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Predictive Modelling in the Netherlands
The prediction of archaeological values in Cultural Resource Management and academic research

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In the autumn of 1997 the Dutch State Service for Archaeological Investigations (ROB) published the first version of its Indicative Map of Archaeological Values (IKAW), a map at scale 1:50,000 purporting to indicate the predicted density of archaeological find locations for the whole of the land area of the Netherlands. This map first brought the field of archaeological predictive modelling to the attention of a larger public.

Introduction

The Netherlands is one of the most densely populated countries in Europe. Nearly 16 million people live and work in an area of just over 36,000 square kilometres. Urban and infrastructural developments continue to change the Dutch landscape. The present rate of change is so high that the archaeological record is under heavy threat in many areas. It is estimated that more than 30 percent of the archaeological record in the Dutch soil has been lost in the last 40 years without even having being looked at by archaeologists (GROENEWOUDT 1994) – and, if left unchecked, this rate will surely increase in the future!

There is a growing awareness with both urban planners and archaeologists, that archaeology should be considered at the earliest possible stage in the process of land development. Planners attempt to structure modern land use in such a way that known historical and archaeological values are respected. Preferably, these values should be integrated and made visible in modern suburbs, since visualisation of archaeological remains, for example in parks and street pavements, stimulates the public's awareness of its cultural heritage. Professional archaeologists are eager to preserve as many sites as possible, since these are their source of information and inspiration for the future. In order to do so, planners need a tool: a map not just showing dots representing the currently known sites and monuments, but one with full coverage of the area including all its known and potential archaeological values – a predictive model. Archaeologists working in Cultural Resource Management (CRM) have been developing such models, not just as documents to be consulted when plans are being developed and the potential impact on the archaeological remains is estimated, but also as tools for guiding fieldwork if further archaeological research proves necessary. Predictive modelling has become a valuable new tool in Dutch archaeology since the early 1990s.

„Predictive modelling is a technique to predict, at a minimum, the location of archaeological sites or materials in a region, based either on the observed pattern in a sample or on assumptions about human behaviour“ (after KOHLER/ PARKER 1986:400)

However, between CRM and academic modellers some important differences in approach have become apparent. CRM archaeologists – mainly those working at the State Service for Archaeological Investigations (ROB) and a semi-private field survey company (RAAP) – have adopted a highly practical approach. They produce predictive models using the currently available digital archaeological and environmental data, within con-

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straints of available time and money provided by the customer. Their point of view is best summarised as „better to provide some kind of model, than no model at all“. Do not leave the urban planner in the dark about archaeology, try to get it on the agenda and show them something – even if that map is just a very rough outline of the potential archaeological values.

Since the early years, academic archaeologists have criticised the models produced by cultural resource managers, and have themselves been developing predictive models in order to gain knowledge about the ways the landscape was utilised and perceived in the past. The modelling process is seen as an aid to understanding the complex relation between the currently known archaeological sites, post-depositional disturbances, research effects, modern day land use, environment, and social variables. Academic modellers are generally very cautious and critical of the quality of basic archaeological and environmental data, and of theoretical and methodological assumptions. Their point of view may be summarised as „better to provide no model at all, than a flawed one“ – do not fool yourself and urban planners with archaeological predictions that will turn out not to be very reliable. To preserve the credibility of archaeological predictive models, the methodology and presentation must be adjusted in such a way that the high level of uncertainty in the models is made clear.

To reconcile these differences an informal discussion group was formed by the autumn of 1997, in which representatives of CRM and academic research were both present. All Dutch archaeologists involved in predictive modelling joined forces in order to make an inventory of procedures and problems in predictive modelling and to attempt to find solutions to these problems. The exchanges during the regular group meetings have already resulted in a lot of criticism being replaced by mutual understanding. The current paper is intended to highlight the main issues raised by the group, and to draw conclusions and make recommendations for future predictive modelling. In order to do this we will first sketch the backdrop of the physical, organisational, and theoretical landscape against which current predictive modelling in the Netherlands takes place.

Background

The natural environment and characteristics of the archaeological record

For those not familiar with the characteristics of the Dutch landscape and its archaeological record, a short introduction is given here. Physiographically, the Netherlands can be subdivided into two major areas: the low-lying coastal and fluvial plains, and the somewhat more elevated sandy areas to the east and south (fig. 1).

fig. 1 The Netherlands is geologically divided in a western part with Holocene coastal and fluvial deposits and an eastern part with Pleistocene sands (yellow). Both areas have a very specific archaeological record.

The higher areas have been shaped during the Pleistocene, with ice-pushed moraines and vast areas of cover sands. These areas have been relatively stable during the Holocene, but the landscape has nevertheless witnessed some changes. In some parts, archaeological remains were buried under layers of peat or under „essen" (areas covered with a layer of sod-manure). In others, water and wind were responsible for local erosion of archaeological remains. However, in general archaeological remains are found near the surface, so that, for example, many more Stone Age remains are known from these areas than from the coastal and fluvial plains.

The low-lying coastal and fluvial areas have been an extremely dynamic environment during most of the Holocene. Rising sea levels and the wandering of the major river courses created a continuously changing landscape. It is only by the Late Middle Ages that the landscape was more or less consolidated by human intervention in its current form. Both erosion and sedimentation have occurred in many areas during different periods, leading to complex stratigraphic relationships. This basically means that these areas still hold many archaeological surprises below the current land surface. To give just one example: the Universiteit Leiden recently excavated a Mesolithic settlement at a depth of 7 metres under the current surface. The site was first discovered in an augering campaign for an environmental impact assessment, ordered by the Dutch national railway company. From the excavation perfectly conserved organic remains such as antler axes, human skeletons, and a dug out canoe emerged. A proper understanding of the way in which the landscape in this low-lying part of the Netherlands has evolved is a prerequisite for understanding the distribution of its archaeological remains. Land use in the past was highly structured by the contemporary geography.

Apart from its implications with respect to archaeological interpretation, this also has consequences for the conduct archaeological surveys. In the low-lying regions it is almost useless to do field survey by means of field walking – the most reliable method to obtain a complete inventory of archaeological data is by means of intensive augering.

The changing structure of professional archaeology in the Netherlands

An issue that is also important for the understanding of the development of predictive modelling in the Netherlands is the way in which the structure of the Dutch professional archaeological community is changing.

The State Service for Archaeological Investigations (ROB) is responsible for the implementation of the national protection laws concerning archaeology. Basically, this means that it decides which areas should be given the status of archaeological monuments, and what degree of protection these areas deserve. In the past the ROB did a considerable amount of rescue excavation and scientific research as well, but recently its role has shifted towards archaeological resources management. No longer restricted to the implementation of legislation, the new ROB is to become the authoritative centre of archaeological knowledge for cultural resources management. One of the key elements in this programme is the national archaeological information system ARCHIS (ROORDA/WIEMER 1992). Currently this system contains information about 50,000 find spots and 12,000 archaeological monuments. ARCHIS is seen by the ROB as a means to exert influence on the planning process at the national level. This is done by opening the ARCHIS database via the Internet to a limited number of responsible authorities and by using ARCHIS as the basis for the Indicative Map of Archaeological Values.

Another recent ROB role shift is that of concentrating responsibility at the national level, away from its previous considerable influence at the provincial level. Each province now employs its own archaeologists, who will assess the impact of regional planning on archaeology, and who will be involved in formulating provincial cultural resource management policies, especially in rural areas. Similarly, in many urban areas a municipal archaeological service is responsible for the supervision of building activities.

Private firms doing surveys, excavations and find-analyses for third parties quickly filled the vacuum left behind by this shift towards cultural resource management at the national level, and away from excavations and research. Over the last 10 years Archeologisch Adviesbureau RAAP has been a forerunner in this respect. It has used the niche of field survey to attract the attention of planners to the possibility of doing archaeological inventories, which might estimate the number of threatened sites before the actual work starts. RAAP uses a two-stage approach. In the first stage, a preliminary archaeological inventory is made based on the available information in ARCHIS and other sources, and on the available environmental maps. The intermediate goal is to make a predictive model that distinguishes areas of high and low archaeological potential. In the second stage an intensive archaeological survey by means of augering combined with field walking, is carried out to obtain a more reliable map of the presence of archaeological sites. The spatial extent of such surveys is mostly limited to small regions or transects (railroads, highways, building sites).

A second big player in this area was recently created by the privatisation of the excavation department of the ROB. The Valetta treaty accelerated the founding of this commercial organisation, the Archaeological Service Centre (ADC). The demand for an archaeological service that can organise and perform the necessary rescue excavations is increasing rapidly. Nowadays even the universities participate in this commercial field – all three universities with a European archaeology department (Leiden, Groningen and Amsterdam) have founded excavation firms. Decreasing government funding and a traditionally strong involvement in rescue excavations have triggered this development. At a more specialist level, the analysis of specific find categories has also become privatised. A number of specialists are now self-employed, for example: BIAX (palaeobotanical analysis), ArcheoBone (analysis and conservation of bone material) and RING (dendrochronology). Specialists appointed at the universities are also trying to find additional funding for their research projects in this manner.

The privatisation and commercialisation of the archaeological field, as described above, has unmistakably increased the influence of tight schedules and customers waiting for the end product, on the actual work. Unlike academically employed archaeologists, commercial firms have only limited possibilities to investigate new lines of research, to contribute to the scientific interpretation of their finds, and to improve research methodologies. Good archaeological research in a commercial context is equivalent to efficient research: only a limited number of tried and tested methodologies will be applied. This applies to fieldsurveys, excavations, find analyses and predictive modelling alike.

The theoretical basis of predictive modelling in the Netherlands

In the literature a difference is often made between two competing lines of reasoning used by predictive modellers, for which the terms „inductive“ and „deductive“ are used as a shorthand (fig. 2).

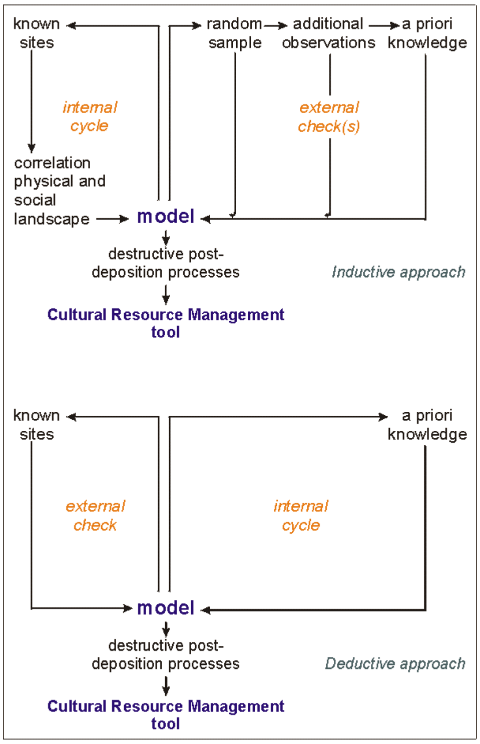

fig. 2 Model of the inductive (above) and deductive approach (below) to predictive modelling, these schemes show the way the model is created and how it can be tested and improved.

The inductive approach starts with a sample of currently known sites and attempts to find a statistical correlation between their occurrence and physical characteristics of the landscape. The quality of the resulting models can be assessed using independent information such as additional fieldwork, the consultation of experts, or a control sample of known sites. Inductive modelling has been the dominant methodology, especially in the United States where state archaeologists were confronted with large tracts of land where little was known of the archaeological record. These archaeologists took the approach of field surveying to obtain information about the archaeology present in small sample areas. Taking into account physical parameters such as distance to water, slope class and soil type of the sites in the sample, and applying a number of different quantitative techniques, it was possible to model the presence of archaeological sites for the whole area.

These results obtained by the middle of the 1980s showed that it was possible to predict the number of sites to be found in unsurveyed areas on this basis. In 1989, a delegation of Dutch archaeologists from ROB and RAAP visited the United States in order to investigate the possibilities of GIS for Dutch archaeological resources management. This visit has stood at the basis of both the national archaeological information system ARCHIS, and of predictive modelling for archaeological resources management in the Netherlands. However, in spite of early optimism, the studies done in the early 1990"s (ANKUM/GROENEWOUDT, 1990; SOONIUS/ANKUM, 1991) mainly proved that setting up a reliable modelling procedure for a typical Dutch landscape was not as easy as it might have seemed. It proved very difficult to comply with all the conditions that should be fulfilled in order to create a valid inductive model. For instance, the requirements of random sampling, the use of independent variables, and a sufficiently large sample size could not be met in most cases. Another problem with these models is that their accuracy has never been tested. This is mainly due to the assumption that only by collecting large amounts of new site locations it was possible to perform such test.

The term „predictive“ in an inductive modelling context should in fact be reserved for statistical extrapolations (which also include the calculation of standard deviations). Extrapolations of site densities can be made using one or more geographical variables, but should be based on a sample from a limited area that is representative both archaeologically and environmentally for a larger region. Many Dutch predictive maps however are not using a representative sample, but all the currently available archaeological sites for the complete study region. These maps are therefore descriptions of the current state of knowledge on site distribution, rather than statistical extrapolations.

At about the same time, inductive modelling began to be applied in academic archaeology as well, where more attention was paid to methodological issues than to actual predictions of site densities. Papers began to appear criticising the predictive models made for CRM as being rather crude, lacking a theoretical foundation and therefore failing to take into account the cultural and environmental mechanisms that produced the statistical correlations that were found (VAN LEUSEN, 1993; 1995; 1996, WANSLEEBEN/VERHART 1992; 1997). Although this criticism was justified, RAAP and the ROB have continued to produce inductive predictions, taking into account some of the methodological critique (VERHAGEN, 1995).

The alternative, deductive approach constructs predictive models on the basis of hypothetical human behaviour in the past. Often an economic model is taken as the starting point. For a particular archaeological period and region an assumption of „self supporting agriculture without manuring, but with long fallow periods“ might be made. On the basis of environmental variables that are relevant to this economic behaviour, the site distribution is predicted and the known archaeological sites are only then used to evaluate the prediction. Hans Kamermans was a pioneer in this field and introduced land evaluation into Dutch archaeology as a fully deductive way of predictive modelling (KAMERMANS et al. 1985; KAMERMANS 1993; KAMERMANS/RENSINK 1998). This work has to date not resulted in a formal methodology for deductive modelling that can easily be applied in the context of archaeological resources management, although some attempts in that direction have been made by Dalla Bona (1994).

The division between inductive and deductive approaches to predictive modelling is in practice not very distinct. Data analysis, independent control and reconstruction of human behaviour are woven together in complex patterns. During the modelling process they each contribute differently to the end product.

Examples

In order to put the contrast between CRM and academic uses of predictive modelling in the Netherlands into perspective, a few examples will be discussed in more detail below.

The Indicative Map of Archaeological Values (IKAW)

The Indicative Map of Archaeological Values, produced by the ROB, covers the whole of the Netherlands and aims at creating a systematic overview of the archaeological resources in the rural areas (DEEBEN et al. 1997; DEEBEN/WIEMER 1999)(fig. 3).

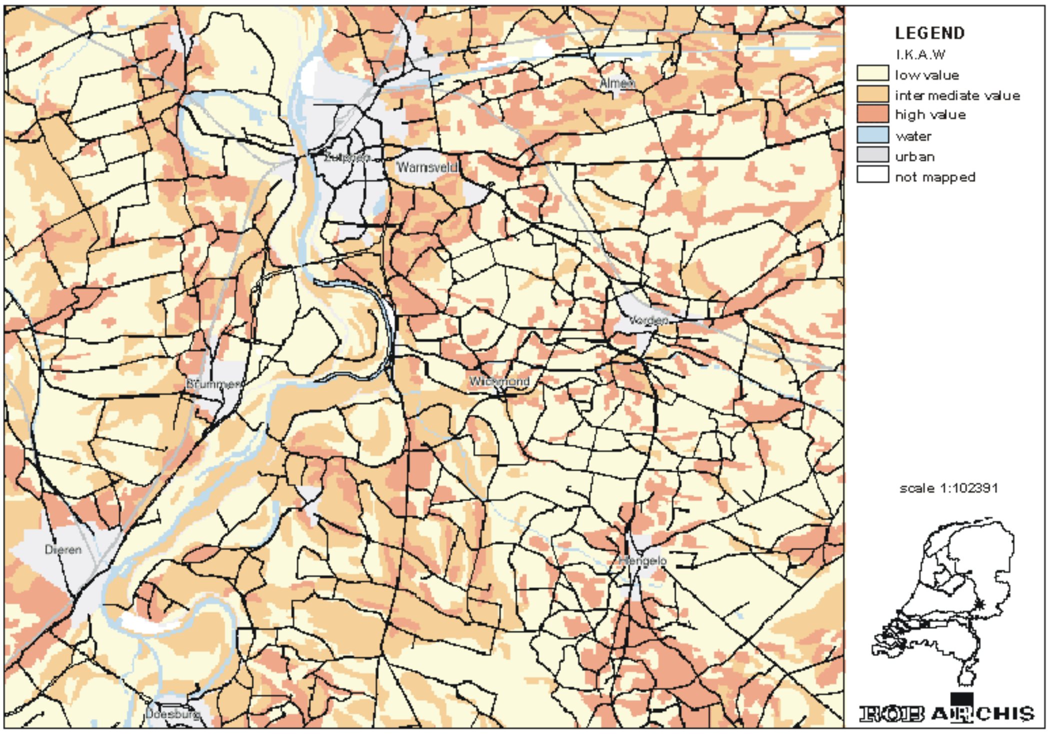

fig 3 A small section of the Indicative Map of Archaeological Values for the Netherlands is shown. Areas with increasing archaeological potential are coloured respectively yellow, orange and red.

The IKAW illustrates the way inductive predictive modelling is currently being applied in CRM on a national scale. The model that it is based on takes the currently available digital information as its starting point. Archaeological information was obtained from the ARCHIS database, while environmental data were obtained from the digital Soil Map of the Netherlands (scale 1:50,000), which contains data on soil types as well as on groundwater tables.

The analysis was carried out separately for 13 areas known as archaeo-regions. These regions roughly share the same landscape characteristics, and also show some similarity in their archaeological record. A pilot model was made in 1996 for the „Eastern Sandy Area“, an area in the Pleistocene part of the Netherlands, which covers 3600 km^2. From just over 2800 observations available in the ARCHIS database, almost 1900 find spots were selected, which could be dated to one or more phases between the Palaeolithic and the Late Middle Ages. The sites were visually and numerically overlaid with the soil map of the area in search for patterns. Each possible combination of soil type and groundwater level was given an individual status as an environmental unit. Most of these units are very small and contain no known archaeological sites. For each unit, the observed (known) number of sites was compared to the expected number of sites (under the assumption of a random site distribution this would be proportional to the size of the unit). The ratio between the observed and expected frequencies was calculated and was called the indicative value“.

Some obvious corrections to this initial indicative value were made in a second stage of analysis. Very small areas were lumped together, and the indicative value of units violating clear trends, such as an increasing number of sites with increasing groundwater depth, were adjusted. The indicative values were then grouped into three classes: „low“ (with an observed/expected ratio of less than 0.6), „medium“, and „high“ (with a ratio of more than 1.5). The divisions between these classes were made on the basis of jumps in the cumulative histogram for each particular archaeo-region. In a final step, the resulting map was sent to various archaeological experts for review, and comments were used to correct some indicative values before the final map was produced.

The current IKAW map is, however, far from a finished product. Its authors do not question the fact that it needs improvement, and a second version is currently being developed. Four fundamental problems can however be identified with their current approach:

Quality of the archaeological input data. The ARCHIS database contains numerous misrepresentations, as clearly acknowledged by the ROB. Research intensity may vary significantly between areas, and the quality of documentation is very unequal. The fact that no areas are excluded in the production process of the IKAW means that the „lack of known sites" in some areas has been interpreted to mean „no habitation in the past". Similarly, taphonomy is considered to have an important influence on the site distribution pattern, but is not incorporated in the model at all. In general, the procedure followed to produce the IKAW has failed to incorporate a stage of source criticism, in which both the archaeological and pedological information should have been evaluated.

Relevance of the environmental input data. The need for a reconstruction of the palaeogeography is acknowledged, but not included in the first version of the IKAW. No distinction is made between the Pleistocene and Holocene areas of the Netherlands. The 1:50,000 scale Soil Map of the Netherlands only describes the soil down to a depth of 1.20 meters, ignoring deeper geology. This makes soil types unsuitable as a model parameter for the western and northern part of the country, where archaeological remains are usually found at much greater depths. And even in the Pleistocene part of the Netherlands, the soil map can not always be used as an adequate representation of the palaeo-landscape, since local erosion and deposition have occurred in many places.

Lack of temporal resolution. Sites from all periods were lumped together in the analysis, and no distinction was made between site types such as settlements and burials. The site location pattern found is therefore global, and is dominated by those periods or site types that happen to be most frequently present. Predictions for the Palaeolithic, Mesolithic and Late Middle Ages turn out to be very weak. It is known that hunter/gatherer sites are more often found in the vicinity of open water and landscape gradients rather than on any particular combination of soil type and ground water level. Similarly, Late Medieval settlements are more closely linked to man-made landscape elements such as roads, field systems and towns than to the natural environment. In order to model such differences in site location preference between sites from different periods, separate analyses should be carried out for each.

Model assumptions. Its authors state that the IKAW is not intended to gain knowledge about the behaviour of past societies. A simple correlative model with one or two physical landscape variables is supposedly adequate for the purposes of CRM. We disagree with this point of view, which has clearly led to serious errors and oversimplification of the way in which archaeological site distribution is depicted on the map. The choice of soil type and groundwater level as the sole environmental variables to be used for the analysis is a pragmatic one, based upon the digital availability of these data for the whole of the Netherlands. Such choices should instead be based upon the relevance of the variable for the historic communities. All kinds of other variables, including social ones, might conceivably be of much greater relevance to site location preferences, and would therefore produce better predictions. The authors do not even attempt to evaluate the chosen variables for their relevance.

It is clear from the discussion above, that the Indicative Map of Archaeological Values was published by the ROB somewhat prematurely in 1997, and that corners were cut for pragmatic reasons (availability of digital data, the imminent needs of urban planners, political positioning of the new ROB). Yet planners have had access to the IKAW map for two years now, and have had the possibility of judging the archaeological impact of their plans using it. Obviously this could have led, and could still lead, to incorrect interpretations of the archaeological record. In practice, planners still consult the ROB or the provincial archaeologist to assess the need for further archaeological research. As such, the Indicative Map is used at the moment more as a tool to guide the archaeological research strategy, than as a tool to select areas with a greater or lesser archaeological value directly (pers. comm. Jos Deeben). However, even when used as a tool for guiding archaeological research, the inaccuracies and highly general nature of the map can lead to debatable choices when it comes to selecting areas for intensive survey.

Midden-Delfland: the importance of palaeo-geography

The necessity of palaeo-geographical reconstruction for predictive modelling in the western Netherlands is adequately shown in the following example. In the case of the Midden-Delfland area, RAAP carried out an archaeological impact assessment for a new motorway between the cities of Delft and Rotterdam (SCHOLTE LUBBERINK et al., 1994)(fig. 4).

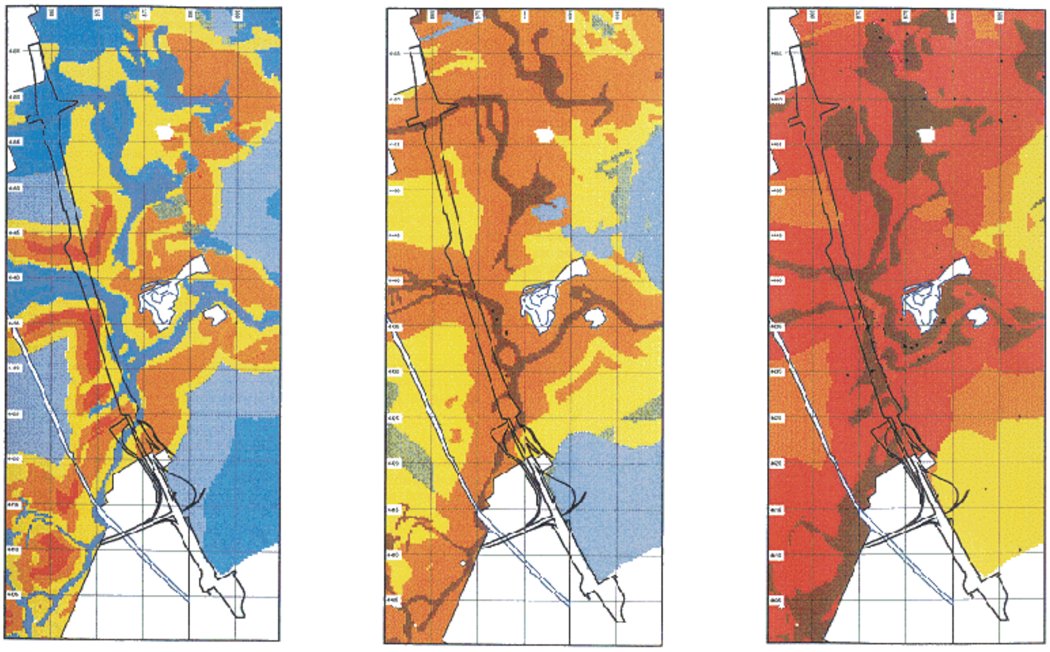

fig. 4 The expected density of archaeological sites in the southern part of the A13 highway in Midden-Delfland for the Iron Age, Roman period and Middle Ages (left to right). Darker shades of red indicate higher expected densities.

The area between these two cities, approximately 170 km^2 in size, is currently under grass and should remain a green buffer zone. This example also stresses the need for separate predictive models for different time-periods.

When trying to produce a predictive model for this Holocene area, it quickly became clear that the modern soil map would be inadequate. In the Midden-Delfland area, much of the topsoil consists of layers of peat dating to the Medieval period. Some of this peat has been exploited for fuel in the Late Middle Ages and later, so that in these areas archaeological remains may be found near the surface. In other places archaeological remains will remain buried, and their locations cannot be inferred from the soil maps.

This meant that the sub-surface geology had to be reconstructed in order to find physical geographical correlates to the location of archaeological sites. Fortunately, detailed geological information could be obtained from previous archaeological surveys by the University of Amsterdam (BULT 1983; BULT/VAN DEN BROEKE 1990) and at the time unpublished maps by the Dutch State Geological Service. The most important palaeogeographical element in these maps is the location of creeks formed during the last transgression phase in which the sea reached the surroundings of Delft, dated approximately 500 years BC (Dunkirk I transgression, or Iron Age in archaeological terms). During this transgression, the banks of the creeks were the highest surfaces in the area, whereas the creeks themselves and the surrounding areas were wet marshes. Here an important rule of Holocene site location theory becomes evident, which is the „principle of dry feet“: in an environment that is frequently inundated, settlement will only be possible in the driest places. It is therefore not surprising that many settlements from this period are found at a distance of less than 200 metres from the creeks. When the sea receded in the Roman period, the landscape underwent relief inversion – peat and clay, when dehydrated, shrink under their weight, whereas sand will more or less retain its original volume. The former creeks had therefore become the highest part in the landscape, explaining why many Roman settlements are found there. After the Roman period, a prolonged period of peat formation took place, which basically meant that when Medieval settlers came into the area, no dry areas were left, so they started to create their own. Medieval settlements are therefore found on artificial dwelling-mounds and in the vicinity of drainage canals, and have very little connection with the underlying natural environment.

The model eventually created is clearly a „hybrid“ model, including both elements from the inductive and deductive approach. Existing knowledge about human behaviour was used to decide which variables would be an important parameter for the modelling. On the other hand, the method used for mapping predicted site densities is still purely quantitative, and is based on the calculation of the density of known sites. In that sense, the model is not very different from that resulting in the IKAW.

Because of the changing settlement pattern through time, it was decided to create separate predictive maps for the three periods. This allowed for a comparison of the impact for each of the chronological periods. However, a combined density map of all three periods was used for the final comparison of the proposed alternative routes for the motorway. The immediate result being that the more abundant Medieval settlements assume a larger importance in the assessment than Iron Age or Roman settlements. In this model, even though the impact assessment still made it possible to choose a „less damaging“ alternative route for the motorway, all proposed road construction plans would potentially damage a considerable number of archaeological sites.

The Michelsberg settlements in the Roerstreek: the limited value of archaeological survey data for predictive modelling

The next example of predictive modelling comes from the Meuse Valley project, an academic research project for which the time-is-money principle is less relevant, and more fundamental research questions can be tackled. As in the previous example, this project also uses a basically inductive approach on a regional scale. This example illustrates that a very critical attitude towards the archaeological and environmental source data had to lead to methodological adjustments for the analysis of the regional archaeological data.

The Meuse Valley project is a long-term regional research project in the southeastern part of the Netherlands (WANSLEEBEN/VERHART 1995). Its main objective is to gain insight into the neolithisation process – the transition from hunter-gatherers to farmers. The current model for this process in the cover sand area of the Netherlands is characterised by a relatively prolonged duration of the Mesolithic. Unlike the loess area in the extreme south, where the Bandceramic colonists introduced agriculture and husbandry around 5300 BC, the incorporation of farming into the food economy of the local hunter-gatherers only took place some 1000 years later. Gradually, different aspects of the Mesolithic society changed and led to a community belonging to the Michelsberg culture with a so-called extended broad-spectrum economy. Hunting and gathering, as well as agriculture and stockbreeding played a role in their food economy. The Meuse Valley project is testing this neolithisation model through the analysis of site distribution patterns in a few specific regions. The Roerstreek, one of these approximately 100 km^2 regions, is an area of cover sands located very close to the boundary of the loess area. Members of the local historic society have intensively surveyed it over the past 25 years. From a total of 390 Stone Age sites, all artefacts where uniformly described by the authors and typologically encoded in order to assign a date and a functional characteristic to each site. Almost 140 sites could be dated to the Michelsberg phase on the basis of the presence of one or more „guide artefacts“ (specific flint tool types or pottery).

Site typology, one element of the settlement pattern that was analysed, is complicated by the very high percentage the sites that were occupied in more than one cultural phase (WANSLEEBEN/VERHART 1998). Artefacts of various occupation phases are found together because of the geological stability of the area. As a result, only a limited number of the Michelsberg sites are culturally „clean“ enough for use in a site typological analysis. Furthermore, since the project mainly uses surface finds, the number of artefacts of each type could not be used for statistical purposes – each new visit to the site or additional season of deeper ploughing would change the known number of artefacts drastically. The raw counts or percentages therefore provide an unstable and inaccurate description of the artefact composition of a site. The level of measurement therefor has to be adapted to the specific quality of the regional archaeological data, and this is done by using an „ordinal“ instead of a „ratio“ scale of measurement. The multivariate ordinal information can then by displayed in a graphical form using rose diagrams, a technique frequently used in Exploratory Data Analysis. These diagrams highlight the great similarity between the Michelsberg sites and arguing against site differentiation with the attendant need for separate site location analyses.

For the site location analysis several environmental maps of the area were available, ranging from an old topographical map from around 1800, several geological maps to the modern soil map. Neither of these maps could be used without further processing. The soil map, for instance, had to be corrected for recent geological processes like peat formation and eolian deposition and erosion. The modern soils were mainly formed after the occupation phase we are studying, so even in the eastern part of the Netherlands the modern soil types are not always particularly relevant for site location. However, other information in the soil map could still be used. Both soil texture and relative humidity of the soils are documented in the Dutch soil classification system, and can be extracted from the digital maps by means of reclassification. In a further step, the soil texture map was used to calculate the number of different textures occurring within a circle of 500 m. of each (50 by 50 m.) grid cell, thus defining a homogeneity / heterogeneity index. This is an environmental variable expected to be relevant for hunter/gatherer activities. A total of 15 different environmental variables were created in this way. Most of the input maps had to be digitised and reclassified. This large amount of work was justified by the expected benefits of using each selected variable for the site location analysis, based on our existing knowledge about these prehistoric communities.

A further step in the site locational analysis was to incorporate the uneven coverage and intensity of the archaeological research. Applying two filters to exclude parts of the study region reduced the effect of the discovery bias in the known site sample. The first one accounts for differential archaeological visibility (arable fields and grassland versus forested and built-up areas), and the second one for the extent of the actual field surveys conducted in the region. The combined filters show that the actual area for which we have fairly reliable information covers only 25% of the region as a whole. If this step were left undone, we would have unjustifiably assumed that almost no human occupation occurred in 75% of the area, whereas in fact we have no systematic archaeological information for those areas (fig. 5).

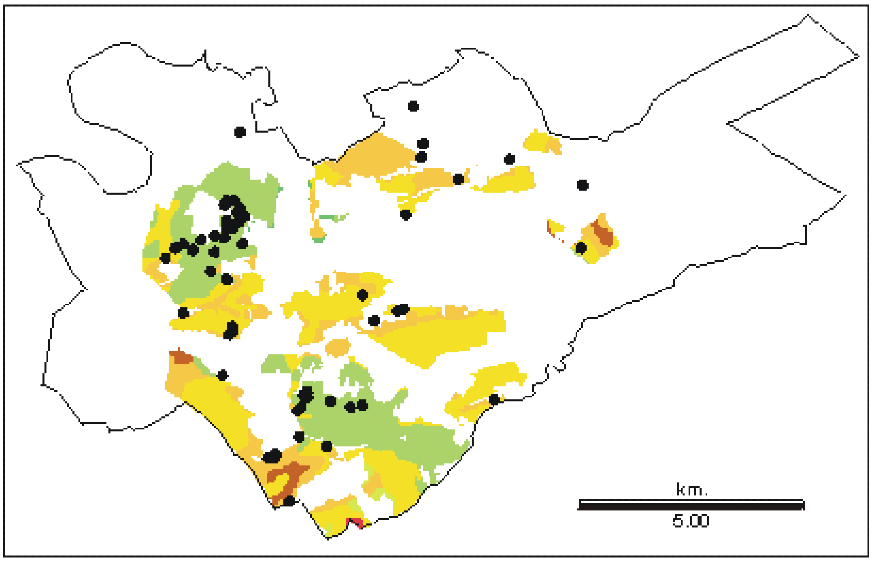

fig. 5 **Background filters used in the site locational analysis in the Roerstreek to correct for survey bias. For only 25% of the area the archaeological information is considered reliable enough to analyse the location of the Michelsberg sites (black dots) against the soil textures (coloured areas).**

Only 95 of the 140 Michelsberg sites mentioned earlier were located in the „reliable“ area, and only these were analysed against each of the 15 landscape variables. These sites showed a preference for five more or less independent landscape variables, which could very well fit in the model of a very broad-spectrum economy. Only a very global trend in the Michelsberg site location strategy could be detected. With this result, the initial goal of the analysis was reached and the scientific curiosity sufficiently satisfied. But the observed pattern in the sample can also be extrapolated to the 75% of the Roerstreek in which no systematic research had taken place. The five relevant site locational variables were used to produce relative indexes of site preferences for the whole of the region. The resulting predictive model shows very sharp boundaries and large differences in site preferences over short distances. Since the field survey data used is biased in several ways, the final modification was to smooth the model, resulting in a blurred (fuzzy) image. Which, in our opinion, appropriately mimics the limited predictability of archaeological sites.

The application of land evaluation in archaeology as deductive predictive modelling

This last example also comes from an academic background and represents the „deductive“ approach on a regional scale. It illustrates a more formalised way of choosing environmental variables for the prediction of archaeological sites.

Land evaluation is a technique developed by soil scientists and widely used in the 1970’s and 1980’s by the FAO (Food and Agriculture Organisation of the United Nations) in third world countries for estimating the potential of land for alternative kinds of use (FAO, 1976). Land evaluation requires information from three sources: landscape characteristics, land use, and economics. Kamermans et al. (1985) introduced the land evaluation approach into archaeology as a framework for studying the relation between human occupation and the natural environment in the Agro Pontino, an area 60 km long and 15 km wide south of Rome, Italy.

There are some important differences between the FAO method and archaeological land evaluation (fig. 6).

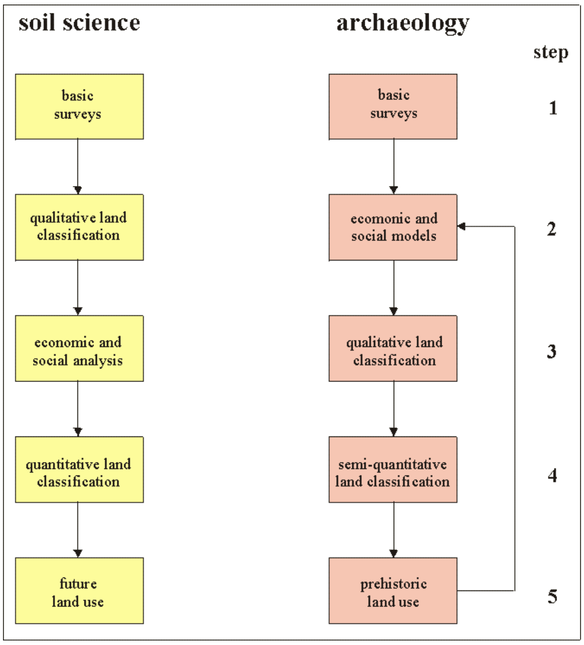

fig 6 The difference between the way land evaluation is used in the soil sciences by the FAO and in archaeological research.

Firstly, models of prehistoric socio-economic situations must replace the modern-day economic and social analysis. To construct these models, information on the ecological and technical requirements of different kinds of land use, as well as data on the economic and social context, has to be generated using ethnographic, archaeological, and historical sources. The outcome of the land evaluation is an expected form of land use for every chosen socio-economic model. Secondly, it is of course impossible to measure prehistoric land qualities directly; they have to be reconstructed from data obtained by surveys of recent land characteristics and palaeo-ecological reconstructions. Thirdly, the purpose of using the land evaluation approach in archaeology is to evaluate our models of prehistoric land use. Comparing the expected form of land use with the archaeologically recorded land use provides a basis for modifying the models. This procedure can be repeated until the models conform to the archaeological record.

Archaeological land evaluation proceeds in five steps:

Identify the relevant physical and biotic factors. The Agro Pontino is geologically speaking very similar to the Dutch Holocene landscape, with a low-lying graben, mainly filled with peat, and a dune area along the coast. A soil map of the area by Sevink et al. (1991) was used to classify the Agro Pontino landscape into 17 different land units. In the FAO approach, a land mapping unit is defined as having a specific combination of landscape characteristics (soil, vegetation and landform) which are believed to have a significant effect on the types of land use under consideration. This classified landscape is used as a starting point for all the subsequent analytical steps. For each phase and each land unit the vegetation was reconstructed on the basis of palynological information and the occurrence of larger mammals is reconstructed on the basis of a comparison with their current habitats.

Define socio-economic models. For the Agro Pontino, nine different socio-economic models were considered for societies of hunter-gatherers, agriculturalists and pastoralists. For hunter-gatherers three models were defined: the generalist (practising residential mobility), the specialist (practising logistic mobility), and the fisherman. Wolf (1966) provides useful models for agriculturalists, derived from ethnographic examples. He describes five models for agriculture: shifting cultivation with long term fallow, shifting cultivation with a sectorial fallowing system, a short-term fallowing system, and two systems of permanent cultivation, one with or without some reliance on a hydraulic system and the other with cultivation of favoured plots. Finally there is one model for pastoralists: transhumance over great distances.

and

Qualitative and semi-quantitative land evaluation. The next step in the land evaluation is to estimate the suitability of each land unit for the different land utilisation types. For the hunter/gatherer/fisherman the land evaluation is not directly based on the soil properties. The reconstructed flora and fauna are of much more relevance for these communities. For the agricultural land utilisation types the land units are evaluated on the basis of the availability of nutrients, oxygen and water, salinity, the flood risks, and tillage complexity. For transhumance the possibilities of grazing, sensitivity to erosion and availability of water for the livestock are considered. First a rough, qualitative evaluation is made, followed by a quantitative estimation of the suitability of each land unit for each land utilisation type. The FAO procedure is however adjusted: only a semi-quantitative evaluation is made on an ordinal scale of measurement in order to account for uncertainties in the reconstructed environmental data. Each land unit is given a ranking according to its expected intensity of usage. Any land units that geologically were formed later than the archaeological phase under consideration were excluded from the analysis.

Compare the archaeological information with the land evaluation. The total area of the Agro Pontino is approximately 750 km^2. Neither the money nor the manpower was be available for a survey of the entire area, so it was decided to sample it (LOVING et al, 1991). The survey yielded a total of 360 sites, of which 289 were multi-period sites. For the comparison of the land evaluation to the actual prehistoric land use in the Agro Pontino, the site density per land unit in the actually surveyed transects was used. These absolute site densities were degraded into rankings as well to correct for differential visibility in the survey results. The rank orders of each different land unit were then compared with the expected rank order of the land unit, as predicted by the different socio-economic models. A statistical rank order correlation test was used to identify which expected rank order showed the best agreement with the actual ranking based on site density. For example, for the Middle and Late Palaeolithic the model of general hunter/gatherers exploiting a wide range of animal and plant resources by means of a high residential mobility seems to fit best with the results of the survey. For the Neolithic the rank order for permanent cultivation with or without some reliance on a hydraulic system showed a significant correlation with the observed rank order.

The technique of archaeological land evaluation clearly can be used as a method of comparing prehistoric land use models to current site distribution patterns. Obviously, the choice of environmental and social variables is directly based on ethnographic models. The uncertainties in the environmental and archaeological data are acknowledged and the FAO procedures adjusted accordingly. However, despite its strong theoretical foundation, the deductive modelling procedure described here is relatively time-consuming, and the end results are still very general. This is not caused by the method chosen, but by the restricted quality of regional archaeological data.

Lessons Learned

The Indicative Map of Archaeological Values was presented here as an example of predictive modelling in the field of CRM. Given the limited goal of producing a predictive map for the whole country with the available information, money, and time, the IKAW is, although heavily criticised, considered to be a valuable product. The other three examples presented above illustrate that other theoretical and methodological approaches could have been followed as well. During every process of predictive modelling fundamental as well as pragmatic choices must be made, even in an academic setting. Comparing and discussing these different choices have taught us a number of lessons.

Predictive models, and especially their attendant maps, already play a useful role in the cultural resource management process. Not just because they provide a structured and formal archaeological participation in this process for the first time but, at a technical level, because they have helped shift attention from site-based to zone-based conservation. This is a great advantage of these models because it is not just the known settlements that deserve protection, but also the burial sites, field systems, and roads that have formed part of the cultural landscape.

Predictive modelling has proved, however, not to be the simple exercise that it seemed to be at first. There is no single predictive model for the whole of the country or for all archaeological periods. Each time a separate prediction is needed and the modelling procedures have to be adjusted to the local circumstances. Combining elements of the inductive and deductive lines of reasoning will probably result in models that make the most of our current archaeological knowledge, merging statistical inference with archaeological expertise and knowledge about the behaviour of the communities in the past.

Neither the practicalities of digitally available data nor the prerequisites of statistical tests should ever take precedence over archaeology itself. Some of the choices that went into the Indicative Map of Archaeological Values demonstrate this. In particular, the lumping together of all known sites in one model, disregarding the presence of different site types or different economic systems, is not a very good choice. If grouping of scarce data is necessary, settlements should instead be grouped into large-scale economic systems, such as hunting/gathering, self-sufficient agriculture, or market orientated agriculture. If a clear site typology exists, the analysis should be repeated for each separate site type.

The currently known archaeological distribution patterns are mostly the result of archaeological research bias, whether this is influenced by modern land use, the difficulty of detecting buried sites, or specific interests of archaeologists in certain areas, kinds of sites or artefacts. A phase of source criticism of both archaeological and environmental input data should therefore be mandatory, and the modelling methodology should be sensitive to the characteristics of the available data set. Taphonomical maps that assess the nature and extent of the distortions of the known material heritage should be an integral part of any predictive model. If this is not done, „low potential“ zones run the risk of being regarded as „zones of no interest“, whereas they may in fact be zones of insufficient archaeological data. Predictive maps run the risk of turning into self-fulfilling prophecies if these zones, because of their „low potential“, are not included in subsequent prospection.

Past and current predictive models have barely touched the question of how to model quality, rarity, nature, and indeed „value“ of archaeological remains. Incorporating these factors will bring predictive models closer to true expert systems and must be regarded as the next major stage in the development of geographical models for archaeological resource management.

There are still major quality problems with current predictive models. They do not yet have sufficient spatial, functional, and temporal resolution to provide predictions to rival those of experts, they do not allow for the formal inclusion of archaeological theory and expertise, and they do not formally incorporate stages of source criticism (bias correction) and quality testing. We recommend that a joint research/implementation plan be put forward by CRM- and academic researchers.

Research into, and discussion of, predictive modelling has been hampered by a lack of definition of core notions, e.g. what exactly is a predictive model supposed to predict? How do we decide what is a „good“ model? Many „predictive“ models in fact do no more than describe the input sample of archaeological site data, and none have formal quality criteria that were actually tested. We recommend that such definitions and criteria should be a required part of any predictive model.

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