SCIRES it
SCIentific RESearch and Information Technology
Ricerca Scientifica e Tecnologie dell'Informazione
Vol 10, Issue 2 (2020), 53-64
e-ISSN 2239-4303, DOI 10.2423/i22394303v10n2p53

CASPUR-CIBER Publishing, http://www.sciresit.it

GIS AND DTM FOR THE ANALYSIS OF THE ARCHAELOGICAL DATA IN VASTE (SOUTHERN APULIA)

Giovanni Mastronuzzi, Giacomo Vizzino**

*Università del Salento, Dipartimento di Beni Culturali - Lecce, Italy

Abstract

The use of digital technologies has brought about a remarkable development in the field of archaelogical research. The combined use of tools such as GIS and DTM has guaranteed the possibility of simulating a few aspects of ancient landscapes, contributing to recognise the strategies on which the choice of the sites destined to become settlements in ancient times was based. In the Vaste-Poggiardo area (province of Lecce), systematic research made by the University of Salento has produced an incredibile amount of knowledge on archaelogical evidence dating back to between the Bronze Age and the Middle Ages; on the very basis of this data the experimentation of a spatial analysis in order to reconstruct the ancient landscape has been conducted. The management of the DTM, processed through QGis, has made it possible to use the outcome of spatial analysis to propose a clearer reconstruction of settlements in the Vaste area.

Keywords

Archaeology, spatial analyses, GIS, landscape, Digital Elevation Model, viewshed analysis

Introduction and aims

The archaeology of landscapes aims at reconstructing ancient landscapes and their stratification in different geographical areas. The sources of information for this kind of study are many, but among them we favour the possibility of recognising the traces left by the transformations imprinted in the environment by nature and man (Cambi, 2011); digital technology facilitates the registration of the position and typology of every single element, enhancing overall interpretation with respect to cronological periods and territorial areas (Forte, 2002).

In the last decades archaeological research has relied on a growing use of GIS tools and theoretical systems of spatial analysis, usually adopted by modern geographical sciences, in order to reconstruct the ancient geography of a site and the interactions between the morphology of the landscape and the settlements (Chapman, 2006). Obviously, it is useful to remember that successful spatial research is closely connected to the good quality of the archaeological documentation available.

The recent revision and updating of the Vaste Archaeological Map – in the municipality of Poggiardo (LE - Apulia) (Figure 1) (Mastronuzzi, Ghio & Melissano, 2019) – has provided a chance to experiment with intra-site and inter-site GIS analysis. In particular, an exploration of the landscape in three dimensions has been attempted, through the realization of a complex cartography, which could enable not only to register the position of archaeological traces and/or constructions, but also to represent the context in which they are situated, with respect to the topographical characteristics of the surrounding environment in particular (Remondino & Campana, 2014). This approach has enabled to confirm previous interpretations and to formulate new hypotheses with regard to the evolution and to the reason why a particular area of settlement was chosen.

Vaste is a small village in the borough of Poggiardo, located in the south-east of the Salento, in the Otranto hinterland, about 5 km from Castro. The village lies at the foot of the "Serra di Poggiardo", a hilly ridge going from north to south, made up of limestone and clay covered with paleogenic, miocenic and pliocenic-quaternary deposits; the area is characterized by a difference in height between 78 and 127 m above sea level. The widespread presence of limestone rocks has always enhanced the extraction and the use of building material, as the thick presence of ancient

and modern quarries in the whole area demonstrates (Zezza, 1997).

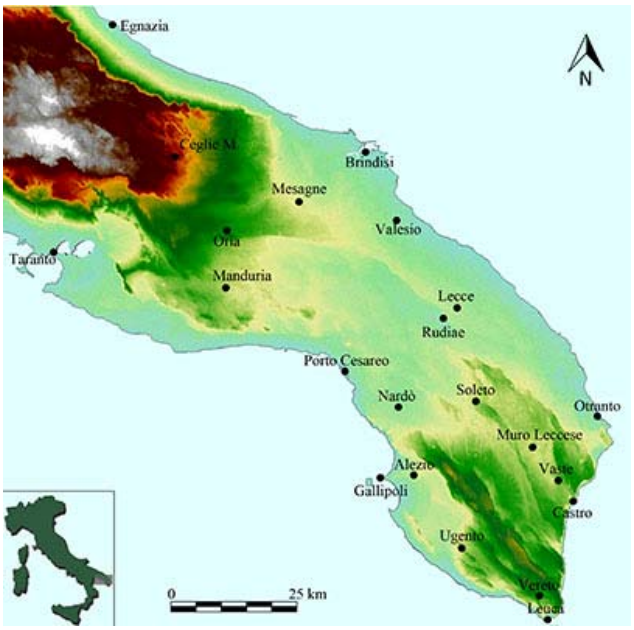

Fig. 1: Southern Apulia, map of the principal settlements of preroman period.

From the beginning of the 1980s the University of Salento conducted systematic archaeological research in the Vaste area, under ministerial permission (MIBAC), and under the direction of Francesco D'Andria, until 2011, and, successively, under Giovanni Mastronuzzi, in close collaboration with "Soprintendenza Archeologia, Belle Arti e Paesaggio per le Province di Brindisi, Lecce e Taranto" and with the Town Council of Poggiardo. In actual fact, the story of archaeological findings in this area of Southern Apulia dates back to the end of 15th century, when humanist Antonio De Ferraris signalled the presence of remains of the Messapic Civilization, which developed in the Iron Age and until the Roman Conquest (De Ferrariis, 1558).

Archaeological research has enabled to establish that the most ancient stages of territorial occupation go back to the Final Bronze Age, with only one context in which it is possible to fix a more ancient chronology: in the "Grotta Campana d'Oro" ceramic fragments and anthropological remains have been found which can be explained in a funerary context in the second half of the third millennium BC (Eneolitic) (Aprile & Orlandi Barbano, 2008). However, the element which best characterizes the Vaste landscape is represented by the remains of city walls built between the 4th and the 3rd centuries BC. They make up a perimeter of over 3 km which encircles an area of about 80 ha. The main nucleus of dwellings lies in the central area, comprising about 20 ha; all around it there are wide spaces destined to agricultural or production activities or reserved for cemeteries and places of worship.

In the last years archaeological research has been concentrated outside the village which was inhabited in ancient times in the area named SS. Stefani. Here, back in 1991, an extraordinary paleo-Christian complex was identified, characterized by three overlapping buildings of worship probably dating back to between the 4th and the 9th centuries, to the most ancient of which a wide cemetery embedded in the rock is closely connected (D'Andria, Mastronuzzi & Melissano, 2006).

The accumulation of a remarkable amount of data has posed the need to file and manage it. An updated database containing the documentation of the most recent systematic excavating campaigns, along with the outcome of preventive archaeology interventions, emergency recovery and accidental findings represents the starting point to reconstruct the story and the evolution of the settlements in the Vaste territory.

Over the year 2019 the writing of the Vaste and Poggiardo Archaeological Map has been completed, as the updating and revision of a previous piece of work dated 1981 (Carluccio, 1981), but especially as an essential tool for the analysis and the global understanding of the dynamics of occupation and exploitation of the area in a diacronic perspective.

The main periods in the life of the settlement (between the 13th century BC and the 15th century AD) are nine and they are mentioned in a series of cartographical drawings based on data acquired over the years first through the GEODOS software (Baratti, 1997) and then in CAD format. These processings have been positioned on the digital model of the terrain available in open access mode which can be downloaded from the SIT portal of "Regione Puglia".

2. Methods

2.1 DTM for archaeological interpretation

The cartographical drawings relative to the nine main periods in the life of the Vaste settlement (13th century BC - 15th century AD) have been positioned on the digital terrain model

(DTM) (Miller & Laflamme, 1958; Mazzolai, 1965; Peverieri, 1995; Li, Zhu & Gold, 2005; Balasubramanian, 2017) available in open access mode which can be downloaded from the SIT portal of "Regione Puglia". By putting one phase plan on top of another it is possible to further investigate into some of the motivations underlying the choice of settlement.

The programme used to develop the Digital Terrain Model is QGis (v. 2.8 and 3.2), software open source, which includes a wide range of plugins, designed to develop, analyse and represent the data which are more suitable for the final objective of the work.

The territory under investigations corresponds to twelve DTMs of the sheet "527 Otranto" of the portal of "Regione Puglia". The DTM files are distributed in ASCII raster format and look like a regular grid (8x8 m).

The reference system (system of projected coordinates) is WGS84, with geographic datum UTM zone 33North. The single DTMs have been imported on the software QGis, by setting the right system of coordinates, and have been joined so as to form a single digital model.

From the DTM it has been possible to retrieve a number of elements like the contour, the slope raster and the hillshade raster.

The next step was to reclassify the "graphic vest" of the Digital Terrain Model: the DTMs, in fact, exported in raster format, enable to associate to every single image pixel a precise grade of elevation depending on the colour represented by a colourimetric scale (Hutchinson & Gallant, 1999, 2000).

Some of the properties of the model have thus been modified, in particular its style, by selecting a single band of pseudo-colour, in continuous mode. The range of colours chosen to represent the different heights/altitudes has been personalized for a better vision (it must be remembered that the Salento does not have very sharp differences in heights, and this has made it necessary to mark the elevation differences by adequate colouring). In this way the highest peaks are marked by dark brown, while the lowest are a lighter shade, yellow ochre (Figure 2).

This model has made it possible to create the hillshade, which enables to determine a hypothetical lighting of the surface according to the height of the sun on the horizon (Figure 3).

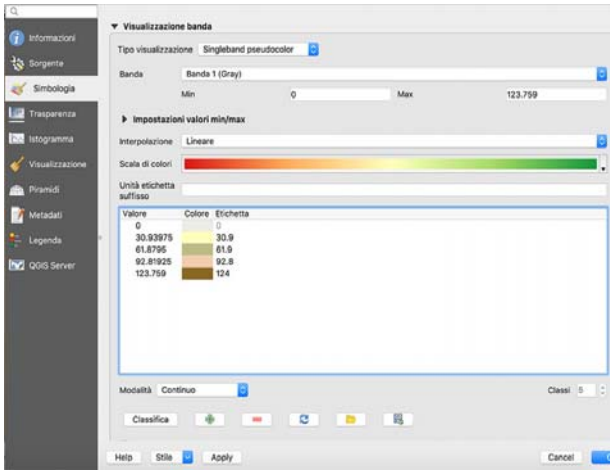

Fig. 2: QGis Singleband Pseudocolor Window.

This option offers the opportunity to better "read" the terrain morphology and also to detect possible imprecisions and/or gaps in the digital terrain model. The two layers have then been overlapped by relying on the transparency of the overlying layer.

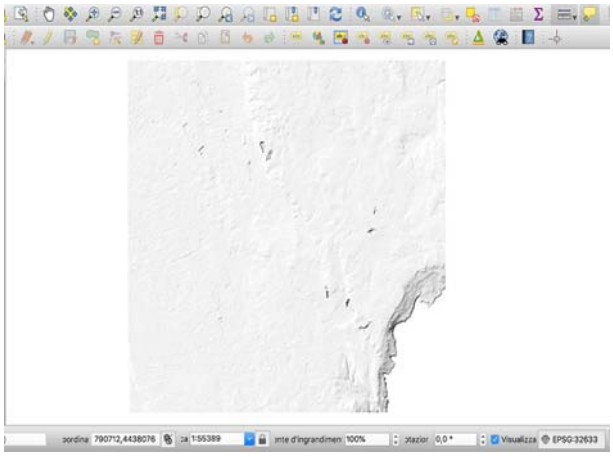

Fig. 3: Hillshade.

After making the reference model, the next step was to overlap the phase plans, which are the result of the vectorization of the detailed technical drawings in CAD mode edited by architect Fabrizio Ghio in the last twenty years (Mastronuzzi, Ghio & Melissano, 2019).

Finally, thanks to the plugin of QGis "Visualise new 3D Map", it was possible to appreciate the phase plans placed on top of the terrain altimetric model in three-dimensional mode. Through the system settings the layer to visualise has been chosen and the value of the vertical range has been modified (vertical exaggeration), making the height difference more evident (Figure 4).

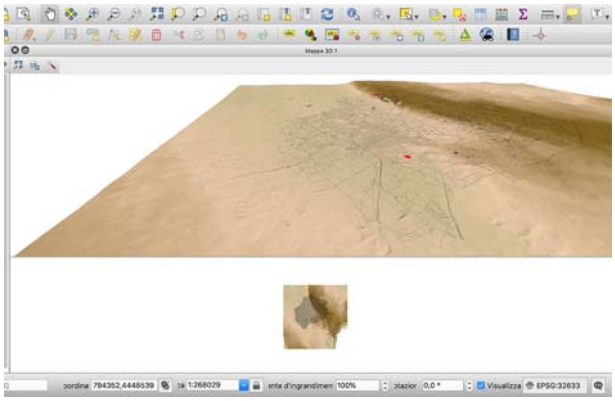

Fig. 4: 3D Model Visualisation.

2.2 Viewshed analysis

In the study of ancient landscape a very suggestive perspective analysis, as it sheds light on how ancient communities perceived their environment, is represented by the reconstruction of what the inhabitants of a certain area could see, that is the piece of land they could observe with their own eyes. This type of investigation can be developed through viewshed analysis (Casarotto, De Guio & Ferrarese, 2009; Cuckovic, 2016). By viewshed analysis we mean the analysis of the extension of how far a human can see starting from a given point of observation. This is a fundamental analysis for the study of archaeological landscapes with respect to perceptual reconstruction: it is in fact possible to determine what and how much could be seen when standing and looking at the horizon at 360 degrees.

This analysis allows the complex simulation of relationships between landscape morphology and settlment systems (Papa, 2016).

By processing the data we have chosen, the applications generate the observation field corresponding to the visual horizon of an observer, so they show the relationships between various settlements and surrounding environment, based on the concept of "*will to visibility*" (Wheatley & Gillings, 2002; Brughmans, Keay & Earl 2015; Brughmans & Brandes, 2017).

Viewshed analysis is a spatial technique that has been successfully integrated within Gis software and is widely used in archaeological studies.

The outcome of the analysis is usually a raster file whose cell values represent the level of inter-isibility from an observer to the surrounding area (De Montis, Caschili, 2012).

The definition of the visible field from a given position on the earth surface satisfies one of the aims of landscape archaeology, that is the complex reconstruction of the possible relationships between landscape morphology and the settlement systems (Pecere, 2006; Di Paola & Trotta, 2013).

From a practical point of view a viewshed corresponds to a grid in which every cell has a visibility value that represents the number of points of observation from where it can be observed. This type of analysis is applied on a DEM or DTM, by calculating, according to the altimetry of the point of observation and the observed area, which part of the terrain enters the field of view of a hypothetical observer (Forte, 2002).

Viewshed techniques can be differentiated in three categories:

- *Binary viewshed*: in this model the analyst assumes perfect inter-visibility between the observer and the targets. The cells take the value 0 in case of no inter-visibility or 1 in case of visibility.
- *Probable viewshed* (Fisher, 1992): introduced in order to better simulate the inter-visibility between points. This technique uses Monte Carlo method to create a perturbation of the results by introducing random errors. The raster cell values range between 0 and 1, while cells with values closer to 1 are more likely to be visible from the source.
- *Fuzzy viewshed* (Fisher, 1994): introduced to model the decrease of inter-visibility between two points depending on factors such as weather conditions and distance.

A researcher's possible question is whether the visibility may represent a determinant factor for the choice of settlement.

With respect to this question, the most ancient phase of settlement of the mentioned area, the Bronze and the Iron Ages (13th - 7th centuries BC), have been chosen for analysis.

In this study we apply a binary viewshed analysis where we suppose a perfect (or absent) inter-visibility between the different selected areas.

With regard to these periods we can recognise at least three different nuclei of evidence concentration.

Besides the findings in the area where the modern village lies, different areas have been identified characterized by the dispersion of pottery fragments near the heights of the "Serra di Poggiardo" (Figure 5). A number of "observation

points" have been placed on top of these elements to obtain a further processing through the plugin "Cumulative viewshed analysis" (Wheatley, 1995), which consists of grouping the single viewsheds and producing a single synthetic map.

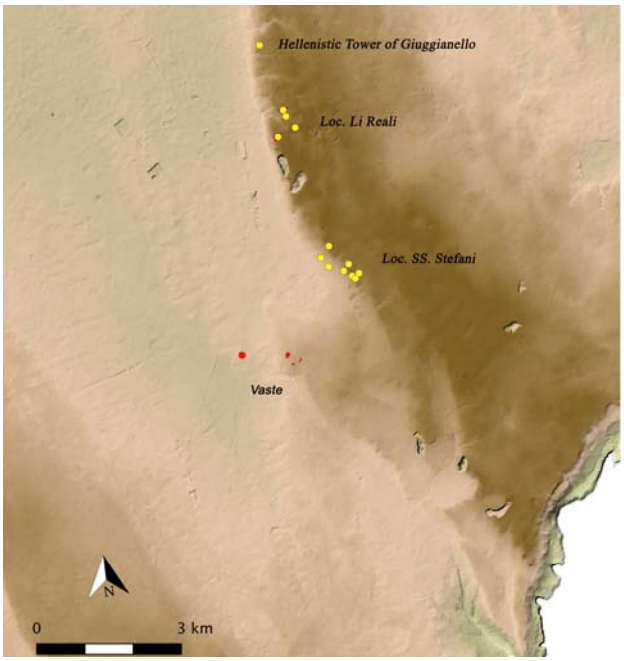

Fig. 5: Bronze Age sites.

As mentioned above, the basis used for this type of analysis is DTM in raster format of the Poggiardo area, which has been overlapped by some points of observation corresponding to the areas in which it has been possible to hypothesise the existence of settlements dating back to the Bronze and Iron Ages. In detail, the observer's height has then been fixed at 1,60 m (it is the average, hypothetical, but reasonable height of an individual, lacking any anthropological data with respect to this chronological context (Lombardo, 1994; Mastronuzzi & Tulumello, 2016) and the visual radius at 5 km (Figure 6).

The algorithm GIS thus drew a visibility map, starting from the different points of observation, with a two colour mask, assigning to the DTM pixels boolean values equalling zero to invisible pixels, as they are obscured by the micro-relief or by natural obstacles, and values equalling 1 to visible pixels. The latter have been assigned a dark colour, while the invisible areas turn out to be "transparent" and, therefore, they are not perceptible on the different layers.

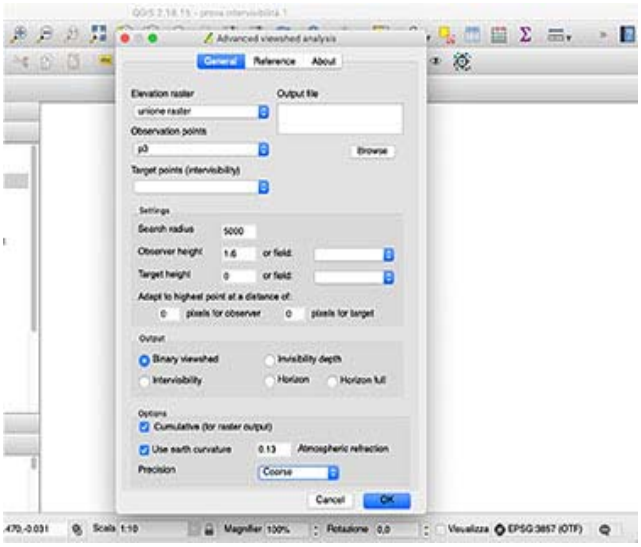

Fig. 6: Viewshed analysis plugin.

3. Spatial analyses

3.1 From the Bronze Age to the Iron Age

Through viewshed analysis it is evident that some factors might have influenced the choice of places for human settlement. Starting from the Final Bronze Age, a polycentric occupation of the Vaste territory has been demonstrated, with two higher nuclei and at least one in correspondence with the modern town. The choice of the settlement in a high position is a strategic one with respect to controlling the surrounding area: in fact, from these points of observation the vision of the underlying plain in the western dials is extremely broad (Figure 7a, b, c). However, it is necessary to notice that the visibility analysis indicates that territory control is not to be examined separately for each of the other points of a piece of a given area. This control is the consequence of such a complex and organized system so that, in this case, we can assume there is a link between the areas with many findings on the Serra di Poggiardo and the whole northern sector. Here stratigraphic investigation has enabled to date the first building phase of the Giuggianello tower/specchia to the Medium Bronze Age (Mastronuzzi & Masiello, 2019). This one, in the Hellenistic age, turns out to be linked to an apparatus of sites strategically widespread according to the area morphology (Mastronuzzi, 2018; Semeraro, 2009).

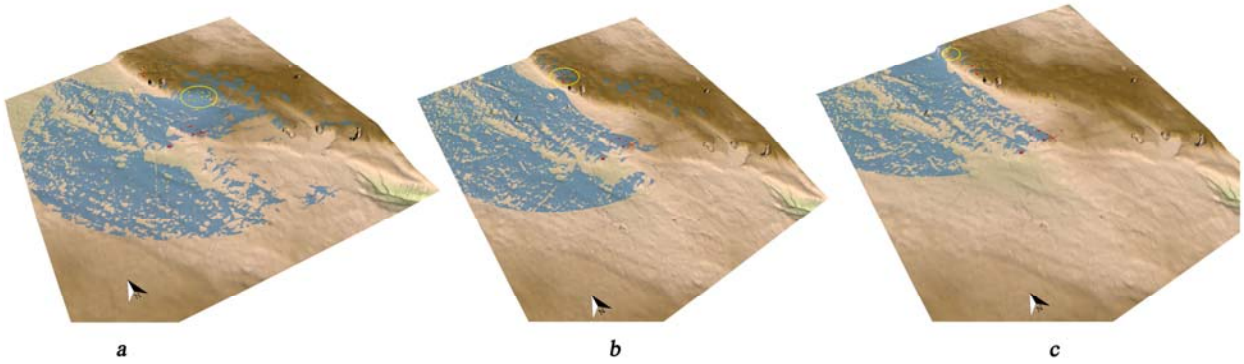

Fig. 7: a) Cumulative viewshed analysis from loc. SS. Stefani; b) Cumulative viewshed analysis from loc. Li Reali; c) Cumulative viewshed analysis from the Hellenistic tower of Giuggianello.

Thus, there were many sites linked to a single settlement system which ensured the control and management of a wide area of the Otranto hinterland between the late Bronze and the early Iron Ages. From this settlement organisation the system of the towns of Muro Leccese and Vaste was later developed and they both were included in the cantonal organization of Messapia since the 6th century BC (D'Andria, 1991; Burgers, 1998; Yntema, 2013).

As for the Iron Age, we can observe a continuous occupation of the sites on the heights of the Serra di Poggiardo. With respect to this period, however, archaeological investigation has also demonstrated a higher density of the sites in the whole area at the foot of the Serra: in particular, the excellent vision over the surrounding territory might have favoured the occupation of plain spaces where today's town of Vaste lies. From the 9th century BC this nucleus acquired a predominant role over the surrounding sites.

The morphological characteristics enabled to declare a wide area suitable for living, not exceeding 10 ha, fenced by enclosures or fortifications. Several huts or elements linked to huts have been found, particularly in the area called "Fondo S. Antonio", but also the area devoted to worship of the "Fondo Melliche" and the aggere (rampart) brought to light in Via Isonzo (Mastronuzzi et al., 2019) are of some importance. From the Iron Age onwards we cannot identify any significant interruption in the occupation of the village of Vaste, which on the contrary developed constantly and incessantly until the contemporary age.

As regards the occupation dynamics of the territory in the chronological horizon between the 9th and the 7th centuries BC a new analysis has been carried out, through an instrument of GRASS, "Raster costs points"; this analysis regards the "cost" estimation with respect to the energy that an individual uses to move between two given points.

With this application we can evaluate how a region was crossed and how long it took and try to reconstruct the roads and routes inside an ancient landscape. The basic principle is to assume that as one goes away from a hypothetical centre more energy is dissipated.

By establishing the sector on the Serra di Poggiardo as our reference point, with the sites where settlement is demonstrated from the Bronze Age onwards (unfortunately the archaeological data, all of which coming from surveys, are insufficient to detail the chronology of each site, observing synchrony and diachrony between them), it is apparent that the area demanding the lesser "energetic cost" to reach it is the one corresponding to the modern inhabited area of Vaste (Figure 8).

In this way, the settlement built in the point that for many reasons was the most advantageous acquired a position of reference and preeminence. The inhabited zone located in a plain area had the characteristics of a grouped settlement, defined and fortified; since it was located in the middle of a wide plain, it ensured better chances for agricultural and aquifer exploitation; it was also easier to reach the sites in the surrounding area using it as a starting point.

This dynamics is confirmed by the fact that in the very early Iron Age the settlement near contrada Li Reali was abandoned for good (northern sector of the Serra di Poggiardo).

The shift of the settlements and the birth of concentrated inhabited areas bigger than small conglomerations of huts are variously documented phenomena in Apulia between the late 2nd and the early 1st millennium BC, and they are linked to other processes such as demographic growth, development of agriculture and sheep-farming, social differentiation and stratification and settlement specialization (Radina & Recchia, 2010).

3.2 Water in the Hellenistic period

Another example of spatial analysis, connected to the morphology of the Vaste territory, can be proposed on the basis of the distribution of wells and tanks in the district we are examining. On the cartography and, later, on the DTM the position of structures for intercepting aquifers and preserving water was registered (Figure 9). The data come from IGM cartography (perennial and non-perennial wells), from the CTR of the "Regione Puglia", and from the information coming straight from field investigation regarding particularly the inhabited area in the Hellenistic period.

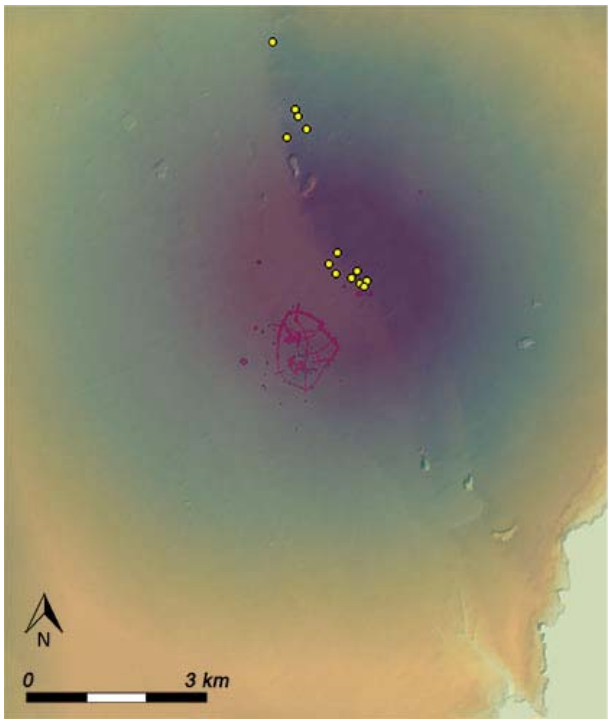

Fig. 8: r. costs points from loc. SS. Stefani

The inhabited area is characterized by an irregular network of roads following the morphology of the terrain which the domestic units overlook. Among the residential complexes the so called "L shaped building" stands out for the

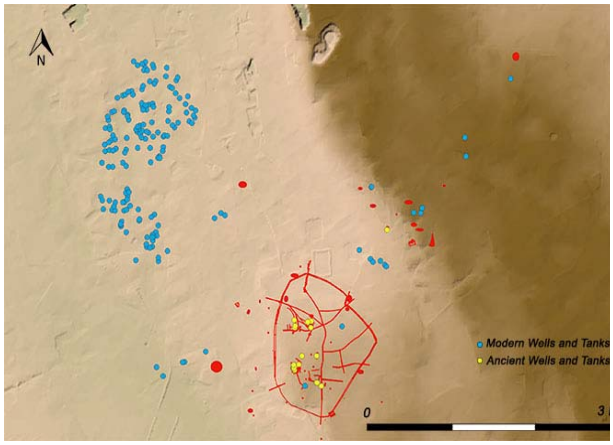

Fig. 9: Ancient and modern wells and tanks in Vaste area during the Hellenistic period

width of its covered area, for its connection with a large internal courtyard and an open space occupied by tanks (D'Andria, 1996). It can be associated to a family group of aristocratic rank, like other monumental buildings such as the hypogeous chamber tombs, in particular, in the Vaste area, the so called "Ipogeo delle Cariatidi" (Valzano, Mannino, Bandiera, Brogi, & Zannoni, 2010; Mannino, 2015). However, in this period, the whole Salento region, which ancient Greek writers called "Messapia", went through a period of demographic growth and progressive organization of inhabited areas, integrated into a complex cantonal system which represents the conclusion of a structuring process dating back to the archaic age.

The Vaste settlement developed coherently with the preceding phases confirming that the choice made in the Iron Age must be explained according to the natural characteristics of the site: morphological, hydrological and pedological. The area is flat, with terrains mostly made of arenite, and, due to this, the surfacing rock represents a perfect source of good quality cutting stone for building.

The groundwater table is abundant and shallow and, nowadays as well as in ancient times, in the Vaste area most wells are concentrated in the northern sector of the inhabited area (Lamboley, 1996), in the low plain, where it is easier to reach water (Tölle-Kastenbein, 1990) (Figure 10). Much more remarkable is, however, the concentration of modern wells in the inhabited area of Poggiardo, located at an even lower level than Vaste.

Many structures have been spotted and investigated during the stratigraphic excavations:

they mostly date back to the period between the second half of the 4th and the 3rd centuries BC The abandonment of the wells can be traced back to the final years of the 3rd century when the process of their reallocation as rubbish dump began and continued until the 2nd century BC. Next to them there are wells which are still in use, probably going back to an ancient period, as the blocks used to build their mouths and top parts would seem to suggest.

Most of these structures seem to be somewhat connected with little sanctuaries or places of worship on the northern margin of the inhabited area (Melissano, 2012); however, wells and tanks are not missing in other points of the inhabited area either, and, above all, we must consider their presence near and in close complex previously mentioned.

In this perspective it is clear that the control of water reserves played a decisive role within the community of Vaste, and this is even more evident when we think that they were directly controlled by aristocratic groups or, alternatively, they were indirectly under the control of elites through sacred places.

4. *Concluding note*

When interpreting the archaeological data coming from different sources of information – excavations, surveys, recoveries, reports, archive documents etc… – digital technology represents a precious tool as well as an inescapable one. It is particularly useful for the development of spatial analyses, on both micro and macro scales, and, nevertheless, it has a few limitations which we must take into consideration.

The greatest of them, when dealing with ancient contexts, is represented by the difficulties in reconstructing the site in its geomorphological details but, even more so, with respect to surface hydrography and to how much the territory is covered with trees.

This element strongly affected visibility in a piece of a given area and its practicability. Archaeobotanical and palynological data undoubtedly enable us to recognise the species present in ancient times, and to speculate about the presence of forests and woods and different areas devoted to agriculture.

It is much more difficult to establish how thick forested and wooded areas might have been so as to become an obstacle to visibility and even more so to the possibility of crossing certain areas, especially near settlements.

The uncertainties relating to surface hydrography seem to be even greater as the latter is strongly affected by the wood system which, if it is particularly thick, causes runoff water to be reduced (McCormick, Büntgen, Cane, Cook, Harper, Huybers, Litt, Manning, Mayewski, More, Nicolussi & Tegel, 2012).

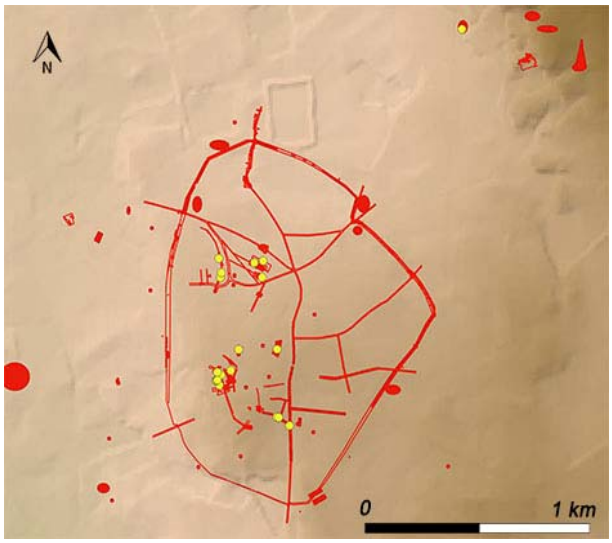

Fig. 10: Ancient and modern wells and tanks inside the city of Vaste during the Hellenistic period.

The spatial analysis conducted with reference to viewshed analysis and cost surface analysis is a tool that supports the diacronic interpretation of the transformations of the settlement in the district of Vaste, with particular respect to the period between the late Bronze Age and the early Iron Age. The interpretation of data based on these applications precisely matches the hypotheses on the dynamics of how the territory was occupied which were made in the past on the basis of traditional historical-archaeological indicators: the passage from scattered settlements to grouped settlements due to demographic and socio-economic factors.

In an even more structured historical context, like the inhabited area of the 4th and 3rd centuries BC the spatial analysis of the distribution of wells and tanks contributes to spotting the social dynamics underlying the control of water resources, handled directly by dominant aristocratic groups or, indirectly, through the control of sanctuaries, places of worship and sacred areas.

Collecting, filing and handling archaeological data represent the starting point to analyse

ancient settlements in a specific area. The study of the district of Vaste demonstrates how technology enables to go into some subjects thoroughly and allows us to have a glimpse on the possibility to direct investigations towards a predictive perspective, supplying further elements which help to investigate and analyse ancient landscapes[1].

[1] Giovanni Mastronuzzi: Paragraphs 1, 3.2, 4; Giacomo Vizzino: paragraphs 2, 3.1.

REFERENCES

Aprile, G., & Orlandi Barbano, F. (2008). La Grotta Campana d'Oro di Poggiardo—Lecce. In *Atti della XLIII Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria* (pp. 767–769). Firenze: Istituto Italiano di Preistoria e Protostoria.

Balasubramanian, A. (2017). *Digital Elevation Model (DEM) in GIS*. University of Mysore.

Baratti, F. (1997). Il sistema per la gestione dei dati di scavo. Elaborazioni cartografiche. In F. D'Andria (Ed.), *Metodologie di catalogazione dei Beni Archeologici* (pp. 85–95). Lecce-Bari: Martano Editrice, Edipuglia.

Brughmans, T., & Brandes, U., (2017). Visibility Network Patterns and Methods for Studying Visual Relational Phenomena in Archaeology. *Frontiers in Digital Humanities: Digital Archaeology*, 4, 17. https://doi.org/10.3389/fdigh.2017.00017

Brughmans, T., Keay, S., & Earl, G., (2015). Understanding inter-settlement visibility in Iron Age and Roman Southern Spain with exponential random graph models for visibility networks. *Journal of Archaeological Method and Theory*, 22, 58- 143.

Burgers, G.-J. (1998). *Constructing Messapian Landscapes*. Free University of Amsterdam.

Cambi, F. (2011). *Manuale di archeologia dei paesaggi. Metodologie, fonti, contesti*. Roma: Carocci.

Carluccio, G. (1981). La carta archeologica di Vaste*. Studi di Antichità*, 2, 87–107.

Casarotto, A., De Guio, A., & Ferrarese, F. (2009). Action GIS: un modello predittivo del movimento antropico in un paesaggio antico. Il caso di studio archeologico della Val d'Alpone (VR). *Archeologia e Calcolatori*, 20, 291–307.

Chapman, H. (2006). *Landscape archaeology and GIS*. Cheltenham: The History Press.

Clini, P., Cerquetti, M.G., Bertuccioli, L., Invernizzi, L., & Gasparini, M. (2016). Integrated methodologies for the study, enhancement and sharing of archaeological heritage: the ArcheoFano project. *SCIRES-IT - SCIentific RESearch and Information Technology*, 6(2), 81-92. http://dx.doi.org/10.2423/i22394303v6n2p81

Cuckovic, Z. (2016). Advanced viewshed analysis: A Quantum GIS plug-in for the analysis of visual landscapes. *Journal of Open Source Software*, 32(4). Retrieved from https://doi.org/10.21105/joss.00032

D'Andria, F. (1996). La casa in Messapia. In F. D'Andria, K. Mannino (Eds.), *Ricerche sulla casa in Magna Grecia e Sicilia*, Atti del colloquio (pp. 403–438). Galatina: Congedo editore.

D'Andria, F. (1991). Insediamenti e territorio: L'età storica. In *Atti del XXX Convegno Internazionale di Studi sulla Magna Grecia* (pp. 383-478). Taranto-Lecce: Istituto per la Storia e l'Archeologia della Magna Grecia.

D'Andria, F., Mastronuzzi, G., & Melissano, V. (2006). La chiesa e la necropoli paleocristiana di Vaste nel Salento. *Rivista di Archeologia Cristiana*, LXXXII, 231–322.

De Ferrariis, A. (1558). *De situ Iapygiae*. Basel.

De Montis, A., & Caschili, S., (2012). Nuraghes and landscape planning: coupling viewshed with complex network analysis. *Landscape and Urban Planning*, 105 (3), 315-324.

Di Paola, G. M. F., & Trotta, V. (2013). La Viewshed analysis in ArchGis 10.1. I casi di Populonia e Segesta. *Archeomatica*, 3, 12–15.

Fisher, P.F., (1992). First experiments in viewshed uncertainty: Simulting fuzzy viewshed. *Photogrammetric Engineering and Remote Sensing*, 58 (3), 345-352.

Fisher, P.F., (1994). Probable and fuzzy models of the viewshed operation. In Worboys M. (ed.), *Innovations in Gis* 1 (pp. 161-175). London: Taylor and Francis.

Forte, M. (2002). *I Sistemi Informativi Geografici in Archeologia*. Roma: MondoGis.

Hutchinson, M. F., & Gallant, J. C. (1999). Representation of terrain. In P.A. Longley, M.F. Goodchild, D.J. Maguire, D.W. Rhind (Eds.), *Geographical Information Systems: Principles, Techniques, Applications and Management* (pp. 105–124). Hoboke, New Jersey: John Wiley & Sons.

Hutchinson, M. F., & Gallant, J. C. (2000). Digital elevation models and representation of terrain shape. In J.P.Wilson, J.C. Gallant (Eds.), *Terrain Analysis* (pp. 29-50). Hoboke, New Jersey: John Wiley & Sons.

Lamboley, J.-L. (1996). *Recerches sur les Messapiens. IVe-IIe siècle avant J.-C.* Rome: Ecole Française.

Li, Z., Zhu, U., and Gold, C. (2005). *Digital Terrain Modeling. Principles and Methodology*. Boca Raton, Florida: CRC Press.

Lombardo, M. (1994). Tombe, necropoli e riti funerari in "Messapia": Evidenze e problemi. *Studi di Antichità*, 7, 25–45.

Mannino, K. (2015). Ipogeo delle Cariatidi. In G. Mastronuzzi (Ed.), *Vaste e Poggiardo. Il patrimonio culturale e ambientale* (pp. 29–33). Maglie: Cea Serre Salentine.

Mastronuzzi, G. (2018). Una "torre" di età ellenistica presso Giuggianello—Puglia meridionale. *Fold&r*, 2018–423, 1–15.

Mastronuzzi, G., Ghio, F., & Melissano, V. (2019). *Carta archeologica di Vaste – territorio comunale di Poggiardo (Puglia meridionale)*. Oxford: BAR Publishing.

Mastronuzzi, G., & Masiello, L. (2019). *Giuggianello e il suo territorio tra mito, storia e archeologia.* Galatina: Editrice Salentina.

Mastronuzzi, G., & Tulumello, G. (2016). "Deviant burials" nella Puglia tra l'età del Ferro e l'età romana. *Antike Kunst*, 59, 19–37.

Mazzolai, A. (1965). Ricognizione della Via Aurelia e Clodia nei tratti compresi fra il fiume Fiora e Populonia. *Bollettino della Società Storica Maremmana*, 11, 17–61.

McCormick, M., Büntgen, U., Cane, M. A., Cook, E. R., Harper, K., Huybers, P., Litt, Th., Manning, S. W., Mayewski, P. A., More, A. F. M., Nicolussi, K., & Tegel, W. (2012). Climate Change during and after the Roman Empire: Reconstructing the Past from Scientific and Historical Evidence. *Journal of Interdisciplinary History*, XLIII(2), 169–220.

Melissano, V. (2012). Ricerche archeologiche a Vaste, Fondo Melliche. L'età ellenistica. In K. Mannino, R. D'Andria (eds.), *Gli allievi raccontano*, Atti dell'Incontro di Studio per i trent'anni della Scuola di Specializzazione in Beni Archeologici Università del Salento, I (pp. 79–92). Galatina: Congedo editore.

Miller, C.L., & Laflamme, R.A. (1958). The digital terrain model—Theory & application. Cambridge, Massachussets: M.I.T. Photogrammetry Laboratory.

Notarstefano, F., Pecere, B., & Semeraro, G. (2018). Integrated methodologies in the study of pottery function. *SCIRES-IT - SCIentific RESearch and Information Technology*, 8(1) 139-148. http://dx.doi.org/10.2423/i22394303v8n1p139

Papa, M.A. (2016). L'intervisibilità. Analisi del paesaggio nella chora della colonia greca di Himera. In *Multi, inter- and transdisciplinary research in Landscape Archaeology. Proceedings of the 3rd International Landscape Archaeology Conference LAC2014* (pp. 1-12). Amsterdam: University Library Vrije Universiteit Amsterdam. http://dx.doi.org/10.5463/lac.2014.48.

Pecere, B. (2006). Viewshed e cost surface analysis per uno studio dei sistemi insediativi antichi: Il caso della Daunia tra X e VI secolo a.C. *Archeologia e Calcolatori*, 17, 173–213.

Peverieri, G. (1995). *GIS. Strumenti per la gestione del territorio*. Milano: Il Rostro.

Radina, F., & Recchia, G. (2010). *Ambra per Agamennone. Indigeni e Micenei tra Adriatico, Ionio ed Egeo.* Bari: Adda editore.

Puglia.con: Conoscenza condivisa per il governo del territorio. http://www.sit.puglia.it/portal/sit_portal

r.cost - GRASS GIS manual. Retrieved from https://grass.osgeo.org/grass78/manuals/r.cost.html

Remondino, F., & Campana, S. (2014). *3D Recording and Modelling in Archaeology and Cultural Heritage. Theory and Best Pratices*. Oxford: BAR Publishing.

Semeraro, G. (2009). Strumenti per l'analisi dei paesaggi archeologici. Il caso della Messapia ellenistica. In M. Osanna (Ed.), *Verso la città. Forme insediative in Lucania e nel mondo italico fra IV e III sec. a.C.*, Atti delle Giornate di Studio (289–306). Venosa: Osanna.

Stoico F., D'Altilia L. (2012). Analisi spaziali in archeologia dei paesaggi: il progetto N.D.S.S. (Northen Daunian Subappennino Survey). In F. Cantone (Ed.), *ARCHEOFOSS. Open Source, Free Software e Open Format nei processi di ricerca archeologica.* Atti del VI Workshop (Napoli, 9-10 giugno 2011) (pp. 245-252). Pozzuoli: Naus Editoria.

Tölle-Kastenbein, R. (1990). *Archeologia dell'acqua: La cultura idraulica nel mondo classico*. Milano: Longanesi.

Valzano, V., Mannino, K., Bandiera, A., Brogi, A., & Zannoni, M. (2010). *L'Ipogeo delle Cariatidi di Vaste. The Hypogeum of the Caryatids at Vaste* [DVD-ROM]. Lecce. IT: Coordinamento SIBA Università del Salento & CASPUR. DVD-ROM was awarded nationally among the best digital content in the "eScience and Technology" and "eCulture and Heritage" categories of the Italian eContent Award 2010. Retrieved from http://www.ceit-otranto.it/index.php/progetti/32-zeus-di-ugento (DVD-ROM); Video-Documentary: https://vimeo.com/407020593 (IT), https://vimeo.com/407121650 (EN).

Wheatley, D. (1995). Cumulative viewshed analysis: A GIS-based method for investigating intervisibility and its archaeological application. In G. Lock, Z. Stancic (Eds.), *Archaeology and GIS: a European Perspective* (pp. 171–185). Boca Raton, Florida: CRC Press.

Wheatley, D., & Gillings M. (2002). *Spatial Technology and Archaeology. The Archaeological Applications of Gis*. New York: Taylor and Francis.

Yntema, D. (2013). *The Archaeology of South-East Italy in the First Millennium BC.* Amsterdam: University Press).

Zezza, F. (1997). Indagini chimico-fisiche sui materiali lapidei dall'area archeologica di Vaste (Le). In F. D'Andria (Ed.), *Metodologie di catalogazione dei Beni Archeologici* (pp. 229–241). Lecce-Bari: Martano Editrice, Edipuglia.