Iterative approach to ancient paths modelling in the Iron Age study of the Dolenjska region (Slovenia)

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Abstract: In this paper we analysed the potential routes between Iron Age settlements. In order to obtain optimal paths, classical GIS-domain algorithms based on the least-cost distance grid analyses, involving isotropic and anisotropic friction and applying different weights based on cognitive perception and common knowledge of the landscape were employed. Our model employed the digital elevation model (DEM) only as spatial data. Our case study area was the central-southern part of Slovenia, named the Dolenjska region, which is limited by natural boundaries of the river Krka on the south-west side and the river Sava on the north-east. Taking archaeology into account, this is the most explored territory of Slovenia. More than 400 late prehistoric sites have been registered with surveys, excavations and digging trenches. Within the framework of the project "Late prehistoric settlement pattern in Dolenjska", conducted by the Institute of archaeology, records have been gathered for the last 20 years. It can be seen that paths in the hilly terrain generally follow the ridges, however on the flat plains numerous potential routes can be noticed. Alternative paths have been statistically

and visually evaluated and related to the known late prehistoric remains and evidences.

Key words: ancient roads, least-cost distance analyses, optimal paths, DEM

Introduction

Our research focussed on the potential relationships between Iron Age sites, based on the anticipation that prehistoric people used natural paths (Bellavia 2002) in order to move through the landscape, and the general idea that the natural topography has not changed significantly since the prehistoric period. Furthermore, it might be expected that the paths of movement run between the sites and monuments placed near to them, and that the most basic personal spatial experiences are shared with prehistoric populations in our common biological humanity (Tilley 1994).

The study area is the central-southern region of Slovenia, named Dolenjska, which is limited by natural boundaries of the river Krka on the south-west side and the river Sava on the north-east (Figure 1). 14 Iron Age settlements from a total of 38 documented in this area were selected and we studied 18 paths that run between them.

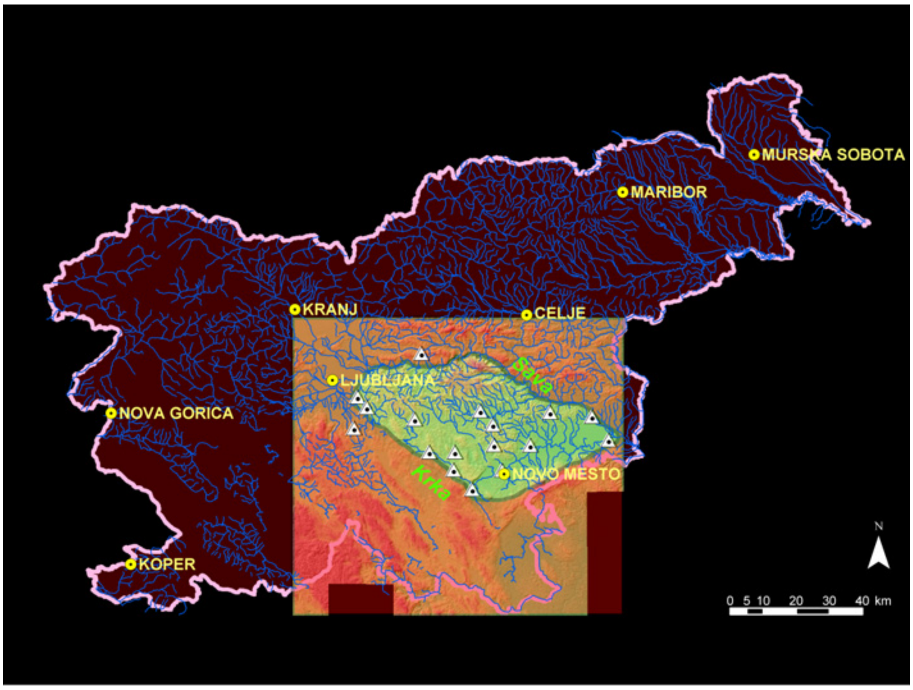

Figure 1 - Case study area: Dolenjska region (100 x 90 km).

Geographic features

The major part of the Dolenjska region is represented by a hilly terrain with altitudes ranging between 200 m and 600 m, except for the north-west part, where the altitude exceeds 600 m above sea level, and the floodplain, extended along the lower course of the river Krka, where the altitude does not reach 200 m. The typical difference between the valleys and ridges is less than 300 m (Figure 2).

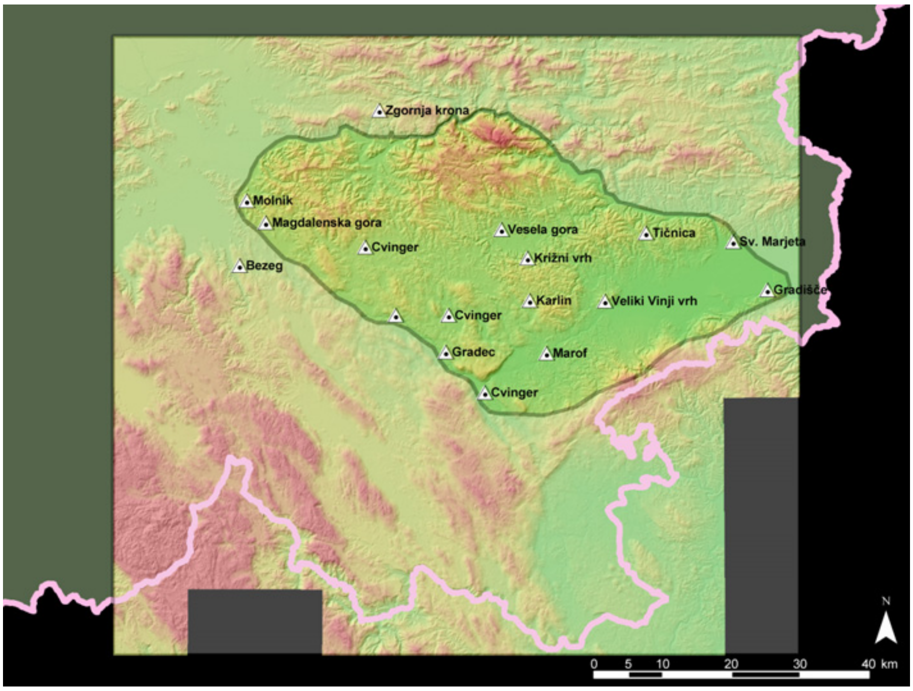

Figure 2 - Terrain.

The surface of this region is predominantly covered by limestone formations and dolomite karst with deposits of lead, zinc and iron ore (Figure 3).

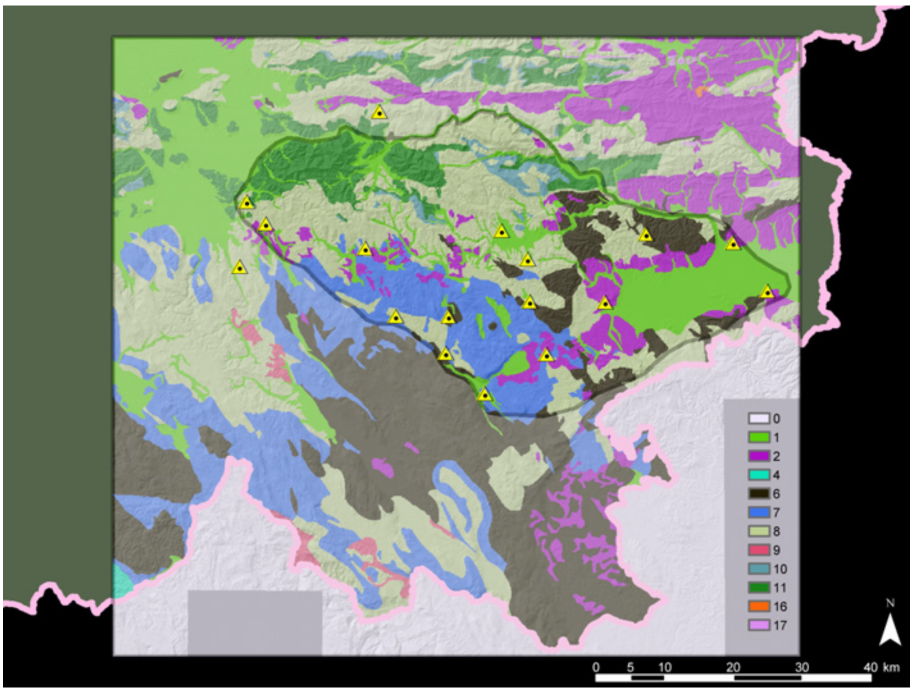

Figure 3 – Geology (1 = alluvium; 2 = orogenetic sediments; 4, 5 = flysch; 6, 7, 8, 9, 17 = carbonate sediments, 10, 11 = classtic sediments, 16 = Andezite and Dacite).

The territory is rich with water with the exception of the western part, named Suha Krajina, which means dry country (region). The watercourses are short and passable and do not represent a serious natural barrier for movement, except for the rivers Krka and Sava, which are navigable (Figure 4).

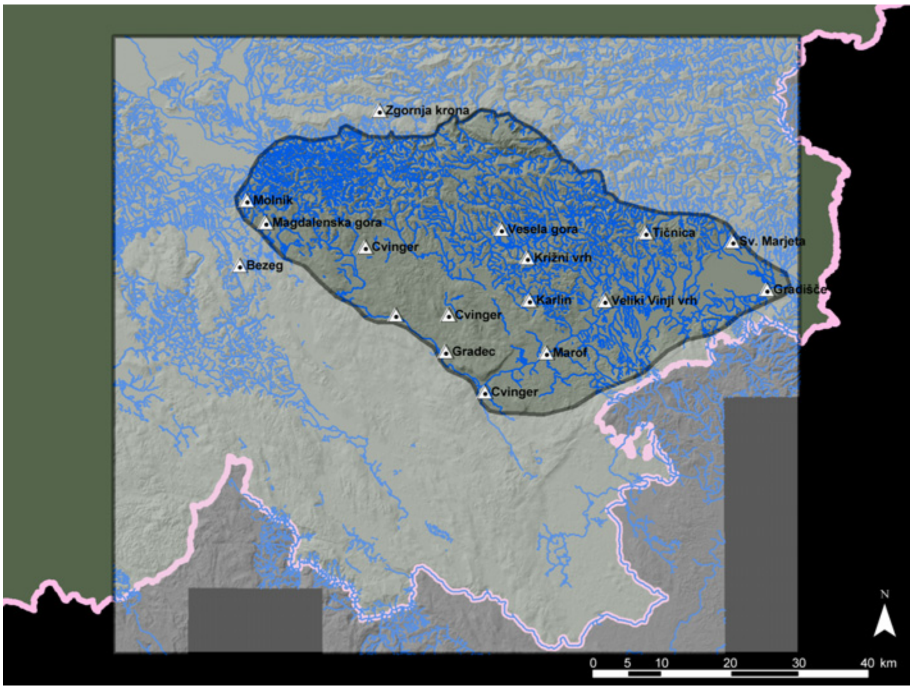

Figure 4 - Watercourses.

It has a moderate continental climate. The precipitation regime has its peak in the summer and the lowest point in the winter. The threat of avalanches is barely likely. Floods seasonally occur along the river Sava and in the plain of Krka, which is partially marshy. Today forests cover two thirds of the surface, while the rest consists of vineyards and cultivated fields or meadows. It can be seen that the variations of the local environmental conditions and climate regime are not drastic, so we presume they have a minute significance for the analyses of paths.

Archaeological records

Concerning archaeology, this is the most explored territory of Slovenia. More than 400 late prehistoric sites have been registered with surveys, excavations and digging trenches. Within the framework of the project Late prehistoric settlement pattern in Dolenjska, conducted by the Institute of Archaeology (Dular 1994) records have been collected for the last 20 years (Figure 5).

Figure 5 - Iron Age settlement of Cvinger by Dobrnič (photo J. Hanc).

Archaeological records consist almost entirely of settlements, tumulus cemeteries, single barrows and deposits of artefacts. Until now no remains of prehistoric roads were discovered, except for a probable road, which is still under discussion. This probable road has been revealed last year during a preventive excavation for the purpose of motorway construction and so far it is not clearly confirmed as a prehistoric road.

The predominant type of the late prehistoric settlement is a hill fort, situated on top of the hill (Stančič et al. 1995). The majority of burial barrows are located on the ridges of hills (Dular 2003). This choice of localities on landmarks that must have been dominant within the local environment seems highly significant, and this fact is also considered in our study (Figure 6).

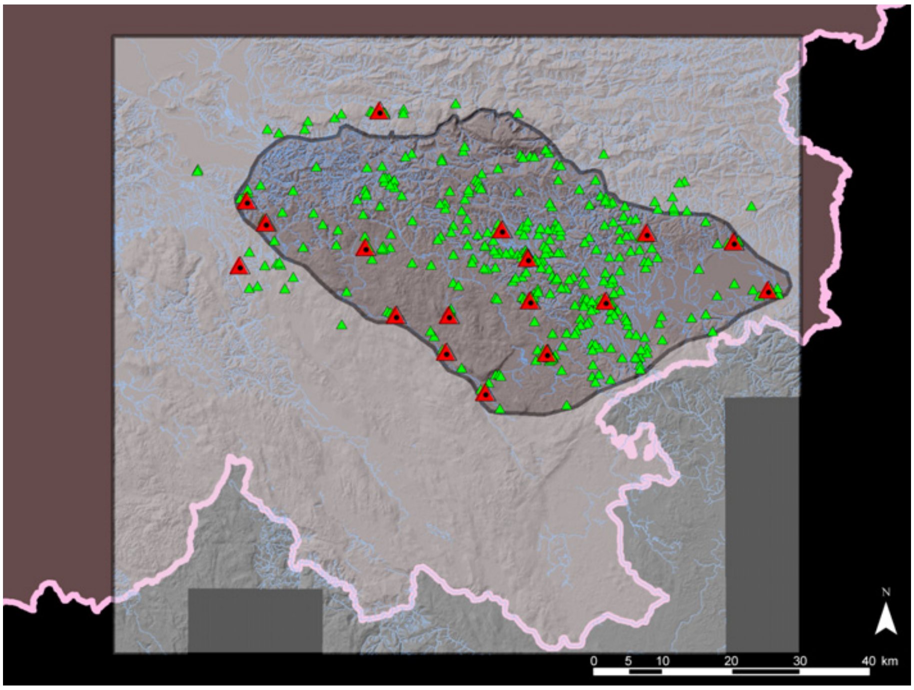

Figure 6 – Archaeological sites.

Assumptions of the model

On the basis of the similarities of archaeological remains, we assume strong contacts and exchanges between the settled Iron Age centres (Figure 7). Our assumptions of the optimal paths modelling were the following (see also Harris 2000):

- on the predominantly hilly terrain in our case study geomorphology is assumed as the most important factor,
- climate regime and other environmental conditions such as marshy soil, size of the rivers, vegetation, geology could also be of importance; however, we suggest that these conditions have not been changed drastically to the present day,
- evidence of boats for river movement and wagons are not available, so we assume the settlers used to walk between the chosen settlements within the landscape,
- the impact of cultural and socio-economic factors on the decision making process.

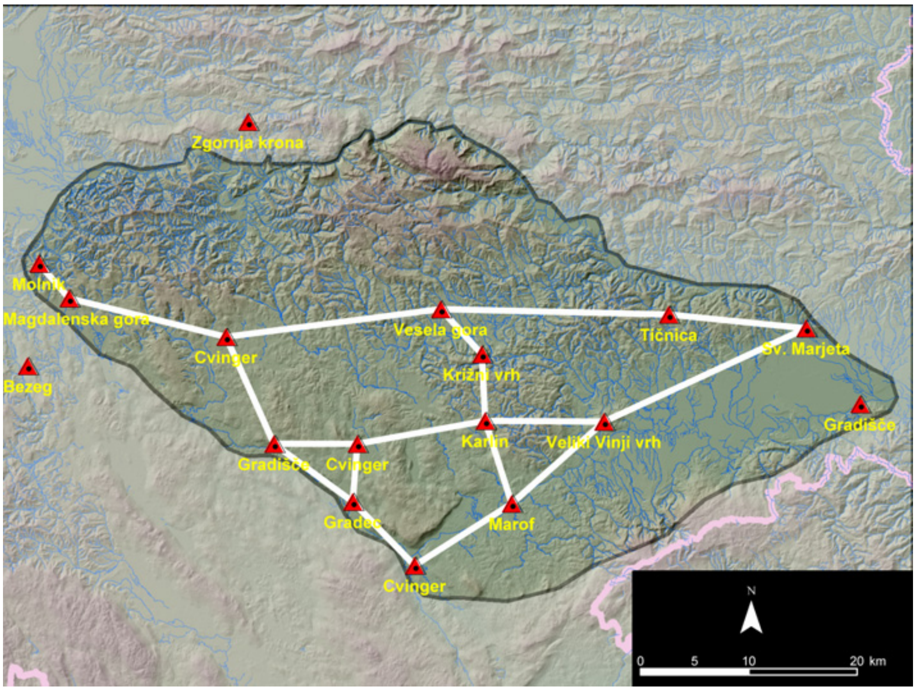

Figure 7 – 18 links between case study settlements.

The model of the ancient paths simulation

Our task was to find an appropriate algorithm for predicting the optimal natural path between Iron Age settlements using the best walking strategy. We used classical GIS-domain algorithms and tools based on the least-cost distance grid analyses that are in most cases useful for determining optimal paths from one or more points of origin to one or more destination points (Lee and Stucky 1998). The optimal path may be based on numerous criteria. The basic friction surface could be the Euclidian distance that produces a straight path. More complex paths with different applied frictions are scenic, strategic, hidden, withdrawn, etc. (Lee and Stucky 1998, Bellavia 2002). Our friction surface was based on the slope of DEM and a path modelled under such conditions is considered to be the optimal economical path. We involved isotropic and anisotropic frictions. The anisotropic approach allowed different friction regarding both possible directions between two settlements (Figure 8).

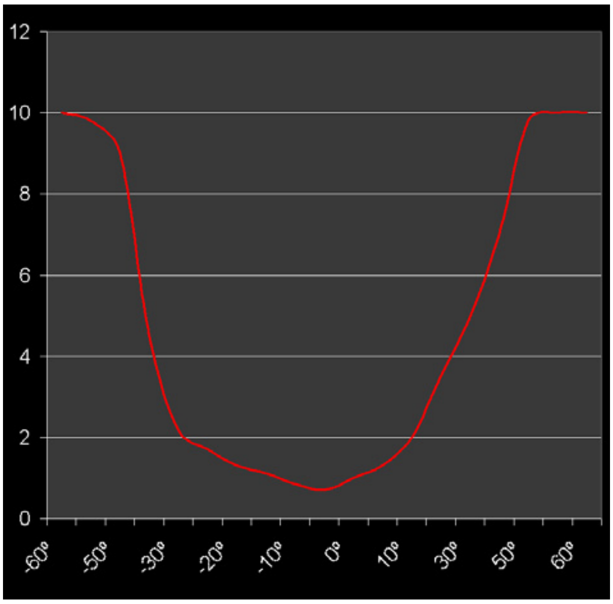

Figure 8 - Anisotropic friction (down-/uphill) as friction.

As we assumed at the beginning, the most important factor that influenced the path modelling was geomorphology. For this purpose we used a high accuracy InSAR DEM 25 – digital elevation model with the resolution of 25 m, produced with radar interferometry and enhanced with other DEMs (Podobnikar et al. 2000). Its main advantages are found in geomorphologic homogeneity, high height accuracy of approximately 5 m and low appearance of gross errors. For path modelling it is important that DEMs resolution, height accuracy, expanse of gross errors, smoothness and other attributes that approximate a real surface, are appropriate as regards the strategy of movement (walking, driving…) and the possible intervention into the landscape (paths, roads and even bridges, tunnels…). For example, it is preferable to use a smoother DEM to model road lines instead of paths.

It is well known that even with a slightly different quality of DEMs we can obtain completely different results of path simulation. A possible way to test such conditions is to apply the Monte Carlo simulation of DEMs heights. However, we decided to change some other model parameters:

- friction surface regarding different slope classification,
- applying isotropic and anisotropic friction,
- biasing the modelled path direction by applying an additional transversal slope to DEM (linear and parabolic) towards the shortest line between two settlements.

With the listed empirical adjustments of the model parameters we produced different routs (Figure 9). With intermediate control by an experienced field surveyor and considering a greater number of assumptions for the behaviour of walkers, we gradually produced more realistic paths with less spatial variations (step by step the paths were more similar to the previous ones). To illustrate the described procedure: at the beginning we produced friction surface using legends of hiking maps, than we comprised more sophisticated knowledge regarding Llobera (2000:71), Bell and Lock (2000), Pandolf and Givoni (1977)… According to Minetti (1995) we assumed that a longer path means higher energy consumption, we can not obtain energy on the way down, human muscles are less effective than man made machines, metabolically the minimum is reached by 0.15–0.17 m/s uphill and 0.20–0.50 m/s downhill, metabolic and speed optimisation is at slopes ± 25 %. We should also suggest (but we did not apply) that a slightly different position of the starting point (settlement, approximated with a point) in some geomorphology configurations could cause simulated paths, which would be considerably different.

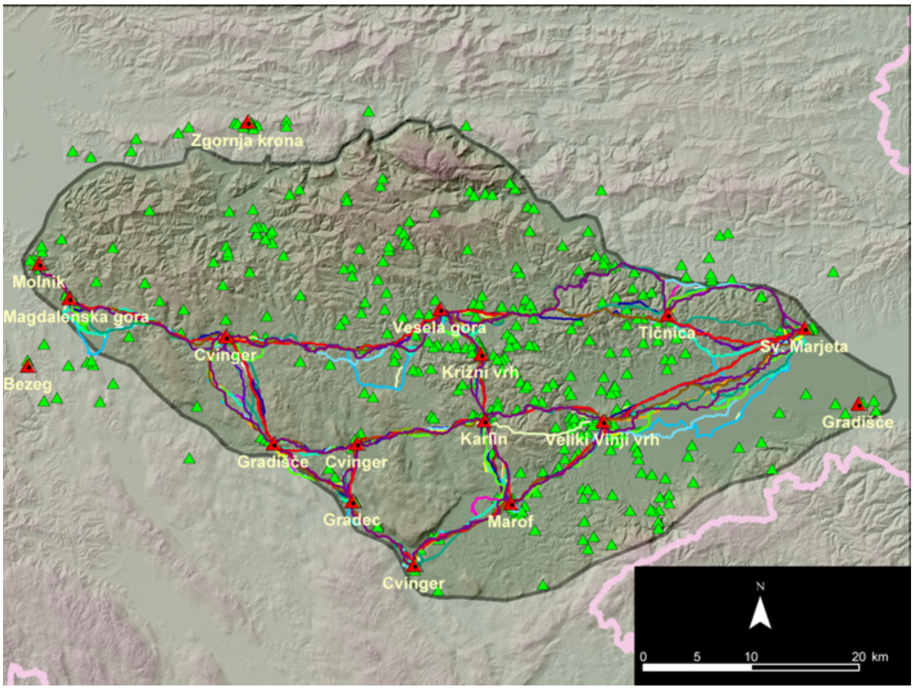

Figure 9 - Path distribution according 648 simulations.

Testing the path models

After producing nine different algorithms, all with iso- and anisotropic frictions, on 18 links between settlements, using various parameters to produce path models, we decided to extract the best ones. For this purpose we suggested to use or produce the following reference data:

- (1) *empirical and deductive*: a field surveyor with the knowledge of the archaeological sites drew paths using digital maps in the background (using hill-shaded DEM, the hydrological network, springs and lakes),
- (2) *empirical and subjective* (cognitive mapping): four non-archaeologists with not a lot of knowledge about ancient paths and topography drew paths

using digital maps in the background (hill-shaded DEM, the hydrological network, springs and lakes),

- (3) *mathematically*: generating Euclidean distances between pairs of settlements,
- (4) *using a database*: selecting barrows that are near to the paths (Figure 10).

In all the cases we calculated the deviation between the described paths (or barrows) and the modelled paths. Thus we calculated the following parameters: minimal distance, maximal distance, mean distance and standard deviation of divergence for both groups of lines. As the most important we considered the minimal and mean distance. Empirically we also suggested a relevance list of the described four groups of data, ranges from (1) to (4) with the highest relevance of the view of the experienced field surveyor and with the lowest relevance of the significance of barrow positions. It was also not really reasonable that the cognitive mapping (2) in our case was not as relevant as we expected. The problem lies in the different previous knowledge of the landscape, the level of interpretation of topographic maps (hill-shaded DEM), imagination of ancient paths, different perception of the environment, etc.

However, after all the set criteria the best considered algorithms are those with numbers 6, 9 and 7. Within all of them we implemented frictions according to Minetti (1995) with the condition that slopes over ± 30º were more weighted. In algorithm 6 we employed an additional moderate transversal linear slope of 5% to DEM, in algorithm 9 – an additional moderate transversal parabolic slope, and in 7 – an additional high transversal linear slope of 12 %. The best considered algorithm was that with number.

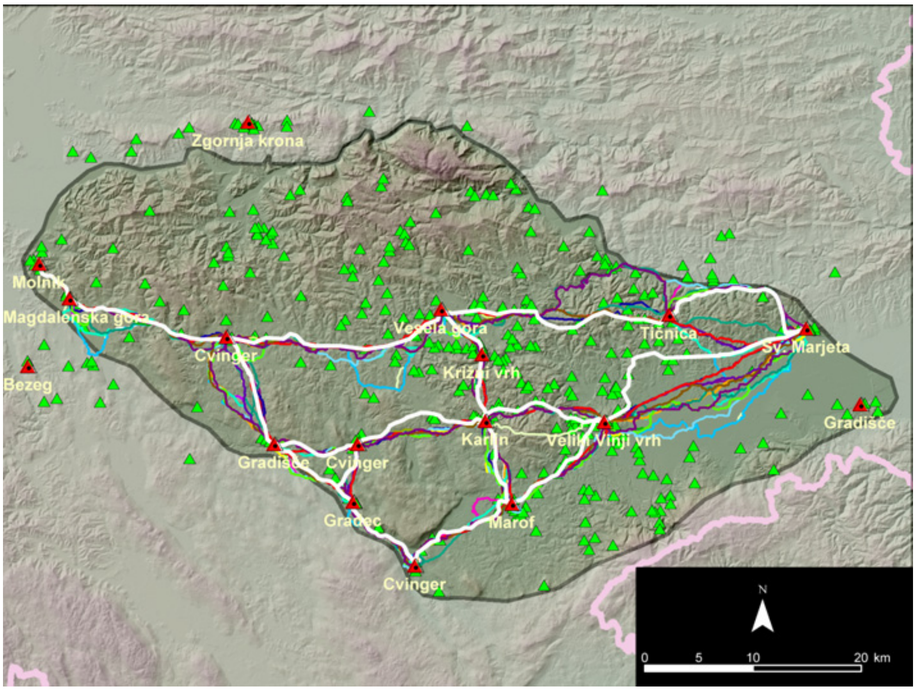

Figure 10 - Path distribution using different algorithms and other parameters between 18 settlements and barrow distribution.

Conclusion

In our research we introduced an iterative and empirical methodology for modelling paths. Hypothetical ancient paths were simulated with variations of parameters using the least-cost algorithm and DEM (as environmental variable) only. With the use of different algorithms we eliminated the possible gross errors of DEM and iteratively produced the most probable paths.

On a hilly terrain the simulated paths generally follow the ridges (or valleys), however, in plains they are more unpredictable. The geomorphology has a significant impact on the predicted paths on a rough and hilly landscape, while in plains it would be necessary to consider also other factors, such as for instance the local environmental conditions i.e. marshy terrain, larger rivers, vegetation, etc. It is important to note that the concept of natural paths does not explicitly imply their human use as a path, but only their potential to be used as such. The applied path model has to be further verified or estimated with the following additional investigations:

- observation simulated paths towards the entrances of settlements,
- highlighting visibility and inter-visibility from different archeologically significant points along the routes,
- comparison with the traces of Roman roads and with the courses of modern roads,
- physical walk along the hypothetical roads generated by algorithms,

- evaluation proximity of archaeological sites to the simulated paths, and explanation of certain monumental cultural features from the perspective of movement along the optimal path,
- exploration of the ability to navigate the rivers, etc.

At this stage of the study the most relevant result for archaeological interpretation is that some locations of isolated barrows and artefacts became understandable within the context of movement.

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