found on such gentle slopes. Additionally, only 18.5% of Rock shelters are located on slopes between 10% and 20%, while this figure rises to 46.8% for Livestock Architecture sites. This difference likely stems from the physical constraints imposed by the availability of natural rock cavities. In summary, across these three variables (distance to water,

Table 4.3 P-values Dunn's Kruskal-Wallis Multiple Comparisons test (Bonferroni correction) comparing quantitative variables between the different archaeological site types. P-values <0.05 are shaded

Altitude				
	Rock shelter	Charcoal kiln	Stone circle	Other
Livestock architecture	1.00000	**7.380489e-05**	**1.062453e-02**	7.591575e-01
Rock shelter		**1.102287e-04**	2.135778e-02	1.00000
Charcoal kiln			**2.968338e-07**	**1.312003e-03**
Stone circle				**2.119180e-03**
Distance to water (Geometric/Euclidian)				
	Rock shelter	Charcoal kiln	Stone circle	Other
Livestock architecture	1.00000000	0.11859450	1.00000000	1.00000000
Rock shelter		0.15991582	1.00000000	1.00000000
Charcoal kiln			**0.03951237**	0.51720344
Stone circle				1.00000000
Visibility				
	Rock shelter	Charcoal kiln	Stone circle	Other
Livestock architecture	1.00000000	0.1273350	0.4321247	0.5024504
Rock shelter		0.1578120	0.5101780	0.6779761
Charcoal kiln			1.00000000	1.00000000
Stone circle				1.00000000
Slope (%)				
	Rock shelter	Charcoal kiln	Stone circle	Other
Livestock architecture	**4.091724e-06**	4.143113e-01	1.00000000	2.211087e-01
Rock shelter		1.00000000	2.021551e-01	1.00000000
Charcoal kiln			7.630935e-01	1.00000000
Stone circle				9.794277e-01
Aspect/Slope orientation				
	Rock shelter	Charcoal kiln	Stone circle	Other
Livestock architecture	1.00000000	1.00000000	1.00000000	1.00000000
Rock shelter		1.00000000	0.9277808	1.00000000
Charcoal kiln			0.5521466	1.00000000
Stone circle				1.00000000
Solar radiation (June)				
	Rock shelter	Charcoal kiln	Stone circle	Other
Livestock architecture	**1.911861e-03**	**5.349399e-03**	**9.191554e-03**	1.148501e-01
Rock shelter		6.642989e-01	**5.692028e-05**	1.00000000
Charcoal kiln			**1.177507e-05**	1.00000000
Stone circle				**2.276089e-04**

(continued)

Table 4.3 (continued)

Altitude				
	Rock shelter	Charcoal kiln	Stone circle	Other
Solar radiation (December)				
	Rock shelter	Charcoal kiln	Stone circle	Other
Livestock architecture	0.7545140453	**0.0062877133**	0.0872037743	1.00000000
Rock shelter		0.1015502722	**0.0159024091**	1.00000000
Charcoal kiln			**0.0001660926**	0.1835351543
Stone circle				**0.0493606808**
Topographic ruggedness (TRI)				
	Rock shelter	Charcoal kiln	Stone circle	Other
Livestock architecture	**4.099170e-07**	2.399940e-01	1.00000000	**4.465572e-02**
Rock shelter		1.00000000	2.537559e-01	1.00000000
Charcoal kiln			9.142790e-01	1.00000000
Stone circle				8.322254e-01
Morphometric protection (MPI)				
	Rock shelter	Charcoal kiln	Stone circle	Other
Livestock architecture	1.085299e-01	2.426311e-01	**1.486596e-03**	1.00000000
Rock shelter		1.00000000	**4.534693e-05**	1.00000000
Charcoal kiln			**1.048466e-04**	1.00000000
Stone circle				**0.0043244727**
Topographic prominence (TPI)				
	Rock shelter	Charcoal kiln	Stone circle	Other
Livestock architecture	1.00000000	1.00000000	**0.0009972952**	1.00000000
Rock shelter		1.00000000	**0.0004611063**	1.00000000
Charcoal kiln			**0.0157942977**	1.00000000
Stone circle				**0.0064333247**
Wind exposition (WEI)				
	Rock shelter	Charcoal kiln	Stone circle	Other
Livestock architecture	1.00000000	**4.600180e-02**	**9.992828e-04**	1.00000000
Rock shelter		7.208761e-02	**4.020612e-04**	1.00000000
Charcoal kiln			**1.132951e-05**	9.558078e-01
Stone circle				**6.943169e-04**

TRI, and slope inclination), archaeological sites consistently exhibit distinct characteristics compared to the random points, reinforcing clear spatial patterns in their distribution.

This relative uniformity disappears when considering altitude, where differences between site types are both notable and, in most cases, statistically significant. Several key aspects stand out. First, the Rock shelters, Livestock Architecture, and Others

sites—both associated with livestock and human habitation—exhibit similar elevations, following the general distribution of archaeological sites described earlier. In contrast, Charcoal Kilns are concentrated at lower elevations, with 54.5% situated below 2000 m asl and 100% below 2150 m asl. At the opposite extreme, all Stone Circles are found above 2150 m asl, with 55.6% located above 2500 m asl.

When considered as a whole, archaeological sites do not show a clear differentiation from the surrounding terrain in terms of winter solar radiation. However, significant differences emerge between specific site types, particularly between Charcoal Kilns, Livestock Architecture, and Stone Circles. The Charcoal Kilns are predominantly found in shaded areas, with 63.6% receiving less than 0.5 Wh/m^2 of irradiation on December 21, and 100% below 1 Wh/m^2. In comparison, these figures are 20.6% and 68.3% for Livestock Architecture and 0% and 22.2% for Stone Circles, respectively. The high winter solar exposure of Stone Circles is largely due to their higher elevation.

In summer solar radiation, archaeological sites exhibit distinct patterns compared to the surrounding terrain, with even greater discrepancies between site types than in winter. Once again, Stone Circles receive significantly higher solar radiation than all other site types, with 77.8% exceeding 7 Wh/m^2. Livestock Architecture sites also tend to be in sunnier locations compared to most other site types, second only to Stone Circles. 58.7% of these sites receive more than 6.7 Wh/m^2 at the summer solstice, whereas this proportion never exceeds 39% for the other site categories. In contrast, Charcoal Kilns are again located in the least sunny areas, with 72.7% receiving less than 6.5 Wh/m^2.

Overall, archaeological sites are not situated in particularly prominent locations relative to their immediate surroundings. This pattern holds true for all site types except for Stone Circles, which are found in highly elevated and prominent areas. This is illustrated by the fact that 88.8% of Stone Circles have $TPI > 4$ and 66.7% a $TPI > 8$. In contrast, the other site types predominantly return negative TPI values, with 54% to 66.7% of sites falling below $TPI = -1$, and 15.9% to 36.4% even below $TPI = -8$.

For the remaining quantitative variables, such as the Wind Exposition Index (WEI) and the Morphometric Protection Index (MPI), archaeological sites as a whole show a significant divergence from random points. However, notable differences exist between site types, particularly in WEI. Once again, Stone Circles are located in highly wind-exposed areas, showing a distinct overexposure compared to general terrain patterns. Their wind exposure is even significantly higher than that of random points—78.8% of Stone Circles have a $WEI > 1.1$, whereas only 38% of random terrain points exceed this value. In contrast, the other archaeological site types display much lower WEI values, even lower than the terrain average. Charcoal Kilns, along with Rock shelters and Livestock Architecture (to a lesser extent), are particularly associated with sheltered locations that offer protection from the wind.

A similar pattern emerges in MPI. Here, Stone Circles exhibit significantly lower values than all other site types. At the opposite extreme, Charcoal Kilns show somewhat higher MPI values, but the other three categories—Rock shelters, Livestock

Architecture, and Other—display more homogeneous behaviour, with no significant differences between them.

The analysis of qualitative variables further highlights differences between site types (Table 4.4). One of the most notable divergences between archaeological sites and random points is in land cover type, where distinctions between different site categories are also evident. A key difference is the exclusive occurrence of Charcoal Kilns in forested areas. Additionally, significant differences emerge between sites with architecture and Rock shelters/Other sites, primarily due to the latter being more frequently located in rocky areas (25.9% and 26.9%, compared to 17.1% for architecture sites) and forested regions (16% and 19.2%, compared to 4.8%). However, across all site types except Charcoal Kilns, the most common ground cover is Meadows and Grasslands. In all cases—except for the "Other" category (38.5%)— more than 50% of the sites are found on this type of ground cover.

The differences observed in the landform units where the sites are located are mainly due to the specific situations of the Stone circles, which 66.7% are found in notably elevated areas such as "Mountain Tops/High Ridges" (55.6%) and "Midslope Ridges" (11.1%). These are landform units where the other site types have a very marginal presence, with the exception of the Other category, which in 25% of the cases is located in "Mountain Tops/High Ridges". The predominant landform unit in the other five archaeological site types is "Open Slopes". Only in the Other group

Table 4.4 Fisher's Exact Test for Count Data P-values comparing qualitative variables between the different archaeological site types. P-values <0.05 are shaded

Land Cover				
	Rock shelter	Charcoal kiln	Stone circle	Other
Livestock architecture	**3.572371e-02**	**2.303776e-11**	1.000000e+00	**2.429353e-02**
Rock shelter		**4.079571e-02**	1.000000e+00	1.000000e+00
Charcoal kiln			**5.953799e-05**	**1.170338e-03**
Stone circle				1.000000e+00
Landform				
	Rock shelter	Charcoal kiln	Stone circle	Other
Livestock architecture	1.000000000	1.000000000	**0.001428209**	**0.045801016**
Rock shelter		1.000000000	0.058504397	1.000000000
Charcoal kiln			0.472731603	1.000000000
Stone circle				1.000000000
Lithology				
	Rock shelter	Charcoal kiln	Stone circle	Other
Livestock architecture	1.000000	**1.375729e-03**	1.000000	**6.145568e-05**
Rock shelter		**9.769856e-05**	1.000000	**3.713778e-05**
Charcoal kiln			**4.524887e-02**	1.000000
Stone circle				1.000000

does this not reach 45% of the cases, specifically representing 33.3%, which creates a significantly different pattern compared to the sites with architecture. On the other hand, charcoal kilns stand out because 36.4% of them are found in valley areas ("U-shape Valleys" and "Canyons/Valleys"), a higher proportion than in the other types.

Finally, certain particularities in the type of lithological substrate where the different types of archaeological sites are located can also be observed. In this case, Charcoal kilns are significantly distinguished from all other types because 90% of them are located in areas with sedimentary rocks, a situation explained by their geographic concentration in a specific area of PNAESM. The significant difference between sites with architecture and rock shelter sites comes from the lower presence of the latter outside plutonic rock zones. Similarly, the difference between the former and the Other category mainly lies in the remarkable presence of the latter in calcareous areas (20.8%).

4.4 Discussion

The spatial analysis of the archaeological sites in PNAESM provides valuable insights into their spatial distribution. The Nearest Neighbor Index quantifies the observed tendency for aggregation in the dataset, though it does not explain the factors influencing the irregular arrangement on the ground. Analysing the locations of these sites based on 14 geographical variables and comparing them with the terrain behaviour in the study area, using a set of random points, yields further interesting insights.

Overall, the archaeological sites are preferentially and significantly located in the upper fringe of the current subalpine belt, in proximity to the alpine one. Specifically, 60.3% of the sites are found between 2000 and 2400 m asl, near the current timberline. Their frequency significantly decreases both below this altitude and above it. Additionally, these sites tend to be near water, situated on slopes with moderate inclinations, and located in grassy areas.

These four factors define parameters that attract the presence of archaeological sites, which we had previously noted (Gassiot 2016). Their distribution is consistent with the hypothesis that links the archaeological record with cattle ranching activities. The present-day grasslands are the result of extensive historical processes and, without doubt, at some periods below 2400 metres, they were former forested areas (Catalán et al. 2013, Gassiot et al. 2020b). However, the presence of archaeological sites in them introduces a possible cause for the disappearance of the forest in these places or indicates an incentive for human settlement in an already deforested area. Access to pasture—whose productivity decreases with increasing slope—and water are fundamental for herd management. The scarcity of sites below 2000 m asl can be partly explained by the fact that this altitudinal range largely corresponds to steep slopes in the main valleys, and perhaps by the preference for reserving lower altitudes as forest areas, which could provide materials such as firewood (Obea 2024).

The presence of these types of sites in high mountain areas is generally linked to the use of high-altitude pastures during the summer and early autumn (Garcia-Casas et al. 2022; Gassiot 2016; Palet et al. 2017; Rendu 2003; Rendu et al. 2016, among others). Although more detailed archaeozoological analyses are lacking, this inference is based on circumstantial evidence, such as the high altitude of the settlements. The soil acidity in PNAESM restricts the preservation of skeletal remains, making archaeozoological studies challenging and limiting the ability to determine the season of death of the animals consumed. While the analysis of the position of the archaeological sites in the terrain does not directly provide specific evidence to resolve this issue, it can offer additional clues that strengthen the inference of seasonality.

Historically, permanent settlements in the Pyrenees' mid-mountain areas, which have not been located above 1600/1700 m since the twelfth century, have been positioned on south-facing slopes that receive more sunlight than surrounding areas. These factors lead to higher daytime temperatures year-round and, during the colder months, a thinner and shorter-lasting snowpack. Snow thickness directly impacts mobility and, in particular, the ability of livestock to feed independently on pasture.

Following this reasoning, any potential winter or year-round occupation of the archaeological sites in PNAESM would be reflected in their location on south-facing slopes and in areas with high solar radiation, particularly in winter. However, the analyses clearly show that, as a whole, the archaeological sites in PNAESM do not exhibit a preference for southern orientations. Similarly, they do not tend to settle in areas with high winter solar radiation (Garcia Casas 2018). On the contrary, their behaviour mirrors the parameters of the terrain, even avoiding areas with higher solar radiation, which are mainly located in elevated peak areas.

On the other hand, in the case of summer solar radiation, archaeological sites appear to be located in sunnier areas to a greater extent. This can be correlated with several factors: higher daytime temperatures (even on cold summer days in high mountain areas), an earlier disappearance of the snow cover, and greater pasture productivity, as aridity is not a limiting factor for grass growth in these mountainous regions. In this sense, it is plausible that the overall archaeological record is related to summer occupations.

The archaeological sites are also situated in areas with notably low roughness compared to the surrounding terrain. This aligns with their association with pasture areas and their relatively low presence in rocky and scree-covered areas. On the other hand, there is no evidence that these sites sought out particularly prominent locations in relation to the immediate environment, despite their low occurrence in ravines and closed valleys. This lack of prominence is further reflected in the visibility of the sites, both in terms of their external visibility and their visibility from the surrounding area. This suggests that maximizing these two variables—prominent position and high visibility, which are often associated with defensive functions and territorial control—was not a priority for the settlements. This is consistent with the near absence of defensive elements or indications of military functions as well as with the prevalence of direct access to water.

In general, archaeological sites are found in areas relatively sheltered from the wind compared to the surrounding terrain. This may be a consequence of their limited presence on peaks and ridges. However, there is no evidence to suggest that the sites were specifically chosen for topographic protection against erosion or other geomorphological phenomena.

The detailed analysis of the behaviour of different site types reveals some nuances within a general pattern dominated by the overwhelming presence of "livestock architecture." Stone circles and charcoal kilns tend to differ from this pattern in many aspects, often in opposing directions. The diversity within the category Other, which serves as a catch-all, is reflected in the wide variability of its values. Stone circles are located at much higher altitudes, show less proximity to water, and are more frequently found in rocky areas. The position of stone circles in elevated and prominent areas is also evident in their notable presence on "Mountain Tops/High Ridges" and "Midslope Ridges", as opposed to the "Open Slopes", where most cattle ranching settlements are found. This results in significantly higher values in topographic prominence, visibility, and wind exposure, and conversely, in morphometric protection. Paradoxically, they have a greater southern orientation, which, combined with their prominent location, leads to higher solar radiation levels both in summer and winter.

On the other hand, charcoal kilns tend to be at the opposite extreme to the Stone circles: they are located at lower elevations, much closer to water, are found exclusively in forests, and have some presence in closed or narrow valleys. In parallel, they exhibit low values for topographic prominence, wind exposure, and solar radiation during all seasons.

4.5 Conclusions

Archaeological surveys in high-mountain areas have yielded consistently positive results. As in other parts of the Pyrenees, those conducted in PNAESM have revealed an extensive and hitherto unpublished archaeological record, both in terms of the number of sites and their broad diachrony. A number of large-scale excavations are significantly complementing the surface data, refining some of the aspects initially noted during the surveys. However, excavations are time- and resource-intensive activities and are carried out at a limited number of sites. For this reason, a substantial proportion of the information currently available derives mainly from surveys and small test excavations. These records stem from a comprehensive research programme conducted by the same research team (GAAM), ensuring methodological consistency in sampling strategies and data collection. This makes the PNAESM archaeological site database an ideal framework for spatial analyses, providing insights into human presence and processes of occupation within this mountain area over time.

During its documentation, most of the archaeological sites in PNAESM have been linked to livestock-related activities. Consequently, their spatial analysis enables us

to characterise some of the parameters that have shaped this high mountain area as a livestock-raising territory over the millennia. The location of the archaeological sites follows specific patterns across a significant portion of the variables used to characterise the physical space. In this sense, they illustrate how archaeological sites are situated in certain types of places while excluding others. Additionally, specific patterns are identified for different types of archaeological sites according to their morphology. For example, sites with functions clearly different from herd management, such as Stone circles and Charcoal kilns, exhibit distinct behaviours in relation to several variables.

Regarding the identification of key factors in pastoral occupation within PNAESM, access to water and grass appear to be decisive factors in the construction of settlements, which were mainly located between 2000 and 2400 m asl. Simultaneously, it seems clear that these sites were not chosen for their milder winter conditions, which supports the hypothesis that, in general, they were settlements occupied during the warmer season. There is also no clear preference for locating the sites in easily defensible positions with territorial control, suggesting that conflict did not significantly influence the configuration of this territory, at least during most periods.

This analysis has deliberately excluded the temporal variable, which is central to archaeological research and has been extensively addressed elsewhere. Furthermore, it has chosen to work with broad site aggregates, grouping many different morphologies into five main categories, two of which are associated with livestock occupations. This approach has been adopted to define general parameters in the characterization of pastoralist territories in high mountain areas, territories that can be viewed as a succession and accumulation of temporal realities in constant evolution. In other words, like a palimpsest. Future work will need to refine this perspective with more detailed chronological analysis and a deeper understanding of the different morphologies within each type of settlement.

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Ermengol Gassiot-Ballbè is an Associate Professor of Archaeology at the Autonomous University of Barcelona (UAB). Since 2001 he has conducted research in high mountain areas on the southern side of the Pyrenees, focusing on landscape archaeology and long-term chronological sequences. He is one of the PIs of the High Mountain Archaeology Group (GAAM) from the UAB-CSIC.

David Garcia-Casas is a landscape archaeologist and postdoctoral researcher at the Institute of Heritage Sciences (Incipit), CSIC. His research focuses on the origins, development and historical changes of seasonal pastoralism in mountain landscapes over long-term timescales. He uses archaeological methods, ethnographic datasets and geospatial technologies to understand the cultural and social processes underpinning the formation of rural landscapes.

Laura Obea-Gómez is a prehistoric archaeologist and anthracologist, lecturer at the Autonomous University of Barcelona (UAB). Her research focuses on the use of wood by past communities and human-environment interactions in high mountain landscapes, particularly the Pyrenees. She has contributed to key projects on Neolithic occupation and resource management in upland settings.

David Rodríguez-Antón is a postdoctoral researcher in Prehistoric Archaeology at the Autonomous University of Barcelona (UAB). His expertise includes phytolith analysis, archaeobotany, and geoarchaeology, focusing on human-environment interactions in high mountain regions. He has contributed to studies on Neolithic and Bronze Age occupations in the Pyrenees.

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