Landscapes of the “Coast of Death”: dolmen topographies of NW Iberia

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ABSTRACT

This paper investigates the landscapes of Neolithic communities found within Costa da Morte (Coast of Death), Galicia. Its goal is to uncover whether or not the megalithic monuments of a particular and coherent area of the south-eastern side of the Atlantic Façade are situated in relation to complex locational variables. In particular, in this paper, we explore the entirety of their surrounding horizon. For the very first time, we were able to demonstrate that very specific natural landscapes surrounding the dolmens of this region in Iberia were likely selectively drawn upon, expanding our understanding of the Neolithic of this area and the people’s relationship with their natural world.

KEYWORDS

Megaliths; Neolithic; Iberia; Atlantic Façade; landscape; GIS;

Introduction

The wide-spread erection of dolmens in Galicia provides evidence for some sort of “symbolically-mediated behaviour” (Criado, Aria Rodríguez, and Díaz-Fierros Vi-Queira 1986, 172–176; Mingo et al. 2021), however, dolmen research in Galicia to date reveals little about what lies beneath this complex social activity. To further explore this, we investigate the possible relevance of the places chosen for the dolmens to inhabit. Similar to Higginbottom’s previous works (Higginbottom, Smith, and Tonner 2015; Higginbottom 2020a, 2020b; Higginbottom and Mom 2021) and Criado-Boado and Viloch-Vázquez’s research, we “approach the project of building an Archaeology of Perception” (Criado-Boado and Viloch Vázquez 1998, 63), which uses a clear systematic strategy for examining the visual features of past landscapes such that we can “approach a phenomenology of prehistoric perception without falling into mere subjective solutions” (Criado-Boado and Viloch Vázquez 1998, 63). Thus we use specific hypotheses and statistical tools for our determinations.

As previously stated, our main objective is to determine whether or not particular horizons visible from each site appear to be selected according to shared criteria. The criteria we shall be investigating are specific quantifiable qualities of a horizon. These are the horizon’s distance and angular height as viewed from each monument, where measurements of these qualities are taken every 0.01° around the entire 360° viewshe. We ought (to) approach the project of building an Archaeology of Perception.

Criado-Boado, F; and Viloch-Vázquez, V. (2000, 188–216).
Essentially, these qualities can be said to affect the visible profile of an horizon.

Our first step in this set of analyses is to observe, on a descriptive level, how different or similar the horizons of each monument might be from each other in terms of altitude. We can observe this by calculating the mean altitude of points around the entire horizon along with the variance or the standard deviation. Our second set of analyses, asks more specifically, “do our sites share the same horizon qualities in terms of altitude linked to direction and/or the distance of the horizon in terms of direction?” Essentially, we would expect that if sites share similar qualities of either altitude and distance, linked to direction, they will cluster together in defined groupings. Then, by testing whether or not these same qualities of monument horizons are different to those horizons of random locations in the same region, we would be able to further uncover the likelihood of the deliberate choice of specific horizon types by dolmen builders.

**Background**

**Brief archaeological setting**

Using high resolution LiDAR & field work, 3,305 mounds were confirmed in Galicia (q.v. Carrero-Pazos and Rodríguez Casal 2019). Out of these, 67 megalithic dolmens have been discovered through erosion, vandalism and excavation (Figure 1). Nevertheless, due to the number of confirmed dolmens in

the rest of Iberia and the percentage of Galician dolmens revealed when mounds have been removed, it has been hypothesised that at least c. 85% of mounds likely contain a dolmen (Criado-Boado pers comm, Feb 2022).

Costa da Morte is a shire or small region (“comarca” or “pequeña region”) within the municipality of A Coruña. A Coruña contains a variety of dolmen forms, but it is possible to more generally divide them into the likely earlier smaller, lower dolmens and the significantly larger styles. The smaller megalithic structures are covered by mounds about 50cm to 1m high (like Dombate Antigo) and the larger structures have orthostats up to 4 m, large capstones, polygonal chambers and long corridors, covered by mounds of up to several meters and are 20–50 m in

Figure 1. Costa da Morte region is coloured blue in the NW region of this map of Galicia, beginning along the coast. The case-study area is defined by the regional watershed model (outlined in black). This watershed defines a clear geographical region within Galicia. See § Choosing the study area, below. Created by Maria Gomez Faro.

Figure 2. The small polygonal tomb of Anta Zaramaceda. Photograph Gail Higginbottom.
Figure 3. Examples of dolmens found in Costa da Morte. (a) Pedra da Arca (Regoelle), also known as Casa dos Mouros, at top; (b-c) Pedra da Arca (Malpica de Bergantiños) bottom two images. Note that the chambers of these dolmens are below ground as they are both still partially covered by their mounds. Images by Gail Higginbottom.

Figure 4. (a-b) Further examples of corridor-chamber dolmens located in Costa da Morte (A: Dombate; B: Parxubeira), and (c) C: field plans of several of them. Pedra Cuberta is the tomb seen in Figure 3 (a), and Pedra da Arca is seen in Figure 3 (b-c). Plans in C by Anxo Rodriguez-Paz, modified after Rodríguez Casal: 1990. Image A by Gail Higginbottom, B by Benito Vilas-Estévez.
diameter (Dombate Nuevo). Naturally, there are some which combine features like the smaller polygonal chamber of Anta Zaramaceda, with its small corridor (Figure 2).

Within Costa da Morte, we can see some of the most important Galician dolmens, such as Casa dos Mouros, Arca da Piosa, Pedra Cuberta, Parxubeira and Dombate (Figures 3 and 4). The dates we have for the dolmens within our study area are few and even fewer are high-precision determinations from recent excavations. So, for some consideration of the dates for the construction and use of dolmens within Costa da Morte, we have constructed a table that includes some sites within the north of A Coruña and one from central A Coruña, the latter is Chousa Nova (Supplementary Table 1). Where there are several dates for one site available, only those from the original database that were equal to and over 95% Cal (2σ) BC probability are included. These were then recalibrated with the most recent calibration curves (IntCal 20). Currently, there are two sites with very early dates situating their possible construction in the middle of the 5th Millennium BC (Chousa Nova, Silleda, and Forno dos Mouros no 5a, Ortigueira).

The general consensus is that dolmens were constructed within the 5th millennium to the late 4th Millennium, with some possible new tomb building occurring in the early 3rd millennium, and that the various necropoleis were likely used from ca 4300 BC to around 2000 BC over millennia (see Supplementary Table 1). Whilst not millennia apart in construction, Dombate is a good working example of the incorporation of a previous monument plus the reuse of dolmens through millennia (Cebrián del Moral et al. 2011, 167). Here there was first a small megalithic tomb covered by a small mound (Dombate Antigo; 3770–3630 cal BC, 95.4%). The more recent and superlative dolmen of Dombate (the mound of which incorporates the first), was built very soon after the first, possibly causing the likely single use of the first dolmen (3850–3630 cal BC, 95.4%; Cebrián del Moral et al. 2011, 168). Second phase use-date examples from the second tomb are that of 3100–2920 cal BC, 93.8%, and 2620–2460 cal BC, 95.4%, illustrating its utilisation over a long period. In agreement with Criado-Boado and Villoch-Vázquez, the second dolmen of Dombate is likely an act of reaffirmation of what has come before, and of negating it or over-coming it. Thus, it can be seen as “a strategic use of the past in order to legitimize a new order” (2000, 210).

Previous research

The consideration of landscapes and monuments has been widely undertaken along the Atlantic Façade, especially by scholars in Ireland and Britain (Ruggles and Martlew 1992; Tilley 1994; Richards 1996a, 2013a, 2013b, 2013c; Bradley 1998; Cooney 2000; Fraser 1983, 1988, 1996, 2004; Cummings 2002; Cummings and Whittle 2003, 2004; Higginbottom 2003, 2020a, 2020b). We know that the people of Late Neolithic and Bronze Age Scotland, on the north-western façade, erected standing stones and other monuments in very considered landscapes (Burl 1993, 2000; Richards 1996a, 1996b, 2013c; Ruggles 1984; Higginbottom, Smith, and Tonner 2015). Cummings and Whittle’s work on tombs in Wales and SW Scotland discovered that, similar to Higginbottom’s 2015 work on standing stones:

a whole range of different landscape features were referenced from each monument. 90% of monuments have a restricted view in one direction, whilst 74% have a view of mountains and 59% of the sea. Thus sites were frequently positioned in order to have a … combination of features. (Cummings and Whittle 2004, 88)

It seems clear that these landscapes were already familiar to, and/or inhabited by, the builders (Jones et al. 2011; Ashmore 2016; Card et al. 2018).

There are also landscape studies of Galician megalithic monuments (dolmens) and mounds. The pioneering works by Federico Maciñeira helped to define the regional patterning in the megalithic sites of Galicia, concluding that there was a firm relationship between mounds and ancient paths (Maciñeira 1943–1944), whilst Lesnner (1938) and López Cuevillas (1959), examined possible relationships between dolmens and raw material and outcrops.

Essentially, the earlier research during the XIXth and XXth centuries approached the Galician Neolithic landscapes from a regional perspective, understanding “geographical or geomorphological criteria or current administrative divisions such as counties, as natural regions that typically share physical, human and historical characteristics that determined their traditional landscape” (Eguileta Franco 1999 in Carrero-Pazos and Rodríguez Casal 2019, 3). Notably, in general terms, the regional approach has been carried out right down until today but with different methodological approaches. Therefore, in more recent times we see works on spatial networks & visibility (Criado-Boado and Villoch-Vázquez 2000; Llobera 2015), intra-site visibility, astronomy & GIS (González-Garcia, Criado-Boado, and Vilas 2017), and GIS & spatial statistics to investigate further ideas about mounds (commonly known as “mamoas”) in Galicia, with large raw datasets for the whole region (Carrero-Pazos 2018; Carrero-Pazos and Rodríguez Casal 2019). These papers all fall, to one extent or the other, into the genre presented by García García and García Miraz (2017), namely that of using landscape to reverse engineer materiality and memory of the past.
Criado-Boado and Villoch Vázquez’s 1998 work, based on the Barbanza peninsula, specifically engages with the landscape in which the dolmens are located. Barbanza, like Costa da Morte, is also located along the Atlantic coast. It contains a sharp inclining landscape upon which sits a Sierra with its highest elevation of 680 m above sea level. Much of the higher elevations are made up of a flat plateau around 550 m above sea level. Criado-Boado and Villoch-Vázquez’s 2000 inter-visibility analysis was field-based, rather than GIS-based, and as their study area was a Sierra, it was essentially devoid of trees (1998). This meant that they could see all of the land and any visible mounds, therefore their visibility outcomes were automatically ground-truthed and they did not have to rely on the then less resolved elevation data available at that time (late 90s). Thus, their general data is field-confirmed. They described their work as a “systematic revision of the location of barrow monuments of their Barbanza Sierra” (2000, 193), where elemental forms of space allowed them to identify the different lines and key forms of movement, thus uncovering a relationship between barrows and the geography of movement on the Sierra (2000, figures 4 and 5). Relevantly, they found that the visual border of the dolmen panoramas (near and at horizons) is noticeably marked by natural features and artificial monuments and that “the horizon is closer and higher towards West and North while it is lower and far towards East and South” (Criado-Boado and Villoch Vázquez 1998 in González-García, Criado-Boado, and Vilas 2017, 96–97; González-García 2018). Essentially, they upheld that there were specific patterns of proximity and visual relationships between dolmens, which in turn created paths that ran between these same dolmens. Criado-Boado and Villoch-Vázquez proposed that the dolmens of Barbanza were deliberately positioned in order to indicate the best route to cross the Sierra through the plateau and that particular dolmens were intervisible as you made your way across the Sierra. Other later works showed that if you model the natural transit through the landscape or the proximity of mounds to traffic areas in Barbanza (Llobera 2015; Rodríguez Rellán and Fábregas 2019), the sites are located in areas of potentially high pedestrian movement and were visibly located on the horizons (Carrero-Pazos et al. 2020). Whilst Llobera and others confirmed that there is a relationship or coincidence between mounds and natural movement areas to say the sites were built to indicate the best route through the Sierra has been considered arguable (Rodríguez Rellán and Fábregas 2019). However, one of this paper’s authors (GH) has experienced the sudden appearance of thick fog when on the Sierra. Coming across landscape markers at such a time is very reassuring. Nevertheless, Criado-Boado and Villoch-Vázquez interpreted that such a series of relationships served “to convert the totality of physical space into a constructed space… as movement creates links between the artificial (barrows) landmarks” (2000, 201).

For their 2019 initial analysis of monument locations, Carrero-Pazos and Rodríguez Casal examine the entirety of Galicia and its 3,305 mounds using a variety of spatial GIS and statistical applications. The positions of these mounds had been already established using field prospection and/or high-resolution LiDAR data of the entire area (Rodríguez Casal being the instigator behind this database). They use pure point density analysis and the kernel density approach to determine the density of megalithic monuments across Galicia. By mapping the results, they effectively offered insight into the geographical locational patterning. They ascertained that, whilst there were several seemingly independent locations, there were significant major groups of megalithic sites in Galicia, such as Costa da Morte, along with six other clusters across Galicia (Carrero-Pazos and Rodríguez Casal 2019, 7, figure 6(A,B); see Supplementary Material).

For the second part of their 2019 work, Carrero-Pazos and Rodríguez Casal focused on Costa da Morte. They examined the possible association of mounds with natural lines of movement to explain the barrow distribution pattern and also found a connection between major natural passes and the locations of dolmens. More specifically, using multivariate statistical analyses Carrero Pazos and Rodríguez Casal focused on Costa da Morte. They examined the possible association of mounds with natural lines of movement to explain the barrow distribution pattern and also found a connection between major natural passes and the locations of dolmens. More specifically, using multivariate statistical analyses Carrero Pazos and Rodríguez Casal observed that overall “geology, slope, the potential transit and the topographic prominence of the landscape (large scale – 1000 m) are the variables that better predict the location of megalithic mounds of Costa da Morte(and) thus characterise the different megalithic landscapes of this area”. Ultimately monuments were said to be found in the open and smooth-slope landscapes geologically characterised by igneous acidic and metamorphic rocks, concluding that a “strong interrelation seems to exist between the location of the mounds and the areas of the territory most suitable for transit, although it is the confluence between all of the covariates that truly explains and predicts the megalithic monuments” (2019, 23).

Overall, then, we see that their work emphasised that, whilst such multivariate cases appear to hold true, certain individual variables did not exclusively explain the data well, that is, on their own. For example, the univariate regression indicated that the altitude is not a good predictor for the megalithic sites, as there are megaliths in several altitude groups in this area (read elevation masl), which means that it’s difficult to find a specific pattern. The same might be said of transit routes and visibility (see also Carrero-Pazos 2021), for whilst there are quite a lot of sites near the transit routes, there were quite a lot
of sites far from them and there are quite a lot of sites located in areas of high visibility (topographically speaking), but there are many others that do not show this trend. Thus Carrero-Pazos and Rodríguez Casal uphold that overall, there is a high variability in the landscape patterning in Costa da Morte, but also this seems to be the case for the whole region, Galicia (Bustelo Abuín et al. 2018; Carrero-Pazos, Bevan, and Lake 2019; Rodríguez Rellán and Fábregas 2019). Whilst the current authors agree that this is quite understandable given that we are facing a territory of high geographic contrasts (sierras, mountains, small or narrow valleys with steep but low mountains, rolling hills and wide open valleys, literally thousands of waterways), we hypothesise that their outcomes possibly indicate that people in the past were taking into account several culturally preferred variables at once in their consideration of monument placement and finding the best balance for their own local area. Thus, like in Britain, sites may have been positioned in order to have a combination of features.

There are also papers that combine cultural and social elements of the megalithic builders in Galicia for interpretive analyses (Criado-Boado and Villoch Vázquez 1998; Criado Boado, Mañana Borrazás, and Gianotti García 2006; Gianotti et al. 2011; González-García 2018; González-García et al. 2019) and even rituals (Rodríguez Casal 1990, 40–9; Gianotti et al. 2011; González-García et al. 2019). Some of these examine the relationship of the more recent dolmens, their structures, the images painted within and the interplay of light within the dolmens, for instance (González-García et al. 2019).

Like Carrero-Pazos and Rodríguez Casal 2019, we are not criticising the validity of previous approaches, but rather we see our landscape work as complementing what we know through the use of quantitative and statistical techniques that allow us to reconsider the previous locational models. Like Criado Boado and Villoch Vázquez, our work as a whole aims to make both a contribution to technical reconstructions of past Worlds (method) as well as to the reconstruction and understanding of the strategies that were used to shape the cultural landscapes of the Neolithic people through their use of megalithic monuments (interpretation). This paper will show convincingly that very specific natural topographic landscapes surrounding the Neolithic dolmens of Costa da Morte in Galicia (Figure 1), were selectively chosen.

Issues of visibility in Galician dolmen landscapes

Due to the lack of research done in Costa da Morte itself, the clear determination of local land-use and vegetation cover in the past is at this stage unclear. Nevertheless, Kaal et al. demonstrate that during the 5th to 4th millennium BC, mountainous or hilly non-sierra areas, like Costa da Morte in Galicia, were primarily covered with mixed deciduous forest, dominated by oak (Quercus) with a light under-story of shrubs and herbs (Kaal et al. 2013, 1522, figure 4). Such Oak forests tend to be open and lose their leaves in early winter, creating a very open aspect until late Spring-early Summer. Added to this, the analysis of the fen of Chan da Cruz, Gañidoaira, Xistral and Chao de Lagozas (Montes de Buio, Serra do Xistral and Toxiza) show the first clear evidence of forest reduction, the preponderance of the ruderal taxa and any degradative shrub formations at the beginning of the first half of the 5th millennium B.C. In this we have evidence of the reduction of forest and the creation of pockets of grasslands (López Saez, López Merino, and Pérez Días 2010). The beginning of these activities coincides with the earliest dates we have for dolmens in A Coruna, like Forno dos Mouros 5a (Ua 2009 5635 ± 50 BP, 4590–4350 cal BC, 95.4% – see Supplementary Table 1). Therefore, viewing topographical features within the Galician landscapes, the primary topic of this paper, could have been a possibility in the past.

Method

For this paper, we use the 25m LiDAR data made freely available by the Galician Xunta. We employ the software Horizon to build 2D-360° vertical view-sheds or horizon profiles (not map views). We use the ASCII data obtained through the same software for our statistical analyses of the topographical features of the horizons surrounding the monuments in our study area. The ASCII data contains three pieces of information sampled at regular intervals (of 0.01°) in azimuth around the full horizon, which gives you 36,000 x (azimuth or direction in degrees from north) and y co-ordinates (altitude or angular height in degrees), along with the distance of each azimuthal point from the observing position to the horizon. In other words, this 2D option draws the visible horizon line only with the co-created ASCII data files containing the distance and direction between the point of origin or monument to all points on the horizon and the altitude of each of these horizon points. Within Horizon you can view an interactive 2D image and by clicking on this you can obtain data about the horizon profile related to these variables. As well as the ASCII data file, a pictorial representation of this data can be created as a postscript image file containing two linked graphs vertically positioned: (i) the horizon line (x = direction-azimuth; y = altitude) and underneath this (ii) a logarithmic graph (x = direction-azimuth; y = distance to the horizon), where azimuth is the number of degrees from north (direction) and altitude is the value in degrees given to the height of the horizon as viewed from a specific
Choosing the study area: Costa da Morte

Costa da Morte is characterised by several valleys and depressions intersected by rivers that drain to the coast, through rugged terrains. The gentle elevations (e.g. O Facho, 312 m.a.s.l.) of this area are surrounded by valleys such as the Vimianzo or Dumbría (Lema Suárez 2010). For our studies of Galician dolmens, we chose to focus on one core dolmen district and its immediate periphery at a time, after which we shall choose to focus on one core dolmen district and its urban areas, such as the Vimianzo or Dumbría (Lema Suárez 2010). For our studies of Galician dolmens, we chose to focus on one core dolmen district and its immediate periphery at a time, after which we shall compare the differences and similarities of each area. Here we have chosen the area of Costa da Morte, a historically well-known core area of Galician megaliths in Northwestern Spain (Rodríguez Casal 1990, 2000; Lema Suárez 1999). For the clear determination of the geographical research area, please see Supplementary Material (SM1.3) and the images within. See Supplementary Table 2 for the list of confirmed dolmens in this study area and used in this study.

Analysis of horizon qualities

In the following, we perform a series of statistical analyses on the horizon profiles. The distances between any of the observed sites is always larger than 750 m. Thus, securing that the horizon profiles are independent and we can rely on the fairness of our statistical treatment. There are only two dolmens that do not follow this rule, and those are the two subsequently built dolmens in Dombate. As New Dombate was built a few centuries after the old one, hiding it inside the larger mound, and to secure the independence condition, we will consider only one profile in this case. Thus, the final number of horizons is $n = 31$.

Analysis 1 – the mean group horizon line and 1-sigma dispersion

On a descriptive level, the first analysis of a population or a sample is commonly done by analysing the first moments (i.e. the mean and the variance or the standard deviation). This is the aim of this section. Using the extracted ASCII data we generated 2D images representing the horizon line surrounding each monument defined by azimuth and altitude using IDL graphing packages and personal scripting ($n = 31$; Figure 5). We have calculated the mean horizon line of these 31 sites by calculating the mean altitude at every 0.01° around the horizon (Figure 5, dashed-line). We then calculated the standard deviation of these altitudes and add this to the mean azimuth of the profiles to give us the 1-sigma dispersion of the 31 profiles, the outcome of which is found in the section, “Results”.

Analysis 2 – K-means analysis – do sites share the same horizon qualities?

Using the ASCII data, we then performed a K-means analysis on the horizon qualities of each site (cluster analysis). The first set of horizon qualities to be tested were points defined by azimuth and altitude, which can be represented by the horizon line itself. Another one was carried out on the distances to the horizon from the monuments connected to direction, for the entire 360 degrees around each site. In general, the K-means approach (Everitt 1995) groups the data into clusters by comparing the qualities of the profile of each data group with a given seed. The seed is chosen following the approach by Arthur and Vassilvitskii (2006). The first cluster centre, $c_0$, is purely random. Then the distances of all other measurements from $c_0$ are computed following the Euclidean distance. These distances are used to define a probability distribution and the next cluster is chosen again randomly, but now we used the probability distribution above (instead of a uniform distribution). The idea was to draw new seeds so that they are far from the first seed. With this idea, the new clusters will not necessarily be at the very edges of the measurement space and it is less likely that isolated outliers would be picked. The method tries to find by an iterative process, the optimal clustering which minimises the distances within each cluster, defined as the sum-of-squares. The optimal number of seeds was obtained through a silhouette calculation (Rousseeuw 1987).

Analysis 3 – comparing horizon qualities with random samples

In this analysis, we tested for a series of systematic differences between the observed horizon qualities of all of our sites ($n = 31$) and those of 320 locations randomly chosen within the area of Costa da Morte (this is one order of magnitude larger than our sample). A larger number would be ideal, but two facts prompted us to use this number. First is the fact that the analysis with the software Horizon to extract the horizon profile is not automated, making this rather time-consuming. The second is that to secure the independence of the horizon profiles in the random sample, we imposed that the minimum distance between the random sites was always larger than 250 m. Given the size of our study area, 320 appeared a sensible number.

For each of our 320 random sites, like for our observed sites, we have a single horizon composed of the 36,000 pieces of data for each of the variables azimuth, altitude and distance, sampled at regular intervals (of 0.01°). Then we run a Monte Carlo simulation to generate particular random data, or samples, for these comparisons. Essentially this means that we...
take 31 randomly selected sites from our pool of the 320 random sites and compare these 31 with our 31 observed ones. We do this comparison 100 times, each time with a different random realisation of 31 sites. In this way building a distribution of altitudes and distances for each azimuth entry.

With our ultimate aim to verify if there is any statistical difference between the horizons of the observed and the random samples, we first run a normality test, by employing the Shapiro–Wilk test under SPSS. The observed profiles showed a $p < 0.001$, discarding normality. This means that our data cannot be described by a normal distribution and directs the statistical test choices that can be made. Under these circumstances, we opted to use the Kolmogorov–Smirnov (K-S) test to compare both samples (observed and random) and to calculate the $p$-values that will be used below to discriminate statistically significant areas in the horizon (see $p$-values in Figures 11–15). Specifically, for each azimuth, we extracted the observed sample altitudes or distances and compared these to each of the 100 samples of horizon altitudes or distances of the random sites. So considered, the two samples (for each azimuth) could be modelled by distributions. The two-sided K-S test allows us to verify whether or not the two samples are drawn from a common parent distribution. Thus, our null hypothesis is that there is no difference and that the horizon altitudes/distances for 31 sites with exposed dolmens do not differ from the random sites. Each calculation provides a $p$-value and we chose here the largest $p$-value of the 100 K-S tests, which is given in the figures found in the results below.

We employ a rather conservative approach and set a limit of $p < 0.05$. This means that if $p > 0.05$, a K-S test cannot reject the null hypothesis, which states that both samples are drawn from the same parent distribution. Specifically, this means there is no significant difference between the horizon qualities of the monuments and those of the random sites in our study region if the null hypothesis is accepted.

Results

Analysis 1 – the mean group profile

In Figure 5, we can see illustrated the altitude by azimuth of all of the 31 horizons (thin solid lines). It is interesting to notice that there is a general tendency to show slightly higher altitudes towards the western part of the horizon. Also, the 1-sigma dispersion of the 31 profiles indicates that there is a larger variation of horizon pattern for the western horizons found at our sites than found for the eastern horizons, which are more similar to one another (Figure 5, thick dotted line). This means that there are likely very high horizons as well as very low horizons in the west, while such variations seem to be smaller in the east.

This diagram, however, does not allow us to extract much further information apart from the general observation that the general mean profile in Figure 5 (thick dashed lines) also seems to indicate the existence of fairly symmetrical features with their centres on cardinal east and west. We could discuss the mean horizon further, but it would probably turn into meaningless conclusions. We therefore preferred to verify if there are certain traits within these profiles, and later compare them to those generated by a random sample in the study area.

Analysis 2 – K-means analysis – do sites share the same horizon qualities?

K-means analysis of horizon direction & altitude

We tried three to seven initial seeds, and the silhouette analysis indicates that the optimal choice is 4, although
with very little difference to 3 seeds. By comparing the three – and four-seeds analysis we found that two of the clusters or groups in each of these seeds include the same elements, however, the third group in the three-seed analysis is divided into two for the four-seed analysis. The largest group comprises 13 of the 31 sites (this is the green group in Figure 6, Group A1), while the second greatest in number has eight (red group: Group A4, n = 8). These two groups are ones that merge together when considering the three seeds case. The others have 6 and 4 members. For ease of understanding, we can see their average horizon profile for each group in Figure 7 and the regional distribution of these sites is the one seen in Figure 8.

At this stage, we are still researching the topographical details of the greater areas around the dolmens, but we can say that the Group A1 cluster (green n = 13/31) is clearly wide-spread across our study area, with Group A4 (red; n = 8/31) being the second most wide-spread in terms of location (Figure 8). Group A3, for which we have the least number of sites (n = 4/31), tends to be located in the north-western area only, with Group A2 running north–south in the western zone of Galicia.

**K-means analysis on the direction & distance to the horizon**

A similar analysis was done by looking at patterns of direction and distances of the horizon. The results are summarised in Figures 9(a,b) and 10. Again, we tried several analyses with three to seven seeds, with four appearing as the optimal choice after the silhouette analysis. There are two main groups, Group D1 with 16 members (in magenta in Figure 9(a,b) and Group D4 with 8 members (purple). Group D1’s preference for the great majority of its easterly horizons (where north and south are the...
dividing lines) being farther away than the majority of its westerly horizons, is clear, however, the monuments in our smallest cluster, Group D2 \((n = 3, \text{khaki})\) have the greatest difference in terms of distance between their easterly and westerly horizons. Group D4 sites have horizons that are generally closer in the east than those in the west. Group D3 \((n = 4, \text{orange})\) seems to have the most extreme

**Figure 9.** (a) Direction & Distance. K-means over the distance for the 31 sites. The plot shows the mean distance profile for each group and the number of elements in each group. Note that the distance scale is logarithmic. Group D1 is magenta with 16 members \((n = 16)\) and the khaki is Group D2 \((n = 3)\). Group D3 is orange \((n = 3)\) and Group D4 is purple \((n = 8)\). (b) Direction & Distance. K-means over the distance for the 31 sites. The plot shows the mean distance profile for each group and the number of elements in each group. Here we have layered the groups. Starting at zero azimuth we can see that the purple group sits below all the other groups for the majority and that close to south \((180^\circ)\) they change positions, with the purple group (D4) sitting above the rest.

**Figure 10.** Direction & Distance. Distribution of sites studied for the distance analysis for the 31 sites. Group D1, \((n = 16)\), Group D2 \((n = 3)\), Group D3 \((n = 4)\), Group D4 \((n = 8)\). Figure created by Maria Gomez Faro.
ongoing undulation in its average horizon profile, nevertheless we can see that the horizons due east (that is, either side of, and at, 90°) are closer than those due west (either side of, and at, 270°). This is also true also for Group D4. In fact, if we focus purely on the cardinal directions of 90° and 270°, Groups D2, D3 and D4 all have the closer horizon points due east than those that are due west, unlike Group D1, despite the fact that, overall, Group D1 and D2 share the more general similarity of greater distances between their easterly and westerly horizons, as pointed out above. Interestingly, Group D2 (n = 3) can all be found in the eastern part of our study area, and Group D1 appears to have the greatest geographic spread in all directions, perhaps due to its comparatively larger number of sites (Figure 10).

**Analysis 3 – comparing horizon qualities with random samples**

In the following, we will display in the different figures the mean horizon profiles as representative of particular qualities (as above), for both the observed and the random samples. It is important to remember that we are testing values at the level of the individual azimuths or directions, not of the horizon profile or line as a single unit. Our assessments will be in line with this.

**Comparing direction and altitude of monument horizons with random sites**

Firstly, we produced a horizon profile for each of the 320 randomly selected locations within Costa da Morte and then we calculated and created the mean profile of the 100 samples of 31 sites randomly selected, defined by direction and altitude. This is shown in Figure 11’s top panel as a thick solid line. The mean observed horizon profile (for all 31 of the exposed dolmens) is shown as a dotted line. The shaded observed horizon profile is defined, as described above, by the dispersions of those samples.

Whilst we are testing the individual orientations, it is visibly clear that the observed profiles (i.e. of the exposed dolmens) are systematically lower in altitude than the (mean) random sites profiles, and whilst these are the mean profiles, they tend to indicate the behaviour of the two samples.

In the lower frame of Figure 11 is the calculated statistical difference between the observed and random samples for each point observed (every 0.01°). Thus, we are seeing the p-value for each azimuth value plotted in the lower frame. We find that the

![Figure 11. Direction & Altitude. Top panel, illustrates the results of our normality test, which employs the Shapiro-Wilk test under SPSS. It shows the random (solid) and observed (dotted) mean horizon profiles of all exposed dolmens in Costa da Morte. The wavy dotted lines above and below the solid ones indicate the 1-sigma dispersion of 100 random selections of the sample. The grey shaded area around the mean observed profile indicates the standard error of the mean for each direction. Black dashed vertical lines indicate the cardinal directions. From left to right the yellow lines are: Sun rise at the summer solstice, equinox and winter solstice: then the Sun set at the winter solstice, equinox and summer solstice (see Discussion). The lower frame shows the statistical significance of the Kolmogorov-Smirnov test (p-values), which compares the observed and random samples seen in the upper panel. The dashed horizontal line here shows the value of p = 0.05. Altitude is the angular height of the horizon as viewed from the monument location.](image)
values are lower than \( p = 0.05 \) for a broad range of directions eastwardly from approximately NNE to just north of SE, while this is not the case along the western part of the horizon. In terms of the null hypothesis then, we can reject the idea that in terms of altitude, a large part of the eastern horizon of the dolmens is no different from those found at random sites, specifically the part of the horizon found between the stretches of c. 20°–108°N and c. 130°–153°N. Therefore, we accept that, in terms of height, the preponderance of lower horizons in the east were clearly of significance to the monument builders of Costa da Morte.

We applied the same form of analysis with the combination of the 21 sites included in Groups A1 and A4 (red and green) of Figure 6, which, as we explained, formed a single cluster in the 3-seed analysis. Also, they were the two dominant sets of clusters which together explain the majority of horizon behaviour in terms of horizon altitude linked to direction. This also creates a larger “signal” of 21 sites than if used individually.

We did the same comparison as before for these 21 sites and the random samples (Figure 12). We can clearly see that the majority of altitudes contained within this mean observed profile fall even lower than those contained within the mean observed profile of all site horizons seen in Figure 11, across the entire horizon profile. The lower panel in Figure 12 indicates that the statistical outcomes have not only lowered for both the eastern and western horizons, but the azimuthal ranges in terms of significance have also expanded. In the east, we now find a difference between the observed and the random horizons nearly all the way from NE towards the south (20°N–175°N). Along the western horizons, with significant ranges between 210° and 285°N, along with range in NNW and around north slightly to the west. Thus, in terms of the null hypothesis for these 21 sites, then, we reject the idea that in terms of altitude (angular height), the horizons of the dolmens are no different from those found at random sites, specifically those parts of the horizon found between the stretches described above. Therefore, we accept that, in terms of angular height, much of the lower horizons in the east and west were clearly of significance to the monument builders of Costa da Morte.

The significance of these 21 sites is even clearer when we compare these results with those of the rest of our sample, where the 10 remaining sites from Groups A2 & A3 (from Figure 6) are combined together for the observed profile data (Figure 13). This comparison was deemed necessary so that we could possibly observe how the horizons of these sites differ from those of Groups A1 and A4. Testing them individually was not deemed appropriate due to low numbers; for instance, Group A3 only had four members. Here it is evident that, unlike the

![Figure 12](image_url)

**Figure 12.** Direction & Altitude. Random (solid) and observed (dotted) mean horizon profiles, where the observed profiles are the combined profiles of the Groups A1 & A4 clusters in Figure 6 (\( n = 21 \) sites). The wavy dotted lines above and below the solid ones indicate the 1-sigma dispersion of 100 random selections of the sample. The grey shaded area around the mean observed profile indicates the standard error of the mean for each direction. Vertical black and yellow lines are as in Figure 11. The lower frame shows the statistical significance. In this same frame the dashed horizontal line shows the value of \( p = 0.05 \). Altitude is the angular height of the horizon as viewed from the monument location. All other methodological details as for Figure 11.
The results can be found in Figures 14 and 15. For Group D1, we can see that the average dolmen profile is clearly lower in altitude than the average random profile, similar to that of Figure 12. However, now that we are testing sites that explain the majority of data in terms of distance and direction, we now see a very clear difference between Figures 12 and 14: For Group D1 sites in Figure 14, almost the entire horizon range in terms of altitude and direction is significantly different to that of the random sites. In terms of our statistical hypotheses, we can state that for those sites with horizon profiles farther in the east than the west, the great majority of the horizon is clearly significantly different from the random sample. Thus, in terms of the null hypothesis for these sites, then, we reject the idea that in terms of distance linked to direction, the horizons of these dolmens are no different from those found at random sites. This contrasts strongly for those sites that have horizon profiles farther in the west than the east (Group D4) where the majority of horizon points are not significantly different from those of the random sites (Figure 15).

**Distance horizon patterns: comparing direction and altitude of monument horizons with random sites**

To investigate the possible nature of the horizons surrounding each monument further, we turned to the results of the horizon distance assessment. We selected all those sites found in the two largest “distance” clusters, for these explain the dominant horizon “behaviours” of our monuments in terms of distance and direction (Figure 9(a,b); n = 16, 8). Figure 9(a,b) clusters contain the “magenta sites” (n = 16; Group D1) which have a farther profile along the eastern horizon compared to the western and the purple sites (n = 8; Group D4), which are the reverse of this. We then compared each of these distance groups’ horizon qualities with those of the random locations as indicated above. The results can be found in Figures 14 and 15, respectively.

In Figure 14 (Group D1), we can see that the average dolmen profile is clearly lower in altitude than the average random profile, similar to that of Figure 12.
Discussion – landscape choices in the “Coast of the Dead”

The tests on the horizon profiles of the monuments demonstrate that the monuments are located at higher local elevations, for the horizon profiles appear generally lower for the monuments than those of the expected or random profiles (Figures 11, 12 and 14). These results reinforce the findings of previous studies, which showed a general preference for monuments in Galicia to be located at higher than average elevations in their local areas (Criado-Boado and Villoch-Vázquez 2000; Carrero-Pazos and Rodríguez Casal 2019). So the once traditional hypothesis, which placed the great part of Galician megalithic monuments within mountainous locations, is not entirely rejected out of hand (Carrero-Pazos and Rodríguez Casal 2019). For whilst it is not so much the highest places that one can find anywhere, but rather the higher places in one’s own area. Nevertheless, our results also reinforce the more general findings of Carrero-Pazos and Rodríguez Casal 2019, which demonstrated that, in terms of spatial analyses at least, the distribution of sites was not likely to be random ($p$-value $= 2.688\times 10^{-6}$; Kolmogorov Smirnoff test).

Added to this, for those sites with greater horizon distances in the east (compared to the west), this pattern remains firm, especially along the eastern section (Figure 14). Thus, there is a statistical consistency for a specific interest in the eastern horizons. Of interest, too, are the apparent systematically lower altitudes for the eastern horizons compared to the western (27/31; Figure 7), which is clearly the opposite to the random sites found in Costa da Morte. However, it seems that altitude and distance may not be interrelated variables. For, unlike Criado-Boado and Villoch Vázquez’s 1998 study of Barbanza, where horizons are “closer and higher towards West and North (and) lower and farther towards East and South” (Criado-Boado and Villoch Vázquez 1998 in González-García, Criado-Boado, and Vilas 2017, 96–97), there is no unique choice regarding which type of horizon in terms of altitude, should be closer – the eastern or western. The lack of this unique quality is clearly illustrated by these 27 out of 31 horizons, where 11 (Groups 3 & 4) had a distinctly closer eastern than western horizon and the remaining 16 had a distinctly closer western than eastern horizon. Nevertheless, with the revelation of Barbanza’s mean horizon profile of all monuments being systematically lower towards the eastern part of the horizon than the west (Gonzalez-Garcia 2016), we can at least see a similarity with one of the two families of horizon profiles found for the dolmens in Costa da Morte. This reinforces what we suggested above, that these

![Figure 15](image)
combined differences and similarities may well point to the idea that “the traditional discourse (about monument placement) should be nuanced taking into account the local scale variances” (Carrero-Pazos and Rodríguez Casal 2019, 22). Regardless, from all of this, we can see that it is very likely that the horizon altitudes are sort after for their unique qualities in comparison with the rest of the naturally occurring landscapes and that altogether these variables of distance, direction and altitude accomplish a raft of complex landscape characteristics for the “ideal” position(s) upon which to position a dolmen.

Of the greatest cultural significance for this project so far, is that for monuments with horizons farther in the east and/or where the altitude is significantly lower in the east in comparison to the random sites, the statistically significant areas of their horizons contain the entire solar sunrise range in this direction (Figures 12 and 14; indicated by the dotted yellow lines). For Costa da Morte, then, this could perhaps indicate a search for a horizon with preferred qualities that connect with the dolmen’s orientation preferences.

Nevertheless, we can see that the first observable quality that connects Figures 12 and 14 is the combination of horizons that are significantly lower when viewed from the monuments than the random sites in the east and the west, though most particularly in the east. If this is the case, what does this mean for our sites that also include lengths of statistically significant horizon in the west (Figure 12) or indeed almost entire horizons that are significantly different to the general lie of the land (Figure 14)?

Now clearly the statistical outcomes and observations just indicated open the possibility to investigate in the future how many of these topographical features (in terms of altitude and direction) occur at individual sites. Other remaining challenges need to be considered for Costa da Morte. For instance, further research is required to discover what might be relevant about the areas outside of the solar ranges along the significant horizon ranges, if any. More work on the topography between the monuments and the horizons is also clearly required. Finally, until a much more thorough investigation is completed regarding the complex astronomical factors that might be connected to dolmen orientations and the types of horizon choices, it is not possible to say what might underlie any horizon type differences in the east or west, in relation to astronomy. All of these are the challenges that we shall address next.

**Conclusion – a symbol of cultural continuity**

In 1986, Criado-Boado et al. argued that the appearance of monumentality in prehistoric Europe signified a cultural change or a shared societal reaction to influxes or appearances of new attitudes and beliefs, which themselves reflected transformations within the outlook of humans towards Nature (Criado-Boado, Aira Rodriguez, and Díaz-Fierros VI-Queira 1986). To grasp something of this new outlook, we chose to investigate the natural landscapes surrounding the dolmens of Costa da Morte to determine if they might have contained unique qualities that reflect this. The underlying assumption is that these material manifestations of new attitudes (the dolmens) would be located within a landscape that would also reflect these same attitudes. The proposition was that if these new shared attitudes were also part of the landscape choices then the landscape elements would contain some consistency or “sameness” across the dolmen locations. These locational choices would be further evidenced as a reflection of shared attitudes if they were indeed also different to the rest of the region of Costa da Morte. These are our first steps towards understanding Neolithic peoples’ relationship with their natural world.

Further, our work theoretically upholds that the dolmens at the least “correspond to (the) humanization of the Wild World” (in our words, Nature), not its artificialisation (Criado Boado, Mañana Borrazás, and Gianotti García 2006, 48) and the dolmens are the “materialization of the collective memory” (2006, 38). Whilst the former statement is linked to the first moments of megalithism, the project as a whole considers this as a likely possibility for the majority of dolmens, for we are effectively witnessing how the landscape organises the dolmens, that is, it is the qualities that landscapes naturally entail that appear to determine the dolmen locations, filtered by the cultural eye. By constructing something that is essentially determined by natural phenomena, people are highlighting their considered focus upon parts of this Nature. In this way, then, our work on the Neolithic does not look to reaffirm the domestication of nature, but to discover the qualities of Nature that appealed to the people of the Neolithic and, eventually, why. Thematically at least, if not theoretically or methodologically, our work on trying to understand the mechanisms beneath human behaviour could perhaps align itself with works like Criado Boado’s 1999 seminal work “Del Terreno al Espacio” (and several others), Montufo Martin et al. (2010), von Hackwitz and Lindholm (2015), van den Beld (2017), and Gebauer (2020). Methodologically, in our drive to understand the placement and landscapes of Neolithic megalithic monuments, our use of high-resolution data and bespoke and GIS software, statistics and modelling are part of the greater trend seen in landscape archaeology and monuments (Balda 1995; Sjögren 2003 in Gebauer 2015; Phillips 2003; Bradley and Phillips 2004; Lindholm 2006; Löwenborg 2010; Montufo Martin et al. 2010; von Hackwitz 2012; Bourgeois
Our use of GIS is to observe landscape profiles from the point of view of an individual or group of people standing at a particular monument, we have shown that very specific natural landscapes are connected to the Neolithic dolmens of Costa da Morte in Galicia. These were highly likely to be selectively chosen and were shared. The people who created them within this region of Galicia appear united through similarities of community practices through time and place, indicating that these dolmens are symbols of cultural continuity and provide some sense of cultural cohesion. The dolmens, through their location, “present” this information to us. 

Whilst von Hackwitz and Lindholm (2015, 143) admit that 

\[(t)he ideology that triggered the various practices in the landscape might… still be very difficult to grasp\], due to the dolmens’ association with the dead, we can at least suggest that the observed locational and visibility patterns are likely connected to more intangible concepts, where entire dolmen landscapes contain shared cosmological belief systems. Though such findings as these do not yet inform us what their multi-layered “meanings” might be, our future work uncovering more of the landscape and astronomical nuance in relation to the placement of the dolmens should help us discover more shared cultural features that may well reveal more about these systems. Thus, in perhaps challenging the opinion expressed in González-García, Criado-Boado, and Vilas (2017, 88), despite the fact that our analyses are data-driven, we can still ask about “the intent of megalith builders”.

**Geolocation**

As explained in the paper, our study area is Costa da Morte is a shire or small region (“comarca” or “pequeña región”) within the municipality of A Coruña within Galicia, Spain. A pin point for a map that is fairly central is: 43° 5’22.82″N, 8° 59’3.47″W.

**Note**

1. IDL 7.1, https://www.l3harrisgeospatial.com/Support/Self-Help-Tools/Help-Articles/Help-Articles-Detail/ArtMID/10220/ArticleID/15848/IDL-71-70-ENVI-47-46-and-EX-10-Platform-and-Feature-Support

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**Disclosure statement**

No potential conflict of interest was reported by the author(s).

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