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From Mounds to Villages: The Social Construction of the Landscape during the Middle and Late Holocene in the India Muerta Lowlands, Uruguay

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Abstract: This paper presents new data on the spatial organization of mound-builder groups in the India Muerta wetlands, Uruguay. This area presents the beginning of land architecture in the region (ca. 4800–5000 years BP), associated with more arid climate. This construction tradition continues and intensifies, mainly from ca 3000 years BP, from the establishment of warmer and damper conditions. New sources of information and geospatial technologies have made it possible to locate mound sites with greater precision, as well as to analyze settlement patterns. Indigenous communities occupied areas of hills, plains and wetlands, showing differences but also regularities in spatial organization in each area. In the whole area, earthen mound complexes form groups of different orders, from regional to domestic units, configured by mounds, negative structures and limited spaces. The location of the mounds is primarily in dry areas, known locally as islands, which are prominent in the landscape during floods in this wetland-dominated environment. Through this analysis of the landscape, this work delves into the underlying logic of the social construction of the territory. The results achieved in this paper are consistent with previous research suggesting planned occupation associated with villages integrated within broader regional systems.

Keywords: settlement patterns; landscape construction; earthen mounds; GIS

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1. Introduction

The transformation and ecological management of the environment have been a constant throughout the process of human population of the South American lowlands. Different types of earthen architecture are evident with regional and local particularities, from the Amazon region to the Southern Atlantic. Residential and funeral mounds [1–3], enclosures demarcated by excavated ditches [3,4], canals and rectilinear earthworks (ramparts, ridges, raised fields) for cultivating low areas susceptible to flooding [5–8] and structures such as dikes and tanks for fish breeding and fishing [9,10] are some of the indigenous constructions which bear witness to social processes of landscape transformation in timescales of medium to long-term duration.

The emergence and development of these architectures have been considered as indicators of occupation processes with extremely heterogeneous sociopolitical trajectories [1,2,4,11–13]. Different types of earthen constructions appear in the flood plains of the Orinoco [14], associated with the main watercourses and deltas of the Amazon River [1,2,12], on the coast of the Guayanas [8], on the Moxos Plains in Bolivia [15,16], in the deltas of the Paraná River and Uruguay River [17], in the wetlands of the upper Paraguay River [18,19] and in the basins of the coastal lagoons of the south of Brazil [20,21], as well as the east and northeast of Uruguay [22–25]. The observation of these transformations has given rise to the recognition of monumental landscapes [26], managed landscapes [27] and domesticated landscapes [4].

The magnitude and geographical scale of South American earthworks are key arguments in debates on environmental modifications, social complexity and regional historical and demographic processes. However, there is still a paucity of studies focusing on distributional and locational analyses of these structures. In Mesoamerican, European and North American contexts these approaches are in the process of development [28–30], but the logistical difficulties of working in lowlands and the costs of mapping techniques have allowed for an approach on a site scale and of geographically limited archaeological phenomena. The growing availability of geospatial information on regional scales (aerial images, digital models, LiDAR, among others) has made it possible to revert this panorama and make progress in the intensive localization of earthworks, particularly in the Amazon region [31–33]. Several of these studies have made it possible to establish eco-archaeological regions, combining the analysis of the distribution of earthworks and their association with ecological environments [33]. The documentation and distributional analysis of round mound villages has made it possible to glimpse possible regional hierarchical patterns [32]. Along the same lines, the modeling of the distribution of archaeological sites together with environmental and topographical variables has shown how interfluves and lesser tributaries of the Amazon sustained high densities of population [31].

In spite of these advances, extensive zones of the South American lowlands with earthworks continue to present vacuums of archaeological information for establishing regional models of settlement, among them the regions of the Chaco, Pantanal, Paraná Delta and the southern Atlantic coast. The latter region stands out for containing the densest and earliest distribution of mounds and earthworks (ca. 5000 years cal BP) [22,24], a phenomenon pointed out as a source of social complexity [22,25,34].

1.1. A Spatial Approach in the South Atlantic Lowlands

During the mid-Holocene, from ca. 4800–4500 years cal BP, the first earthen mounds appeared in the lowlands of the India Muerta region in the department of Rocha, Uruguay [24,35,36]. The mound architecture spread across a wide area ca. 3500–2500 years cal BP, taking in the northeast and southeast of Uruguay and the south of Brazil [25,37,38].

The mounds are earthen constructions with different morphologies and dimensions, known in Uruguay and Brazil as cerritos, aterros or tesos. Their dimensions are variable with heights ranging between 0.5 m and 7 m and diameters from 15 m to 60 m. There are some cases of long mounds of between 100 m and 200 m on their longest axis [24,25,39–43]. Excavations have made it possible to interpret different uses and functionalities, such as housing areas [23,44,45] and villages [24,42], funerary and ceremonial usage [22,25,41,46], territorial and symbolic markers [25,47,48], structures for cultivation [24,49] and a combination of all of the above over the course of time [25,42,48,50].

Access to technologies for the acquisition of geolocation information has influenced the systematic identification and analysis of mounds in different regions of Uruguay. Initially, the availability of historical aerial photographs from the Servicio Geográfico Militar (Military Geographic Service) made it possible to locate hundreds of mounds and to draw up the first archaeological maps [47,51,52]. The integration of these images into geographic information systems (GIS) increased the capacity to generate georeferenced databases of mounds across wide areas with significant vacuums of information. In general terms, based on these surveys, two main patterns of mound aggregation were proposed: the nucleated pattern and the isolated pattern [23]. The nucleated pattern is mainly associated with the wetlands and flood plains, whereas the isolated pattern is more connected with the mid and high plains which surround the wetlands [22,23].

The spatiality of the mound phenomenon has always been a topic of interest in regional research. On different scales, the spatial approaches have revolved around the analysis of settlement patterns [23,51,53] the intrasite spatial organization [37,54–56], the arrangement of mounds with different morphologies within denser complexes [22,39] and the micro-space within the cerrito [50,57]. The results of locational analyses have shown how the quest for prominence, the visibility between sites and the environment, and mobility in areas prone to flooding could be decisive factors in terms of the location and distribution of mound sites [42]. Along similar lines, recent analyses in Patos lagoon (Brazil) propose a model of aquatic mobility which recognizes sailing as a key factor in the pattern of settlement [21] and visibility as a mechanism of territorial control [20]. The conclusions of these studies have been central arguments in discussing aspects such as the social organization of the communities, sedentarism and the nature of landscape transformations.

On the other hand, Iriarte [55], via excavation work carried out in the India Muerta region, proposes a pattern of community-based village settlement with the emergence of processes of social complexity around 3000–2500 years BP. This pattern distinguishes lesser mound sites and central villages with a greater aggregation of mounds, a variability of earthworks (platforms, microreliefs and mounds), well-differentiated internal areas, the presence of squares and areas for cultivation. Based on the comparative locational analysis of mounds in two regions of Uruguay, Gianotti [42] recognizes different patterns interpreted as responses to changes in the social structure of the mound-building populations, which would reflect periods of social aggregation (fusion) and disaggregation (fission). Bracco et al. [35], in a study of the India Muerta-Paso Barrancas area, maintain, however, that the sites cannot be interpreted as villages and that the distribution of mound sites does not present significant variations and centralities in its regional spatiality. This research concludes, unlike the proposal of Iriarte [55], that there is no aggregative hierarchical pattern of mounds and that the distribution is representative of a social space with no great discontinuities [35]. These two interpretations show two almost antagonistic views of the spatiality of the Uruguayan mounds. Key issues such as complexity, intentionality, spatial planning, village organization and monumentalization processes of earthworks have been stressed by several authors [25,38,42,55]. The opposing interpretation questions these aspects, arguing that the distribution of mounds responds to economic decisions local to the sources of resources [35,39].

In this paper, certain elements shall be addressed with regard to this debate employing different procedures of documentation, prospection and spatial analysis of earthworks for the region of India Muerta. New sources of information are employed which have made it possible to obtain and extend data of mounds with greater spatial accuracy, to improve their morphological and distributional characterization and to identify new associated archaeological structures. This documentation favors the trial of statistical and spatial analyses with the aim of characterizing the mound sites, their location, emplacement and patterns of distribution. The results will make it possible to reveal if there are regularities which can be taken as emplacement strategies for mound sites and to identify patterns of settlement. This approach assumes that the mound sites constitute fundamental architectures in the life of the indigenous populations of the region and that, by studying them in spatial terms, it will be possible to examine in depth the underlying logic to the social construction of the territory.

1.2. Study Area

The study area is part of the basin of Merín lagoon and encompasses the wetlands of India Muerta. It is bordered to the north by the Cebollatí River, to the south-southeast by the mid-plains and hills of Campo Alto and the Sierra de los Ajos, and to the west by the Sierra de Averías. The territory is characterized by the presence of low and mid-plains with extensive grasslands, a dense network of rivers, streams, lagoons and permanent and seasonal wetlands [24,58,59].

The reconstruction of sea-level, climate and vegetation variations via multiproxy data from landforms and lagoon bottom core along the Uruguayan Atlantic coast has led to the identification of transgressive event before 7000 years ^{14}C, with a high sea level (3–5 m above sea level) between 6000 and 5000 years ^{14}C and a regressive event with interruptions due to relative sea-level increase of minor magnitude circa 3200 and 1700 years ^{14}C BP, also marked by climatic oscillations [22,60–63]. The genesis of the India Muerta wetlands is linked to this transgressive event through alluvial fans and plains with obstructed drainage of the streams of India Muerta and Coronilla [64]. The mounds are associated with the freshwater wetlands located above levels of +10–15 masl which, a priori, were not greatly affected by the maximum sea levels during the mid-Holocene.

The combined analysis of pollen and phytoliths of a sample from the Los Ajos lagoon (India Muerta) indicates that the mid-Holocene, between ca. 7516 and 4495 cal years BP (ca. 6620 and 4020 14C years BP), was a period of significant climatic fluctuation marked by a growing aridity, the maximum peak of which has been detected around 4495 cal years BP [24,65]. The oldest dating with a precise archaeological context for this region is 4840–4580 cal years BP [44], showing a clear coincidence between the beginning of mound construction and this period of maximum aridity [65]. At that time, the permanent wetlands of the area, which were probably more limited and with concentrated resources, demonstrated favorable conditions for the aggregation of human populations [65]. This aspect is in agreement with the record obtained for the zone of coastal lagoons, which identifies, from ca. 4500 years BP to ca. 3000 years BP, a semiarid or markedly seasonal climate in precipitation which led to the development of vegetation with short grasslands and few woody elements [61]. This drier and colder period extended up to 3000–2000 years BP, according to the records obtained in the stratigraphic profiles of certain archaeological sites [66]. For the period after 3000 years BP, evidence from other sites suggests the beginning of a trend towards warmer and damper conditions [55]. During this period, there was a significant expansion of mound-building groups towards the southeastern and northeastern areas of Uruguay, as well as towards the coastal lagoons of the south of Brazil.

Palynological analyses carried out in the zone of Los Ajos confirm that the permanent wetlands of India Muerta had already been developed from at least ca. 2000 cal years BP, with similar characteristics to today [24]. Following the last marine transgression of the Holocene, the coastal wetlands below +5 masl, stabilized and acquired their current configuration. In the basin of Merín lagoon, these wetlands were connected to tidal flats, paleolagoons, flood plains and abandoned watercourses [64]. The mounds continued to be inhabited and built in the region of India Muerta in those times [36].

Within the alluvial fan system and the wetlands which characterize the Estero de India Muerta and Rincón de la Paja wetlands, areas of higher land are recognized as mesoreliefs with regard to the lower levels of the flood plain. Many of these features are topographically distinguished and accentuated by the location of mound sites. The local peoples used the concept of *isla* (island) to denominate these mesoreliefs, which were also visually recognizable due to the presence of trees, which were absent in the rest of the territory. In the historical cartography of the area, it is common to find the use of the place name *isla* and reference to *cerritos*, which have a direct association with the known mound sites of the region (Figure 1).

These assumptions are proposed as the basis of the GIS-based analysis of the present study with the intention of examining the processes of construction and transformation of the landscape in the India Muerta region. On the one hand, the regional scale of the distribution, characterization and location of earthworks is presented, paying particular attention to the patterns of aggregation along with morphometrical and locational variables. On the other hand, the detailed emplacement is examined via the concept of "insularity" as a significant factor in itself. In this way, central aspects, such as topographical prominence, visibility and the dry/flood zone relationship are systematically and comparatively analyzed as possible factors influencing the location of the mound sites. The results are presented and discussed in the light of the different proposals put forward for the region.

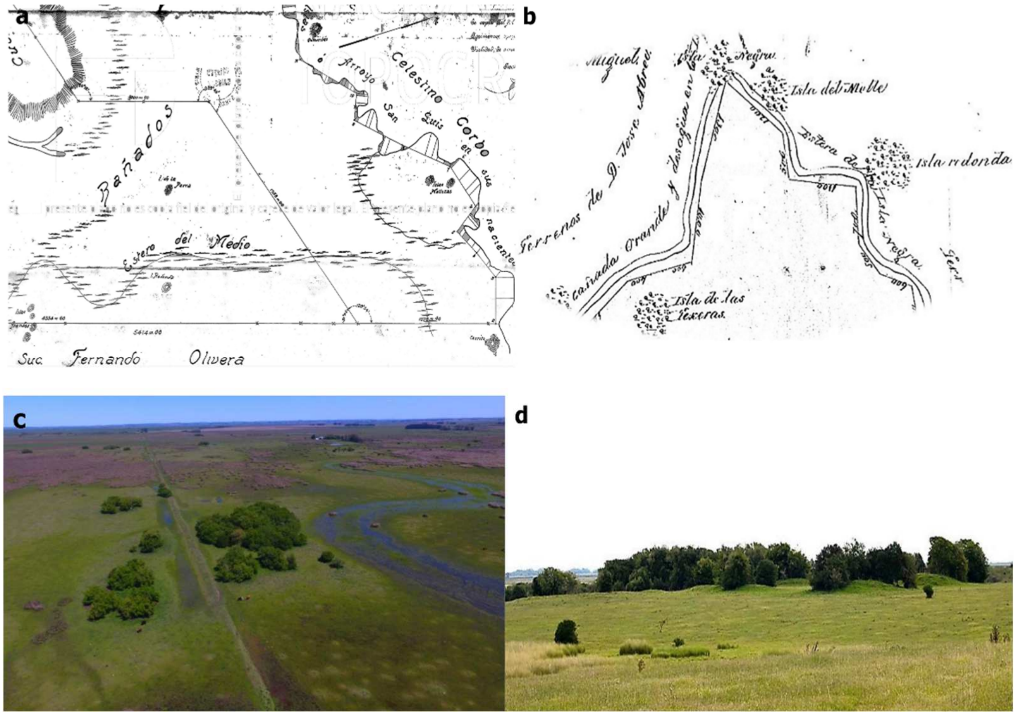

Figure 1. Concept of *isla* (island) and *cerritos* (mounds) in cartography and the landscape. (**a**) Section of the measurement plan of the Estero del Medio zone from 1916 (MTOP 106713): Islas Grandes, Isla de la Perra, Isla Redonda, Islas Mellizas, Cinco Islas and Cerrito. (**b**) Section of the measurement plan of the Cañada Grande and San Luis zone from 1831 (MTOP 106428): Isla Negra, Isla Redonda, Isla del Molle, Isla de las Texeras. (**c**) Group of mounds, Los Huesos in the Rincón de la Paja wetland. (**d**) Group of mounds, Los Ajos in the mid-plain close to the Sierra de los Ajos.

2. Materials and Methods

The methodology proposed contemplates two main stages. The initial phase addresses the geospatial location and documentation of mound sites in order to generate a georeferenced database. This database integrates quantitative and qualitative parameters which enable dynamic interaction with geostatistical procedures. The second stage consists of processing and systematically analyzing the geospatial variables linked to the emplacement, distribution and aggregation of the mound sites.

2.1. Remote Sensing

The starting point was a registry of mound sites from previous studies of around 300 cerritos. These were generally grouped together, with a few cases in isolation [23,66]. In addition, systematized locations of published maps were taken into consideration, which, although the location was relative, enabled some mounds to be recognized [35,39,52]. With the information obtained, a stage aimed at the remote detection of mound sites via digital images and models of the study area was proposed. Historical aerial photographs (scale 1:20,000) from the *Servicio Geográfico Militar* (Military Geographical Service, Montevideo, Uruguay) from 1966 were used, along with different digital information by photogrammetric coverage of *Infraestructura de Datos Espaciales de Uruguay* (Infrastructure of Spatial Data, IDEUY, Montevideo, Uruguay): orthoimages (natural color and infrared) with a resolution of 0.32 m, digitals terrain models (DTM) with a spatial resolution of 2.5 m and vectorial thematic mapping generated by images corrected by aerotriangulation with Inpho Match-T software and improved point cloud after cleaning the digital surface model with DT_Master software. Via the use of different visualization algorithms applied to the DTMs [67], topographical features of the terrain were highlighted, facilitating the detection of mounds.

2.2. Geospatial Data and Fieldwork

The located sites were integrated into a project using the QGIS 3.8.1 software, along with data from associated case histories, archaeological excavations and chronologies, etc. (Figure 2). This process made it possible to document a total of 321 new archaeological structures. Based on these results, an intensive and targeted archaeological prospection was designed to contrast the locations of the mound sites detected in the field, extend the documentation with morphometric and geographical variables and to locate new structures.

c

Code	Toponym	Register Number	Elevation	Long	Width	Height	AREA	PERIMETER	DISTURBANCE	CAUSE	WOODED	X	Y
LO181203Q01	Calle ancha / India Muerta	6952	16	60	60	2	2862	192	Low	Natural	Yes	779,864.13	6,275,177.69
LO181203Q04	Calle ancha / India Muerta	6952	16	40	35	2	1141	122	Low	Natural	Yes	780,070.82	6,275,077.70
LO181203Q05	Calle ancha / India Muerta	6952	16	22	14	0.5	259	61	Low	Natural	No	780,055.06	6,275,042.77
LO181203Q03	Calle ancha / India Muerta	6952	17	11	10	2.5	99	36	Low	Natural	No	780,094.14	6,275,034.23
LO181203Q02	Calle ancha / India Muerta	6952	17	55	46	2.5	2087	165	Low	Natural	Yes	780,095.73	6,275,001.38

Figure 2. Documentation of mound structures. (**a**) Identified in aerial photographs from 1966 (SGM 1:20,000). (**b**) Field record of the central point and polygon. (**c**) Some of the variables recorded in the field and inputted into the GIS.

The survey was complemented by the creation of detailed topographies with a total station in a selection of mound sites (Garcia Richi, La Tapera and Isla de los Talitas). At the same time, aerial photogrammetric surveys were carried out of two of the largest mound sites (Los Ajos and Malabrigo sites, with 90 and 71 earthworks respectively). These data made it possible to identify and analyze with greater resolution morphometrical attributes (heights, areas, volumes, gradients and orientations, among others) necessary for characterizing formal and construction features of the earthworks, and to recognize geoforms associated with the mound sites (micro-reliefs, platforms, squares, lagoons, channels, embankments and connecting spaces; Figure 3).

2.3. Spatial Analysis

The aim of this phase was to understand the distribution and emplacement of the mounds via the interpretation of relevant parameters which characterize the landscape. For this purpose, spatial analysis using QGIS and ArcGIS environments was employed. The analysis aimed at evaluating whether the location of the mounds was random or whether it reproduces one or more patterns in the study area. More specifically, different aspects were evaluated via two analytical designs. The first (see Section 3.3., Distributional analysis) analyses the possible groupings of the mounds and their characteristics in the regions in hierarchical terms, analyzing continuities and discontinuities in their distribution. The second (see Section 3.4. Insularity analysis), taking the results of the first design as a starting point, explores the location of the mounds in relation to their perception as islands, studying whether there is a correlation between the location of the mounds and the prominence variables (visual and topographical) and flooding in the region. The results of both analyses are aimed at discussing possible patterns of mound emplacement and location, evaluating the different population dynamics which may have arisen over such a long period of time.

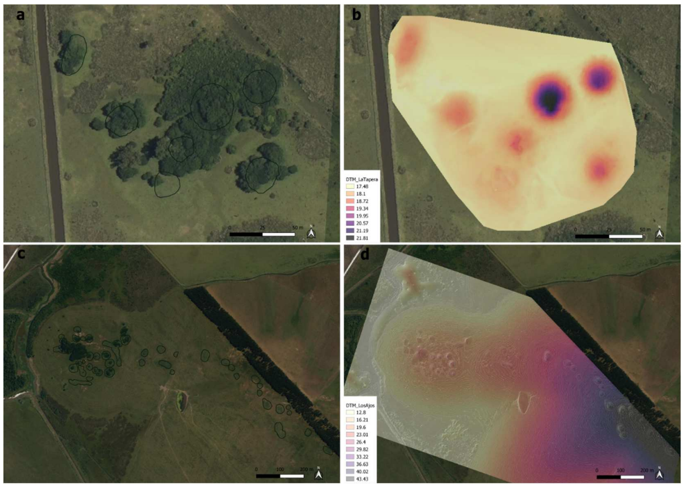

Figure 3. Geospatial record of earthworks in the field. (**a**,**b**) Orthoimage with GPS polygons of the different earthworks and DTM created via topography with total station of the La Tapera ensemble of mounds. (**c**,**d**) Orthoimage with GPS polygons of different earthworks and DTM created via drone photogrammetry of the Los Ajos mound site.

2.3.1. Distributional Analysis

The analysis of hierarchical clusters is particularly useful in exploring the spatial distribution of the mound sites and their spatial associations on different levels, employing the hclust algorithm of Rstudio [68]. The objective is to identify groupings (ensembles of mounds) with more similarities than the objects (mounds) of other clusters and to represent this in a graphic way via a dendrogram. As proposed by Carlson [69], there are three decisions to be taken in accordance with the nature of our data and the research objectives: the selection of variables to be grouped (X and Y coordinates), how to calculate the distance (Euclidian) and how to combine the observations into clusters (complete method). These methodological criteria have been successfully employed in other regions with similar problems [70]. In our case, work was carried out on a regional level, analyzing the first three cutoffs discarded from the dendrogram so as to select from among them the optimal number of clusters for comparative regional analyses. The selection of the cutoff arose in accordance with the correspondence with the traditionally recognized environmental units and ecosystems of mound sites: low plains with flooding, mid-plains and hills. In turn, the degree of grouping of the observations was evaluated via the nearest neighbor analysis (NNA) test [71,72]. The visualization of the groupings was carried out using the Kernel method, which calculates the density of points via the density of the entities around them [70,73,74]. The NNA and kernel analyses focused on being able to determine whether the mound structures were grouped together or if they were distributed randomly. The recognized groupings could be linked to both environmental and intentional aspects of social construction and differential use of the landscape by these indigenous groups.

2.3.2. Insularity Analysis

Evaluating the structure of the landscape is feasible via a series of variables to contrast the degree to which the emplacement of the cerritos is differential in accordance with the concept of insularity. An island is a piece of land surrounded by water, a dry and prominent zone from the topographical and perceptive point of view. This definition is used to evaluate a terrain according to the following variables: flood risk (column of accumulated water), topographical prominence (relative altitude) and visibility (visual perception of the terrain). The analyses were carried out using the ArcGIS 10.4 software, based on the digital modeling of the variables with the DTM and the IDEUY data. The variables have been statistically defined, detailing the study of their distribution. Thus, the distribution of each variable has been analyzed, comparing the locations of the cerritos in the study area.

The analysis of flood risk describes the size of the water column which would form in each cell of the terrain if the same amount of water were constantly poured into it. After this size, the water would overflow into other zones of the terrain which would consequently end up overflowing. The analysis was implemented using hydrological tools of the GIS software, which, based on the DTM, make it possible to calculate the zones in which water would accumulate. For this purpose, the spatial analyst extension and the sink and fill tools were used to analyze the catch basins, calculating the water column based on the altimetric difference between the filling of the catch basin and the DTM.

The analysis of topographical prominence describes the relative altitude of the position of the mounds with regard to their environment in a variable radius of distance. This type of analysis has been used in archaeology for different contexts and archaeological manifestations [75]. In Uruguay, similar analyses carried out to characterize the emplacement of mounds in the fluvial plains of Tacuarembó and the highlands of Potrero Grande demonstrated how the cerritos are located in places with a certain degree of natural prominence in relation to their immediate surroundings [42]. In this case, the relative altitude of the position of each mound was compared with points distributed in a regular mesh each 200 m, resulting in some 10,000 points distributed throughout the study area. From among the different forms that can be used to calculate the relative altitude, a calculation was employed which weighs the altitude against the mean of the surrounding area and makes it possible to compare the relative altitude in any location, independently of the altitude of the terrain [76] (pp. 23–24).

Visibility analyses have been widely used in archaeology, particularly since the development of GIS in the field of landscape archaeology [77] (pp. 1–28). In this case, the visibility analysis (visual perception of the terrain) seeks to characterize the visual prominence of the whole area, comparing locations with mounds and those without. Prominence is defined as the size of the area from which each location is visible from others. That is to say, one position will be more prominent if it is visible from a greater area. Therefore, our analysis is based on visibility calculations more than on visibility [78] (pp. 265–292). These representations have been defined by Loots [79] in GIS software as reflective viewshed. The calculations were implemented with the viewshed tool, adding up the altitude in each pixel and the height of a person (1.7 m) from which each calculation was carried out and limited with different distances in relation to the possibilities of perception potentially permitted by each one [80]. The calculations were made for all of the terrain cells and their representation can be taken to be a total viewshed [81–83] defined as an index with values between 0 (pixels not visible from any other pixel) and 1 (pixels seen from all of the pixels). For both the visibility and relative altitude analyses different scripts were programmed in Arc GIS 10.4., which automates the calculations and were executed over many hours of computation in order to obtain the values from the thousands of pixels of which the DTM of the study area consists.

3. Results

3.1. Remote Sensing

The use of aerial images and digital models made it possible to document 666 mounds in an area of 386 km^2 (2.6 mounds per km^2), with maximum densities in Colina Damonte site, where 59 mounds were concentrated in 0.2 km^2. The IDEUY DTM facilitated the identification of mounds and associated archaeological structures, artificial canals, present-day paths and topographical features linked to productive use, among others. In spite of the good resolution of the DTM, the majority of the mounds are not represented topographically. One possible explanation for this is that, due to the lack of knowledge of these archaeological entities, some mounds may have been eliminated in the photogrammetric processing due to the use of algorithms for the extraction of land elevations which would treat them as outliers (Figure 4), errors in elevation which do not correspond with the reality of the terrain. These absences are clear in the hillshade of Figure 4d, made from 16 directions and displayed as RGB. We have used different visualization techniques in addition to the previous one, such as slope gradient (SG), sky-view factor (SVF) or local relief model (LRM). The application of these techniques was done with the Relief Visualization Toolbox (RVT 2.2.1) [84,85]

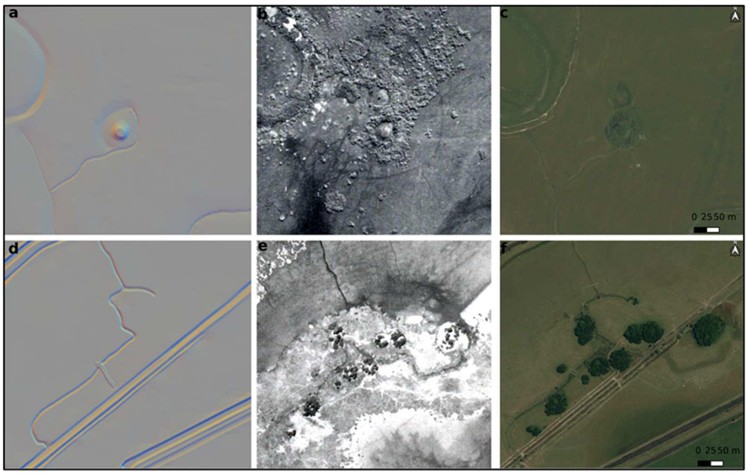

Figure 4. Documentation process of mounds and associated archaeological features using three different sources of information: hillshade calculated from multiple directions. (**a**,**d**), Historical aerial photographs (**b**,**e**), and present-day orthoimages (**c**,**d**). Location of a mound site composed of two mounds (**a**–**c**). In the DTM, a single mound appears (**a**); in the aerial photograph (**b**) and orthoimage (**c**) two mounds are identified. Group of mounds and associated anthropic canals (**d**–**f**): the mounds identified in the aerial photograph and orthoimage (**e**,**f**) are not represented in the hillshade (**d**). Furthermore, the presence of canals and depressed areas in the terrain around the mounds and groups should be noted (**a**,**d**).

3.2. Geospatial Data and Fieldwork

Of the total of 666 mounds geolocated via remote sensing, 421 were observed with their location in the field and data were extended aimed at the documentation of morphometrical, conservation and emplacement (among others) variables (Figures 5 and 6).

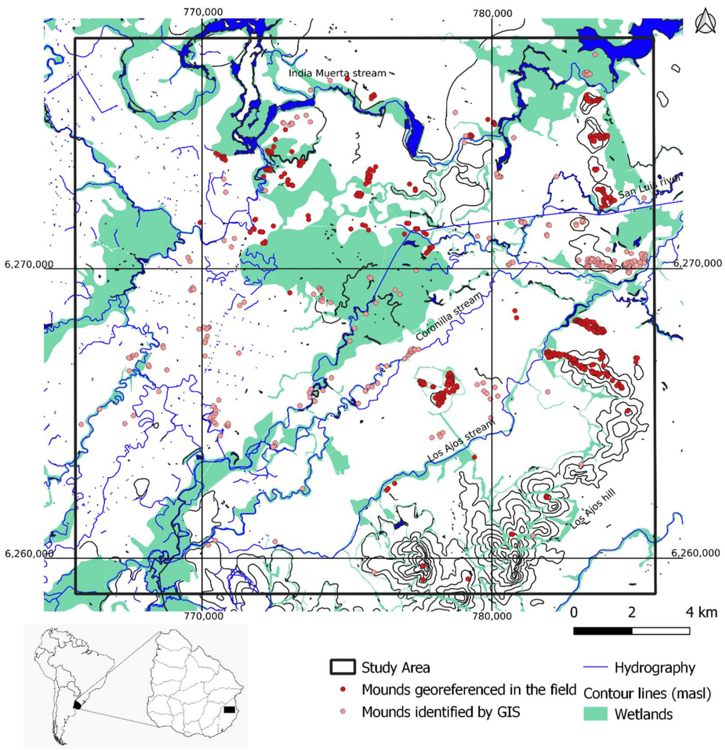

Figure 5. Map of the location of mounds in the macro-region of India Muerta via remote sensing and archaeological prospection in the field. Coordinates WSG84/UTM zone 21S and UTM zone 22S. Masl abbreviation corresponds to meters above sea level.

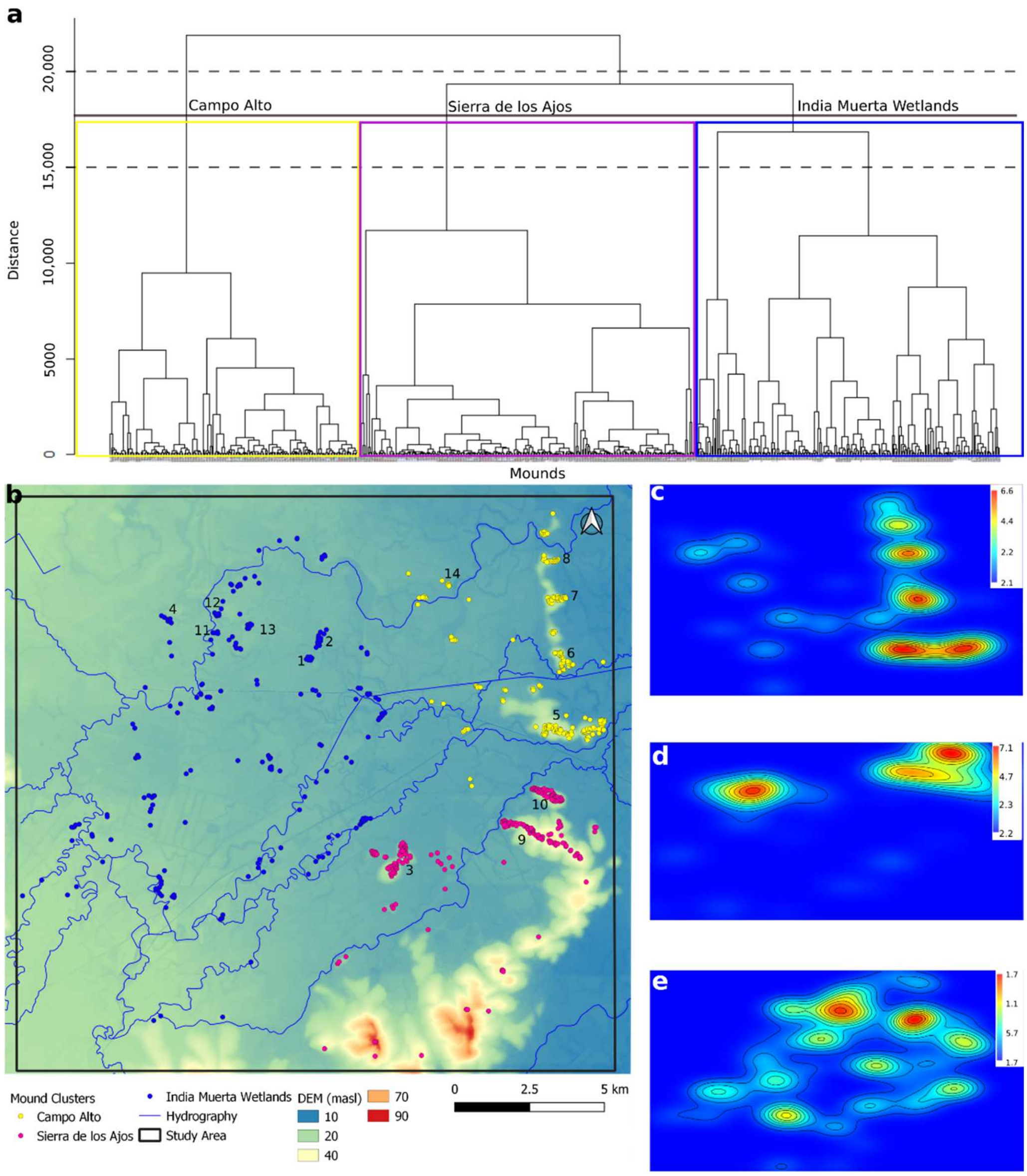

Figure 6. Results of the distributional analysis of mounds (**a**). Dendrogram resulting from the hclust algorithm, complete method in Rstudio. The possible cutoffs are shown for the scale of work by the dotted line, while the continuous black line shows the selected cutoff. (**b**) Spatial distribution of clusters resulting from the selected cutoff of the dendrogram. DEM abbreviation correspond to Digital Elevation Model. (**c**) Kernel model of the Campo Alto cluster, (**d**) kernel model of the Sierra de los Ajos cluster, (**e**) kernel model of the India Muerta wetlands cluster. The numbers indicate some of the most representative mound sites: (1) Isla de los Talitas, (2) Jaula del Tigre, (3) Mal Abrigo, (4) García Ricci, (5) Campo Alto, (6) Cabrera B, (7) Cerro Alto, (8) El Solitario, (9) Los Ajos, (10) Colina Damonte, (11) La Viuda, (12) La Tapera, (13) Los Huesos, (14) María.

On a morphometrical level, the mounds present average sizes of 37 m in length (SD = 15.1), 29.9 m in width (SD = 11) and 1.5 m in height (SD = 1.1; Table 1). In the case of elongated mounds, some (n = 5) were recorded with a longitudinal axis longer than 80 m. These mounds may be constructions of the platform type, probably with different functions, or complex forms resulting from superposition, the union of several structures or from remodeling, as has been documented in the mound sites of other regions [50].

Table 1. Basic statistics of the metric attributes of the mounds.

	Length (m)	Width (m)	Height (m)
Min.	9	6	0.4
1st Quartile	25	21	0.7
Median	34	27	1.2
Mean	36	30	1.5
3rd Quartile	43	35	2.0
Max.	150	83	7.0

3.3. Distributional Analysis

In the dendrogram resulting from the distributional analyses of the hierarchical cluster (Figure 6a) three cutoffs are clearly visible on a regional scale, between 15 and 20 km, which group the mounds into two, three and four large clusters, respectively. The distribution of mounds and their links with the geomorphological and environmental variability of the region is well-represented in the second cutoff from the dendrogram (at 17 km), which results in three large clusters (Figure 6b). In these clusters, the groupings subdivide, identified as smaller groups which present different patterns of grouping (Figure 6c–e).

The results show three large areas of mound distribution associated with different environmental units. The first area is associated with the lowlands and wetlands known as the India Muerta wetlands; the second is related with the mid-plains/hills known as Campo Alto and the headwater of the San Luis stream, which is the limit of the study area coinciding with the watershed; the third area is the line of hills and highlands which define the Sierra de Los Ajos.

The results of the nearest neighbor analysis show clear patterns of grouping throughout the whole area. The Campo Alto and Sierra de Los Ajos areas (Figure 6) are those which show the highest levels of grouping and density of mounds per km^2. On the other hand, the India Muerta wetlands area presents clearly grouped patterns but shows a lower density of mounds per km^2 (Table 2). In addition to the density shown in each cluster, inside of these, much higher densities are registered, and the large sets of the Sierra de los Ajos cluster stand out (Ajos = 79 mounds in 0.4 km^2, Mal Abrigo = 71 mounds in 0.5 km^2, Colina Damonte = 59 mounds in 0.2 km^2).

Table 2. Results of the nearest neighbor analysis for each local cluster.R abbreviation in the table represent the nearest neighbor ratio.

	Mean Distance	Expected Distance	R	Area	Density of Mounds/km^2 (Convex Hull)
Campo Alto	86.367	231.54	0.373	190	4.6
Sierra de los Ajos	87.534	224.14	0.390	50	5
India Muerta wetlands	165.82	361.21	0.459	120	1.9

The mound sites are situated at different levels of the terrain, even inside each mound site with significant differences. The cerritos of the India Muerta wetlands present low variability in terms of emplacement and are located at an average level of 17 masl, which does not correspond with the lower altitudes of the lowlands. Campo Alto is an area with average levels of 19 masl with a greater variability than the previous area. The cluster corresponding to the Sierra de los Ajos presents the highest levels, with an average of 26 masl and a greater variability in emplacement. In these analyses, it is also worthy of note that, for the whole area, no mounds are recorded below 12 masl (Figure 7).

In the lowest areas of the terrain (India Muerta wetlands cluster), not only are the highest cerritos found, but also the greatest variability in the heights of the mounds. Fifty percent of the mounds are between 1.0 and 3.3 m in height and 25% of the mounds are higher than 3.3 m (Figure 7b). The remaining 25% correspond to mounds of up to 1.0 m. The groups corresponding to Sierra de los Ajos and Campo Alto generally present heights lower than 2 m (Figures 7b and 8).

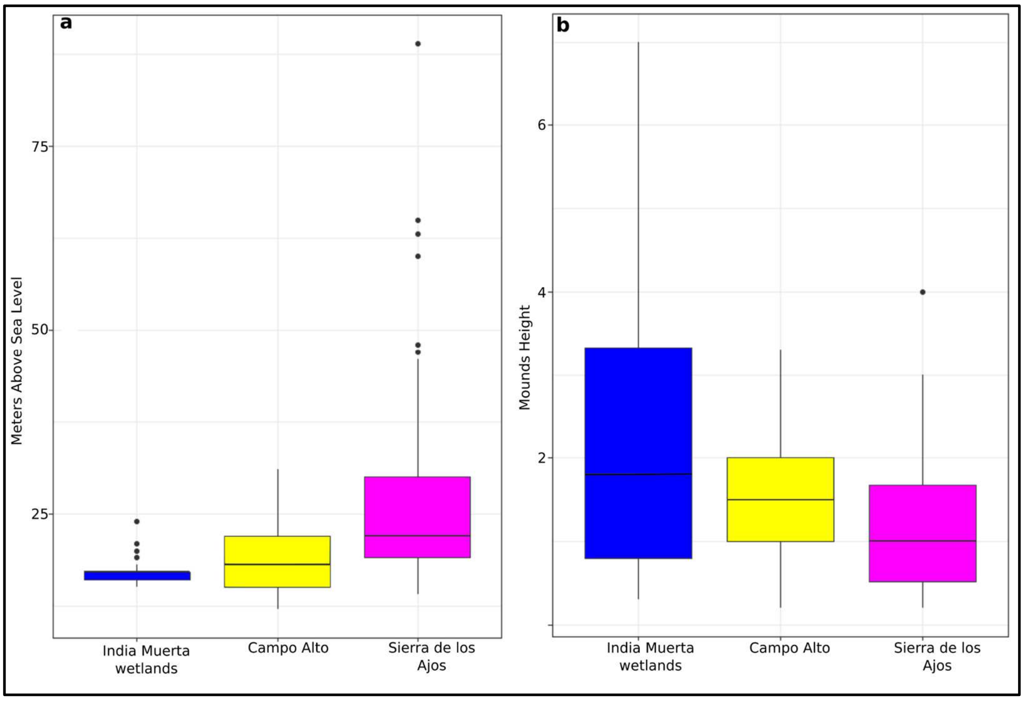

Figure 7. Comparative boxplots among the regional clusters. (**a**) Emplacement level of the mounds; (**b**) height distribution of the mounds.

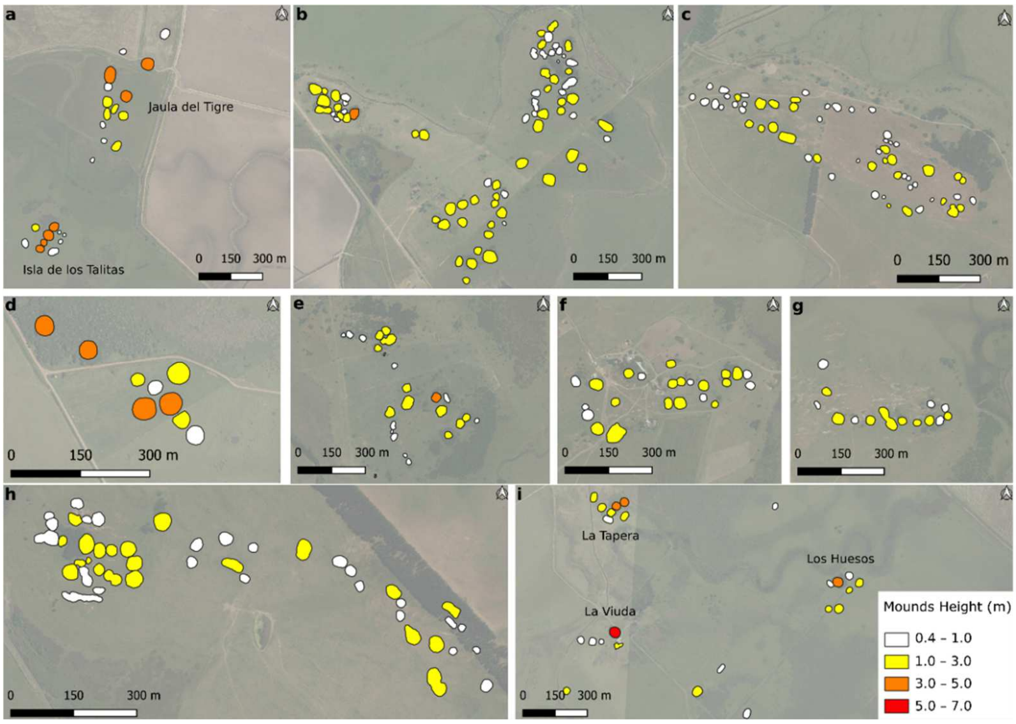

Figure 8. Maps with the spatial configuration discriminated by mound heights in different sites of the study area. (**a**) Isla de los Talitas and Jaula del Tigre (India Muerta wetlands cluster), (**b**) Mal Abrigo (Sierra de los Ajos cluster), (**c**) Colina Damonte (Sierra de los Ajos cluster), (**d**) García Ricci (India Muerta wetlands cluster), (**e**) Cabrera B (Campo Alto cluster), (**f**) Cerro Alto C (Campo Alto cluster), (**g**) El Solitario (Campo Alto cluster), (**h**) Los Ajos (Sierra de Los Ajos cluster), (**i**) La Tapera, Los Huesos and La Viuda (India Muerta wetlands cluster).

3.4. Insularity Analysis

An initial approach to the characterization of the emplacement of the mounds in the study area demonstrates a trend towards the situation of mounds in areas of an insular nature, with a low risk of flooding and slight prominence from the topographical and perceptive point of view.

The result of the flood-risk analysis made it possible to verify that the India Muerta region has many areas which are potentially floodable with maximum levels of water accumulation of 2.7 m. More than 21% of the areas of the terrain are made up of depressed zones with a point of runoff situated at a lower level. However, only 7% of the cerritos are located in these areas (Figure 9). The emplacement of the mounds in areas of an insular nature extends beyond their figurative sense. The paleo-environmental studies confirm that much of the terrain was made up of wetlands and flood plains and the existence of water management structures associated with these types of constructions is recognized in the research. The calculation of flood risk takes into account the riverbeds and presents the plains of the study area with wide flooded areas (Figure 9). Attention is not paid to the canalization of large-scale cultivation which would imply a variation of the water pulses and drainage, particularly within these systems of wetlands with imperfect drainage, in which the presence of bodies of water is a constant over time.

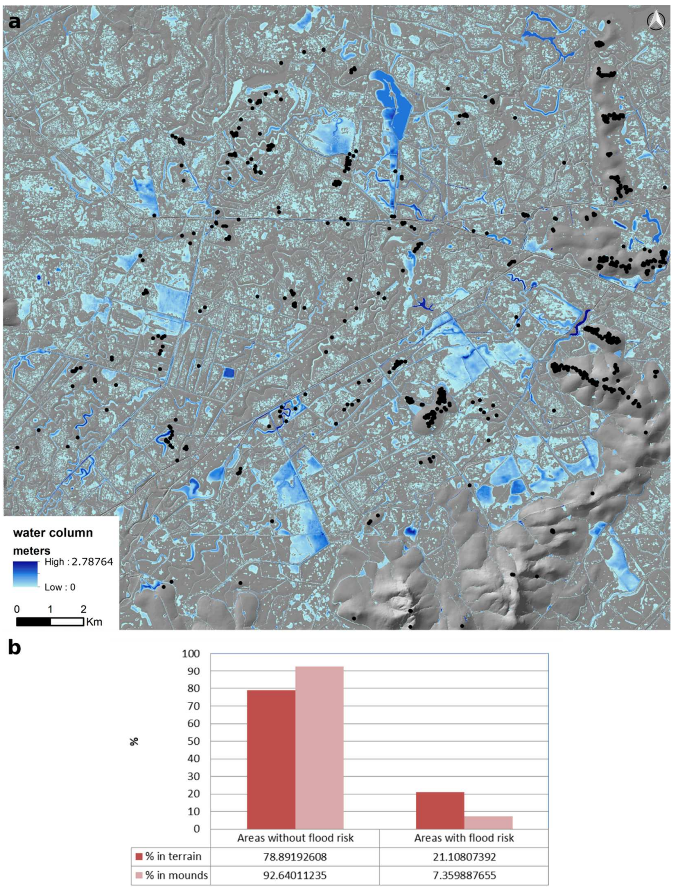

Figure 9. (**a**) Flood risk of the study area and location of the cerritos. The water column indicates the measurement, in meters, at which it would be possible to fill each point of the terrain until it overflows into a catch basin. (**b**) Graph of the comparative flood risk between the zone with the cerritos and the general terrain.

The prominence analysis takes a radius of 100 m as a reference for each point and the results show a clear trend of the prominence of the cerrito in this environment. If the ranges of prominence are distributed, more than 50% of the cerritos are in the maximum range of prominence, whereas only 10% of the random points are within this range. More than 65% of the mounds are more prominent than 80% of the random points. If the prominence of the cerritos is compared with the different radii of distance (variation of the size of the environment), the results show that as the radius increases (100, 200, 300, 1000 m), so does the prominence (Figure 10). The densest location of mounds in the Sierra de los Ajos corresponds with the most prominent geographical feature in the region, although the election of the most prominent areas within this environment is shown for the emplacement of the mounds.

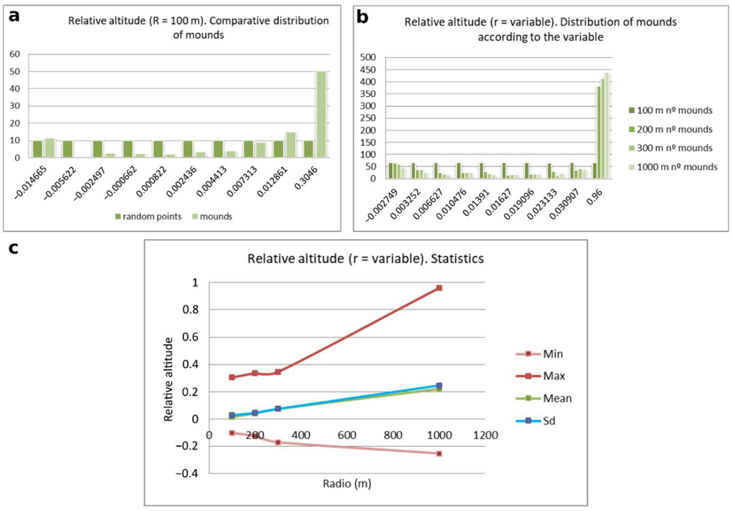

Figure 10. Topographical prominence (relative altitude analysis).

The results of the visibility calculation show how the cerritos are points of visual reference in the landscape if they are compared with other locations in the area without cerritos. More than 35% of the cerritos are visible from 75% of India Muerta, whereas only 6% of the locations of the zone fulfil this condition. If the distance is reduced to the detection threshold of a human being (2092 m), the prominence of the cerritos is still above other locations in the area (Figure 11).

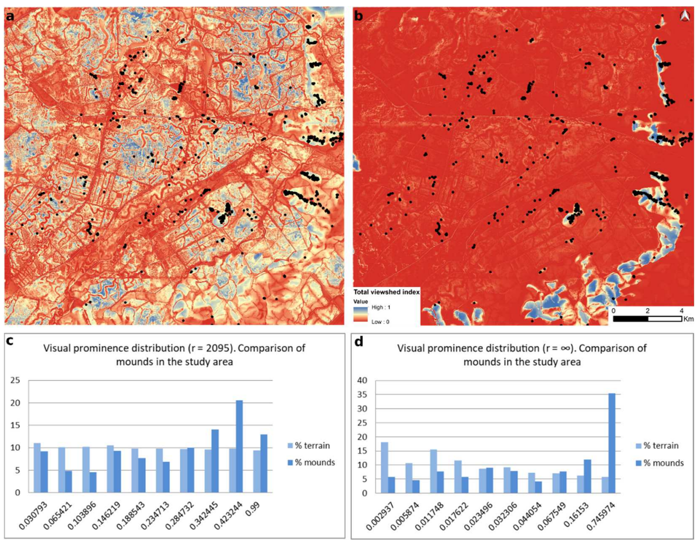

Figure 11. The total viewshed index indicates, for each point of the terrain, the number of points from which it is possible to see the first. The index acquires a value of 1 when it is possible to see a point from all of the points of the terrain, and a value of 0 when it can be seen from none of them. (**a**) From the environment of 2095 m. (**b**) From any point of the study area. (**c**) Graph of visual prominence distribution (r = ∞). (**d**) Graph of visual prominence distribution (r = 2095).

The calculation shows that the trend is not only to elevate these constructions, but also to make them visible via the election of a prominent area over the environment. The areas of visibility indicate, on the other hand, that the cerritos are also points from which it is possible to have an outstanding visual control of the area. The measurements prove a clear trend towards choosing places with visual prominence for the construction of mounds, independently of the scale of analysis, the complexity of the construction phenomenon or other possible factors not analyzed here.

4. Discussion and Conclusions

The systematic application of documentation, prospection and analytical procedures has made it possible to significantly increase the number of known mounds in an area of great archaeological relevance known as being the original geographical focal point of this phenomenon. The availability of new data with a higher resolution extended our capacity of detection, even in sites with prior relative mapping, as is the case of Los Ajos, Colina da Monte and Mal Abrigo [35,55], and made it possible to update relevant data in order to propose future spatial analyses on other scales. For the first time in this region, structures such as ponds and small canals were identified within some mound sites, introducing new question marks around the organization, activities and management of the space inhabited by mound-building societies. Archaeological records from the northeast of Uruguay show that these types of structures have formed part of indigenous technologies for the management of floodable ecosystems. In the Pago Lindo site (department of Tacuarembó), lagoons and canals recorded within mound sites functioned contemporaneously with the use and construction of mounds between 3000 and 1000 years BP [50,86]. These features are also present in other mound sites in the valley of the Caraguatá River [87]. The use and management of these lagoons would have made a reservoir available inside the village for various uses such as the irrigation of crops or even to use as a trap for the breeding of fish at certain times of the year. Several of these uses have been reported in different lowland contexts in South America [7,88] related, among other aspects, to the generation of nearby fishing sites, and are part of a socioeconomic specialization of marshy environments [10] like water reserves and as drainage control structures in times of flooding [5,16].

The spatial analyses carried out reflect patterns of location and distribution which make it possible to characterize the structure and composition of the archaeological landscape of mounds. The results reveal that the mounds are not distributed randomly, but rather present groupings on a different scale with patterns of differential spatial organization. The mounds are grouped in sets with variable densities (min = 4 and max = 90 mounds) identifying small sites and large and complex sites, as well as isolated cerritos in intermediate enclaves. On a regional scale, these groupings correspond to three large zones with particular characteristics, linked to different topographical and environmental units.

The lowland zone (India Muerta wetlands) presents the emplacements at the lowest altitudes and records the highest mounds with the largest dimensions. The groupings characterized are small (4 mounds), medium (10 mounds) and, to a lesser extent, isolated mounds are recorded. The general distributions in the India Muerta wetlands cluster exhibit a linear/curvilinear pattern which accompany the courses of the rivers and are coherent with what is recorded in other areas, such as the alluvial plains of the San Luis, San Miguel [22], Yaguarí and Caraguatá rivers [89]. The construction of the first mounds, during the maximum peaks of aridity (according to contextualized dates ca. cal 4900–4700 years BP.) of the mid-Holocene, is associated with the alluvial plains. At that time, the watercourses and wetlands would be more active and limited as areas with concentrated resources to which the mounds were linked [65]. In spite of the later changes to a warmer and wetter climate (ca. 3000–2500 years BP), several of the early mound sites continued to be occupied, new structures were built and an expansion of the construction of mounds took place towards the higher areas (hills and mountains) and closer to the Atlantic coast [42,55,60]. The marine transgression that began ca 7000 years BP generated the obstruction of drainages (due to a change in slope) and the development of large areas of wetlands. Even when the sea began to fall and climate deterioration began, these areas maintained more stable wetlands with areas of concentration of resources. In addition, low-lying wetlands did not exist or were brackish. Only when the streams and rivers such as Cebollatí and San Luis (3000–2700 years BP) were notched, the high marshes would have lost part of their extension (or permanence, or both), but at the same time the low-level marshes began to develop [60,90].

The second distribution zone, the Campo Alto cluster, coincides with the medium hills which physiographically constitute the foothills of the Sierra de los Ajos and act as the dividing line between the two great wetlands of India Muerta and San Miguel. This cluster, along with that of the Sierra de los Ajos, is the most stable area at lowest risk of flooding due to its topographical altitude. Both areas present mound sites with a more complex spatial organization. They have the greatest density of mounds, with complex and recurrent spatial arrangements exhibiting alignments, enclosures of mounds and the existence of negative archaeological structures (ponds and canals). These large groups of mounds are located on the western slope of the sierra, with broad visibility over the India Muerta wetlands and the mound sites of the low plain. This aspect makes it possible to suggest a closer relationship between the mound sites of the three zones than with those of other regions, for example, those located towards the eastern side of the sierra. If the chronologies obtained to date in the region are taken into consideration, it can be seen that there are contemporaneities between several mounds sites, as well as between mounds within the same group [24,35,36,39].

Unlike Campo Alto, as well as having large groups, the Sierra de los Ajos cluster has a distribution of isolated cerritos strategically located at higher levels. These mounds, although they present the lowest heights, are visual points of reference in the landscape due to their location in prominent areas and can be seen at a distance silhouetted against the horizon of the sierra. This pattern of emplacement, which is present in other mountain chains in the region, has been interpreted as part of a strategy of visibilization and territorial articulation [42,53].

The results of the insularity analysis demonstrated that the conjunction of variables such as prominence, choice of areas with low risk of flooding and visibility–visibilization are characteristics which make it possible to understand the emplacement of the mound sites in the region, particularly in the low flood plain. The majority of mounds were built in naturally raised areas within the lowlands and at prominent points in the hills. In almost all cases, these areas correspond to points with a low risk of flooding. This natural feature is emphasized with the construction of the mounds, highlighting the configuration of mesoreliefs of greater prominence, currently recognized as islands. It is worthy of note how, in the India Muerta wetlands cluster, the highest mounds add a factor which emphasizes the visibility and visibilization of the emplacement. The mound site, taken to be an anthropogenic mesorelief, reduces the flood risk even more, increases conditions of visibility over the terrain and can clearly be identified at a distance.

Our research shows that the distribution, emplacement and spatial organization of the mound sites in the India Muerta region are in line with a complex and integrated system of regional settlement [55]. This system is structured around small mound sites, large and complex mound sites and isolated mounds, results which encourage in-depth spatial analyses on an intermediate scale in order to make it possible to characterize ranges of grouping of the mounds. The large mound sites were interpreted as nucleated villages which functioned as spaces for communal aggregation from ca. 3000 years BP onwards. It is in this period that a generalized use of ceramics begins to be observed and the consolidation of a mixed economy that integrates horticulture (*Zea mays* L., *Cucurbita* sp. and *Phaseolus* sp.). There is also a specialization in the use of space, intense construction activity, formalization of spaces, complex architecture and greater social stratification related to demographic growth and greater territoriality. It is also in this period that some mounds begin to be used as cemeteries [25,42,52]. The small mound sites situated in the wetlands form small villages, whereas the isolated mounds are strategically located on high peaks and abras (hills) which leads to an interpretative hypothesis of their function as "lighthouses" or indicators making relevant geographical points visible for the organization and articulation of the territory. Both patterns of aggregation (small and large mound sites) could be interpreted as part of a logic of seasonal residential mobility between dry and rainy seasons, and/or as part of fission–fusion social processes of indigenous groups for specific events of communal aggregation (ceremonies, events of the annual or seasonal cycle, alliances, among others), as has been proposed for other zones [42]. In this regard, the sierra, noted for these complex mound sites and isolated mounds, functions as a liminal space and/or a border which geographically defines the wetlands with all of their resources, while also proving to be a territory of communication and social congregation. The spatial complexity recognized in these patterns and their characteristics reaffirm the origin and development of a model of community-based village settlement, identified for the region of India Muerta around 3000–2500 years BP [52,55,65]. On the other hand, from a long-term perspective, these patterns are the result of territorial reaffirmation processes and of recurring residential occupation in the same spaces, a factor which has also been identified in other South American regions [21,23,56,89]. In the immediate future, it is necessary to develop new excavation projects aimed at generating new contextual information that will confirm or refute these interpretations.

The results obtained provide keys to understanding the regional particularities of earthen architecture, its origin and development and processes of territorial construction, while also broadening knowledge in order to be able to establish comparative analyses and regional models of occupation of the South American lowlands.

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