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Archaeological Predictive Models
for the Elbe Valley around Dresden, Saxony, Germany

Abstract: Three archaeological studies were conducted preceding the construction of a motorway from Dresden to Prague. In 1996 a predictive model was developed to assess the archaeological relevance of the trajectory. The following year a survey was conducted which demonstrated the existence of several areas with high archaeological relevance. From 1999 to 2003 the full length of the trajectory was prospected by trial trenching in order to assess the precise location and extent of archaeological sites. Subsequently, all sites were excavated. During the following research project the results of these studies were compared and two predictive methods were used to develop new predictive maps for the trajectory and the Dresden Elbe Valley. Both methods were found to be useful depending on the context in which they are applied.

Introduction

The Free State of Saxony lies in the middle-south-eastern part of Germany, adjacent to Poland in the east and the Czech Republic in the south. The State Office for Archaeological Heritage in Saxony is responsible for the archaeological heritage management, monitors all building activities and conducts the necessary rescue excavations. Apart from these responsibilities, the State Office conducts and supports scientific research.

A new motorway from Dresden, the capital of Saxony, to Prague was officially opened to the public in December 2006. Preceding the construction of this motorway, the State Office for Archaeological Heritage had conducted three different studies in the area covering the first 25 km of the motorway trajectory and its immediate surroundings on the southern border of the Elbe valley *(Fig. 1)*. The last 20 km of the motorway, leading to the Czech border through the mountainous region of the Ore Mountains, have also been excavated but are not examined here.

The Elbe valley around Dresden is characterized by a clear structure in its physiography. In the northeast there are high sandy plains, with steep slopes toward the Elbe valley floor. Loess covered slopes gradually rise from the southern and southeastern edge of the valley floor and eventually form the foothills of the Ore Mountains in the south.

Previous Research

In 1996 a predictive model was developed (Hartsch 1996; Hartsch / Smolnik 1998) to assess the archaeological relevance of the trajectory, covering an area of approximately 25 km by 2 km. Several geomorphological features as well as the known sites were mapped and subsequently combined. The features were weighted and then grouped by three main themes: geomorphology, soil types and vicinity to known sites. Subsequently, the themes themselves were weighted and the output map was calculated.

The main goal of this project was to develop a model that could also be used for other areas in Saxony. This goal could not be reached and two main reasons why will be briefly discussed here. Firstly, the method of weighting caused anomalies in the output map, since the weighting of the classes of some features was lost in the subsequent grouping of the features. As a result, areas with poor geomorphological values were nonetheless marked as highly relevant in the output map. Secondly, almost all the known sites in the study area were medieval villages, but their specific locations do not indicate the existence of other, prehistoric settlements in their vicinity.

At the time the model was developed there was not a great deal of experience in Europe on the methodology of predictive modeling. Some studies were in progress for areas in Germany or abroad but not yet published. This project was thus one of the pioneer projects.
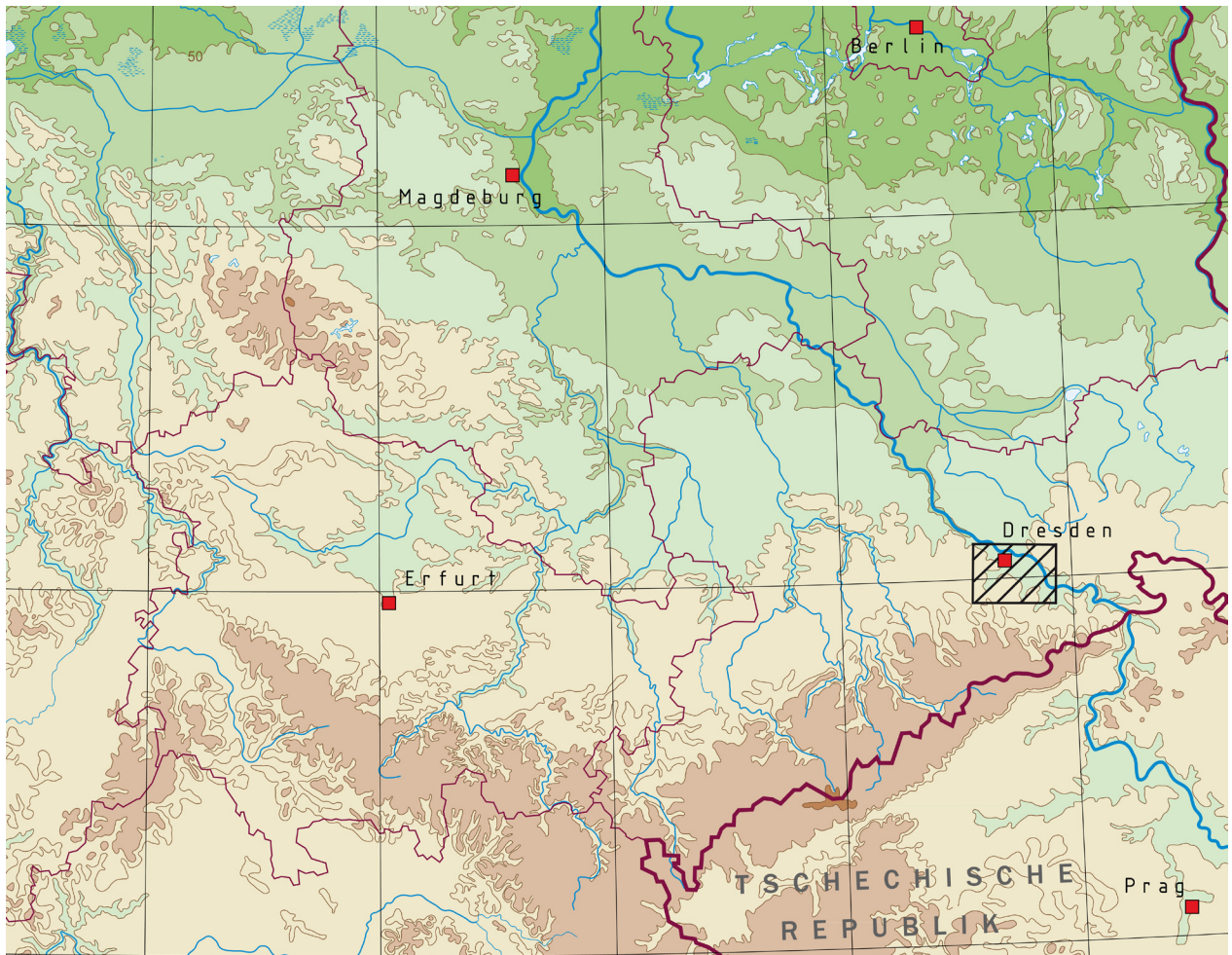
Fig. 1. Location of the study area (in black hatching) in Saxony, Germany.

The survey demonstrated the existence of at least ten highly relevant areas in 1997, mainly situated in regions of average archaeological potential according to the predictive model (Abbingh 1997). The ten relevant areas were defined on the basis of findscatters of predominantly bronze and iron age pottery fragments. The areas did not all lie in the immediate trajectory of the motorway, so that the archaological value of most of these areas could not be verified during the following prospection.

Ultimately, the full length of the trajectory was prospected by trial trenching, removing the top soil in two trenches of about 5 m width, in order to assess the precise location and extent of archaelogical sites. Subsequently, the top soil in those areas was removed and all sites were excavated (Stäuble / de Vries 2002). Prospection and excavations were conducted over a four year period, from 1999 to 2003. A total of 25 sites have been excavated during that time: some with less than ten, most with several hundreds, and a few with over 1500 features. These

sites, all of them settlement areas, dated from the Early Neolithic to the Slavic Period.

Predictive Modeling

As previously obtained knowledge about site distributions and localisation preferences is always inductive, predictive modeling can never be purely deductive. Nevertheless, for inductive and deductive methods some problems can be adressed. In deductive modeling, which depends mainly on the theory-based weighting and combining of geomorphological features, one of the problems is the probability that the choice of a location depended merely on some of many important criteria, as the consideration of all criteria probably would take too much time and effort. To determine which ones are important in a given case is virtually impossible, as they also might vary from case to case. In a previously uninhabited area the choice might even have been
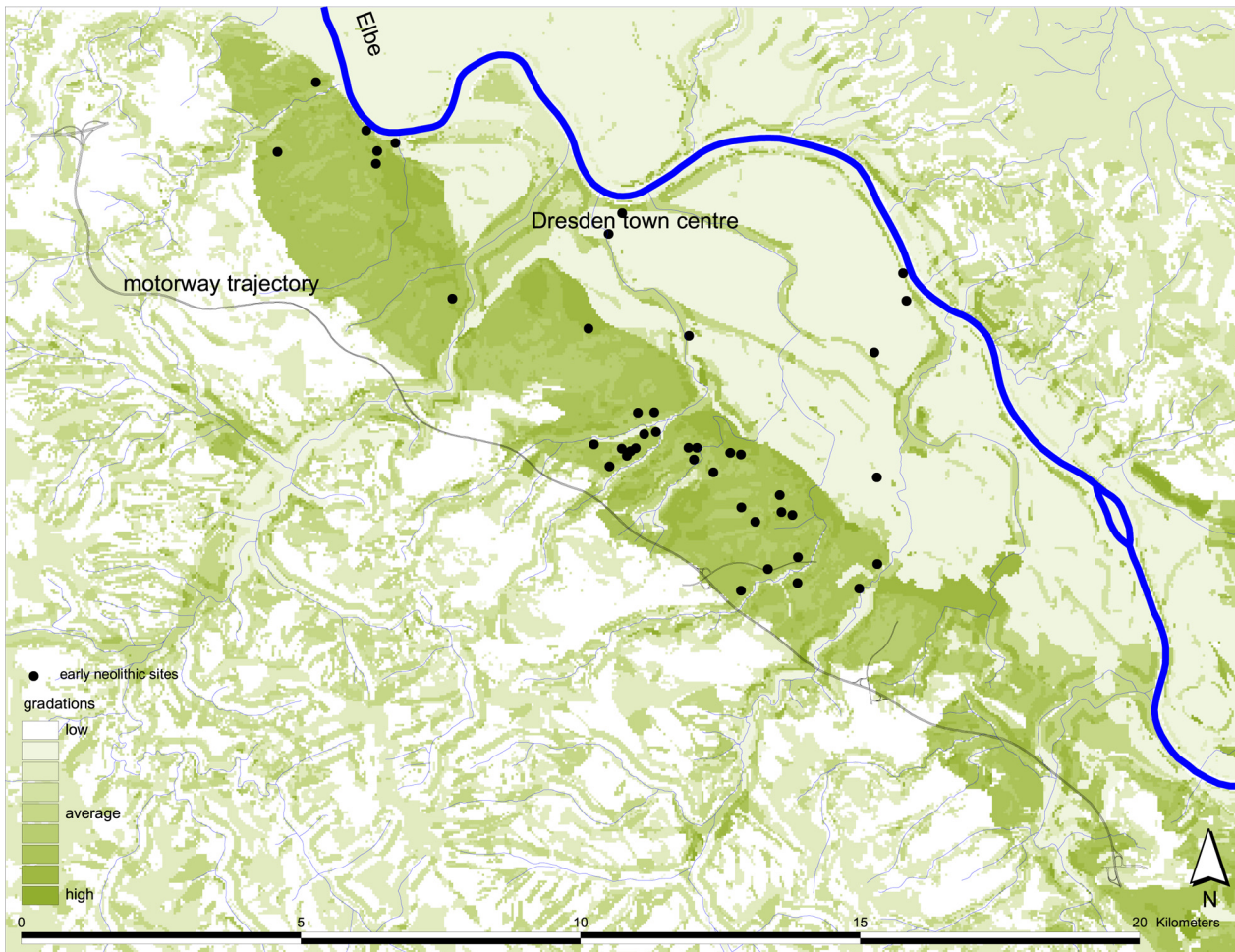
Fig. 2. Weights of Evidence method: preferred location of Early Neolithic settlements.

made on the basis of only one or two criteria. Social or economic criteria probably played a role too, but these are difficult to map and therefore seldom incorporated. The contemporary theories about settlement systems form a problem too, as those theories vary with changes in the interpretation of human behaviour and are modified according to the spirit of the age. The predictive model should be adjusted accordingly each time, but then the question arises if deductive methods can sufficiently model prehistorical location preferences in general (Kohler / Parker 1986).

The problem with any inductive method is that they will predict the occurance of sites mainly in already known or similar locations, because the methods use the – often strongly – biased archaeological record. Areas without any known sites on the distribution map are often interpreted as uninhabited but often can be explained as a hiatus in our knowledge. The results of inductive modeling can only be as good as the quality of the available data. If the

"jack-knife sampling method" – dividing the known sites in two random groups, of which the first one is used to build the model and the second group to verify the results – is used in an inductive method, this will only lead to confirmation of the already existent circular reasoning (Ebert 2000). Furthermore, inductive predictive models ignore the fact that sites are parts of more or less organized systems instead of singular phenomena. Their localisations depend on the localisation of other sites within those systems which of course changed as time passed.

In general, the goal of predictive modeling should be more than just the production of a predictive map. Furthermore, it should lead to an explanation of the existent patterns and settlement systems in which the actual value of the modeling is to be found.

During the research project, the three studies (predictive model, survey and excavations) were compared. The results of the excavations were reviewed and described. Also, new archaeological predictive
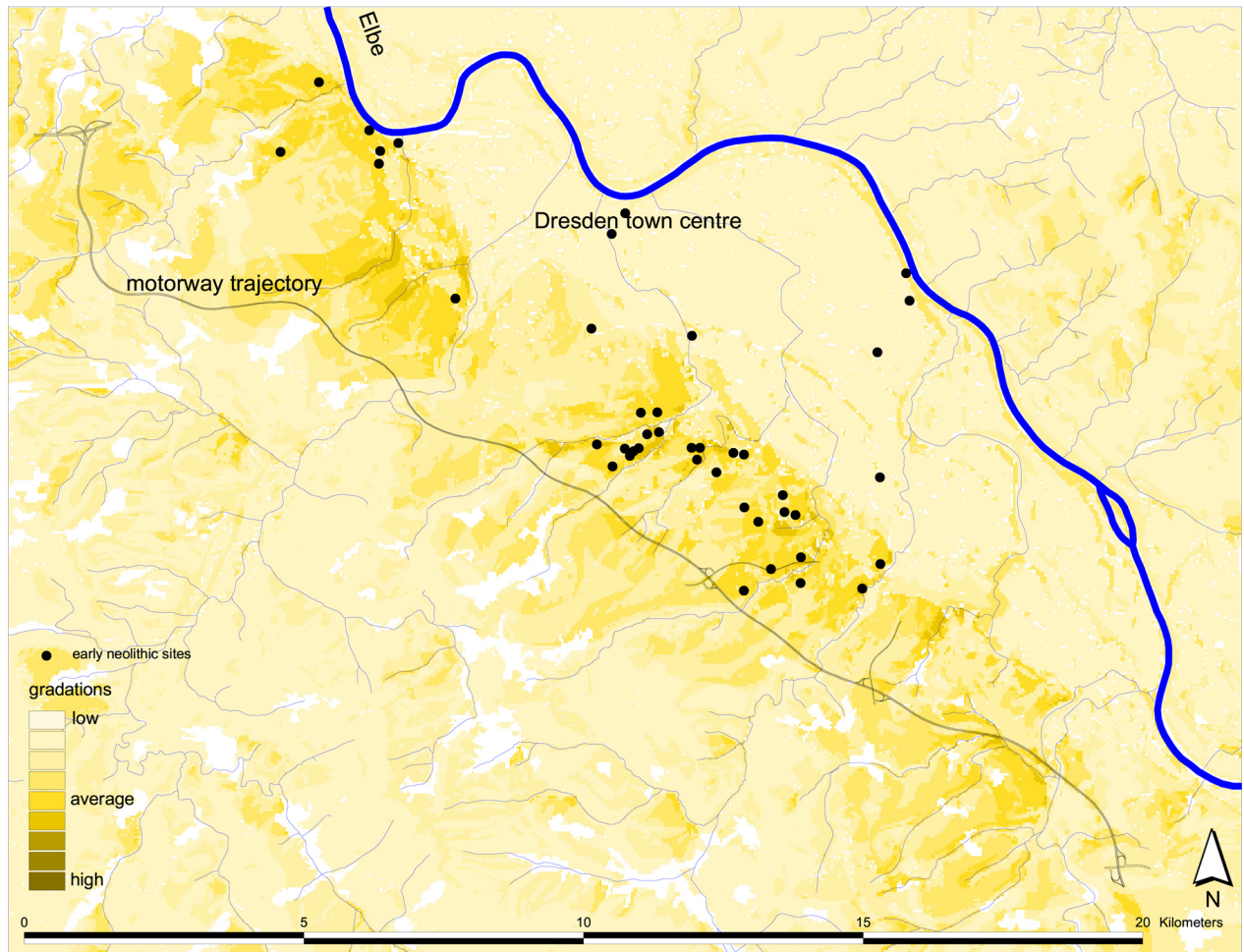
Fig. 3. Belief Model, belief map: preferred location of Early Neolithic settlements.

models were developed, which not only covered the area of the motorway, but were extended to the Elbe valley around Dresden (DE VRIES in press, Fig. 1). For the Elbe valley around Dresden a selection of all known sites in the area under study was made. The inventory lists of the State Office listed many "sites" on the basis of only some stray finds, as well as single finds and depots, which were not regarded in this study. Subsequently, the existing theories about settlement systems in the Dresden Elbe valley in consideration of the recent increase in known sites were then evaluated and, for some periods, slightly revised (cf. JACOB 1982; BRESTRICH 1998).

The predictive models were based on the geomorphological features of height, slope, aspect, soil type and vicinity to watercourses. The mapping of these features was conducted in ArcView, a GIS programme in which also the further combining took place. The models were not applied for all cultures and periods grouped together nor for burial sites and settlements together. Instead, archaeological cultures or periods were distinguished and settlement and burial sites were separated, to be able to visualize differences in settlement and burial systems. Simple chi-squared-tests allowed the recognition of major anomalies in the presumed standard distributions of the sites (SHENNAN 1988).

For the models themselves, two different predictive methods were used and compared, an inductive one and a deductive one, in which the known sites were not integrated[1].

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[1] A list with all relevant literature on the theory of predictive modelling in archaeology would be far too long, so only a selection of the literature used for this study is given here: Deeben et al. 1997; Kamermans / van Leusen 2005; Kvamme 1990; Lock / Stančič 1995; Lock 2000; Wescott / Brandon 2000.
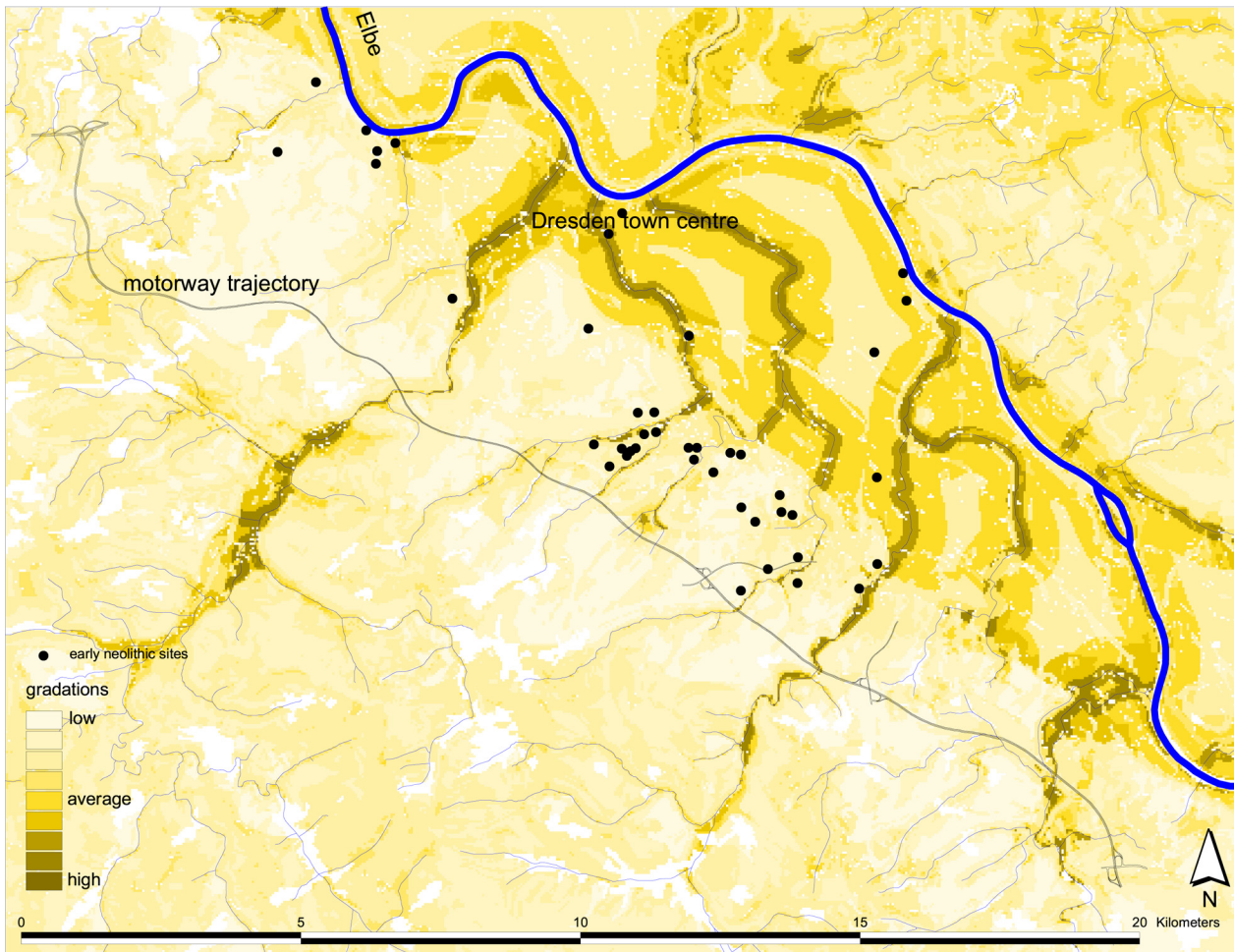
Fig. 4. Belief Model, belief interval map: possibly preferred location of Early Neolithic settlements.

The inductive method used in this study, known as the Weights of Evidence method, had been already programmed as an application for ArcView (KEMP et al. 2001). It was originally meant to predict the occurance of geological layers and features by means of few known other features. It can also be used for archaeological objectives, the known features being the known sites. The easy-to-handle application leads through the modeling steps in which for each feature classes have to be defined and weighted. The application offers more possibilities than described here, as they were not used in this study.

The so-called "belief model" functions without using the distributive pattern of known sites (although they can be incorporated too) and allows uncertainty to be accounted for (EJSTRUD 2003; EJSTRUD 2005; SENTZ / FERSON 2002; SMETS 1994). Not every method that models uncertainty is a Dempster-Shafer method, so here the more neutral term "belief model" has been used. The method was applied following an example of how to develop such a model in ArcView (LORUP 1999). The determined classes of each geomorphological feature can be weighted, and for each feature a separate map is made. The features themselves can be weighted too, and then their maps are combined to ultimately generate the belief map. This method leaves a lot of freedom in modeling and the weightings can be adjusted very quickly.

The belief map models only the best areas for a certain category of sites. This map is basically the same as the maps of most other methods would produce. Those localisations that one would already presume on the basis of present knowledge are emphasized in the map. Then, two more maps can be calculated. The plausibility map not only shows the highly preferred regions, but also models those areas where sites – according to the weighted features – are likely to occur. This plausibility map can consequently model a larger favourable area than the belief map. By subtracting, so to
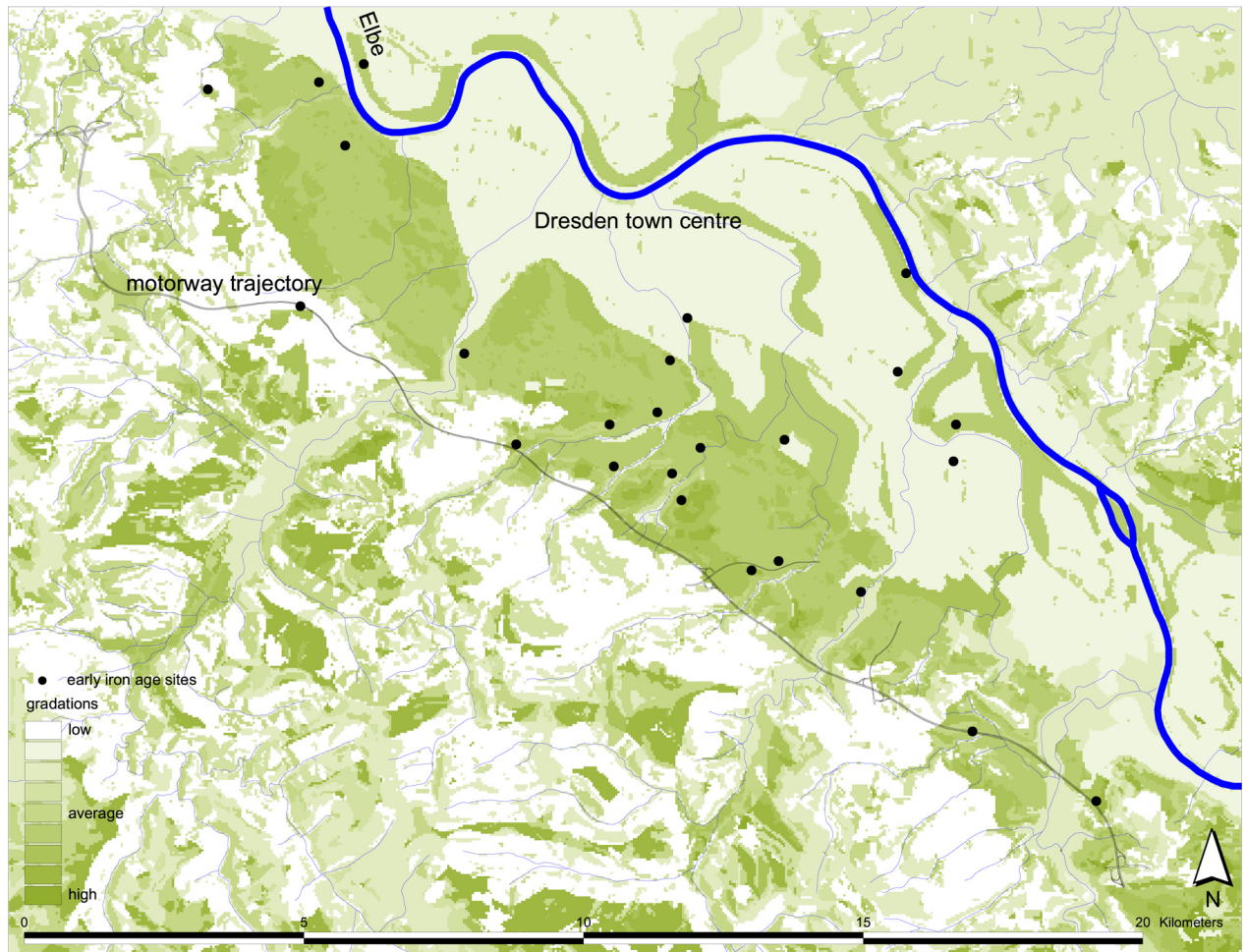
Fig. 5. Weights of Evidence method: preferred location of early Iron Age settlements.

speak, the belief map from the plausibility map, the third map is created. This belief interval map now shows only those areas where an occurance of sites is likely to be, again only according to the features and the weighting of the classes. The areas might have been previously underestimated in their archaeological value, as their suitability for settlement might not have been very clear. From an archaeological point of view this map is therefore the most interesting.

Results

The modeling results of two periods, the Early Neolithic and the early Iron Age, and of both methods will be given in the following. The plausibility maps are not shown here.

The first example deals with the preferred settlement areas during the Early Neolithic period, the linear pottery culture (LBK). The settlement sy-

stem of the LBK is well known: the settlements were mostly situated on not very steep loess covered slopes in the vicinity of brooks and small rivers. This is also the case in the Elbe valley around Dresden and both predictive methods model this very nicely *(Figs. 2, 3)*. The belief interval map *(Fig. 4)* shows those areas where an occurance of sites is likely. For the linear pottery culture this would be the Elbe floodplain.

There was some archaeological proof of the presence of people in this area during the Early Neolithic but it was assumed that the floodplains, for obvious reasons, were not permanently inhabited (Quitta 1969). In 2002 however, an excavation near one of the former Elbe channels presented something different: a small village with at least three longhouses existed here during the period under study. This could be a local adaptation or variation in settlement system, but it is possible that floodplains were inhabited also in other regions in western Europe where this culture was present.
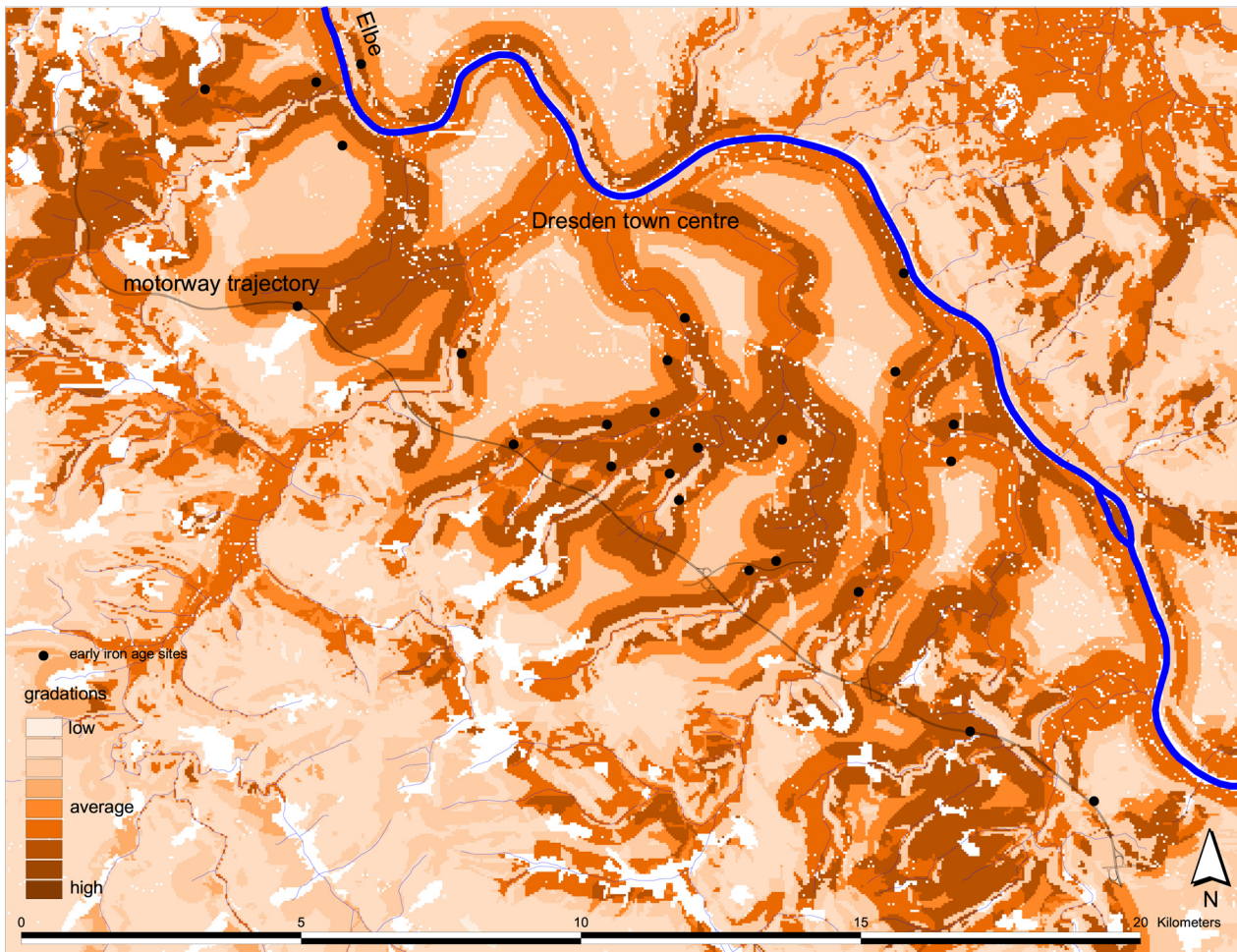
Fig. 6. Belief Model, belief map: preferred location of early Iron Age settlements.

If this were to be the case, then the postulated settlement system for this period will have to be adjusted.

In comparison, the second example deals with the preferred settlement areas during the early Iron Age. The settlement system of this period still appears not to be very clear and only 25 settlements are known in the area. The map of the Weights of Evidence method shows the loess slopes as having been the most preferred settled areas *(Fig. 5)*. The belief map differs quite clearly from that map *(Fig. 6)*. Here, the loess slopes are generally marked as an area where settlements probably occur but the vicinity to watercourses is the main important feature. The belief interval map models areas on the valley floor and areas on the loess slopes in greater distance from watercourses where an occurance of early Iron Age settlements would have been the most likely *(Fig. 7)*.

During the last five years some settlements dating from this period were excavated in geomorpholo-

gically similar regions just outside the study area. This leads to the assumption that this settlement pattern might also be present in the study area. The different choice of locations – near to or far from watercourses – probably reflects differences in subsistence systems during this period, but the finds record of the excavated settlements does not allow explicit statements about this yet.

Conclusion

Apart from the resulting predictive maps and their archaeological interpretation, the comparison of both methods and determination of their suitable appliance might be of assistance when choosing a method for future projects. In this study it was established that the Weights of Evidence method offered good possibilities to assess the archaeologically relevant areas of a previously less intensively researched region. It can also be used to obtain fa-
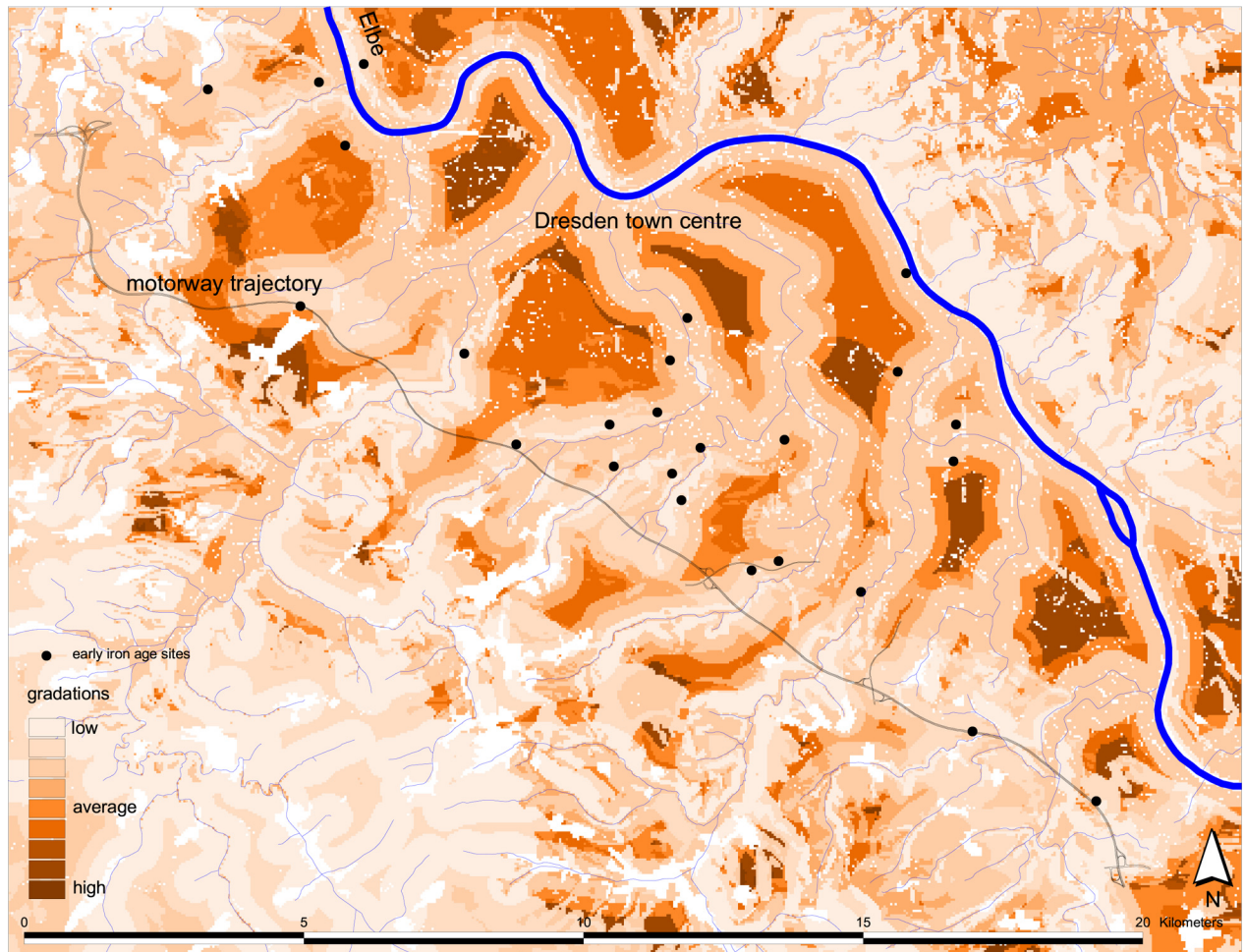
Fig. 7. Belief Model, belief interval map: possibly preferred location of early Iron Age settlements.

miliarity with an area in relatively short time. As soon as the necessary geomorphological features have been digitally mapped the method can be easily and quickly implemented.

The belief method used in this study is the most suitable for regions that have been researched intensively. Whereas it is more difficult to assess the accuracy of the model maps, the deductive method can produce results that will enhance previously obtained knowledge by means of mapping of degrees of uncertainty. In order to gain the best results, the settlement systems of the periods under study should be fairly well known in advance.

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