Applications of GISs to the study of Daunian settlement patterns in the pre-Roman Age

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ABSTRACT

This paper explores the potential for applying GIS techniques to the investigation of Daunian settlement patterns in the pre-Roman Age. The picture of published archaeological evidences, enriched by the results of recent surveys, is fragmentary and suffers from the lack of an overall approach to the study of settlement systems of the area. The relevance of this work is due to the specific kind of archaeological data collected. It starts from collection of published data, which are dispersed, non homogenous and often incomplete, in order to propose new hypotheses about settlement dynamics during the pre-Roman Age. Viewsheds and Cost Surface Analysis have been applied in order to understand settlement dynamics and development of settlement systems in time. The results of spatial analyses can be considered as a base on which to formulate new research hypotheses and surveying strategies. The research presented in this paper can be considered an example of the possibilities and the results achievable by the utilization of the system GIS in the archaeological context.

1. INTRODUCTION[1]

This paper explores the potential for applying GIS techniques to the investigation of Daunian settlement patterns in the pre-Roman Age[2] (Fig. 1).

For a long time, research patterns influenced by stereotypes associated with the idea of "Hellenisation"[3] have favoured surveys of cemeteries and tombs[4]. As a result, the picture that emerges from the published archaeological evidence, although it has been enriched by the results of recent surveys, is fragmentary and suffers from the lack of an overall approach to the study of area settlement systems[5].

The application of GIS and spatial analysis techniques to this field has made it possible to overcome the limitations stemming from the fragmentary character of the archaeological data and to tackle the study of a region in a more complete way, using the available elements (archaeological and environmental) to achieve a greater understanding of settlement systems, their organization and their development over time.

2. METHODOLOGY AND TECHNIQUES OF ANALYSIS: DESCRIPTION OF THE RESEARCH

The theoretical and methodological point of reference of this work is the experience gained in a European context while working on Settlement Archaeology, particularly the development of research on a regional scale. Most of this research

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[1] This study, developed in the course of Doctoral Research, is part of a much larger project taking in the whole of Southern Italy, developed by Lecce University's Laboratory of Archaeological Computing. I wish to thank Francesco D'Andria, Professor of Classical Archaeology at Lecce University for his valuable advice and useful suggestions. I would like to extend special thanks to Grazia Semeraro, Professor of Magna Graecia Archaeology at Lecce University, who provided the methodology of the research; to her I am also extremely grateful for the patience she has always shown in following every stage of the work.

For the initial presentation of the Project see D'Andria, 1999, p. 103-118; see also: D'Andria, 2002, p. 52-59; Semeraro, 2002, p. 107-110; D'Andria and Semeraro, 2003, p. 77-105; Pecere, 2004, in print.

[2] The chronological frame of reference for this work includes the period from the 10th to the 6th centuries BC.

[3] This term, used in the literature on archaeology to indicate the relations between the Greeks and the native populations of Southern Italy, reflects the tendency to consider Greek culture "superior" to that of the indigenous peoples. For an initial discussion of the problem see: Atti Cortona, 1993; see also recent observations in D'Andria, 1999, p. 103-118 and in D'Andria and Semeraro, 2003, p. 77-105.

[4] See for instance, De Juliis, 1988; De Juliis, 1995, p. 549-554.

[5] An attempt to analyse the settlement systems of pre-Roman Southern Italy and Daunia in particular was recently carried out by E. Herring and K. Lomas (Cf. Herring, 1991, p. 33-54; Lomas, 1993, p. 63-78). These British scholars have rightly stressed the need for a global approach to the study of the "non-Greek" societies of Southern Italy, supporting the research with techniques of spatial analysis and interpretative models that take account of Peer Polity Interaction. Nevertheless, their conclusions are weakened by documentary evidence that is in many cases insufficient and incomplete.

involves applying GIS techniques to data from field surveys, the results being interpreted above all in accordance with predictive models[6].

In contrast, the work presented here entails first of all collecting published data, which are scattered, heterogeneous and often incomplete, in order to propose new hypotheses about settlement dynamics during the pre-Roman Age. The spatial analysis of these data provides a basis from which to formulate new research proposals and surveying strategies.

The study was organised on three levels of analysis (micro, semi-micro and macro)[7], based on the need to investigate the system of Daunian settlement on a regional level only after having evaluated the characteristics of the individual settlements. The identification of the "scale" of the settlements, i.e. the site size[8], was the starting point for the organisation of inter-site analyses aimed at understanding the synchronic and diachronic dynamics of occupation and settlement of the region.

3. THE COMPUTER APPLICATION

The GIS developed for the management of the data consists of a relational database (created with *Access*) for the management of the descriptive data (RDBMS)[9], and a geo-database for the management of the cartographical data. *ArcGis* 9 software (operating in the ESRI environment) enables the integration of alphanumerical data with graphical data (Fig. 2).

An important aspect is the specific kind of archaeological data collected: the RDBMS archive is organized into sectors that describe aspects of the settlements (e.g. size, residential areas, sacred areas, necropolis, etc) in relation to the various chronological phases.

4. The GRID Models

The objectives of the research entailed the preparation of two grid models which enabled us to conduct *Cost Surface Analyses* of the territory being studied: a *Cost Surface Model*, indicating the time taken to reach any given target location from a source location, and a *Soil Potential Model*, indicating soil fertility. The two GRID models were constructed by means of the *Weighted Linear Combination* of individual GRID layers corresponding to the geo-morphological, hydrological and pedological features of the area being studied[10].

A strategy based on the linear combination of factors[11], unlike methods which use Boolean sums[12], makes it possible to evaluate situations in which the range of values of one parameter is much narrower than the range of values of another by multiplying the value of each variable by a different factor in order to give them an appropriate weighting. For each cell of the surface grid, the cost of travelling (C) is given by:

$$C = \sum xw$$

where x is the value for each parameter and w is the multiplication factor of each variable included in the calculation. For each variable it is thus necessary to record the raw value and determine its relative "weight" compared to the other variables.

The construction of the *Cost Surface Model GRID layer* made use of the *Weighted Linear Combination* of the GRID

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6   Cf. e.g. Bintliff, 2000, p. 21-34; Stancic and Kvamme, 1998, p. 231-242; see also M. van Leusen who, in his study of the valley of Wroxeter (West-Midlands, England) between the Iron age and "Romanization", goes beyond mere predictive models to interpret the results of spatial analyses based on the most recent approaches of "Cognitive" archaeology. Cf. Van Leusen, 2002.

7   Analysis at the micro level (of individual sites), aimed at identifying "the scale" of the settlements; analysis at the semi-micro level, aimed at understanding the relations of the individual settlements with the surrounding territory; analysis at the macro level (inter-site analysis), aimed at understanding the relations between the settlements and the synchronic and diachronic dynamics of the settlement process.

8   The size of the settlements was not measured purely on the basis of the dimensional parameter, but also on the basis of the presence/absence of fortifications, "palatial" type buildings, buildings with a ritual function, burial structures above ground, workshops, artefacts associated with some social significance, etc.

9   Used for the initial presentation of the application, partly revised and updated in the course of this study: Cf. Semeraro, 2002, p. 107-110.

10   Both models were created on the basis of current geo-morphological and pedological data, enriched with elements of the ancient landscape that may be inferred from recent studies and research (coastline, length of rivers, and anything that could be reconstructed on the basis of the literary sources and archaeological data, as well as the results of other predictive analyses such as those of the hydro-geological model). The geo-morphological and pedological data were obtained from the Puglia and Basilicata Soil Survey, conducted as part of the Multifund Operational Programmes (MOP) funded by the European Union in support of Italian Regions (Acla2 and Corinne Land Cover).

11   Cf. Voogd, 1993.

12   Cf. Stancic and Kvamme, 1998, p. 231-242.

layers corresponding to slope[13], hydrology[14], elevation[15], in order to calculate the overall cost of travelling (see, table 1). Slope is a significant factor in the calculation of surface friction and least cost paths. The values assigned to this variable were calibrated on the basis of the most recent cost studies conducted on anisotropic surfaces, which show that with a slope of up to 6° journeys may be undertaken as easily in one direction as the other[16]. Therefore, in order to make the scale defined by the system (from 0° to 57°) more meaningful for the practicable slopes than the extremely steep ones, it was reduced to just five values: 1 for slopes between 0° and 2°; 2 for slopes between 2° and 6°; 3 for slopes between 6° and 8°; 4 for slopes between 8° and 14°, since human settlement has been recorded even within this range; 5 for slopes over 14°, an angle beyond which human settlement is assumed to be impossible[17].

Table 1 – Variables included in the *Cost Surface Model*

Variables	Value range	Multiplication factor	Weight
Slope	1-5	8	40%
Hydrology	1-10	5.7	57%
Elevation	1-3	1	3%

The construction of the *Soil Potential Model GRID layer* made use of the *Weighted Linear Combination* of the GRID layers corresponding to the geo-pedological characteristics of the soils lying within the area under study: pedology (texture, depth and organic components), drainage capacity and stoniness near the surface; in addition the model also took account of the GRID layers representing slope, aspect, elevation, and the distance from the water source (see, table 2).

Table 2 – Variables included in the *Soil Potential Model*

Variables	Value range	Multiplication factor	Weight
Soil pedology[a]	1-6	5	30%
Soil drainage capacity[b]	1-4	2.5	10%
Soil stoniness[c]	1-4	1.25	5%
Slope[d]	1-5	2.4	12%
Aspect[e]	1-5	3	15%
Elevation[f]	1-3	1	3%
Distance from water sources[g]	1-10	2.5	25%

[a] The lowest values indicate the best agricultural potential of the soils; the highest values were assigned to terrain subject to the greatest limitations in terms of agricultural use.
[b] The lowest values indicate the best drainage capacity of the soils; the highest values were assigned to soils with limited drainage capacity.
[c] The lowest values indicate terrain characterized by the lowest degree of surface stoniness; the highest values were assigned to terrain which was particularly stony.
[d] See above.
[e] Values from 1 to 5 were assigned on the basis of the number of hours of sunlight reaching the terrain in a year, the sunniest areas being considered more suitable and having the lowest values.
[f] See above.
[g] The values assigned to the cells of the GRID model increase with the distance from the sources of water, the areas closest to the water source having the lowest values.

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13   The Grid surface was created from the TIN (Triangulated Irregular Network) using the slope function in terms of degrees from the horizontal: output slope dataset: 0°/57° minimum-maximum range.

14   The Grid surface was created from a hydrology vector file. The assumption was that the surface routes would be influenced by the need to avoid crossing rivers wherever possible. Although the navigable stretches of a river can improve transit in a given territory, embarking and disembarking people and goods have a "cost" of their own (on this question cf. the recent contribution by Van Leusen 2002, chapter XVI). The values assigned to this variable range from 0 to 10: the main rivers (Ofanto and Fortore) were given a high score (10) so that they could be crossed by the cost surface analysis only in the most suitable places, as infrequently as possible. Torrents of a certain size (Celone, Candelaro, Carapelle) were given a high score (7), but below that of the main rivers. Streams of smaller size were given smaller scores (3/1), while minor water courses (valley, named "lame", and the intermittent drainage network of the Gargano) were not given a score as they were not held to constitute a deterrent for surface transit. Lakes, lagoons and marshy ground were given a high score, on the level of the main rivers (10).

15   The elevation Grid derives from the TIN surface. Output elevation dataset (0/1400 m = minimum-maximum range above sea level). The assumption was that an increase in the height above sea level leads to an increase in the "cost of travelling", albeit less significant than the slope of the terrain (Macchi Janica, 2001, p. 154). The values assigned to this variable range from 1 to 3: 1 for the lowest areas, between 0 and 200 metres above sea level; 2 for intermediate heights, between 200 and 500 metres above sea level; 3 for heights in excess of 500 metres above sea level, considering that above this height the cost of travelling increases more sharply.

16   Cf. Llobera 2000, Fig. 2.

17   Cf., e. g., Van Leusen, 1992, p. 111; see also, Minetti, 1995.

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5. DATA PROCESSING

5.1. THE IRON AGE (10TH – MIDDLE OF 7TH CENTURY BC.)

Some interesting considerations have emerged from the analysis of the settlement system of the Iron Age. In the published works it is generally and rather schematically described as a moment of continuity with the late Bronze Age in which new settlements – of a "compact" type along the coast and of a "dispersed" type inland – appear.

In contrast, the organisational framework of our research and the specific kind of archaeological data collected have made it possible to identify a pattern of settlement in the Iron Age that is both sophisticated and diversified. We are dealing here with a radical transformation in settlement organization, datable to the 8th century BC, in which the small hilltop sites were abandoned in favour of more extensive sites on high ground and in the plain.

5.1.1. THE EARLY IRON AGE. (10TH AND 9TH CENTURIES BC)

The settlements identified for the early Iron Age are not very numerous (Fig. 3). From the geo-morphological point of view they were collocated in accordance with a clear pattern of relationships to the landscape; positioned on the summit of small hills, promontories or coastal inlets, they were all characterised by their contiguity with important river valleys (e.g. those of the Ofanto and the Fortore)[18] or a strip of territory near the coast (the eastern Gargano and the southern Tavoliere.

The analysis conducted at the level of individual sites (the micro-level) has shown that these were sites of small dimensions, covering an area of just over a hectare to nearly ten hectares, which do not display significant differences in terms of size, or signs of pronounced social differentiation. The funerary rites, which entailed the multiple inhumations (both simultaneous and successive) of people of different gender and age in the same tomb, suggest the existence of a society of a tribal type funded on close clan ties.

In view of the spatial distribution of the settlements in accordance with precise systems of physical landscape, *Cumulative Viewshed* and *Cost Surface Analyses* were applied to the sites around the Fortore Valley in order to determine whether the Fortore Valley functioned as the link between many settlements belonging to a single system, or marked a kind of border separating two "different" systems (Fig. 4).

The results of the *Viewsheds Analysis* seem to indicate that the water channel constituted a natural border between two systems located on opposite sides of the river (Fig. 5 a-b). The settlements within each of the two systems were located fairly high up the side of the valley, so that they were able to see the other settlements within their system and also to keep watch on an area in the centre of the valley, which functioned as a sort of "buffer area".

Further support for this hypothesis was provided by a *Cost Surface Analysis* carried out in order to determine the territory lying within a radius of two hours' walking distance from each settlement. The combination of the *Viewsheds* and *Cost Surface* analyses produced some very interesting results, reinforcing the hypothesis that the course of the river marked the natural border between the two systems (Fig.6 a-b).

During the late Iron Age those two systems seem to have developed in different ways: while the sub-system on the left bank of the Fortore gradually disappeared, the one on the right bank of the river shows evidence of continuity. In this area the absence of any dominant settlement must be stressed. The settlements would not have functioned individually, but as part of small systems made up of several sites.

The application of the *Cumulative Viewshed Analysis* to the landscape system that developed along the middle course of the Ofanto has produced results that seem to confirm the same dynamics of territorial occupation as those observed along the valley of the Fortore.

The settlements that are distributed around the valley are in "visual contact" with each other and at the same time "control" a broad portion of territory corresponding to the whole of the middle course of the river, an important strategic position in the region. The three sites disappeared at the same time in the course of the 8th century BC; this tends to confirm that the settlements constituted a single system (Fig. 7).

Cost Surface Analysis was applied to the Early Iron Age sites on a regional level (macro-level). The results of the analysis allowed us to identify two distinct kinds of settlement: on the one hand, those located on the Gargano and on the Daunian Apennines, characterized by a not particularly productive and rather limited catchment area; on the other hand, those lying along the river valleys and the coastal lagoon, which in contrast benefited from a larger catchment area and fertile soil (Fig. 8).

The former type of settlement might have housed relatively small communities, in which the same individuals, without distinction of rank, carried out tasks related to building, tool production and food supply. The latter type of settlement, being located in a particularly productive area characterized by a wide catchment area favouring human settlement and demographic growth, enjoyed continuity throughout the late Iron Age, and growth during the following Archaic Age.

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18   On the basis of the literary sources, these rivers constitute the natural "borders" of Daunia.

5.1.2. THE LATE IRON AGE (BEGINNING OF 8TH TO MIDDLE OF 7TH CENTURY BC.)

During the late Iron Age Daunia witnessed a profound transformation of the territory: a number of hilltop settlements (characterized by a similar topographical pattern) were abandoned and new sites in the plain and upland areas arose[19] (Fig. 9).

At the current stage of the research there is little evidence that might enable us to throw some light on the question of the size of these settlements, or indeed to determine the density of the inhabitants who dwelt there (barrow tombs have been found in some settlements such as Arpi, Ordona and Salapia, but there is very little in the way of evidence). However, the large area over which certain groups of settlements seem to have extended (for example the 160 ha of Lavello, the 180 ha of Ascoli Satriano, etc.) lead us to posit the emergence of the first forms of a hierarchy among the sites and, at the same time, demographic growth comparable to what has been hypothesised for other areas of central and southern Puglia (where, however, this process is linked to the increase in the number of sites).

The *Cost Surface Analysis* indicated that the settlements had a broader catchment area than in the early Iron Age, and benefited from the fertile soil. The results of the analysis seem to support the emergence of a settlement hierarchy, as the smaller sites (Melfi, Ripacandida, etc.) had a smaller catchment area (Fig. 10). The change in the settlement system was accompanied by a radical transformation in territorial organization: the pattern of "small systems" made up of many sites was probably replaced by one in which the settlements functioned as political, economic and social communities that were basically autonomous and could support themselves thanks to the high agricultural value of the soil near the sites and their proximity to important communication routes, particularly river courses.

The rise of large settlements in the late Iron Age seems to have taken place against the backdrop of a general reorganization of the whole region; we see a small number of large sites with similar burial rites (barrow tombs) and technological innovations (Daunian geometric pottery).

5.2. THE ARCHAIC AGE (FROM THE MIDDLE OF THE 7TH TO THE END OF THE 6TH CENTURY BC)

Moving on to the archaic age, the most striking phenomenon is the completion of the transformation of the settlement system which began in the late Iron Age and during which the "physical landscape" systems of the Gargano were completely abandoned (Fig. 11). At the current stage of the research, there seem to be few settlements dating back to this period, and these are concentrated in the Tavoliere plain and the river valleys; furthermore, they seem to have stood quite far apart from each other. A striking example is Arpi, 25 to 30 Km away from its nearest neighbours.

The process of settlement aggregation now begins to take forms that are archaeologically more visible. The appearance of the *aggere* structures (which are earthworks preceded by a moat) surrounding Arpi and Salapia makes it possible to accurately calculate the dimensions of the area occupied by the settlements, which had an extension of 980 and 300 ha respectively (Fig. 12 a-b)[20]. During the archaic age a differentiation seems to emerge in the settlement system of the region on the basis of the size; it is now possible to recognise large, medium and small settlements[21]. Observation of the size parameter clearly provides support for the birth of a form of hierarchy between the sites. In addition, an examination of the archaeological evidence also highlights a series of elements that make some settlements different from others (fortifications, "palatial" buildings, and so on).

The *inter-site* analyses were designed to discover further clues concerning possible relationships of spatial hierarchy between the settlements.

To create a model closer to reality, rather than simply calculate the straight-line distances (Fig. 13a), as is usually the practice when using *Thiessen's Polygons* technique[22], "corrections" were adopted that took account of the geography of the landscape; in addition, certain towns (i.e Tiati, Arpi, Salapia, Canosa and Lavello) were given greater "weight" in view of their size (Fig. 13 b-c).

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19   The process of transformation of the area is not an isolated phenomenon. It seems to be common to other areas of peninsular Italy, where starting from the early Iron Age the naturally fortified hilltop settlements were abandoned in favour of sites in the plain and uplands, "dispersed" over a wide area (southern Etruria and Latium Vetus). Cf. Peroni 1996; see also Pacciarelli, 2000.

20   Cf. Guaitoli, 2003a and Guaitoli, 2003b.

21   Concerning the internal structure of the settlements it is possible to distinguish at least two patterns: one involving clusters with both habitation and burial structures (Lavello, Ordona. For Lavello, see: Giorgi *et alii*, 1988; Bottini and Fresa, 1991; for Ordona, see: Mertens, 1995) and one in which the main nucleus of the settlement was situated on the summit of a naturally well-defended hill, with a smaller group of dwellings located in a position of "control" over the communication roots (Ascoli Satriano, Canosa. For Ascoli Satriano, see: Antonacci Sanpaolo 1991a, p. 117-140 and Antonacci Sanpaolo 1991b, p. 117-130; for Canosa, see: Cassano, 1992).

22   Most of the studies that use the Thiessen's Polygons technique to calculate the hypothetical territories of the sites develop the geometrical model by drawing straight lines that do not take account of the natural obstacles such as those formed by steep slopes or water courses. (remaining in the ambit of Italian archaeology cf., for example, Rendeli, 1993).

Application of Cost Surface Analyses made it possible to calculate the extent of the "zone of influence" of the major towns (equivalent to the area within a radius of four hours' walking distance). In the model they "control" large areas of territory, within which lie other, smaller towns, supporting the hypothesis of a hierarchical system of relationships between the sites.

In addition, *Viewsheds Analyses* were performed in order to obtain better knowledge of the role of Arpi in the settlement system of the region; with its 980 hectares it was the biggest indigenous settlement in pre-Roman Italy[23].

On the basis of certain interpretations, the vast proportions of the structure[24] render implausible "a defensive value"[25]. However, spatial analyses calibrated using the most recent information concerning the type and the dimensions of the structure[26] (Fig. 14a) point to a different conclusion.

The *Viewsheds Analysis* provided a visual perception model of the landscape from the summit of the *aggere*. Assuming a series of "observation points" on the top of the *aggere* along its entire length from that height it would have been possible to keep watch over the territory for miles around (Fig. 14b). The site lies in the middle of a plain, and a separate *Viewsheds Analysis* developed assuming the absence of the *aggere* and an observer standing at ground level produces a completely different result: a large part of the territory surrounding the site is no longer visible (Fig. 14c).

A similar analysis was carried out in the case of Salapia, with comparable results (Fig. 15 a-c)

Superimposing the *Viewsheds Analysis* model created for Arpi and Salapia on the territorial Cost Surface model shows how the territory "controlled" by the settlements and the theoretical model of the zones of influence of the two sites tend to coincide.

The results of the spatial analyses, particularly the new aspects that emerge from the application of *Viewsheds Analyses* to the two case studies (Arpi and Salapia), support the notion of a settlement model in which visual control of the territory played a crucial role.

From the evidence now available, it appears that no other settlement in this region apart from Arpi and Salapia developed *aggere*-like structures. This may be partly due to the lack of systematic research conducted in this area, but more probably it has a deeper meaning. By showing how clear the "perception" of the surrounding territory was from the summit of these structures, the results of the spatial analyses suggest that the creation of such imposing constructions could also have had a symbolic value. Such structures, as well having a practical defensive function, plausibly constituted a form of self-assertion, a celebration of the political, economic and social "power" that the inhabitants of these communities enjoyed.

The presence of the *aggere* structures, which distinguish the Daunian landscape so clearly from other areas in Puglia during the archaic age, constitutes one of the clearest signs of the emergence of a hierarchy among the sites and, parallel to this, the creation of a structured society, as the analysis of the archaeological evidence on the level of individual sites shows.

It is important to stress the size of the Daunian settlements, surely indicative of a specific trait of Daunian society, which can be better understood only in the ambit of more extensive research into the archaic settlement system[27].

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23   Clearly the comparison with other better known towns in the region (Lavello and Ordona) allows one to suppose that not all the area lying inside the aggere was occupied by dwellings (in accordance with a model of occupation based on separate concentrations of dwellings and burial sites with open spaces in between. For Lavello, see: Giorgi *et alii*, 1988; Bottini and Fresa, 1991; for Ordona, see: Mertens, 1995).

24   The structure of the aggere in Arpi includes an external trench and an earthwork composed of limestone dug from the trench mixed with earth. It is typical of the aggere-style fortifications of the Italic settlements (See, e.g., Ardea and Satricum; cf. Cristofani, 1990, p. 194; 231; see also Pacciarelli, 2000).

25   According to M. Mazzei, "a defensive function...would have entailed concentrating the population in a more restricted space"; cf. Mazzei, 1995, p. 49.

26   To calibrate spatial analyses aimed at the study of the possible relations between the site and the surrounding territory, dimensional data obtained from recent aerial photogrammetry were used (the aggere was no less than 6 m high and 17-18 m wide: cf. Guaitoli, 2003, p. 185-193).

27   The state and the characteristics of previous studies, from which the data used in the present study were taken, also influence the conclusions and hypotheses reached: further research and the extension of the areas under study in the context of Daunia are required to support these conclusions, enrich them and if necessary correct them.

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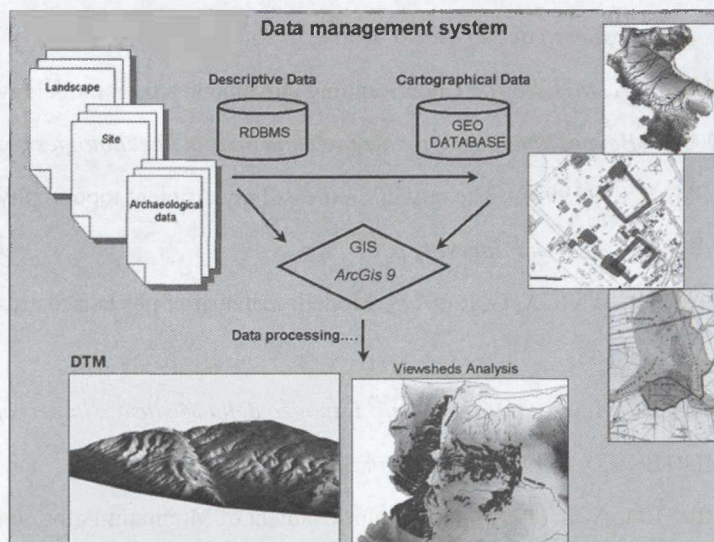
FIGURES

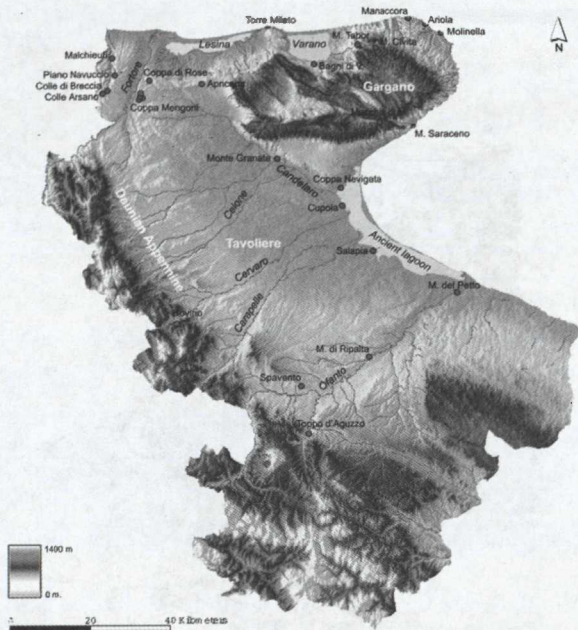Fig. 1 – Study area.

Fig. 2 – Data management system.

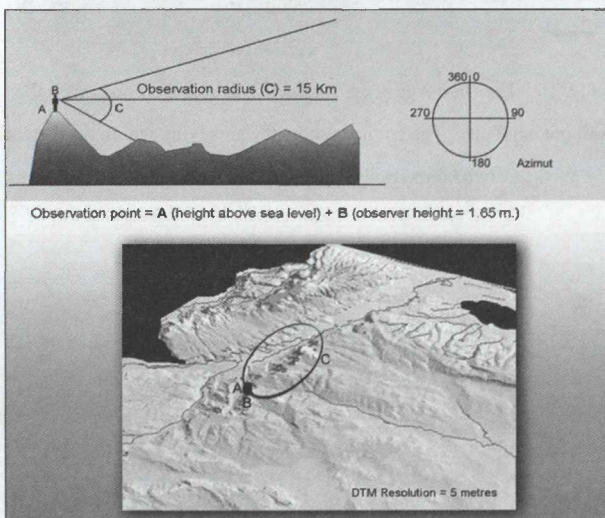Fig. 3 – Settlement distribution map of the Early Iron Age.
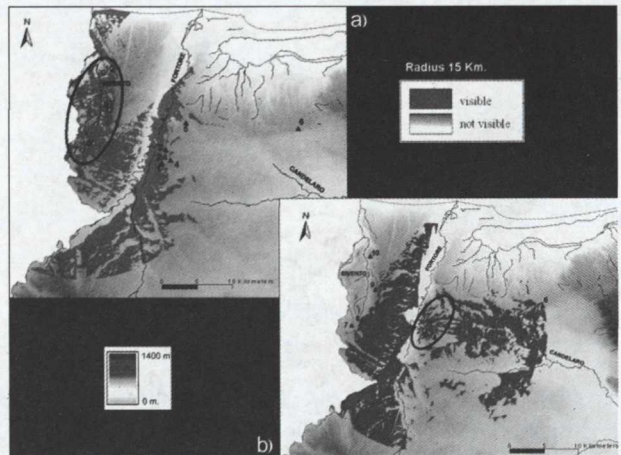

Fig. 5a-b – Fortore Valley. Cumulative Viewshed map, generated from the sites on the left (a) and on the right (b) banks of the river.

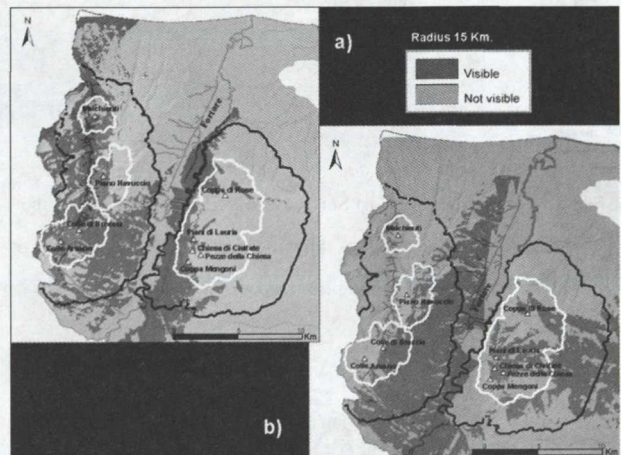Fig. 4 – Parameters used to generate the Viewsheds Analysis.

Fig. 6 – Fortore Valley. Cost Surface Analysis superimposed on the Viewsheds Analysis, from the sites located on the left (a) and right (b) banks of the river. The black lines show the area lying within a radius of two hours walking from the top of the hills.
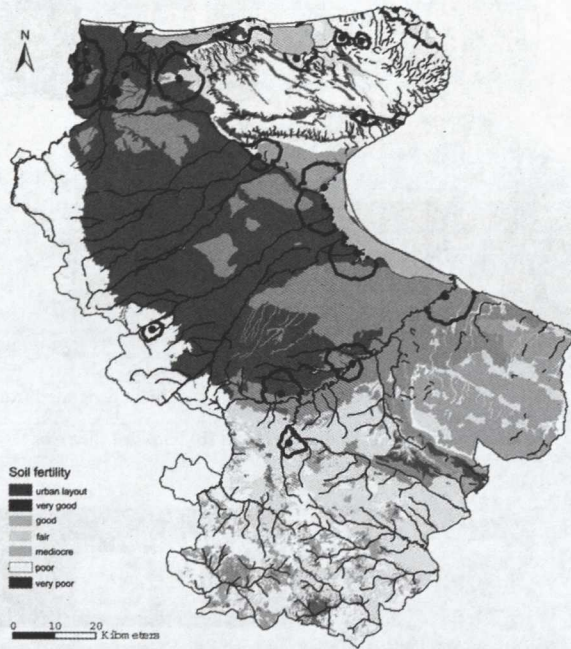

Fig. 7 – Ofanto Valley. Cumulative Viewshed map, showing the visibility from the sites around the river.

Fig. 8 – Early Iron Age. Cost Surface Analysis superimposed on the soil potential map. The red lines show the area lying within a radius of two hours' walking from the top of the hills.
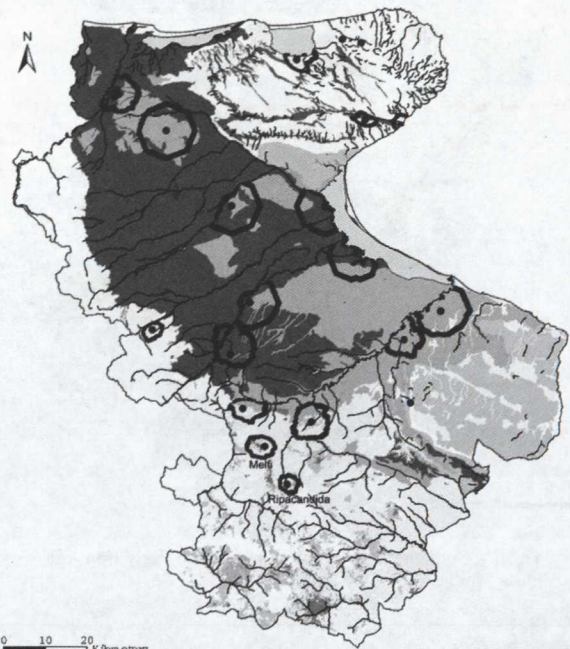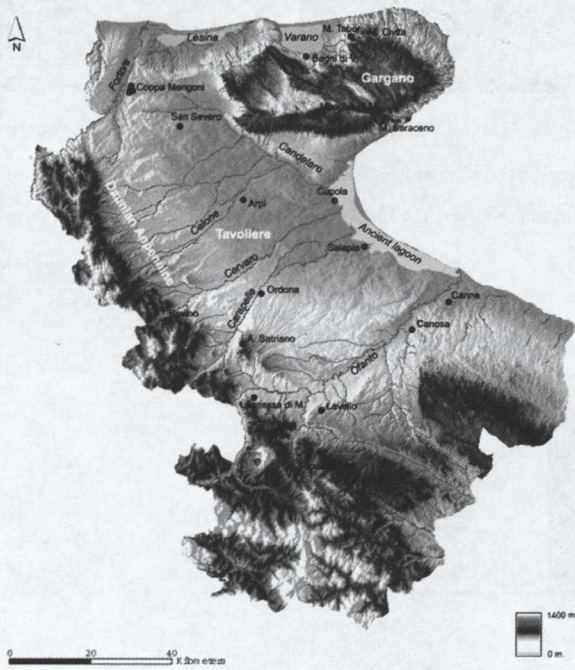

Fig. 10 – Late Iron Age. Cost Surface Analysis superimposed on the soil potential map. The red lines show the area lying within a radius of two hours' walking from the top of the hills.

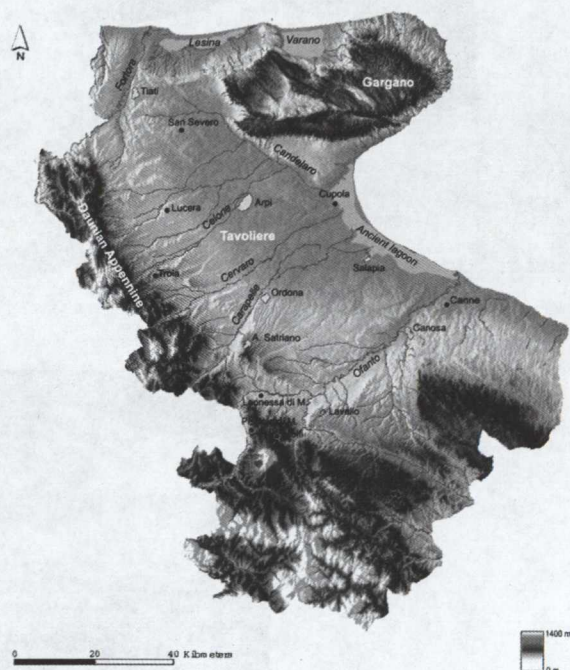Fig. 9 – Settlement distribution map of the Late Iron Age (8th and early 7th centuries BC).

Fig. 11 – Settlement distribution map of the Archaic Age (from the middle of the 7th to the end of the 6th century BC).
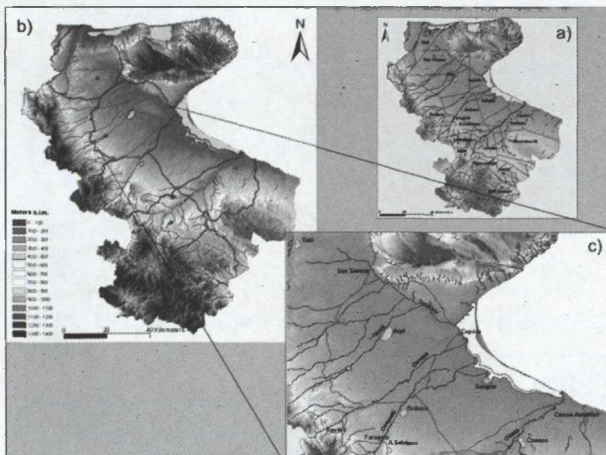
Fig. 12 – Thiessen Polygon Analysis calculated using the straight-line distances (a) and with "corrections" taking account of the geography of the landscape and giving greater weight to certain settlements in view of their size (b-c).
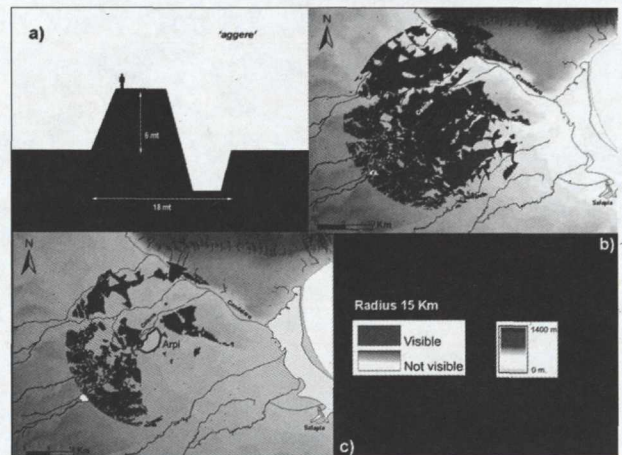

Fig. 13 – Arpi. *Viewsheds Analysis* map. (a) Parameters used to generate the *Viewsheds Analysis* from the top of the *aggere*. (b) Visual perception model of the landscape generated from the top of the *aggere* assuming a series of "observation point" along its entire length. (c) Visual perception model of the landscape assuming the absence of the *aggere*.
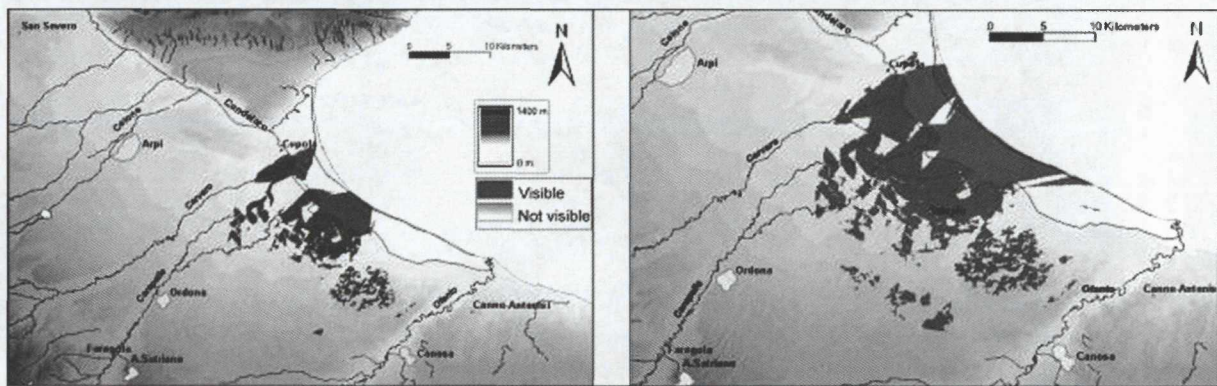

Fig. 14 – Salapia. *Viewsheds Analysis* map. (a) Visual perception model of the landscape generated from the top of the *aggere* assuming a series of "observation point" along its entire length. (b) Visual perception model of the landscape assuming the absence of the *aggere*.
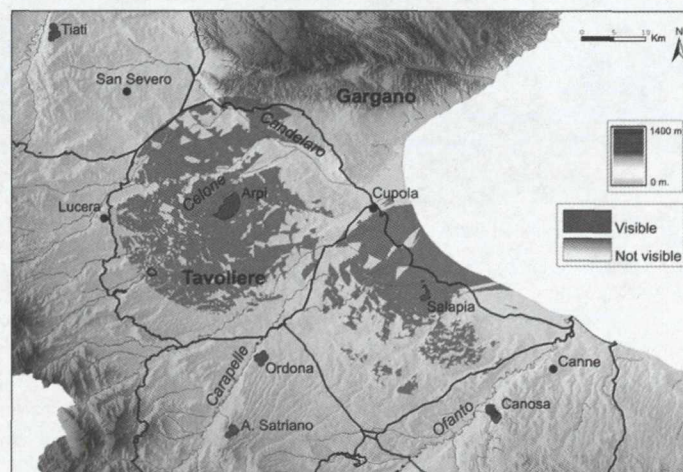

Fig. 15 – Overlay of the Viewsheds and Cost Surface Analyses. The territory visible from the top of the earthworks in Arpi and Salapia seems to coincide with the theoretical model of the sites' zones of influence.