Gaetano Palumbo
The Getty Conservation Institute
1200 Getty Drive, suite 700
Los Angeles, California 90049-1684
U.S.A.

Gaetano Palumbo

A GIS Application for the Analysis of Archaeological Survey Data: Natural Resources and Settlement History of the Upper az-Zarqā' Valley

The Wādī az-Zarqā'/ Wādī aḍ-Ḍulayil Project has the purpose of reconstructing human occupation in a very peculiar environmental zone of northern Jordan, a well-watered area at the edge of the desert, where different responses to environmental constraints are evident still today in the selection of settlement and of economic and subsistence strategies.

During the different phases of the project, all available aerial photographs were studied and the sites with visible architectural remains were marked on 1:10,000 and 1:25,000 maps. The photographs were scanned at a resolution of 1,200 dpi (dots per inch), and analyzed with image processing software (Adobe Photoshop). The use of this software allowed the identification of a number of sites with architectural remains which could not be identified during the first analysis of the photographs. This first phase of analysis brought to the identification of approximately 300 sites with the presence of architectural remains in an area of less than 100 km^2.

The application of image enhancement software is now being experimented. On the basis of the tests conducted so far, it is estimated that an extra 100-150 sites will be discovered through this analysis. All this of course does not tell us anything about the period of occupation of those sites. This is why an intensive survey program has been designed, in order to check all the sites found through the analysis of the aerial imagery, and to integrate that information with the information retrieved directly from the field. In the first year of survey we found 15 sites which were not visible on the aerial photographs. Application of image enhancement to the scanned photographs, revealed that 5 of these 15 sites could actually be seen. This, however, still left out 10 sites, that is 66% of what was found using traditional survey methods. This means that total coverage of the 144 km^2 of the survey area could potentially lead to the discovery of over 800 sites, a figure which should not come as a surprise, since intensive surveys conducted in Jordan so far have identified an average of 6 to 7 sites per km^2.

While a small project like this can afford total or almost total coverage of the area, if we translate this method to the whole of Jordan we would need a large amount of financial and human resources to cope with the size of such a project; on the other hand the exclusive analysis of aerial imagery will only add to our recorded sites with architectural remains, leaving out most of the subsurface sites and possibly all flint and sherd scatters, often the only evidence we have of prehistoric and early historic occupation.

For this reason we are also experimenting the application of a GIS method for the reconstruction of archaeological landscapes in the Upper az-Zarqā' Valley. If successful, this method could be applied to larger areas, and possibly to design a system of site location and monitoring for the entire country.

Before going into detail of this GIS, however, it is necessary to say a few words on the application of remote sensing to the analysis of archaeological landscapes. Present technology does not allow better resolutions than 5 m for available satellite imagery. Color Landsat imagery has a resolution of 20m per pixel; black and white Spot Image a resolution of 10 m per pixel. Even using image enhancement, it is very difficult to pick out even large sites with some kind of surface features well visible in traditional aerial photos. In the Upper az-Zarqā' Valley, half of the sites have a diameter of less than 20 m; another 30% a diameter comprised between 20 and 50 m; an extra 15% a diameter between 50 and 100m. This means that 95% or more of the sites in this area could not be seen with presently available satellite imagery.

The advantage of satellite imagery over traditional analog aerial photography is evident, not only for this imagery being in an electronic format, but also for the possibility of being recorded as multi-spectral data, that is in different and often very narrow wavelengths, including those invisible to the human eye and beyond the sensitivity range of film. Multi-spectral imagery can also be taken by instruments mounted on airplanes. The advantage of this approach is that the imagery obtained has resolutions of 1 m or less. The disadvantage, of course, is the high cost and the huge size of the resulting image files, which have to be broken down in segments or separate wavelength bands in order to be managed by a computer.

Another field of potential application is the imaging obtained through radar, like SIR or CAMS. Radar has an advantage over traditional satellite imagery: it is an active

system which records the energy reflected by the emitted laser beam, and it is not affected by cloud cover. There is still debate whether foliage can be penetrated by radar, while ground penetration is achieved only in extremely arid environments, where bedrock under the dry sand-cover easily returns a clear signal. The resolution of SIR is about 25 m in the horizontal, while CAMS and ATLAS have a resolution of 10 m and less. Unfortunately radar-sensed data does not have total world coverage, and it is not easily accessible to the public, even if airborne radar imaging is also obtainable.

In summary, satellite imagery still needs improvement in terms of ground resolution in order to be applied with some success to the problem of site location and settlement pattern analysis. Airborne (not satellite) multispectral and radar data, when available, are an ideal tool because both provide images from thermal and invisible light sources with a resolution between 50 cm and 2m. This is enough not only to recognize individual architectural features, either above or below ground, but also artificial "disturbances" of the ground cover, such as sherd or flint scatters.

Having said so, and recognizing the impossibility for 99% of the archaeological projects and 90% of the antiquities departments worldwide to afford finances, resources, and equipment for the analysis of high-resolution remotely-sensed data, one could go back to a lower-tech, but perhaps more effective method of spatial data analysis, that is the integration of aerial photography, map-derived geographic information, geo-referenced data, and GIS.

In the case of the upper az-Zarqā' basin, we have built a GIS using PC ARC/Info, available at the American Center for Oriental Research in 'Ammān. In the future, we will try to translate this GIS into G-Sys, a flexible GIS for archaeological applications developed by Dominic Powlesland, director of the Heslerton Parish Project in Yorkshire. G-Sys has recently been adopted by English Heritage to manage the English Sites and Monuments Record (the MONARCH system) and is used at the Getty Conservation Institute to experiment the feasibility of using satellite imagery to monitor change at World Heritage sites.

The GIS of the Upper az-Zarqā' Valley presently includes information on topography, drainage, water courses, geology, roads, modern villages and buildings, and archaeological sites. We are in the process of entering data on soils, vegetation, extent of agricultural fields, from both the 1978 and the 1991 aerial photos, and location of beduin camps, also from the 1978 and 1991 photos. Using these two sets of photographs we will also be able to map the expansion of inhabited areas, as well as the destruction of archaeological resources as a result of human intervention. This will allow us to project in the future the expansion of villages, agricultural, and industrial areas (especially if we can obtain demographic data for the villages in the area), and predict the impact of this expansion on archaeological sites. This will give us the possibility to draw a map of "sites at risk" which could suffer disturbance or destruction in the near future. But our use of a GIS will not stop at this level: while one of our objectives is certainly to demonstrate the usefulness of this tool for cultural resources management purposes, we have specific research questions in mind that could be answered by the use of a GIS, let alone the fact that a GIS is the best tool available today to manage and store the entire archaeological data set and its by-products: maps, photography, video, databases, and object records.

The first question we will try to answer is how much of the present surface was exposed throughout the prehistoric and early historic periods, and how much has been eroded since then. The geomorphologist and the pedologist will provide information on the evolution of the az-Zarqā' river bed and of some major lateral drainages. We hope to be able to identify some parameters (rate of erosion depending on slope aspect and percentage, depth and age of accumulated colluvial deposits, etc) that would allow the use of statistical analysis not only to reach conclusions on the aspect of prehistoric landscape, but also to reconstruct the relationship between site location and exploitation of natural resources.

The second question is what kind of relationship existed between different hierarchical levels of settlement from the beginning of urbanization to the spread of the Hellenistic culture in this area, and how these settlements exploited their natural resources. In this case we will need not only geological and soil data, but also botanical and faunal data from soundings already conducted or in the planning stage at various sites in the survey area.

Another question is concerned with the Roman, Byzantine, and Islamic occupations: did settlements depend primarily on "political" or "environmental" constraints"? In other words, was the selection of settlement location imposed by strategic, military, or otherwise "technical" considerations, or was it dictated by the presence of "natural" factors? In this case the GIS will help us to study the spatial distribution of settlements, linking observed function (villae, castra, etc.) to the physical environment, and comparing it diachronically in order to try to isolate the reason for change.

We also need to better explore the cairns, or towers, found on ridges and hilltops across the entire area. Using the data coming from soundings at some of those structures, we will use the GIS to match real and predicted cairn locations against soil types and settlement distribution during various periods, in the attempt both to date and explain the function of these structures.

Finally, an ethnographic study will be conducted in cooperation with the local beduin population, mainly to identify their preferred camp locations (this information will be derived from the 1978 and 1991 photos and from the present field checks). Interviews will be conducted in order

to understand the mechanics of site selection for the installation of a camp, evolution in time of the camp size and modification of functional areas through time, and so on. The availability of earlier photos is an important addition to our data, since it provides time-depth to an "ephemeral" occupation of space such a nomadic camp is often conceived by our uneducated eyes. In this final case, the use of the GIS will help us to compare present and past beduin land-use and settlement patterns, and hopefully will generate a model based on modern observations which can be experimented for the location of ancient nomadic camps.

In conclusion, while still in construction, we believe that the use of a GIS will help the Upper az-Zarqā' Valley Project in a number of ways: in managing the information which is being accumulated, in providing a map of the sites threatened by the expansion of agricultural areas and modern settlements, and in helping to analyze and answer the research questions emerging during our work. It is still too early to say whether or not some of these questions will ever be answered, but we believe that the integration of well-designed data collection strategies and processing tools will help to clarify most of the problems we still face in understanding the evolution of human activity and settlement in this critical area of north-eastern Jordan.