GIS and Landscape Archaeology: A Case of Study in the Argentine Pampas

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Abstract

The aim of this paper is to present GIS methodology applied to a landscape archaeological research of hunter-gatherer societies in Buenos Aires Province, Argentina. Some theoretical remarks about space representations are mentioned; and Argentine archaeological cases using GIS approaches are briefly cited.

The research strategy followed in our landscape archaeology study is detailed and the materials are described.

We highlight the importance of GIS tools for the different steps of the research process: for the preparation of fieldwork, for laboratory questions and resolution of problems and for the presentation of results.

Key Words: GIS- Landscape archaeology-hunter gatherers-digital elevation model-pampean region-Argentina

1. Introduction

Landscape in hunter-gatherer groups is a complex issue for the archaeological study. Thus, we introduced the idea of an archaeological place as a key concept to address the problem. The characterization of places results from the integration of different lines of evidence including information about objects, space and bodies, as essential elements of the materiality of human life. We follow a research strategy centered on archaeological places that alternately focus on the field, the objects, and the virtual field (Mazzia, 2013a). Based on these characterizations, in terms of the material and spatial relationships between

places, we outlined a spatial and social network. Past social landscapes are defined as a net of interconnected places through the material evidence of the human practices and embodied experiences.

In this paper we present GIS methodology applied to our landscape archaeological research of hunter-gatherer societies that dwelled, visited and moved around the central-east portion of the Tandilia range (Buenos Aires Province, Argentina) at the end of Pleistocene and early Holocene.

The developed research plan combined a wide variety of activities, including archaeological fieldwork, image processing and interpretation from a geomatic approach. These activities were complemented with anthropological fieldwork with the local community and archaeologists contributing with a subjective view to the spatial analysis. The geomatic approach was mainly guided by questions about the visual relationship between archaeological places and the surroundings, place intervisibility and about the distances between places and the possible paths that connected them.

Before presenting our case of study, some theoretical remarks about space representations are mentioned and Argentine archaeological cases using GIS approaches are briefly cited.

2. Different Forms of Space Representation and Landscape Archaeology

"*No spaces can be controlled, inhabited or represented completely. But the map permits the illusion of such possibilities. Mapping is a creative process of inserting our humanity into the world and seizing the world for ourselves*." (Cosgrove, 2008: 168)

Different kinds of space representation, such as maps, photographs and digital elevation models (DEM), are incorporated into archaeological investigations as an unquestionable tool. Rarely, their characteristics and origins are challenged. But, any space representation implies a conceptualization and a particular point of view. This statement does not try to discard the use of such images; instead it seeks to explicitly recognize that space representations are based on historical development and theoretical perspectives.

During the Renaissance, the origin of the idea of landscape was linked to innovations on the graphical representation of space. There is a close relationship between the development of landscape painting and the modern notion of landscape. Since then, a variety of graphics media has been used to represent the space, among them: maps, drawings, photographs and digital images. These different graphic representations have shaped their features according to the ways in which nature was

conceived, designed and communicated in the history of Western society. All of them embody a particular way of word view as well as an instrument to communicate it; they are elements of spatial, social and environmental practices (Harley, 1989; White, 2002; Cosgrove, 2008).

Particularly, maps were linked to the appropriation of space. They have provided means of control to modern States, and a legitimization of their power outside and within its boundaries. Thus, this kind of space representation played a central role in the physical and cultural colonization of people, territories and nature. Also, mapping was useful to the positivist approach of science, since it helped to codify and promote the word view that scientist reproduced. In this context, the map was considered an objective reflection of reality. However, based on critical thoughts on the mapping practice, maps began to be identified as graphic representations that allow a spatial understanding of objects, conditions and processes in the human world. As a result, maps were conceived as a document generated from social knowledge and lost their status of objective source of spatial information (Edson, 2001; White, 2002; Cosgrove, 2008).

Something similar has happened with photos. Since its introduction in the 19th Century as a technique for capturing images, photography was presented as a medium capable of performing a faithful record of reality. Therefore, it became ideal for an objective documentation of the world. Those spaces that were formerly subjectively recorded by hundreds of artists could be captured by a single person with a few shots. The distant and exotic landscapes became something tangible even for those people who had never traveled.

Photography received the same criticism as cartography. Instead of an objective reflection of reality, photos have been recognized as an iconic representation feasible to offer multiple readings and an infinite number of uses. Each shooting always conforms both to general artistic trends and photographer's criteria; the last one can be influenced in turn by aesthetic standards, and by his/her theoretical framework, objectives and background (Sontag, 1977; Bustamante, 1999; White, 2002; Gamboa Cetina, 2003).

The 20th Century began with the achievement of reaching a visual perspective of the Earth's surface from the air. With first flights, the way in which the scenery could be seen and interpreted was deeply transformed. Since then, important technological developments have allowed getting images of different places at scales that were previously impossible. This happened with the introduction of remote sensors; first, through the introduction of aerial photography and then with the images recorded by satellites in orbit, as the Landsat series. However, the possibilities offered by such images did not develop their full potential until the emergence of digital tools such as Geographic

Information Systems (GIS). The GIS approach, able to synthesize a wide spectrum of spatial representations, provides multiple options to those studies focused on the spatial dimension.

Archaeological research often includes maps, plans and photographs, either with traditional or digital formats. From the very beginning of the history of archaeological investigations, the spatial aspect of the human past was a relevant issue. Since then, spatial representations have been both a point of departure, by providing background information, and a final stage of the research through the graphical presentation of results (Orejas, 1991; Kantner, 2008).

The aerial and satellite exploration with archaeological purposes has been used for the discovery of new sites, for analyzing patterns of territoriality of past societies in relation to the topography or the drainage networks, and even for illustrating the form and the extent of studied sites (González de Bonaveri, 1989). Spatial and landscape archaeological research has been enriched with the emergence of digital cartography, Global Positioning System (GPS) and GIS projects. The latter include a variety of software for the management of databases with spatial components (González Aguayo, 1994). These software are used for capturing, handling, analyzing, recovering and displaying georeferenced data. Any geographical information can be coded in a GIS project; large datasets from sources as diverse as conventional maps, aerial photographs and satellite images, can be combined (Gómez, 1994). In addition, GIS quickly and easily support queries, updates, changes or corrections (Kvamme, 1989).

GIS also enables high resolution digital landscape modeling that can be applied to simulate the topography in a dynamic way. In fact, the creation of digital elevation models (DEM) is one of the most used applications in the archaeological practice. DEM are three-dimensional representations of the topography used to understand the shape of the land in the laboratory (Kvamme, 1989; García Sanjuán, 2005; Kantner, 2008). Since it is not possible to reconstruct the exact nature of vegetation in the past (the skin of the Earth's surface), DEM analyses use structural features (the bones of the landscape) known from geomorphology (Llobera, 1996).

A DEM facilitates the characterization of archaeological sites, environments and the development of visibility studies. Indeed, visibility analyses have been carried out in archaeology with independence of GIS projects (for example: Thomas, 1993; Bender *et al.*, 1997); according to a phenomenological approach, visibility is a subjective characteristic resulting from the interaction of people with their environment and not an objective attribute of the environment. Therefore, an integrated strategy includes an outline of what can be seen from each location, both as a subjective image taken during

fieldwork and as a visibility graphic on the DEM. The aim of this integration is to generate a comparative database. The combination of these two forms of visual perspective record tries to avoid mixing up vision and perception, a common mistake among GIS visibility analyses (Lake and Woodman, 2003). A definition of perception based only on what can be seen and what cannot be seen is a simplification of human reality. Indeed, it is difficult to incorporate the notion of perception in archaeological research because perception is always multi-sensory and it is also mediated by memory, experience and expectations (Gillings and Goodrick, 1996; Lake and Woodman, 2003).

Visual determinism has been an important criticism that GIS faces in archaeology, since visual preponderance is cultural and historically located in our Western present. Another criticism that many archaeological studies based on GIS received is related to the lack of theoretical basis and the occurrence of deterministic and functionalist interpretations. Environmental determinism, framed by the traditional dichotomy between nature and culture, is related to the emphasis on environmental data obtained from maps and pre-existing images. One more objection to these approaches is that they implicitly refer to a dehumanized, abstract, empty, external and neutral space; and that this kind of space lacks meaning and agency. Also, some GIS projects tend to reduce archaeological data complexity to statistical analysis points without meaning (Gillings and Goodrick, 1996; Llobera, 1996). Ethically, since GIS projects are often linked to modern control and domination technologies it is strongly criticized for studying the past (Thomas, 1993; Curry, 1998; Wheatley and Gillings, 2000; Lake and Woodman, 2003). A shared criticism with Google Earth points out that a virtual and digitized land may lead to a misrepresentation of reality, and it makes the real world irrelevant (Allen, 2009).

Each limitation and criticism can be overcome with a reflexive application of these digital tools. The use of GIS in an archaeological research has to be always based on explicit theoretical models (Diez Martín, 2007).

Of course, not all archaeological research that uses GIS and incorporates environmental and visual information is destined to be deterministic. Determinism is not inherent to GIS, but the concepts used to study the spatial aspects of human existence, the way in which the information is presented and the interpretations that emerge from it are deterministic (Llobera, 1996).

GIS, as flexible mechanisms for exploration and analysis of the landscape, become more and more a tool to reflect and propose new questions about the past social spaces.

Different images produced by the application of GIS have an enormous graphic power because they are able to increase the cartographic illusion of a synoptic view of the represented space.

As maps, these digital representations are means to extend the capabilities of the human body, as they permit the access to a view of spatial scales too vast for the naked eye (Cosgrove, 2008). When it is considered a tool in the archaeological research, GIS can be used to explore spatial and material evidences of human activities and their relationship with topographical features; it is included in a methodology that combines an interpretive approach with an empirical experience (Llobera, 1996). Summing up, the incorporation of new technologies in archaeological practice provides a range of new opportunities rather than finished solutions (Hodder, 1999).

3. GIS Studies in the Argentine Archaeology

Since 1990, GIS projects have been increasingly introduced in archaeological papers. Even different theoretical approaches to the study of human space often share the use of this technology. In 2004 this was really noticeable in Argentine archaeology because of the publication of 21 abstracts sent to the *Use of geographic information systems (GIS) in archaeology* Symposium that took place in the XV CNAA (National Congress of Argentine Archaeology) (Tamagnini and Mendonça, 2004). Papers presented at the Symposium were extremely diverse, a clear example of the versatility of these digital tools. Among them, the elaboration of databases with spatial reference is one of the most widespread applications, either to design future surveys, record the collected information, generate thematic maps or to prove locational hypothesis (Gómez and Magnín, 2008; De Feo, 2013; Quiroga and Korstanje, 2013; Magnín, 2013; Manzi *et al,*. 2013). Processing images with GIS has been useful to generate predictive models of the location of archaeological sites based on the potentiality of environments, a proposal that was framed by an ecological perspective (Figuerero Torres *et al.,* 2013; Scheinsohn and Matteucci, 2013). Another use of GIS is presented in the reconstruction of occupational histories and the characterization of the spatial distribution of human evidence in relation to topographic and environmental features (for example: Andolfo and Gómez, 2004; Assandri, 2004; Berardi, 2013). Different actions in the management of archaeological heritage have also been enriched with the use of GIS because it helps in the visual identification of risk situations associated with spatial variables, and for its ability to generate regional inventories (for example: Chalabe, 2004; Grinstein, 2004; Actis Danna *et al.,* 2013). More specific studies have also been developed such as the quantification and spatial distribution of lithic raw materials in the environment (Cattáneo *et al.,* 2007) and zooarchaeological analysis inside a site, changing the analysis scale (Izeta, 2013). A PhD thesis on archaeological distributions in the central massif of Santa Cruz, and

the implications for hunter- gatherers mobility and use of spaces, studies was carried out based on GIS methodology (Magnín, 2010).

In Argentina, GIS archaeological research has been focused mainly in Patagonia and NOA (the Northwest region). In the Pampean region, where we work, the use of GIS does not share the same wide spread. Even though the papers are fewer, the GIS approaches are also diverse and heterogeneous. In the Ventania range (Buenos Aires), a GIS study was developed in order to identify the lithic raw materials distribution in the environment and to characterize the use patterns of those rocks in archaeological sites (Moirano, 2004; Oliva *et al.,* 2004). In La Pampa Province, the spatial and temporal distribution of *Ranqueles,* settlements (post conquest period) was analyzed through thematic maps that pointed out the spatial relationships among different sites, movements' paths and environmental characteristics (Tapia, 2008). Finally, several studies focused on the Tandilia range in the Buenos Aires Province. In the central portion of the range an aerial photograph analysis was carried out on lithic built structures of the post conquest period (Pedrotta *et al.,* 2005; Duguine *et al.,* 2008). Also, the relationship between these kinds of stone constructions with movements_ paths were also studied using GIS (Ramos *et al.,* 2004). In the eastern section of the ranges, a DEM was made in order to have a detailed representation of a small hill where Amalia archaeological locality is situated (Farenga, 2002). The research strategy present in this paper was included in a PhD thesis on Pampean hunter-gatherer places and landscapes (Mazzia, 2010–2011).

4. A Virtual Fieldwork: Image Processing and Data Analysis using GIS

Bearing in mind the zoom idea taken from photography, we developed our research program in a way that the angle of view can vary as the scale considered So, we can move from an extreme close-up frame or macro of the details of archaeological artifacts to regional approach of the sites and their environment with a wide angle perspective. This broader perspective was only possible by means of a GIS project: a georeferenced database that can be visualized and analyzed, showing a global vision of the terrain. In our case of study, the use of this methodology was based on geomatic techniques, discipline oriented to spatial information knowledge, from the capture to the final presentation of the spatially referenced data (Flores, 1996). It was like a virtual fieldwork where we asked about the visual relationship between archaeological places and their surroundings, and place intervisibility. Also important, the virtual fieldwork pointed to analyze the distances between places and the possible paths that connected them.

The materials used in our GIS project include: topographic maps published by the IGN* at scale 1:50,000, aerial photographs at scale 1:20,000 taken from flights from 1981 to 1984 and published by the Geodesy Direction (Buenos Aires province), satellite images Landsat 7-ETM+9 (2001) and reference ground points taken with GPS Garmin Vista during fieldwork. In order to reference topographic maps, aerial photographs and satellite images, the datum used was WGS84 and the projection system was TMARG5.

Satellite images were processed using geometric correction techniques and control points that were marked with GPS. These points were located on the ground using natural and anthropogenic features that were easily identified as reference in the images (Gómez 1994). A mosaic of satellite images was made through *Image Display and Mozaic Wizard* application of ER Mapper 7.1. Multispectral satellite images exhibit a cell size of 28.5 m; however, when we merged them with a panchromatic image we got an image mosaic with 14.25 m of cell size: Thus, the result was a processed image on a higher resolution.

Once satellite images were corrected, they were used to georeference aerial photographs by means of *Geocoding Wizard* application of ER Mapper 7.1. Control points were evenly marked on each photo and they were correlated with the same points identified on satellite images. Then, aerial photographs were saved as raster images in a GeoTIFF format and they were joined together in a mosaic through *Image Display and Mozaic Wizard* application of the above- mentioned ER Mapper 7.1. This mosaic of aerial photographs exhibits cell size of 1 m.

Afterward, we worked on topographic maps. Since the topographic variable cannot be completely comprehended in a two-dimensional map, DEM three-dimensional analysis makes this variable visible. Part of the cartographic information, already digitized, was given by Dr. Mauricio Quiroz (CONICET-UNMdP) in a dwg file format from AutoCAD 2006. We added height information to each contour line and grouped layers.

Subsequently, we summed spatial information of other topographic maps on paper that were scanned and corrected through the *Geocoding Wizard* application of ER Mapper 7.1. Each one was saved as georeferenced raster image in a GeoTIFF format. Using AutoCAD 2006 we assigned height values to each contour line. A DEM was created by means of *Gridding Wizard* application of ER Mapper 7.1 based on the vectors file containing digitalized contour lines. Once created, DEM was the starting point for subsequent analyses, allowing 3D views from different angles (Figure 1).

This last part of image processing takes too much work, but it is possible to omit the step by downloading a DEM with ASTER images of the TERRA satellite, which is available by the Japanese Government

*National Geographic Institute (Argentina)

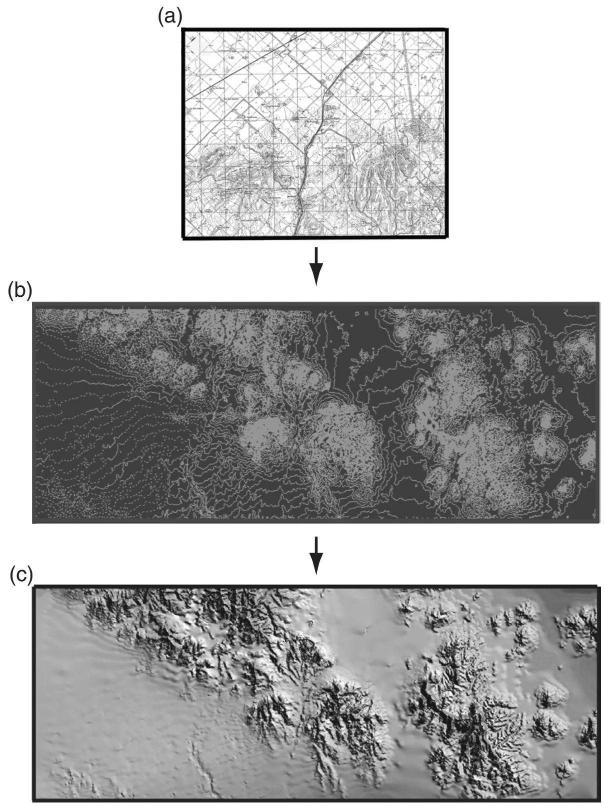


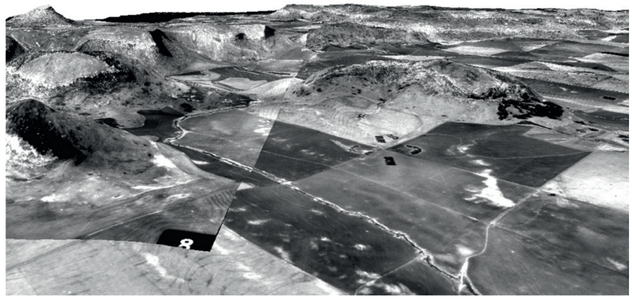
Figure 1. DEM creation process; a-topographic map, b-contour lines digitalized, c-DEM.

and NASA in http://www.gdem.aster.ersdac.or.jp/. However, the spatial resolution of these two DEM is quite different, while the downloaded DEM has a spatial resolution of 30 m., the created image exhibits a cell size of 5 m. Based on the need for better spatial detail we decided to develop our own model.

In order to work with images that show even more detail of the terrain, the DEM was combined with a mosaic of aerial photographs and satellite images. As a result, we obtained georeferenced high resolution images of the studied area with a real appearance 3D (Figure 2).

As mentioned above, our case of study is focused on archaeological landscapes of the Pampean hunter-gatherers. When considering the mobility of these societies (Politis, 1996; Politis *et al.*, 2003) it became necessary to enlarge the scale of analysis beyond the microregion in the central east portion of the Tandilia range, where fieldwork was carried out. Therefore, in order to obtain a broader spatial perspective, images of other geographical areas of archaeological significance were added. For example, we included areas of potential quarries located 40-60 km northwestwards the study area (Flegenheimer, 1991; Bayón *et al*,. 1999; Colombo, 2013); the

Figure 2. 3D image combining DEM with aerial photographs and satellite images mosaic.



southwards plains where possible related sites next to lagoons or rivers may have significance (Bayón *et al.,* 2004; Politis, 2008; Flegenheimer *et al.,* 2010; Martínez and Gutérrez, 2011; Mazzia, 2013b; among others) and the Atlantic coast where some resources found in the microregion came from (Mazzia and Flegenheimer, 2013). The total area of the land covered by the digital model is approximately 800 km^2, with a 5 m resolution. As it included other archaeological research areas, this DEM is presented as a spatial database open to the introduction of archaeological information from different areas and available for other researchers.

5. USES OF IMAGES

Different kinds of spatial analyses were carried out such as visibility analysis and distance calculations. Mobility is a key issue when studying hunter-gatherers, archaeological evidences (Binford, 1980; Kelly, 1992). From a landscape perspective, we consider archaeological sites as chosen places that were inhabited or visited. Those places were connected with each other through different paths that wove a social network. Weaving a network of connections among different places and paths materialize body movements throughout the space (Potter, 2004; Tuan, 2008 [1977]).

Distances refer to those movements. Using GIS tools we calculated possible distances travelled by the hunter-gatherers in the Tandilia range and the surroundings plains, considering key points to traverse the space such as water courses and a hill pass. Thus, this georeferenced 3D space representation was the point of departure for proposals about past Pampean people's paths and movements through the space.

There are seven archaeological places of hunter-gatherers assigned to the end of Pleistocene and early Holocene in the studied microregion (Mazzia and Flegenheimer, 2012). Using the application *measure distance* of ArcMap 9.2 and the software MapInfo Professional 8.5 SCP we estimated distances between those places. For example, we analyzed different routes from Cerro La China locality, a

small hill where domestic places of early hunter-gatherers were identified (Flegenheimer, 2004), to other related places (Figure 3). There is a distance of 15 km from there to Cerro El Sombrero locality (Figure 3: from 1 to 4 and 5). Also, the distance between domestic places in Cerro La China and three quarry areas of lithic raw material was measured (Figure 4).

Paths, as possible communication routes between two locations, were considered according to ground's permeability criteria (Criado Boado, 1999). Noteworthy, the software used calculates the distance between two points according to the kilometers (or any other unit of length) that separate them. However, distances expressed through metric values do not refer to the experience. For this reason, we consider more accurate to measure routes, for example, by estimating the time that would have been necessary for travelling. Of course, too many variables must be taken into account. For example, time and speed may vary depending on the circumstances of the road, environmental features and the travelers' characteristics. In social

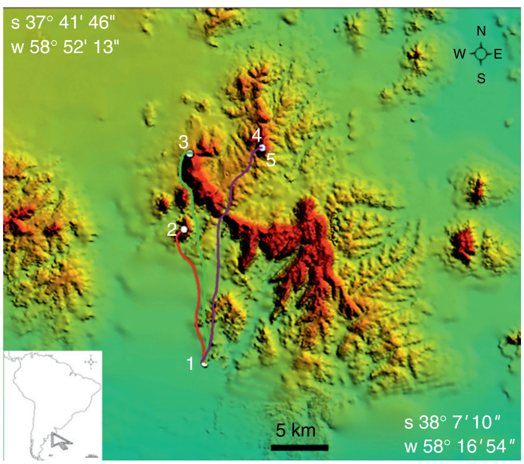


Figure 3. Example of distance calculation between Cerro La China locality (1) and other early archaeological places in the microregion.

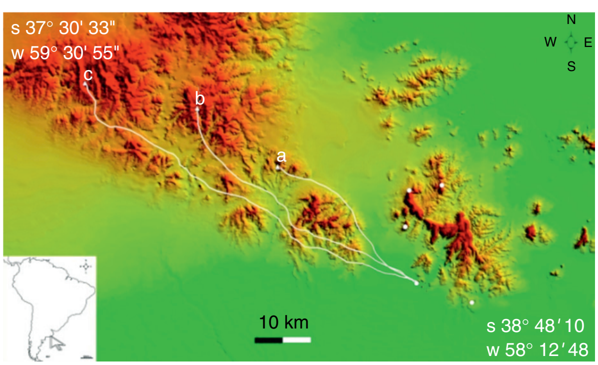


Figure 4. Example of distance calculation from Cerro La China (1) archaeological locality to three quarry areas of lithic raw material: a) to San Manuel 35 km, b) to La Numancia 61.5 km and c) to Barker 74.5 km.

landscapes the distance between two places is the experience of the journey, it is the body's movement from one place to another and the changing views along the route (Ingold, 2000). These theoretical considerations have been included in the final interpretation of the possible paths that connected different places of the hunter-gatherers in the past. Therefore, data obtained through GIS analysis were related to subjective experiences recorded in the microregion during archaeological fieldwork (Bender *et al.,* 1997); and they were also related to the stories compiled in anthropological fieldwork in the same studied area and ethnographic sources from different regions (Llobera, 1996).

Based on our anthropological fieldwork, we estimate that it takes about seven hours to go 6 km over the hillsides, gathering plants and carrying more than 50 kg of load on the back. Also, another record shows that 6 km of distance between two hills took about three hours. So, a round trip from Cerro La China to Cerro El Sombrero could be taken as an example of what people moved in a given day. In addition, we have recorded that approximately 12 hours are needed for a walking hilly path of 20 or 25 km. Thus, a round trip from Cerro La China to the nearest quarry area would take two or three days and almost seven days to the most distant one.

Visibility analyses were also carried out. A viewshed analysis was generated for the different places of early hunter- gatherers using the 5 m DEM. The viewshed function was performed on each site with ArcMap 9.2.

Our analysis is based on Criado Boado's definitions (1993) of visibility as the panoramic view from a place, visibilization as the way in which a place is seen, and intervisibility as the visual relationship that can be defined between two places.

As an example, we briefly introduce the case of Cueva Zoro site (Figure 3:3), a small rock shelter next to the hilltop of Sierra Larga that was ephemerally occupied by early settlers of the Tandilia range (Mazzia, 2013c). The computer generated visible landscape from the site is depicted in red in the Figure 5.

Since GIS visibility descriptions are based on the location of an observer in a point of the georeferenced space, the graphics represents a neutral observer. For this reason, we decided to complement this analysis with the visual perceptions of people during fieldwork. Also, sounds, movements, smells, memories were used to complete the image. In Cueva Zoro case, the commanding view northwestwards that was pointed in the graphic was confirmed on clear days in the field from the entrance of the rock shelter (Figure 6). However, from inside of the cave visibility conditions are drastically reduced because of the presence of an outcrop at the entrance (Figure 7). Subjectively, this gives a protected aspect to the inside

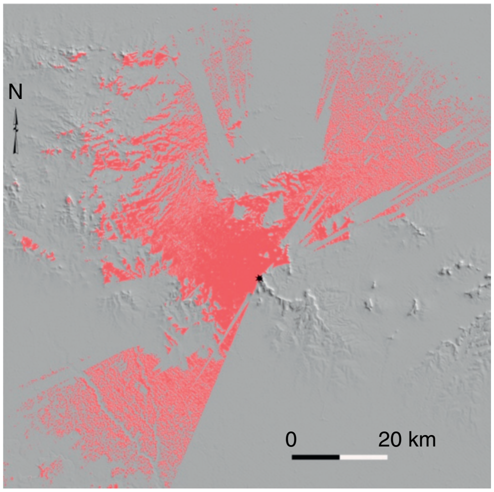


Figure 5. Example of viewshed analysis using GIS, from the archaeological site Cueva Zoro.

Figure 6. Visibility conditions registered from the entrance of Cueva Zoro.

Figure 7. Visibility conditions registered from inside of Cueva Zoro.

space. People at the entrance and inside the cave cannot be seen either from the surroundings or from the foothill. Among the outcrops, it is not possible to clearly identify the rockshelter. Thus, the visualization of Cueva Zoro is limited and it is only possible to identify the area where it is located. Because of viewshed and subjective analyses, we know that there is no visual relationship with the other sites of the microregion (Mazzia, 2013c).

Both visibility and distance analyses through GIS may lead to describe inert and empty spaces, without the people who inhabited there. So, it is extremely important to combine these GIS analyses with information from other sources. In our case of study, we use both information from an anthropological fieldwork developed in the same portion of the Tandilia range were archaeological sites are located and archaeologists' perceptions recorded on the field diary (Mazzia, 2010–2011).

The final step of our GIS project was the creation of an animated journey along the DEM that allows us to virtually return to the field over and over again. The animation was made using ArcScene. In addition,

the tridimensional and dynamic representation of the studied area results in an excellent means of the available spatial information for the exhibition, both for academic circles and general audience such as local community or students.

6. Final Words

In sum, in our case of study, the use of this methodology makes it possible to handle different spatial scales and covering large areas: more than 800 km^2. It represents a wide-angle perspective in our archaeological research. It is also useful to come up with new questions to bring to the field. For instance, if it is possible to have a visual relationship between archaeological places or if the estimated distance between two sites can be walked by in a single day. GIS approach allows rethinking different interpretations about the spatial situations of sites, as well as presenting the results to all audiences. The final product of the image processing labor is a high resolution spatial database, open to add information from future own research and from other researchers. Thus, it becomes an important tool to science communication.

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