Archaeological Evaluation of Ground Disturbance Sites in Modern Greek Cities

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The first half of the paper focuses on the process of recording data from ground disturbance sites in an urban context, where archaeological remains are often discovered. Data from both archaeological and non-archaeological excavations are used for predicting answers to a series of questions related to archaeology and urban development, apart from the usual question of presence/absence of archaeological sites. Three such questions, in the form of anthropogenic variables, are examined in the second half of the paper. Their predictive strength is explored with the use of different types of statistics: logistic regression and geostatistics. The predictive models for which statistical significance is confirmed can be disseminated to urban planners, heritage managers, developers, etc., so that they may reach learned decisions regarding the location and extent of development works and the type of management required. This is particularly useful for modern Greek cities that are built over ancient settlements.

Keywords: Urban archaeology, Urban planning, Geographical Information Systems, Spatial analysis.

1. Introduction

The aim of this contribution is to demonstrate how the evidence of ground disturbance actions in modern cities can be used to evaluate the possibility of finding or not finding archaeological remains in any part of the urban landscape, and to what extent this can affect the progress of construction works. Although intra-site studies often employ spatial analysis to explore archaeological data from stratified contexts (FRONZA *et al*., 2001), the transition from “sites” to “non-sites” in densely inhabited modern cities has been poorly explored so far, and its implications for heritage management have not been well outlined (AMORES *et al*., 1999: 354-355; BIGLIARDI, 2007). While observations on “sites” are recorded, this is not the case with “non-sites”, which can also serve as useful sources of evidence (VAN LEUSEN *et al*., 2009).

Curators of the Archaeological Service are encouraged to integrate new datasets within their existing archaeological databases. After employing spatial analysis, the results can be modeled and disseminated to planners, landowners, investors, etc., so that they may reach learned decisions regarding the location and extent of development works and the type of management required. This is particularly useful for the modern Greek cities which are built over ancient settlements. In order to illustrate this process, a case study is provided, for which the procedure for the selection of the appropriate new datasets, and the elimination of others, is presented.

2. The current setting

2.1. Implementation of building permits

According to Greek Legislation (Law 3028/28-6-2002, Presidential Decree 8/7/1993), construction works or any other action that involves ground disturbance must be inspected by a member of the Archaeological Service, a public branch of the Ministry of Culture. If archaeological remains appear during soil removal, the works stop and a rescue excavation takes place. When the excavation finishes, the Local Board of Monuments makes a decision regarding the treatment of the immovable architectural features (in situ conservation, reburial, exposure, deconstruction, etc.) and may demand modification of the original construction plan in order to protect the archaeological remains and allow the construction works to continue. When construction is associated with the implementation of a project for the public sector or a major private development scheme, the costs are covered by the developers. Otherwise, archaeological research is government-funded, though many minor investors voluntarily pay for the archaeological interventions in their plots, in anticipation of avoiding much unwanted delay in the resumption of building tasks.

As the majority of ground disturbance activities in Greek cities occur on small private house plots, and to a lesser extent on the road network, it is obvious that both the delay as well as the cost of archaeological operations represent a heavy burden for landowners and citizens.

Despite the fact that numerous building permits are issued every year and their unearthing works inspected by guards from the Archaeological Service, limited documentation exists on the likelihood of not finding archaeological features at a certain depth on a given site, while the opposite is better documented through excavation reports and publications. There is no evidence that the interested parties are actually informed or alerted to the possibility of discovering archaeological remains on their site prior to investment. They are also not given an estimation of the duration of archaeological interventions, the consequent delay, and the likely cost.

Yet such information is valuable to archaeologists, planners, landowners, etc. These individuals often interact poorly due to conflicting interests. Avoidance of "high risk" plots and choice of plots with low archaeological potential might be preferred by some investors, while others would like to know in advance the potential time delay for construction plans and whether it would be worth self-funding the archaeological research in order to accelerate the process.

2.2. Ground disturbance reports

Since the late 1990's the archaeological guards that attend the soil removal from house plots and other excavations in Patras, a town of approx. 200,000 inhabitants in northern Peloponnese, submit a written report about the operations they inspect, the finds, if any, in the soil deposits and the total depth of the ground disturbance. So far, the use of the reports was merely bureaucratic, that is to confirm the guards' attendance on the site as part of their job. Yet these reports provide the only existing documentation for the sites that do not contain antiquities, and they serve to complement those that were later excavated. The fact that their potential for any type of quantitative analysis, let alone spatial analysis, has not been considered natural, as urban archaeologists, opposed to landscape archaeologists, are not very much "in the thing" (HUGGETT, 2000: 117).

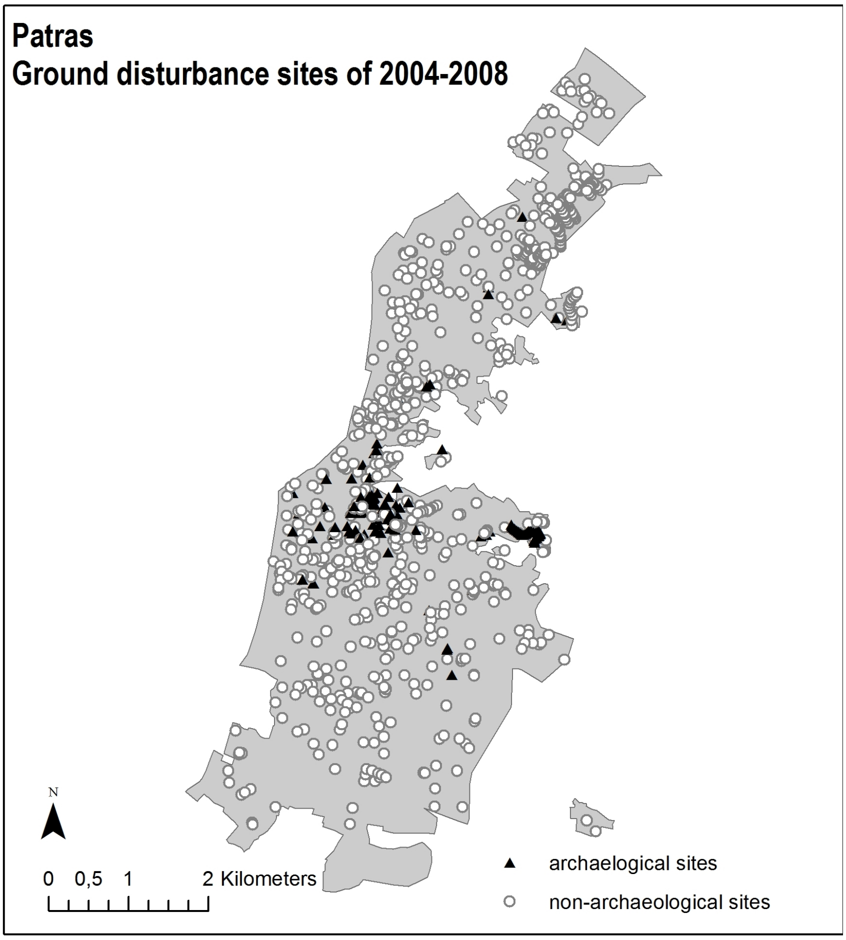

Figure 1: *Distribution of ground disturbance sites in the City Plan of Patras.*

3. Spatial analysis

3.1. What information do I (the archaeologist) collect?

The present analysis makes use of a set of reports on ground disturbances in the town of Patras between 2004 and 2008. The area under study comprises the "Official Building Regulations" of 2008 for Patras (Figure 1). The total area is 2,270 hectares in which 947 digs took place between 2004 and 2008.

For those sites at which an excavation was needed, additional information generated from the excavation diaries and reports was included. After standardizing the information and creating a database, 947 records were produced, each corresponding to a single dig, either in a house plot, or on the road network. The database was then linked to a map of the town plan of Patras with 947 points representing the sites (SIMONI and PAPPAS, 2010).

3.2. What secrets do I (the planner) need to know?

The distribution of the points (Figure 1) reveals clusters on the surface. For example, a concentration of archaeological sites is visible in the center of the figure; in fact, this concentration occurs in the same district in which lies the heart of Roman and Medieval Patras (PETROPOULOS and RIZAKIS, 2005). Obviously, locations with densely preserved archaeological deposits need longer periods of excavation. Landowners of such properties or neighboring plots prefer to pay if they do not wish to experience a serious delay. Nevertheless, the map reveals nothing about the thickness and depth of the archaeological deposits.

When data points are densely concentrated and values vary, visual observation is not enough. Point distributions may be used as predictors for the remaining area, the unexcavated/unsurveyed locations that will form the targets of managers, planners, investors, etc. in the future. Usually, predictive models of potential archaeological territory are then produced. This type of analysis has already been carried out and has been published elsewhere (SIMONI, 2010). Although Voronoi tessellation is considered a crude interpolator with many drawbacks (RUGGLES and CHURCH, 1996: 150-164; WHEATLEY and GILLINGS, 2002: 151, 183; CONNOLY and LAKE, 2006: 211-213), it has been used quite successfully to allocate the existing space to archaeological and non-archaeological points (SIMONI, 2010). It is not my intention to elaborate further here, but I would like to emphasize that despite the fact that tessellation was based only on the unpublished digs of the last five years (2004-2008), the generated plan of potential archaeological areas within the city corresponds with the archaeological pattern known from older excavations (SIMONI, 2010). Therefore, the ground disturbance sites recorded during this period form a representative sample of the archaeological record in Patras and can be used for more refined spatial analysis and predictive modeling as illustrated below.

3.3. Where do I (the investor) invest?

Predictive modeling has a longstanding history in Archaeology and Cultural Resource Management. Although its application is no longer confined to American research, as was the case in the early 1990's (SIMONI, 1999), it is usually combined with regional surveys outside of modern urban contexts and with careful consideration of environmental parameters (WESTCOTT and BRANDON, 2000). Even non-environmentally deterministic approaches tend to use environmental data in order to develop cultural variables for consideration, such as visibility or movement across the landscape (LLOBERA, 2001).

Such an approach is not always easy in urban archaeology. In modern times, cities tend to dominate the prevailing environmental systems and take little account of urban digs in the field of development and construction. As a consequence, much environmental and palaeoenvironmental material exists in disturbed strata or has vanished. Patras, however, has an even older tradition in transforming the landscape. In the 1st c. BC Roman colonists founded Colonia Patrensis in a marsh and fully exploited the surrounding area, creating flourishing urban and rural communities, the core of which is now being discovered below the modern city of Patras (PETROPOULOS, 2006). In addition, the environmental variation, often visible at a global or regional scale, is less visible at a local scale, such as that of a middle-sized Greek city (ALLEN, 2000:102).

Inevitably, this approach focuses less on environmental variables (e.g., geology, distance to water, elevation, etc.) for building predictive models, and more on anthropogenic ones, such as the presence or absence of archaeological deposits, known maximum depth of archaeology-free soil, delay of working days due to archaeological intervention, voluntary private funding of the archaeological research, distance from other excavated or known sites, typology of finds, chronology, post-excavation treatment, etc. Moreover, the goal is not merely to answer the question of the potential presence or absence of archaeological material on unsurveyed sites. Several models are created that respond to a range of questions posed by planners, investors, and heritage managers. This procedure contributes less to the prediction of site presence/absence, but provides "a means of quantifying patterns in the data allowing comparisons over space and time" (WOODMAN and WOODWARD, 2002: 22).

Finally, there is a certain advantage which is rarely possible in archaeological research (WHEATLEY, 1996: 285). New applications for ground disturbance activities are submitted every year, and the involved sites may offer a new sample to test the models and update them on a regular basis. In due course, Patras will have been largely documented and there will no longer be a need for predictive modeling. Planners and heritage managers will then be able to provide sufficient information so that archaeological discoveries will come as no surprise to investors, especially minor landowners, therefore can then be reasonably treated and managed.

4. The good, the bad, the ugly; a case study

In this section, data that come from the ground disturbance sites of Patras between, 2004 and 2008 are used to test the predictive capability of certain variables. Before embarking on any type of spatial analysis, logistic regression was performed. Although it was implemented on an a-spatial context, it provides a useful start for assessing the predictive capability of the three different independent variables. The results are illustrated in Table 1.

Next, interpolations were carried out. The creation of a continuous surface is based on the application of Kriging to the variables of the available dataset. This is a method that uses information about the stochastic aspect of spatial variation and therefore reveals the structure of the spatial distribution of variables that are not randomly distributed (BURROUGH, 1986:180; WHEATLEY and GILLINGS 2002: 193; LLOYD and ATKINSON, 2004: 151).

	regress. coeff.	**std error**	***Sig* *(a= 0.05)***	**Exp (B)**
Variable 1: depth	-0.483	0.104	0.000	0.617
Variable 2: delay	0.000	0.002	0.894	1.000
Variable 3: private funding	-0.690	0.469	0.141	0.501
Constant	2.787	0.264	0.000	16.228

Table 1: *Results of logistic regression.*

Although there is a limited use of Kriging in archaeology because of its demanding nature (LLOYD and ATKINSON, 2004: 152), it is employed here for its acknowledged benefits. It is local, exact, continuous, and constrained (CONTRERAS, 2009: 1012). Unlike other methods, it is not affected by "edge effects" because "… it assumes that the surface continues outward from its edge values according to patterns that can be deduced from the data and requires no specification of missing values" (ROBINSON and ZUBROW, 1999: 79, 82). Furthermore, it is the only method of spatial interpolation that yields estimates of the errors associated with interpolation and also reveals weaknesses in the sampling strategy (EBERT, 2002: 88-89). BURROUGH (1986: 162) calls it "in principal … the ideal interpolator". Yet it cannot be applied everywhere, as shown below.

To illustrate this process and the models' potential as predictors, the most representative examples will be presented. The examples given below illustrate three different aspects of the difficult, but determining procedure of selecting variables for predictive modeling. The selection is challenging, because it is not based on environmental factors, but on anthropogenic factors closely related to individual attitudes and social and legislative constraints.

4.1. The good …

The first variable to be interpolated is the known maximum depth of non-archaeological deposits in both archaeological and non-archaeological excavations. First, the interpolation used data from disturbance sites (training sample) from 2004-2007 to estimate values at sites (test sample) dug in the following year. Next, data from the entire record of 2004-2008 were input for interpolation.

As there are numerous types of Kriging which can be performed, the successive construction of several different models can lead to the selection of the best one. EBERT (2002: 83-84) provides a detailed description of the steps for selecting a model:

→ Understanding the distribution of data. If the distribution is not normal, the data needs to be transformed.

→ Identification of the presence/absence of a trend and subsequent trend removal (the trend will be added back before the final surface is produced).

→ Understanding spatial autocorrelation and incorporating anisotropy into the model.

→ Defining neighbourhood.

→ Cross-validation. This is the most crucial step of the procedure because it provides evidence of the usefulness of the choices in the previous steps. Several methods exist for assessing a model's performance (VERHAGEN, 2009: 92-93), bearing in mind that there are no perfect models and the element of "prediction error" is always present. Both cross-validation and validation tests were applied whenever possible. In this way statistics for the prediction errors are calculated, and these can be used as diagnostic tools for determining the predictive power of a model (JOHNSTON *et al.*, 2001: 34). Cross-validation is a type of internal testing that uses all of the data to estimate the trend and the autocorrelation model, while validation is an external test that uses all of the data from only one dataset (training) to predict values for an independent dataset (test) of which we know the observed values.

→ Comparing Models. At this stage the results of two prediction models are compared and the best is identified.

The extent to which a model provides accurate predictions is examined according to the following criteria:

1. The mean prediction error (mean) should be near 0.

2. The mean standardized prediction error (mean st.) should be near 0 and near the mean prediction error.

3. The average standard error (S.E.) should be close to the root-mean-square prediction error (RMSE).

4. The root-mean-square standardized prediction error (RMSE st.) should be close to 1 (JOHNSTON *et al*. 2001, 35).

In general terms, the model fits with the criteria (Table 2). Results from logistic regression also demonstrate that this variable qualifies as a predictor ($p<0.05$) (Table 1). For the above-mentioned reasons, the model can be used as a predictor of maximum depth of non-archaeological deposits.

PREDICTION ERROR (depth)	Cross validation 2004-7	Cross validation 2004-8	Validation training sample 2004-7 test sample 2008
Mean	-0.00398	-0.0013	-0.00195
RMSE	0.8674	0.8826	1.05
S.E	0.7316	0.7654	0.7545
Mean st.	-0.00355	-0.0019	-0.01369
RMSE st.	1.175	1.144	1.394

Table 2: *Results of prediction error statistics for known maximum depth of non archaeological deposits in both archaeological and non archaeological excavations.*

4.2. ...the bad …

The second variable to be interpolated is the delay in working days due to the involvement of the Archaeological Service in the soil removal process at both archaeological and non-archaeological disturbance sites. The same steps were followed.

PREDICTION ERROR (delay)	Cross validation 2004-7	Cross validation 2004-8	Validation training sample 2004-7 test sample 2008
Mean	-7.195	-6.03	-12.19
RMSE	50.92	49.25	43.25
S.E	25.18	43.29	26.97
Mean st.	0.2964	0.1774	-0.2799
RMSE st.	2.36	1.741	1.295

Table 3: *Results of prediction error statistics for delay in both archaeological and non-archaeological excavations.*

As is obvious, the criteria are not met (Table 3) and the results of logistic regression do not allow us to reject the Null Hypothesis ($p>0.05$) (Table 1). The model is therefore not successful and the variable will not be used as a predictor.

4.3. ...the ugly

The third variable is the voluntary private funding of archaeological research in low budget projects, a nominal variable that contains only two values, YES and NO. Its spatial distribution was considered in the event that some meaningful pattern could be discerned. One should bear in mind that archaeological work on public land is by law funded by the investor and certainly no prediction is required!

Geostatistics are not appropriate for nominal values, so another tool was sought. The basic assumption of Kriging is the 1st Law of Geography (EBERT, 2002: 82), according to which entities nearer to an entity with a known characteristic (in our case presence/absence of archaeology) are more likely to demonstrate a related characteristic than those further away (TOBLER, 1970). Spatial statistics offer tools to test spatial autocorrelation, such as Moran’s I and Getis-Ord G. However, spatial autocorrelation can be assessed only for numeric values, which is not the case here. Based on the results of logistic regression ($p>0.05$) (Table 1), this variable does not qualify as a potential predictor. Further research is necessary to identify quantitative parameters behind voluntary covering of cost.

Conclusions

The first half of the paper focused on the process of recording data from ground disturbance sites in an urban context. Data from investigated archaeological and non-archaeological sites can be used for predicting answers to a series of questions related to archaeology and development elsewhere in the same city, apart from the usual question of presence/absence of archaeological sites.

Three such questions in the form of anthropogenic variables were chosen in the second half of the paper. Their predictive strengths were examined through the use of different types of statistics (classical and geostatistics). The “known maximum depth of archaeology-free soil deposits” qualified as a potential predictor, which may prove to be a useful tool for those wishing to know how deep they can dig in any given part of the city without putting buried antiquities at risk. On the other hand, “delay because of archaeological interventions” and “likelihood of self-funding archaeological operations” were eliminated. Obviously, these were influenced by other factors, which likely account for the spatial distributions of the two parameters. A thorough interpretation of the phenomena, as well as the generation of new datasets, probably of a socio-economic character, are required.

The results of this analysis suggest that further research is warranted, and undoubtedly there is a future in this ‘untouched’ field of urban archaeology and urban planning.

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