The Potenza Valley Survey: Towards an Explanation of the Settlement Patterns Through the Combined Use of GIS and Different Survey Techniques

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Abstract

In 2000, Ghent University started an international geo-archaeological survey project in the valley of the Potenza River, which links the Apennine hills to the Adriatic coastline of Central Italy (Marche region). Under the direction of Prof. Frank Vermeulen, the Departments of Archaeology and Geography aim to measure the evolution of social complexity within this valley and evaluate the phenomena of acculturation, in time as well as in space.
In addition to systematic fieldwalking and geomorphological research, aerial photography is also undertaken in an exhaustive way. The implementation of the data achieved by these survey techniques into a GIS will be outlined, as well as the difficulties of attaining this in an accurate way.
Besides this function of GIS as a spatial data management and visualising tool, it also offers possibilities in analysing settlement patterns, as some results of locational analysis will make clear. Furthermore, the results of spatial analysis will permit incorporation into the archaeological heritage management of the region in the near future.

Introduction

Since Ward-Perkins started his South Etruria Survey in the early 1950s, archaeological Mediterranean field surveys sprang up like mushrooms. Especially in Italy, systematic prospections really expanded in the form of many small-scale and large-scale projects. In these fifty years, the Marches in Central Italy as well witnessed a lot of smaller and bigger survey projects, almost -if not all- executed by Italian researchers. Nevertheless, an area that still had not been subjected to a major archaeological survey was the valley of the Potenza. This river flows over its ca. 80 km long course from the Umbria-Marches Apennines through a wide and fertile Apennine foothill landscape before it ultimately runs into the generally flat Adriatic coastline zone. Already important in Prehistory (Percossi Serenelli 1981:135-144), the Potenza river valley became one of the most commercial routes of the Central Italian Protohistory and even in later periods the valley remained an important corridor for political, economical and cultural contacts between the Thyrrenian and the Adriatic coast. In Roman times, several cities developed in or near the valley floor (Potentia, Helvia Recina, Trea, Septempeda & Prolaqueum) and even a southern branch of the Via Flaminia passed through it. In the subsequent period, the area remained of importance as it formed the contact zone between Longobards and Byzantines.

These are only a few of the reasons why a geo-archaeological survey called the 'Potenza Valley Survey' -PVS- was initiated in January 2000. This interdisciplinary project was set up by Ghent University (Belgium), more in particular by the Departments of Geography and Archaeology. Under the direction of Prof. Frank Vermeulen, the major aim of the PVS was - and still is, as the project will last till at least 2006 - to measure the evolution of social complexity within this valley and evaluate the phenomena of acculturation, in time as well as in space. Therefore, the project got the subtitle 'From Acculturation to Social Complexity in Antiquity: A Regional Geo-Archaeological and Historical Approach'. To forefill the initially outlined goals[1], three specific sample zones, systematically spaced around the Potenza river, are focused on.

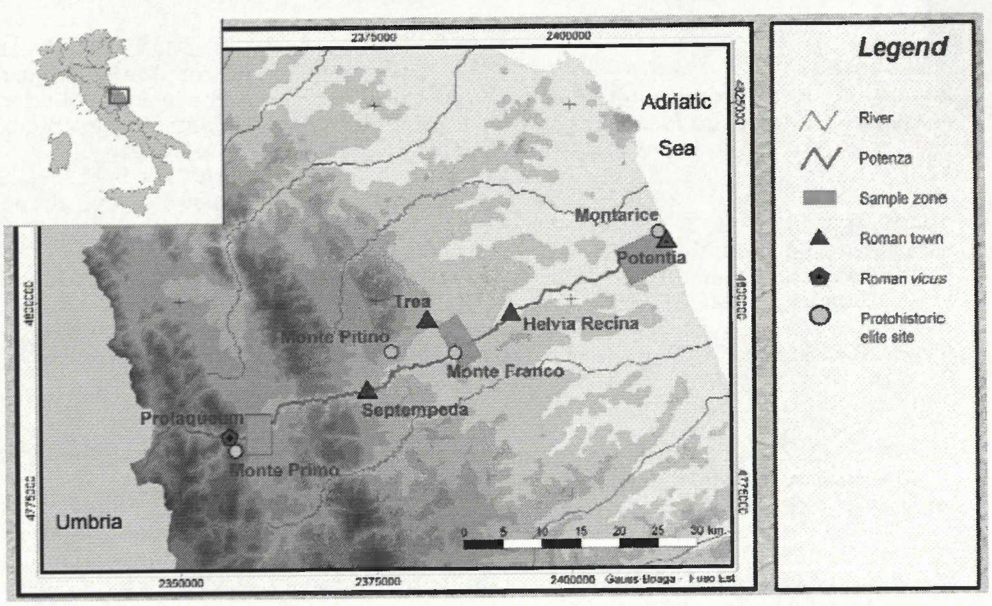

Figure 1 Location of the three sample zones

(Fig.1) The geo-archaeological research consists of four important cornerstones: aerial survey, field survey, geomorphological survey and a historical survey. The aerial survey comprises the collecting of as many vertical photographs and satellite images as possible. Besides this passive part, this survey also has an active part: taking oblique aerial photographs from a low flying aircraft. Till now, this has been done in a very thorough way: on the one hand, different flights were made in different seasons; on the other hand, pictures were taken of the whole valley with a specific interest in the three sample zones. Systematic prospection of the ploughed fields, always carried out in the month of September, is the method used in the field survey. In search for archaeological evidence, intensive linewalking was chosen as prospection method. Therefore, an interval of 10 to 15 meter between different walkers is aimed for. Scholars of the Department of Geography conduct the geomorphological part of the project by making as many field observations as possible. Additionally, some augering is also performed to reconstruct the evolution of the coastline and study the problem of alluviation and colluviation.[2] Finally, an intensive historical survey to study known archaeological sites of all periods into detail is implemented as well. Moreover, some research of toponymical and historical written information is on-going.

Since the PVS started more than three years ago, one can be convinced that the amount of gathered information is substantial.[3] Managing such quantities of -almost all geographically linked- data has become much easier with the introduction of Geographic(al) Information Systems. From the beginning of the project, it was the aim of director Frank Vermeulen to incorporate all gathered survey data into a GIS-context.

Building the GIS

In fact, before data could be managed and analyses computed, the building of the GIS had to occur. Working with different researchers in different disciplines, each of them with own particular data, a centralization of all information seemed to be necessary. The creation and storage of data was for a long time performed on different computers, but in January 2003, one central PC was purchased and configured to contain all possible data in an orderly and easily accessible way. In consequence, this PC also functions as the centre of all GIS-analyses.[4] The data stored in the GIS consists of access-databases (although they should lead to one, all-embracing database which contains all data of the four surveys) and a lot of raster and vector files. The greater part of the vector files are digitized topographical maps (scale 1/10,000, CAD-format), obtained thanks to the Regione Marche. Where needed, manual digitizing (with digitizer tablet or on-screen) completed the vector data. However, spatial data can also be stored as raster, a fundamentally different format. In ArcView, a distinction is made between raster images and raster maps, also called grids. Till now, the number of grids is very limited (some DEMs and distance grids), in contrast with the image data. Besides the huge collection of aerial and on-ground photographs (mostly of artefacts), some scanned maps (topographical, orthophoto and cadastral), a few Landsat satellite images and a -fast expanding- number of rectified images complete the GIS-data at present.

After outlining the project, the structure of the GIS and the data that are available, just one more step has to be taken before one can start visualising and analysing: be(come) aware of the data quality. After all, it is important to understand that it is possible to have 'error free' attribute data (in terms of the method employed), but impossible to have 'error free' spatial data, because our multi-dimensional reality will always be different from the digital representation of it. Therefore, the entering of spatial information can rightly be seen as the Achilles' tendon of almost every GIS (Voorrips 1998:255).

Quality affecting factors that can be mentioned are the accuracy and precision of the source data, the interpolation methods employed, the scale of the data, the georeferencing system used, the data collection technique and the sampling strategy that are applied, the process of scanning and digitizing, etc. In this respect, a lot of attention is paid to metadata and -a limited amount of- quality control.

Metadata and Quality Control

Metadata can be seen as 'data about the data' as it describes the content, quality, condition and other characteristics of data. It provides us with information about the who, what, when, where, why and how of a data set. In consequence, proper metadata are critical in preserving the usefulness of data over time and it is crucial to supply all kinds of GIS-data with this information. Different metadata standards exist. In the PVS, the geospatial data is documented using the Federal Geographic Data Committee's (FGDC) Content Standard for Digital Geospatial Metadata, which the Federal Geographic Data Committee approved in June 1998 (Federal Geographic Data Committee 1998). To build FGDC-compliant metadata, an easy-to-use application called the ArcView Metadata Collector was achieved, allowing to create metadata for any data type supported by ArcView.[5]

Besides metadata, quality control is another important topic in the PVS-GIS. Using spatial data in a GIS-operation implies that error (defined as the discrepancy between a given - digital - value and its value in reality) in the input will propagate to the output of the operation. In this respect, the resulting output is a function of the input values and inaccurate input values will automatically affect the computed results (Heuvelink 1993:23-5). Therefore, it is significant to test the accuracy of some digital maps. One example is the Digital Elevation Model or DEM. In the majority of GIS-data sets, the DEM is the most important layer. Except information about the height, it is also used to generate slope and aspect and it serves as well as basis for cost path analysis, distance calculations etc. As a consequence, it is the fundamental basis to study the topographical features of archaeological sites.

One always needs an interpolation algorithm to construct a usable DEM. Some digitized high points or contour lines form the basis of the DEM, but they do not form a continuous surface with height values yet. To retrieve this, an interpolation method is ran and will attribute the places without data a figure that represents the height of that specific place. However, different interpolation methods produce different terrain values. We must surely accept that the final DEM will be an approximation of a continuous phenomenon, but how closely this approximation reflects reality can be calculated (Hageman and Bennett 2000:114-5).

Presently, the accuracy of the DEM applied for the first sample zone was calculated. This control occurred on the basis of two tests. Initially, the digitized contour lines were checked visually by generating a TIN (Triangulated Irregular Network).[6] A closer look at the characteristic points and lines as well as the hillshaded relief revealed some profound errors, owed to the manual labelling. Afterwards, a quantitative test was ran. Eleven different interpolation methods[7] were executed. The predicted elevations for a given DEM were compared to some reference points (none of them was located on a contour line) and the discrepancy between both was calculated. With these figures, a global RMSE (Root Mean Square Error, which is mathematically the same as standard deviation) could be calculated for a given DEM. This procedure was repeated for each interpolation. Subsequently, different errors could be compared and the lowest RMSE revealed the preferable DEM. In the near future, homogeneous computations will be used to create the DEMs for the second and the third sample zone. Furthermore, it is also hoped some more digital files can be tested on their accuracy as these tests really give a good idea of the quality of the files one is working with.

First Analytical Results

Setting up the GIS on the one hand and still on-going analysis from the different researchers on the other, caused the analyses to be very limited and temporary till now. The executed computations presented here are all applicable to the first sample zone.[8] The research was divided into two parts: analyses of data linked with the cadastral maps and analyses of the environmental characteristics. The first part covered items as the calculation of the precise prospected area (3.2 km²), the determination of the proportional ratio of the visibility classes (19.6% bad; 3.4% moderate; 77% good) and the computation of the proportional ratio of the fields with erosion (29.9%). Furthermore, a chi-squared test of goodness-of-fit revealed for a significance level a = 0.05 that sites are equally distributed across fields with and without erosion. A determination of the off-site proportions (0 = 5.7%; 1 = 56.5%; 2 = 19.2%; 3 = 18.6%)[9] as well as a calculation and visualisation of the total and periodical site density (total = 17.19 sites/km²; pre- and protohistoric = 3.13 sites/km²; Roman = 13.75 sites/km²; medieval and post-medieval = 1.12 sites/km²) complete this first part. One can notice the high density of Roman sites. However, a further subdivision per period is needed and was on-going during the writing of this article.

The second part dealt with the relation between the sites and the environmental characteristics as height, slope, distance to the nearest water source, etc. The analyses of these environmental characteristics are based on a study by Hodder and Orton (1976:226-229). They examined the distribution of 173 Iron Age coin finds in relation to Roman road locations in central and southern England. Using manual methods of pre-GIS days, they performed a statistical analysis which revealed a significant association between the coin distribution and the Roman road network. With GIS, such analyses can be executed a lot faster and with results that are even more pre-

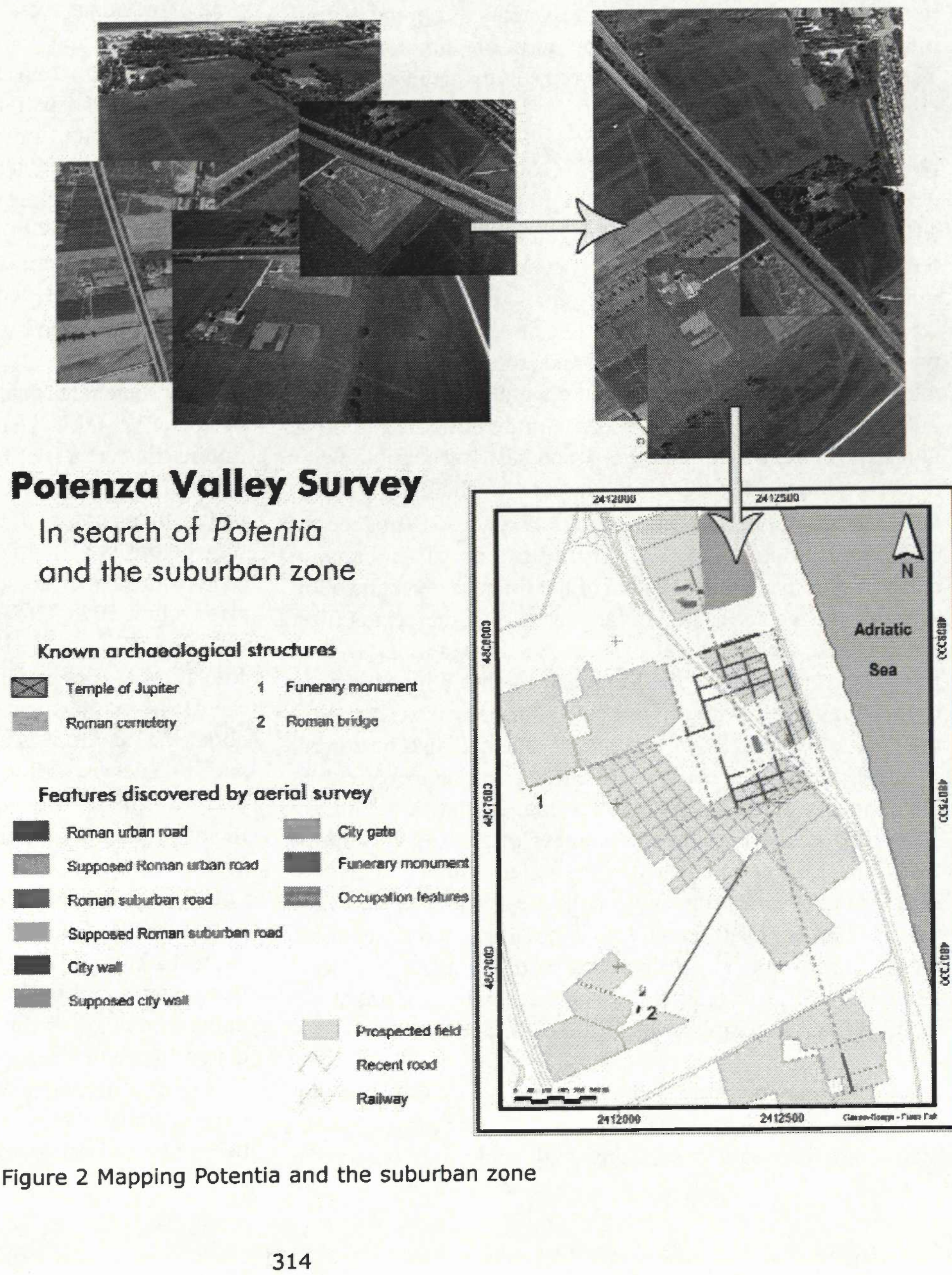

Figure 2 Mapping Potentia and the suburban zone

cise and accurate. Using the Kolmogorov-Smirnov one-sample test, the relation of the sites (per main period) and isolated finds to the following environmental characteristics was determined: elevation, slope and aspect; distance to the waterways, to the Potenza, the springs and the total hydrographical network; distance to the nearest road, to the nearest flint; view on the Potenza. Some relations did occur (e.g. the isolated Stone Age artefacts were obviously linked to the springs and the Roman sites to the contemporary rural roads), but generally spoken, no specific connection between the environmental characteristics and the sites could be deduced for the moment, partly due to -as underlined before- the fact that the periods were too broad delineated for detailed analyses.

Prospects

In the near future, more and new analyses should replace these preliminary results, although the small number of sites for some periods will make analysis -even in the future- problematical.

For the moment, a new kind of research is in progress: rectifying oblique aerial photographs to map all crop, soil and shadow marks. Of course, a thorough interpretation of the aerial images will follow, but we want to take the research one step further by comparing the field data with the oblique photographs. Do features of both data sources match perfectly? What is the amount of artefact scattering due to ploughing or erosion? Are these relations constant in one sample zone and -of course- how big are the (dis)similarities between the zones? These are just some questions that could be asked. Furthermore, the combination of both data sources can also give a surplus value to each data source, leading to a better interpretation of the archaeological features and a greater understanding of the site's structure and its occupation phases. The Roman site of Potentia can function as a nice example. Using AirPhoto 2.20[10] and a digital topographical map, the most interesting photographs of the former Roman city were rectified. On the photomosaic, a lot of different archaeological features could be spotted and interpreted. (Fig. 2) Besides the city, also some images in the suburban area were rectified. Here, some Roman roads and several funerary monuments could be distinguished. In the near future -i.e. when the material processing has finished- these results will be compared with the data from the field survey. On the one hand, the oblique images will give a better idea of the 'real' proportions of the city, on the other hand the sherds and pieces of marble, glass and tesserae can tell something about the intra-site spatial organisation and temporal delineation of the features.

Besides, this highly significant data can -and will- be combined with the geomorphological and historical information in the three survey zones, just to make the whole settlement process easier to understand and the interpretations more reliable. In this way, the capabilities and advantages GIS offers will be completely expressed in the PVS-project. Apart from the amount of work that still needs to be done, it can already be stated that the combination of GIS and different survey techniques is answering a lot of questions posed at the start of the project.

1 For a detailed overview of the main goals, the reader is kindly asked to consult Vermeulen 2002a.

2 An overview of this work as well as the first results can be read in Vermeulen, De Dapper, Boullart, De Vliegher and Goethals 2002.

3 For more detailed information about the project and the work performed till now in the three sample zones, the following articles are recommended: 'Vermeulen 2002b', 'Vermeulen and Boullart 2001' and 'Vermeulen, Monsieur and Boullart 2002'.

4 Hardware: 2.4 Ghz processor; 512 MB RAM; 75 GB hard disk; 1,44 MB floppy drive, CD-R/RW 48/16/48 and several printers. Software: ArcView3.2 as GIS-software, Minitab 13 to perform statistical analyses, AirPhoto 2.20 to rectify images and Photoshop 7.0 to edit images. All programs are working on a Microsoft Windows XP operating system.
It is also worth to underline that, besides this central PC, every member of the PVS-team has his own PC, sometimes with some important peripheral instruments as a CalComp 9500 digitizer tablet, an A3-scanner (EPSON 1640 XL) and a slide scanner (Canoscan 2700F).

5 See http://www.csc.noaa.gov/metadata/text/download.html.

6 This is a vector-based structure, composed of a set of triangular facets.

7 Exponential, Circular, Spherical, Gaussian and Linear Ordinary Kriging, Universal Kriging -with linear and quadratic drift-; Spline, Inverse Distance Weighting; Trend and TIN. All of them were run with different values for the variable parameters. As a result, 35 grids were calculated.

8 A detailed report of all analyses, including the computation of the DEM, can be read in Verhoeven 2002.

9 Off-site 0: 0 artefacts /50m; 1: <=5 artefacts/50m; 2: <15 artefacts/50m and off-site 3: >=15 artefacts/50m

10 Designed by Irwin Scollar, this software is specifically developed to rectify archaeological images made with hand-held uncalibrated cameras (Scollar 2002, 167).The quality of the program has to do with the amount of interesting features. It's one of the only low-cost programs that offers different transformations, with and without height values. Furthermore, it offers three interpolation methods, a calculation of the mismatch between the source and the target image (control of the accuracy of the rectification!), has a lot of image processing techniques and supports different GIS-formats.

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