# Are Current Predictive Maps Adequate for Cultural Heritage Management? The Integration of Different Models for Archaeological Risk Assessment in the State of Brandenburg (Germany).

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**Abstract.** For north-eastern Germany it is for the first time possible to introduce predictive models with high temporal resolution. Based on this, an archaeological risk assessment was built for the usage in cultural resource management which took source critisism aspects into account. These aspects are part of different models and provide statements about preservation and uncertainties of archaeological remains. The inclusion of these models distinctly improves the expressiveness of the predictive model and will be for the first time discussed with examples.
**Keywords:** Predictive modelling; GIS; Landscape archaeology; spatial analysis

## 1. Introduction

Archaeological predictive maps are used as a tool for cultural resource management (CRM) in many countries (Deeben et al 1997). In the course of the research project "Archäoprognose Brandenburg" we produced various indicative models for different archaeological periods and geographical areas in the federal state of Brandenburg in north-eastern Germany (Münch 2003; Fig. 1).

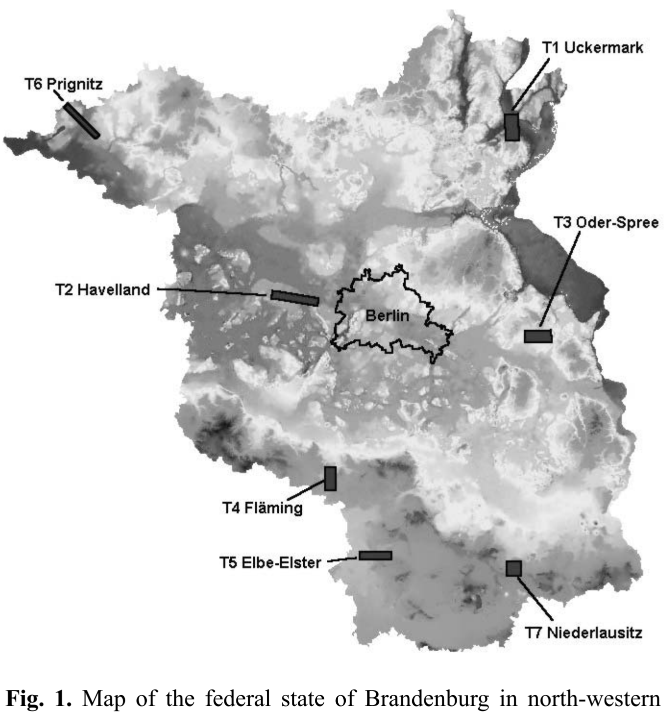


**Fig. 1.** Map of the federal state of Brandenburg in north-western Germany with test areas.

## 2. Current Situation

But do current predictive maps provide an adequate starting point for risk assessment in CRM? The high density of archaeological remains in Central Europe, including the state of Brandenburg, and the intensity of construction work make great demands on a predictive model.

This is reflected in the current population density of about 87 people per square kilometre, which is relatively low when compared to the rest of Germany, and the density of known archaeological sites: approximately 0.8 per square kilometre. In addition rescue excavations have shown again and again that only a small fraction of archaeological sites are known (Eickhoff 2001, Kunow 2001).

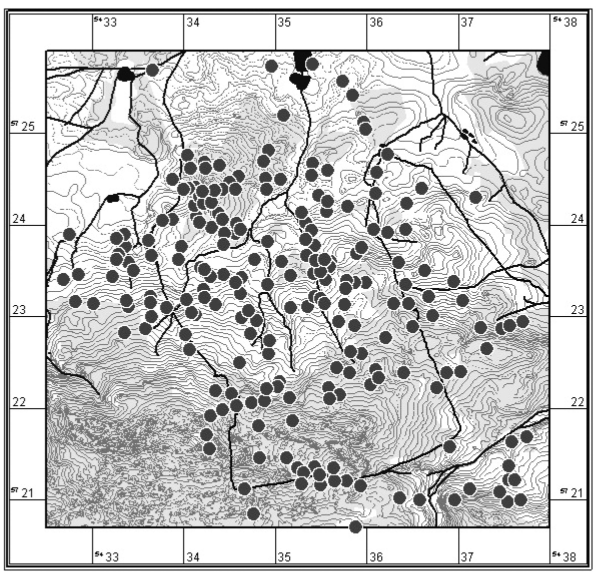

**Fig. 2.** Spatial distribution of reported sites in test area 7, clearly showing the boundary of survey work in the mining area (black line).

The situation is clearly shown in the open-cast mines of test area 7, where the extraction of lignite is constantly monitored and the endangered archaeology recorded (Fig. 2). The large number of sites within the area marked in black gives the impression of a continuous "archaeological landscape" which should be protected (Bönisch 1996). However this is difficult to prove and impossible to justify to the investor.

## 3. Realising the Demands

Archaeological risk assessment demands a lot from a predictive map. In order to provide cultural resource managers with the best possible information, it is necessary to integrate the many factors involved in the formation of the archaeological record. Therefore only carefully selected, well-surveyed and small test areas form the basis of the indicative models.

The original predictive maps were combined with a landscape development model, a land use model and a data bias model. They visualise the changes in the landscape, different survey conditions and other influences on the quality of representation in the model. The inclusion of these models definitely improves the original predictive maps.

Figure 3 shows a hierarchical view of the principal components in risk assessment. If read from the bottom ('Data acquisition'), to the top ('Application'), the workflow and information dependencies can be traced as they were devised and used for the research project "Archäoprognose Brandenburg".

The main focus of this article lies on the section 'model building'.

## 4. Predictive Models

The predictive model aims to show the suitability of a location for prehistoric settlement (Kvamme 1999). The so-called "suitability model" developed during the research project is an indicative one and computes a metric value for the assumed suitability of a location for settlement.

The first step is to examine the environmental variables that characterise locations with known archaeological sites using explorative statistics and to define spatial correlations between them and the distribution patterns of sites. These correlations are taken to represent the causal relationships between prehistoric settlement activity and actual site occurrence.

In a second step these correlations are used to quantify the suitability of a specific location. In the case of Brandenburg four variables were taken into account: distance from water, height above sea-level, gradient and soil-substrate.

Testing different statistical methods with logistic regression it was possible to create predictive models with high spatial and temporal resolution. Test area 7 was particularly well-suited for statistical anaylsis.

Constant monitoring and documentation of the archaeology destroyed in this area has yielded a large quantity of high quality data. At the time of our research 295 archaeological sites had been recorded, mainly in the years after 1990 (Fig. 2). Open-cast mining areas are unique in that they provide 'total-survey' areas, in which it is almost certain that no site was destroyed without being at least superficially recorded.

The spatial pattern of the sites can therefore be considered to be representative and predictive models based on such a sample should be very reliable – ironically there will be nothing left of the predicted sites once the mining companies have finished their work.

One main result of the statistical calculations was the dominance of the variable soil-substrate as a factor in deciding where to settle in prehistory. In Figure 4 and 5 you can see similar boundaries in the soil map and the predictive map. The landscape parameters distance from water, height above sea-level and gradient are of relatively low importance. This result

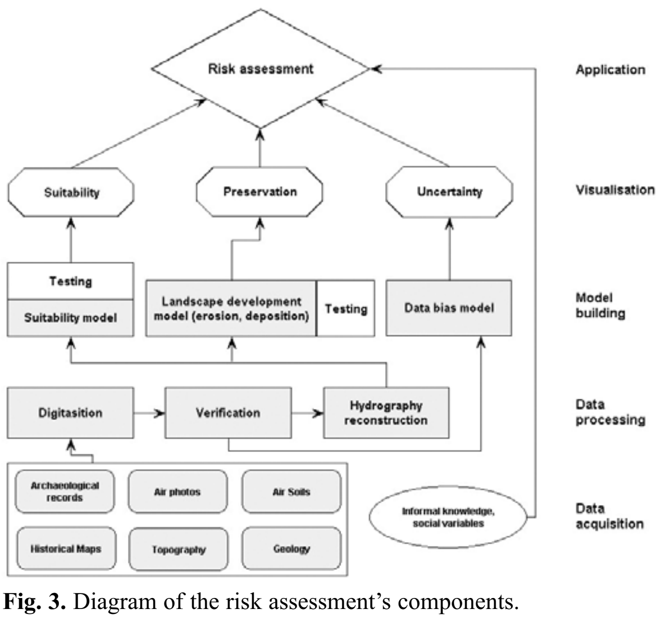


**Fig. 3.** Diagram of the risk assessment's components.

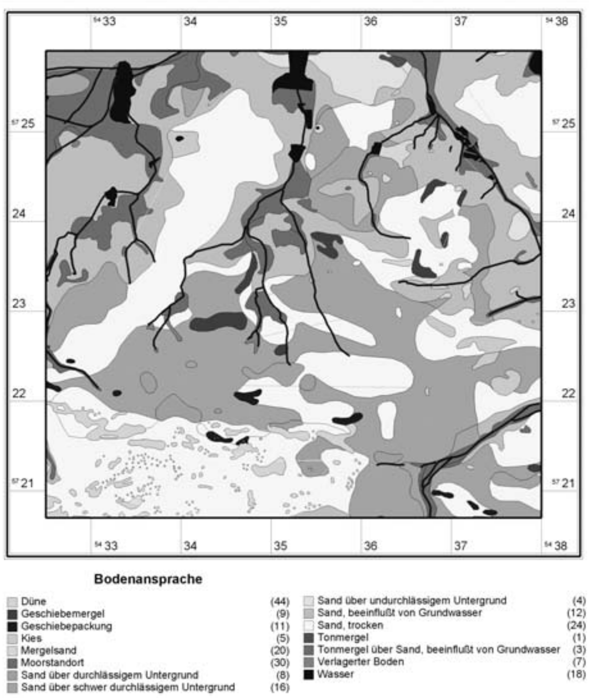


**Fig. 4.** Geological map of test area 7.

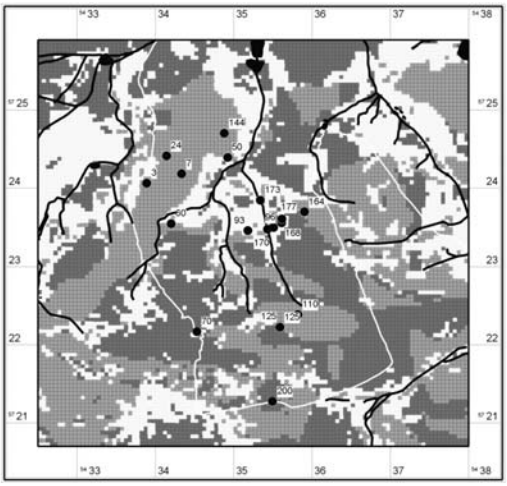

**Fig. 5.** Test area 4: suitability model based on logistic regression of environmental variables (medium grey = high suitability; white = medium suitability; dark grey = low suitability). Based only on sites of Corded Ware period and the early Bronze Age.

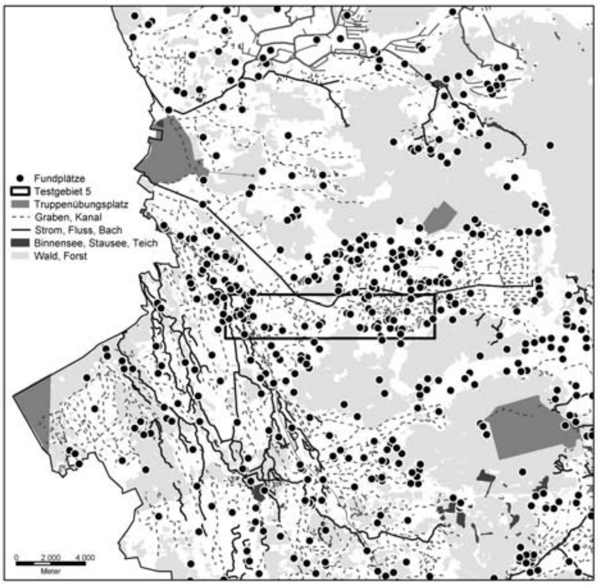


**Fig. 6.** Archaeological sites in areas of different land use (dark grey = military area; light grey = forest; white = fields).

was at first unexpected but the importance of soil type to farming cultures is not actually surprising. Soil development is also strongly influenced by relief and hydrology.

The predictive model shown in Figure 5 was calculated for the Corded Ware period and the early Bronze Age. The relative "suitability values" for prehistoric settlement in the area were divided into 'high' (marked in medium grey/red), 'middle' (marked in white/yellow) and 'low' (marked dark grey/green). The predictive models provide precise data for different periods and can distinguish between settlement and cemetery sites. This makes them not only suitable for use within cultural resource management but also of value in academic research as they can be used to illustrate changing settlement strategies.

## 5. Improving the Accuracy

In order to improve the accuracy of the predictive model and of archaeological risk assessment a number of models were developed to filter out biases.

A high-quality predictive model assumes that the data it is based on is as representative as possible. In practice, however, site-patterns are influenced by several different factors which influence the probability of detecting buried sites, their state of preservation and the strategies for managing and protecting them.

These research biases must be carefully observed and evaluated, and integrated into the predictive model. To keep the bias as small as possible, the test areas were carefully selected so they would be of characteristic type and as well surveyed as possible.

### 5.1 Land Use Model

The land use model provides information about the representativeness of the archaeological data base. Current land-use divides the landscape into areas of varying `archaeological visibility'. Figure 6 shows the known archaeological sites in areas of different land use.

In the military areas (marked in dark grey/orange) it is impossible to undertake survey work to find new sites and in the areas used for military training it is likely that they will be destroyed unrecorded.

The surface vegetation also has an effect: very few sites are known in areas covered by forest and most surface finds come from ploughed fields.

That test area 7 (the area with the largest number of archaeological sites) had approximately 50% forest-cover prior to the start of open-cast mining clearly shows that the impression of a 'find free' forest is merely a gap in the data.

### 5.2 Data Bias Model

The spatial pattern of the sites also depends on the amount of research which has been undertaken and the way in which the research was conducted. The resulting differences in the quality of the archaeological data produced can be summarized in a data bias model.

Field walking by students of the Humboldt University in the 1980s in the western half of test area 3 revealed a total of 64 new archaeological sites (Fig. 7).

The eastern part shows the situation as it was before any surveys took place, that is to say without any known sites. Pollen analysis from the area confirmed that this picture is due to a lack of sampling, not the absence of prehistoric settlements.

The pollen samples were found to contain quantities of cultivated cereal pollen that were significant enough to confirm the existence of agriculture in the area as early as the Neolithic.

Most other areas have been sampled by amateur archaeologists, resulting in non-representative site distributions that are determined by the amateur archaeologist's personal interests and habits. By far the largest proportion, about 80%, of all known sites fall into this category.

Figure 8 shows an example from test area 4. In this area Mr. Dietz, an amateur archaeologist, prefers to walk the fields

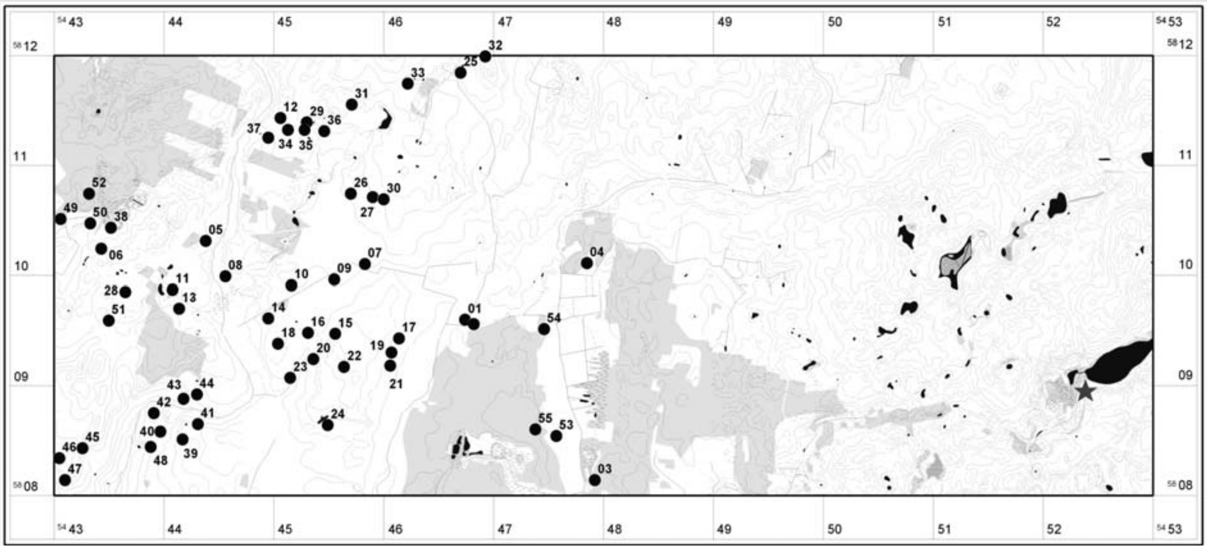


**Fig. 7.** Spatial distribution of reported sites in test area 3, clearly showing the boundary of students survey work (black dots)

near the Nuthe river where he has found several early neolithic sites in the past.

To get to his preferred areas, he uses his motorcycle, which limits his action radius to those areas accessible by road. In addition, he does not want to leave his vehicle entirely unattended and tries to keep it within sight.

As a result he does not walk the fields on the higher areas in the south of the test area. Aerial photographs and other surveys carried out in the southern area show that he would have a good chance of finding something there if he ever tried to!

### 5.3 Landscape Development Model

As an aid to decision making in cultural heritage management the state of preservation of a site is of as much importance as its assumed presence.

Site preservation is largely dependent on landscape development and usage.

In the areas of interest the development of the landscape is predominantly determined by processes of soil erosion and deposition. The spatial pattern of the direction and magnitude of these processes can be derived by applying a fully data-driven model.

Input data consists of basic topographical properties (concavity, convexity) and soil-substrate distribution – both of which have not changed their principal spatial pattern since prehistoric times. In this way, a reliable estimation of the preservation and visibility of sites in individual locations can be made and summarized in a landscape development model (Ducke 2004).

### 5.4 Additional Information

'Informal knowledge' (social variables) represent information which is hard to quantify and convert into a GIS layer. Social and cultural processes in general are considered to belong to this class of information. Not all spatial patterns can be attributed to easily quantifiable variables. Some locations would have certainly carried symbolic or other meanings that may have been manifested in the building of structures or deposition of artefacts.

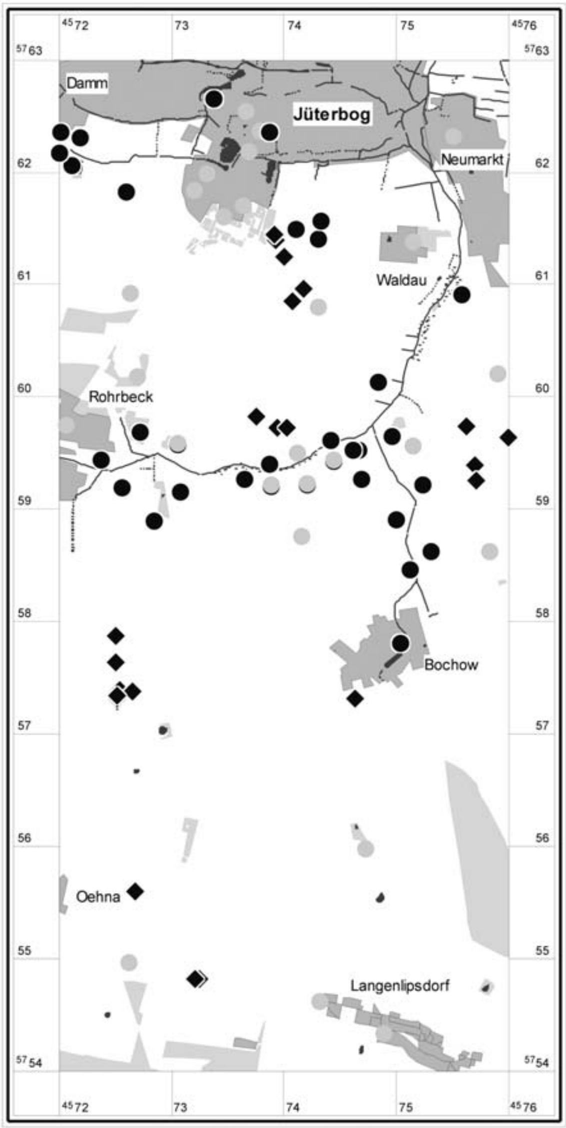


**Fig. 8.** Spatial distribution of reported sites in test area 4. The void uphill areas in the south reflect the local amateur archaeologist's movement pattern (black dots = Mr. Dietz; grey dots = other amateur archaeologists; black rectangle = survey done after integration of aerial photos and predictive models).

Nevertheless it is possible to integrate additional information. For well-researched periods minimum distances between settlements and settlement groups, their size and the regularity of settlement pattern are known. These site patterns, when compared with known sites, allow estimates to be made of the possible location of additional undiscovered sites.
It also becomes clear which periods and types of monument are possibly under-represented in the current archaeological record and therefore need special attention.

## 6. Conclusion

As has been explained, archaeological risk assessment is influenced by three types of 'information':

a. suitability for settlement
b. site preservation
c. uncertainty

The high number of known archaeological sites and the large amount of data on many prehistoric periods allows the calculation of precise predictive models. As an improvement on current practice, the final risk assessment can now take "site formation" processes into account which is essential for improving the standard of cultural resource management.

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