An Experiment in Archaeological Site Location: Modeling in the Netherlands using GIS Techniques
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An experiment in archaeological site location: modeling in the Netherlands using GIS techniques

Roel Brandt, Bert J. Groenewoudt and Kenneth L. Kvamme

Introduction

Much of the archaeology in the Netherlands is hidden beneath the ground surface, making the process of archaeological discovery a labor-intensive and expensive activity. On-the-ground field inspection requires the examination by trained professionals of hectare after hectare of open fields, ditch-sides, molehills, and other exposed areas. The consequence is that choices must be made concerning the most suitable places to conduct the limited amount of survey it is possible to undertake given available resources.

It seems a logical step, then, to make use of the decades of archaeological work that has been performed in many regions of the Netherlands to aid in the survey planning process. If the results of previous surveys can be employed to help guide present work to the most archaeologically sensitive areas in current regions of study, significant benefits could be realized. With such planning tools, not only would archaeological field survey be made more efficient but future building, developments, and other earth-disturbing activities could be directed to less archaeologically sensitive areas. The latter could result in a reduced impact on the resource base and lower costs for archaeological work. Thus, there is a great need in the Netherlands to develop archaeological sensitivity models for regions under study.

In the United States there has been a large concentration on such archaeological models for more than a decade (for overviews see Kohler and Parker 1986; Kvamme 1990). Many of these models have been designed not only to portray archaeological sensitivity but actually to ‘predict’ or indicate where sites might be found in the future. Importantly, a number of these models, when tested through additional field survey of both archaeologically sensitive and insensitive regions, were shown to perform quite well and within the bounds specified by the model formulations.

With this promising background it was hoped that similar results could be achieved in the Netherlands. This paper describes an initial experimental approach to archaeological site-location modeling undertaken in the Regge Valley region of the Netherlands by the first two authors, Brandt and Groenewoudt. The third author, Kvamme, with experience...
in several modeling projects gained in the United States (e.g. Kvamme 1988; 1990), has provided critical comments on difficulties and weaknesses of the Regge Valley modeling effort and has helped to place this research within the context of the current modeling literature. In the following sections we discuss some of the theory and method of archaeological locational modeling, how the model for the Regge Valley was formed, and tests of its performance; furthermore, we focus on a number of problems and difficulties not previously faced in the modeling literature.

**Model theory and background**

*Theory*

It is a fundamental premise of modern archaeology that human behavior is patterned; therefore, locational behavior – that is, where sites or settlements are placed across the landscape – should exhibit non-random tendencies. Numerous studies of empirical settlement data have repeatedly demonstrated significant regional patterning of archaeological distributions against a wide range of phenomena (e.g. Kellogg 1987; Shermer and Tiffany 1985; Thomas and Bettinger 1976). The basic theory behind the development of an archaeological location model is that if tendencies or patterns exist between site locations and one or more regionally distributed variables, then a model can be constructed through the exploitation of those tendencies.

Most modeling studies have examined environmental patterning exhibited by archaeological site locations – such as preferences for specific soil conditions, elevation classes, water access, and terrain contexts (e.g. Jochim 1976; Bettinger 1980; Parker 1985). Others, however, have emphasized the importance of the ‘social landscape’ where such factors as the locations of roads, religious centers, markets, and large villages structure patterns of settlement (e.g. Johnson 1977).

For several reasons environmental factors are usually pursued in archaeological modeling studies. Environmental data in the form of soils, geologic, hydrologic, and topographic maps are relatively easy to obtain for a region. Additionally, all cultural types – ranging from simple hunter-gatherers and early farmers to advanced agriculturalists and urban peoples – respond to environmental conditions in siting their activity areas or settlements. This is not necessarily the case for the social category of phenomena. For example, roads, central places, and markets generally are not meaningful concepts in most hunter-gatherer contexts. A more important restriction, however, is that the social landscape – contemporaneous roads, villages, and population centers – must be reconstructed for each period under consideration in a modeling effort, a task often beyond our data retrieval possibilities. For these reasons the present study focuses exclusively on environmental relationships with the sites in the Regge Valley Project Area.

*Problems and difficulties*

Most archaeological location modeling has been conducted in the western United States under conditions generally quite different from those in the Netherlands. In the western
USA, with large tracts of open and uninhabited public lands, it is possible actually to perform random sample surveys and therefore employ various probability and statistical models to produce methodologically rigorous archaeological sensitivity maps that possess a predictive capacity (Kohler and Parker 1986; Kvamme 1990). Moreover, so much of the archaeology is on the surface or is manifested on the surface – owing, in part, to the low density of vegetation throughout much of this arid region – that it is possible to develop a comprehensive understanding of the spatial organization and distribution of sites across the landscape based on surface data alone.

Not so in the Netherlands. While many sites yield surface indications, it is undoubtedly true that many more are buried under alluvium or are covered by dense vegetation; thus, their locations are unknowable without some form of subsurface testing or prospecting. Furthermore, in many regions where models are needed, it is not possible to conduct random sample surveys because surface inspection must be confined to a limited number of irregularly placed plowed fields, drainage ditches, and other exposed areas. In these regions it is typically the case that existing site records obtained through haphazard archaeological reconnaissance over the past century must be employed.

Other difficulties exist. Most American models focus on a single site type such as Mississippian sites (Parker 1985). Because much of the Netherlands has been densely occupied throughout much of the past, a rich record covering tens or even hundreds of thousands of years exists that cannot be ignored. In other words, any model in the Netherlands must encompass the broad cultural diversity stemming from multiple periods of time.

Finally, most models that have been constructed thus far rely upon features of terrain form (e.g. elevation, slope, aspect) in highly variable and even mountainous areas (Kohler and Parker 1986; Kvamme 1990). Consequently, the variables typically considered in archaeological modeling are continuous in nature, allowing a host of powerful modeling techniques based on quantitative data (e.g. multivariate discriminant functions). In the Netherlands, except for a few regions, much of the terrain is lacking in relief if not completely flat, and most of the variables that can be considered are only categorical in nature (e.g. soils or geological classes).

Faced with all these dilemmas, the Regge Valley Project needed a direction in which to proceed. Archaeological distribution maps of known sites from multiple periods provided strong suggestions of pattern with respect to environment; it therefore could be concluded that the development of a model would be a worthwhile undertaking. However, random samples of sites clearly could not be obtained, nor could extensive subsurface sampling for the many buried sites in regions of study be carried out given time and funding constraints. Models therefore had to be based on known surface sites, and furthermore on relationships with present environmental conditions, because of the impossibility of detailed paleoenvironmental reconstructions over large areas. Given these constraints, together with the fact that most of the available environmental information exists in discrete categories, it was decided to employ a weighted map-layer approach to modeling in a Geographic Information Systems context.
The weighted map-layer approach to modeling

Geographic Information Systems (GIS) are computer software designed for the handling and manipulation of regionally or spatially distributed information. It is not our purpose to review the technology here; adequate descriptions of GIS technology have been presented elsewhere in the archaeological literature (e.g. Wansleeben 1988; Allen et al. 1990).

In the GIS literature, reclassification, overlaying, weighting, and summation of map themes is as old as the technology itself (see Burrough 1986); numerous examples and applications of these approaches exist, where they often are referred to as 'map algebra' (Berry 1987). In the archaeological literature, a very early application of a GIS-based weighted map-layer approach to archaeological modeling exists (Brown and Rubin 1981), and recently Dala Bona (1989) has further pursued this approach.

The weighted map-layer approach makes use of categorical or classed map layers. Within a single map layer, each category is assigned a weight pertaining to 'favorable' or 'poor' conditions relative to archaeological site location. For example, in a soils layer certain soil types might be favorable for settlement (e.g. for farming) while others are not. In the simplest situation, a binary outcome with only two results (bad/good) is achieved; otherwise some type of weight or rank is assigned to each class. This process is then repeated for each map layer; for the final result, a simple sum is computed across all the map Themes. This sum is computed at a fixed interval, say every 25m, where a weight is obtained from each map layer and a sum of the weights is calculated. The summed weights, when mapped over space, represent the archaeological sensitivity model where large weights indicate more favorable places across all the layers.

A problem with this weighted map-layer approach, of course, lies in the selection of weights. By simply changing the size or ordering of weights, it is possible to achieve profoundly different results. Some American researchers, for the most part 'hard-core' processualists (see Judge and Sebastian 1988), have advocated that all archaeological location models should be based on 'theory' and that the weights should be arrived at by what Kohler and Parker (1986) refer to as a 'deductive' process. This stance seems rather presumptuous given the current state of archaeological theory (or for that matter anthropological or geographical theory), where little more than rough notions or suggestions can be obtained pertaining to human locational behavior. The previously described archaeological weighting approaches to modeling by Brown and Rubin (1981) and Dala Bona (1989) were based on their experience as archaeologists and on various notions and ideas about settlement behavior that they were able to derive from the theoretical literature. Nevertheless, it should be recognized that their methodology was highly subjective, employing what has been referred to by Thomas (1979) as 'seat-of-the-pants' deductions about locational behavior.

In the Regge Valley Project a similar approach was applied but with a number of important differences. First, it was decided to link the layer weighting approach to actual empirical data, thereby introducing an amount of objectivity to the analysis. For example, in examining the variable 'distance-to-water', sample data showed that two-thirds of the sites under examination occurred within 700m of open water. Consequently, a map
category representing all locations in the project area less than 700m from water was created that was assigned much more weight than a second category indicating those places greater than 700m from water. Second, because the model had to incorporate so many different cultural systems over multiple periods of time, only strict associations between site locations (of any period) and environment were sought. The goal of the modeling effort was not explanation nor a model that ‘made sense’ in terms of past behaviors; rather, the purpose was to produce a workable model for practical application that would provide archaeologists with some advantage in locating sites. This approach makes additional sense when one considers that past environments in the Netherlands were vastly different from the present, but that the modeling effort was forced to employ maps of the modern environment. The project had no recourse but to seek only simple associations between sites and modern map categories.

**GIS computer methods**

It should be clear that the weighted map-layer modeling approach can be readily implemented by employing raster GIS technology. The raster GIS employs a grid cell approach where the entire encoded region of study is gridded into rows and columns of cells, each representing a fixed area on the ground (Burrough 1986). Within each map layer encoded in the GIS, a weight is assigned to each grid cell that indicates a class category weighting factor. For example, in a binary soils layer those cells rated as poor are coded as '0' while those cells representing favorable soils are coded with a '1'. Such weights are assigned to every cell in each of the GIS map layers. To produce an archaeological location model based on the weighted layers approach, it is simply a matter of summing the weights, cell-by-cell, across all the layers to achieve the modeling outcome (Brown and Rubin 1981; Dala Bona 1989). GIS cartographic techniques then can be employed to map the model result.

**The modeling application**

**Nature of the study area**

The Regge Valley, situated in the eastern part of the Netherlands, is 120km² in size. It is characterized by a varied landscape consisting of lateral moraines, ridges and plains covered by wind-borne sand deposits, peat ridges and brook valleys. The main features of this landscape were formed during the Salien-glacial. Nowadays most of the region is agricultural land. Some remainders of heaths and moorlands have been preserved in nature reserves. The earliest habitation of the area dates from the Late Paleolithic (Table 1). The research was partly financed by the Government Service for Land and Water Use of the Ministry of Agriculture, Nature Management and Fisheries.

Because of the archaeological diversity, the heterogeneous nature of the environment, and the relative stability of the landscape for a long period of time, it was felt that this area would offer an ideal test site for the Netherland’s first experiment in archaeological
Modeling in the Netherlands using GIS techniques

Table 1 Distribution of sites by period.

<table>
<thead>
<tr>
<th>Period</th>
<th>Dates</th>
<th>Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late Paleolithic and Mesolithic</td>
<td>30,000–5,000 BC</td>
<td>15</td>
</tr>
<tr>
<td>Neolithic to Mid-Bronze Age</td>
<td>5,000–1200 BC</td>
<td>18</td>
</tr>
<tr>
<td>Late Bronze Age to Iron Age</td>
<td>1200 BC–AD 1</td>
<td>16</td>
</tr>
<tr>
<td>Roman Period to Early Middle Ages</td>
<td>AD 1–1000</td>
<td>8</td>
</tr>
<tr>
<td>Late Middle Ages</td>
<td>AD 1000–1500</td>
<td>19</td>
</tr>
</tbody>
</table>

Table 2 Environmental variables employed in the archaeological model and summaries of analytical results.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category weights in model: 0–3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soils texture</td>
<td>Clear associations exist between sites and several soil texture classes, while a few soil texture types contain no sites. The nine original soil texture types were reclassified to four.</td>
</tr>
<tr>
<td>Geomorphology</td>
<td>Category weights: 0–3</td>
</tr>
<tr>
<td></td>
<td>Several landscape units were defined on the basis of geomorphology. One of the strongest site associations in the study was with the later Pleistocene sands unit.</td>
</tr>
<tr>
<td>Unit surface area</td>
<td>Category weights: 0 = surface &lt; 100ha</td>
</tr>
<tr>
<td></td>
<td>2 = surface &gt; 100ha</td>
</tr>
<tr>
<td></td>
<td>GIS methods were employed to obtain a cross-classified map containing the intersection of all soils and geomorphologic classes. The area of the resulting classes then was obtained, and sites were found to yield a preference for categories with larger surface areas.</td>
</tr>
<tr>
<td>Ecological border distance</td>
<td>Category weights: 0 = distance &gt; 400m</td>
</tr>
<tr>
<td></td>
<td>3 = distance &lt; 400m</td>
</tr>
<tr>
<td></td>
<td>Boundaries between the two major landscape zones in the study region were digitized. These principally include the high lateral moraines and sandy areas versus the low, wet brook valleys and moors. Although some differences were found by period, two-thirds of all the sites are located within 400m of this ecological boundary.</td>
</tr>
<tr>
<td>Distance to water</td>
<td>Category weights: 0 = distance &gt; 700m</td>
</tr>
<tr>
<td></td>
<td>3 = distance &lt; 700m</td>
</tr>
<tr>
<td></td>
<td>It was assumed that all valleys at one time carried water, although surface water of distinctly anthropogenic origin was excluded. Sites of nearly all periods were found to exhibit strong tendencies for proximity to water, particularly Stone Age sites.</td>
</tr>
<tr>
<td>Distance to water or ecological border</td>
<td>Category weights: 0 = distance &gt; 400m; 3 = distance &lt; 400m</td>
</tr>
<tr>
<td></td>
<td>GIS methods were used to obtain a cross-classified map containing both water sources (valley drainages) and the ecological borders. Sites of all periods showed major tendencies for proximity to the resulting combination.</td>
</tr>
</tbody>
</table>

Sensitivity modeling. Complete results, with detailed presentations of the data, methods, and analysis findings are given in Ankum and Groenewoudt (1990). What follows is a brief overview of that study.
Figure 1  Illustration of the Regge Project Area showing the locations of known sites (stars). Inset, 1: Location of the Regge Valley Project Area.

Archaeological and environmental data

The Regge Valley Project Area contains a wide variety of archaeological remains discovered over the past fifteen years. In order to reduce some of this variability, the numerous isolated artifacts and small find spots that occur throughout the region were first eliminated from consideration, as were cemeteries and various burial grounds. This
allowed an exclusive focus on the environmentally more patterned ‘settlements’. The distribution of the seventy-six sites in the study region is shown in Figure 1 and, by period, in Table 1.

The environmental information considered by the project was limited by the nature of the available thematic maps. All information was derived from three maps: a topographic map (1:25,000 scale), a soils and hydrology map (1:50,000 scale), and a geomorphological map (1:50,000 scale), which were computer-encoded with an in-house produced digitizing program called RAGE and later manipulated with a GIS program called MAP (Tomlin 1983). A grid cell size of 100 x 100m was employed to allow a fairly detailed modeling outcome. Although thirteen environmental variables obtained from these maps were initially examined, subsequent analysis and other considerations ultimately reduced this number to six, which were then employed in the modeling effort. These variables and analytical results are summarized in Table 2.

**Analysis**

An artificial data set of eighty random points from the study area was generated to represent the background environment in the analysis. These data provided a means to

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**Figure 2** Differences between the seventy-six sites and eighty random points on four environmental variables in the Regge Valley Project Area. A distance to water; B distance to ecological border; C distance to water or ecological border; D distribution of sites and random points on four geomorphological units: I high cover sand deposits, II pleistocene ridges, III low cover sand deposits, IV brook valleys, 5 sites, 6 random points.
identify major site location associations. For example, if 30 per cent of the random points occur in soil class A, 20 per cent in soil class B, and 50 per cent in soil class C, then it could then be argued that significant relationships between the known archaeological sites and soils exist if, say, 50 per cent of the sites occur in soil class A, 40 per cent in B, and 10 per cent in C. These data would suggest locational preferences for soil classes A and B with an avoidance of class C (see Shennan 1988 for a review of this methodology). A chi-square statistic was employed as a simple index to aid in the determination of major differences between the known sites and random points. These differences for four of the variables are shown in Figure 2. This process was undertaken for each variable; those with large associations between sites and environmental categories (major differences between the site and random point distributions) are listed in Table 2 and are mapped in GIS means. It is these variables that formed the basis of the modeling effort.

The archaeological expectation model

Within each of the six GIS map layers, a weight was assigned to each category that indicated its relative ‘favorableness’ for site presence in the known site sample. The weights were arrived at judgementally but through consideration of the empirical site associations realized during analysis. Each 100 × 100m grid cell in each map layer, then, possessed a weight representing the relative suitability of the cell for site occurrence in terms of the map’s theme (e.g. distance to water). This weighting scheme, employed for each layer, is summarized in Table 2.

The archaeological expectation model simply is a composite of all six map layers, obtained by summing the weights associated with each cell across the layers, cell-by-cell. In the model (Fig. 3), the highest values indicate areas that were consistently rated as ‘most favorable’ in each of the map layers. Conversely, lowest values point to areas generally rated as ‘poor’ in the individual maps. This composite, if our analytical assumptions, methods, and results are correct, should best summarize the nature of the observed pattern of archaeological distribution in the study region.

Model testing

The foregoing modeling exercise remains useless without some form of test. Given the numerous difficulties and data limitations that confront archaeological model development in the Netherlands, together with the many simplifications and assumptions that one must make, it is imperative that sufficient tests be performed before any serious consideration of a model is undertaken.

Visually, there appears to be a good correspondence between known sites and the model in Figure 3. In fact, fifty-six (74 per cent) of the seventy-six sites occur in the two highest expectation zones, which include only 28 per cent of the study area, pointing to an excellent correspondence between the site sample and the model.

Other researchers, for example Kohler and Parker (1986), have emphasized the importance of obtaining new and independent data to test a model. It is quite possible, especially with the modeling approach employed and the biased site sample available, that the nature of the model outcome reflects too particularly the site sample used to develop it.
Figure 3 The GIS-produced archaeological site location sensitivity model for the Regge Valley Project Area. 1 areas of low archaeological expectation; 2 areas of medium archaeological expectation; 3 areas of medium-to-high archaeological expectation; 4 areas of high archaeological expectation; 5 newly discovered sites; 6 test areas.
Consequently, the model may perform poorly when compared with other site samples and when used to indicate archaeological potential in general. By obtaining a new and independent site sample of both high and low archaeological expectation from model-indicated regions, a better indication of the model’s true utility in predicting archaeological potential can be obtained.

Since the development of the model in 1989, approximately 200 new hectares have been field-inspected by archaeological teams. Of the 52 new sites discovered (Fig. 3), 24 per cent occur in the highest expectation zone, 57 per cent in the two middle zones, and the remainder of 19 per cent in the lowest expectation zone. These statistics are enhanced when one considers the relative areas of each of the four model zones which are, from low to high, 60, 12, 22, and 6 per cent of the total Regge Valley study area. Thus, although only 6 per cent of the region is rated as high expectation, and we therefore would expect only 6 per cent of the sites to occur in it if the model has no bearing on archaeological location, the fact that 24 per cent of the sites were actually found there shows the model’s utility for indicating archaeological potential. Similar observations can be made for the other model classes.

This remarkable success rate suggests that in our model (1) we were able to zero-in on critical locational factors; (2) that biased site samples obtained from existing records can be employed as a basis for modeling; and (3) that the somewhat rough methods we used can yield results that appear to stand up under testing.

At the same time, it is realized – and emphasized – that such a modeling approach can only indicate pattern in the nature of surface-observed archaeological distributions. These models cannot specify the nature of subsurface distributions which are quite likely different. Thus, great caution is necessary when using archaeological models as planning tools because a rich and equally important resource base exists beneath the surface which deserves equal attention and conservation.

**Future directions**

The foregoing archaeological modeling effort was a preliminary attempt in the Netherlands conducted under time and budgetary constraints. Since the initial work (Ankum and Groenewoudt 1990), a number of directions have been pursued in order to enhance future modeling efforts.

One obvious weakness of the weighted-average modeling approach is the element of subjectivity that remains in the weights assigned to each category (Table 2). Although we attempted to be objective by basing the locational analysis on the empirical data, the size of the weights was actually based on a subjective appraisal of the relative magnitude of differences between the site and random point data. A more objective weighting scheme has been designed for models now under development that makes use of observed and expected site frequencies in map categories. For each map category an expected number of sites is computed that is simply a function of the category’s proportion of the total study area multiplied by the total number of sites under examination (under a null hypothesis of no relationship between sites and environment). The weight for each map class, then, is defined as a function of the ratio of observed to expected sites.
A second area of improvement is that each archaeological period will be analyzed separately in future efforts, and a distinct model will be generated for each period. The overall sensitivity model for a region, then, will be a simple composite of the individual models (Fig. 4). This approach recognizes the incongruity of lumping sites from vastly different periods and cultures into a single site class for modeling purposes. Different cultures undoubtedly respond to the environment in a variety of ways, and we believe that the new approach will allow greater sensitivity to this factor.

Our GIS capabilities have greatly improved in recent years, too. We now utilize a GIS called the Geographical Resources Analysis Support System (GRASS) (Westervelt 1991) that is linked with an Informix (Thompson 1991) database management system on SUN work-stations. The power of GRASS will allow greater flexibility and efficiency in future modeling efforts. More importantly, database links will allow us to more easily investigate site location patterns within future project areas and additionally, in areas adjacent to a project. This approach confronts yet another weakness of current modeling efforts: small sample sizes. Assuming that sites in surrounding regions exhibit locational tendencies similar to sites in an area of study, and that the nearby areas possess similar landscapes, then by expanding the study area somewhat to incorporate additional sites, more trustworthy associations may be established upon which models may be based.

Finally, as a last step in our new modeling process, modern land use and recent environmental changes are considered (Fig. 4). Although an archaeological expectation model may indicate high site potential at a particular locus, this information is of use only if
that locus is intact, for example. Through a rigorous review of current land status, the archaeological expectation model is transformed into what we term an ‘archaeological sensitivity model’. We feel that the latter better reflects true archaeological sensitivity because in addition to indicating archaeological potential, it also shows areas where clearly no archaeological deposits are possible.

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References


**Abstract**

**Brandt, R., Groenewoudt, B. J. and Kvamme, K. L.**

**An experiment in archaeological site location: modeling in the Netherlands using GIS techniques**

Regional models portraying archaeological expectation or sensitivity based on knowledge of the current archaeological situation can be of great use to archaeologists in the Netherlands. If past work can be used to guide future efforts to the most archaeologically sensitive regions, benefits in
efficiency, cost-reduction, preservation, etc. can be realized. A GIS-based approach to archaeological modeling is described that summarizes archaeological expectation along multiple environmental dimensions. The approach is based on a mix of objective data together with archaeological experience and expertise. An application to the Regge Valley region of the Netherlands shows excellent results in terms of archaeological expectation and performance on known site samples. These results are placed within the context of the many problems and difficulties that modeling research must address in this area of Europe, and a variety of suggested improvements are offered.