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Digital terrain analysis as a tool for the identification of possible areas with rural post – Roman archaeological sites in the S-W Dacia

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Abstract: The study areas are located in the western part of Romania, in the historic region Banat, with a relatively varied relief formed of low fields, high fields, piedmonts and hills. The identification of areas with a high probability of new archaeological sites was done through the GIS modeling using complex data sources. The first step was to establish the essential factors in the location and the spatial distribution of known sites. The factors considered are: altitude, slope, aspect and distance from water courses; the values of these parameters are slightly different from one type of relief to the other. Based on statistic analysis of the values of considered factors for each archeological site, values intervals with the greatest favorability were identified. The second step had to standardize these factors. Because all analyzed factors vary in space, the most appropriate method to standardize is by using Fuzzy membership functions, different for each factor. With their help, these factors were standardized on a scale from 0 (least favorable) to 255 (extremely favorable). Finally, the combination of all these factors allows the identification of high probability areas for archaeological sites. Because the factors considered don't have the same importance for the favorability of finding a possible site, before the combination of the previous standard factors, each factor was assigned a relative weight to use in the Analytical Hierarchy Process (AHP) implemented by the IDRISI Andes software. The combination of factors considering each weight resulted in the creation of the final model, which presents the probability of identifying new archaeological sites. The probability degree varies continuously in space, from a very high probability (255) to a very low probability (0) depending on the combination mode in a certain area of the considered factors and their weight. Thus generated models, for each relief type, were applied to the archaeological sites from the third and fourth century C.E. and were verified in the field, noting its utility in the identification of new archeological sites.

Mots-clè / Key words: GIS, landscape archaeology, survey archaeology, fuzzy functions

Introduction

The Banat region is a historical province characterized by an old and continuous inhabitance, proved by the very large number of archaeological sites of all epochs. This was sustained by both the varied and rich natural resources, as well as by the shelter provided by the natural environment. As a result the environment has been largely modified as a result of anthropogenic activities, especially in the last 300 years, time during which large areas have been deforested and natural vegetation was almost entirely replaced with crops. Also there extensive hydro technical works have been undertaken which resulted in modifications in the hydrographic structure of the Lower Plain of the Timis River, which was a huge marshland in the past. Keeping this in mind, attempting to analyze the factors which determined the founding of a settlement in a given area is rather difficult, as these elements can't be observed directly, but intuitively. Because of this in the present paper we attempt to analyze the characteristics of from settlement placing of archaeological sites dating the post- roman times (III–IV century AD) from Timis county, which was the south-western area of the former Roman province of Dacia, by use of those elements whose evolution has been slow, insignificant even, in this time frame, these being the geomorphologic factors. By using these in the predictive analysis done with the help of GIS we tried to identify the areas which are most likely to harbor new archaeological sited dating from the same historical period (D. Benea, 1996; A. S. Luca, 2010, M. Mare, D. Micle, 1998).

Data used

GIS ability to operate efficiently with a large volume of spatial data, which varies in methods of acquisition, makes these programs especially useful in the development of predictive models based on multi-criteria analysis (K. L. Kvamme, 1990). Thus the data sources used for the analysis and modeling were complex.

Regarding the terrain analysis we used DTM derived from topographical maps. We opted for this method because the SPOT HRS model, with a resolution of 30 m had positive errors in altitude for both settlements and forested areas, and the SRTM DEM with 90 m resolution does not permit a detailed morphological analysis.

Topographical maps at scale 1:25000 were used for digitizing heights data as well as for the creation of layers used in spatial analysis and the cartographic depictions. Such layers were made for the hydrographical network, settlements and roads.

Locating the areas with known archaeological sites and the drawing of the digital map was made based on the GPS mapping and topographical surveys made using the Leica TC 407 Total Station.

The color orthophotos, at scale 1:5000, were used both for visual analysis on known sites and to verify the obtained models. Verifying the models was accomplished by on site identification, precision localization and the specific geomorphologic elements analysis, for each area in discussion.

Methodology

The methodology is based on the GIS multi-criteria analysis by using complex data sources. After the determining of the geomorphologic factors involved in locating known archaeological sites, the next step required that these elements to be quantified as digital maps. Because the factors were measured in different units (km, meters, degrees, etc.) their standardization is necessary in order for these data to be integrated in the model. All the analyzed factors vary continuously through space and they are seen as data sets with a continuous character, therefore the best method for standardization is the fuzzy functions. In this way the factors can be standardized on scale of integer numbers from 0 to 255 (bytes).

Another important aspect is the type of function chosen for each factor, which should best describe the gradual increase from 0 (condition not favorable for locating) to 255 (favorable conditions) as well as establishing the values of critical points in which a set belonging reaches a value which is either 0 or 255.

After the standardization of these factors a homogenizing is required in order to make the final map regarding the geomorphologic risk. Combining them can be done in a linear way, case in which each factor is attributed an equal importance, or weighted, when each factor is given a different weight. In the present study the multi-criteria weighted evaluation (J. R. Eastman, 2007) was used.

The predictive models were made with the help of IDRISI Andes software because at present it offers one of the most advanced methods based on utilizing fuzzy functions and the analytical process of hierarchic - Analytical Hierarchy Process (P. Longley et al., 2006).

Establishing the factors utilized in the developing of predictive models

The morphometrical characteristics of the relief were determined by the geostatistical analysis with the help of GIS, at pixel level, of each known archaeological site. This analysis, alongside observation made on location, led to the conclusion that the most important morphological factors in the process of locating known sites are: altitude, declivity (slope), the exposure of surfaces relative to the sun, and the distance to water sources.

The altitude. Altitude values were cartographically featured and analyzed using a Digital Model of Terrain (DTM), obtained by the interpolation of the altitude data on the topographical maps. A TIN model was obtained using the Delaunay interpolation method. In order to eliminate errors we used a series of break lines (the skeleton of the relief). The TIN Model was transformed in a raster with a 10 m spatial resolution.

The declivity was automatically obtained from the DTM, with values from 0 degrees for horizontal surfaces to 57.44 degrees for the very inclined surfaces of the valleys' slopes.

The exposure of surfaces relative to the sun (the aspect) was also determined from the DTM, is calculated as the direction of the horizontal projection of the perpendicular line on the surface of the slope, and measured clockwise relative to the geographical north.

The distance to water sources was determined by calculating the Euclidian distance in all directions starting from the digital map of the hydrographical network.

The statistic analysis of factors value taken in concern has permitted observation links between the location of the sites and the geomorphologic characteristics of the landscape. So, it is obvious a certain "preference" in placing this settlements, concerning the distance to water sources, and also the morphometric parameters, understanding the identification of some thresholds, that are not overdone or some values as the media of all data. Although, their value can differ from a study area to another, taking in concern the type of the landscape. For example, it has been observed, that the majority of the sites from Poganișului Hills are placed at a distance between 20 to 500 meters distance to the main water source, but never as far as 590 meters, and in the same time, in the Vinga Plain, these are placed at longer distances, from 40 to 900 meters, but never as far as 1110 meters. (Fig. 1A-1B).

Following this statistic analysis and the field observations, it has been established, for each study area the favorable values for the placement of the settlements. These values have been later used for GIS identification of the areas that simultaneously have the favorable conditions, obtaining so patterns of the areas with possible archeological sites.

For example, the values that considered favorable for the Vinga Plane are: the altitude from 150 to 170 m (with the middle value of 165 m), inclination from 0 to 5.5 degrees (middle value of 2.5 degrees), the exposure S, SE and SV and the distance to the water sources from 20 to 590 m. Generally, we are talking about small settlements, grouped at the effluxes or on the SE and SV slopes of the rivers and their affluents.

1. For the high plane area to the hills, that have the slopes of the river basins with the NV orientation (the Vinga High Plane, Lipovei Hills) (the *Murani, Cornesti*, *Giarmata, Bencecu de Sus* and *Seceani* areas)

Characteristic markers:

Altitude: from 150 to 160 m (middle value – 155 m).

Slope: from 1 to 5.5 degrees, progressively decreasing to 5 degrees (middle value – 2.5 degrees).

Distance to water sources: about 100 to 300 m to the water (middle value – 180 m).

Exposure: S, SE, SV.

Other observation: small settlements, grouped at the effluxes or on the slopes, at the left side (NV) of the rivers and their affluents.

2. For the plain area that have the slopes of the river basines with the V orientation (the High plane of Gataia) (*Folia, Sipet, Tormac, Birda* and *Gataia* areas)

Characteristic markers*:*

Altitude: from 90 to 150 m, because the plane slightly increases in the E (middle value – 110 m).

Slope: from 0.5 to 5.5 degrees (middle value – 2.5 degrees).

Distance to water sources: from 100 to 300 m (middle value – 150 m).

Exposure: SE, S, SV.

Other observation: the settlements are located on the northern side of the rivers, on the middle decks, at the confluence of the right affluents, in the main rivers that have the orientation E–V.

3. For the meadow area (major channel of the Timis River, with the basin slope that has a SE–NV orientation) (*Lugoj, Lugojel, Gavojdia, Victor Vlad Delamarina, Honorici* and *Olosag* areas)

Characteristic markers*:*

Altitude: from 123 to 137 m, because the plane slightly decreases in the NV (middle value-130 m).

Slope: from 0 to 6.37 degrees (middle value – 0.92 degrees).

Distance to water sources: from 0 to 339 m (middle value – 115 m).

Exposure: SE, S, SV.

Other observation: the settlements are located on the southern side of the actual river, on the meadows formed between the fossil channels of the Timis River, that with time have migrated between the northern side of Lugojului Hills and the southern side of Pogănisului Hills.

The standardization of the factors by using the fuzzy sets of functions

Regarding the **morphometric factors** (altitude, inclination and surfaces exposure), two

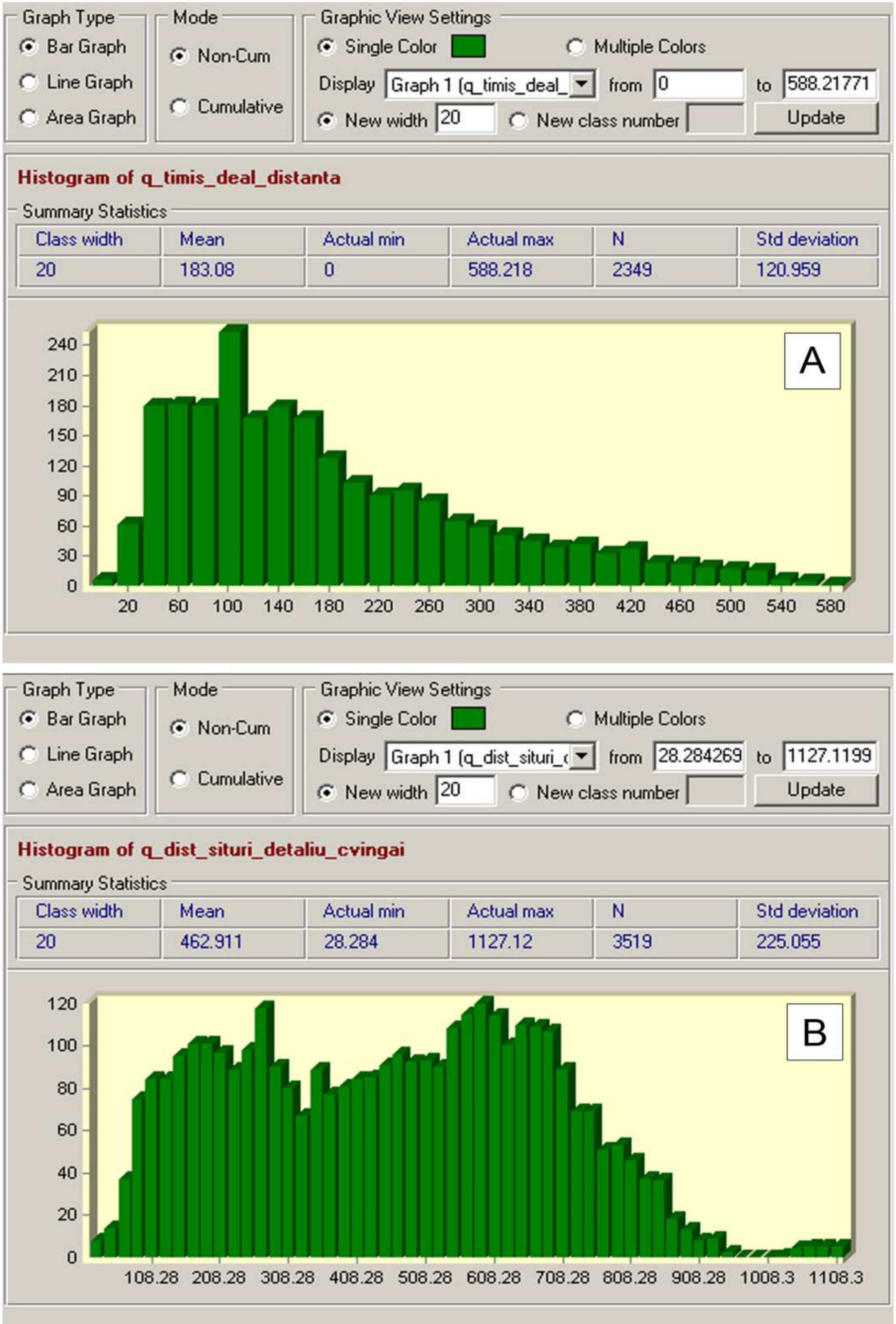

Fig. 1 - The histograms of the distances to the water sources values for the sites from Poganisului Hills (A) and Vinga Plain (B), Timiş County.

types of fuzzy functions have been used: the linear one, and the sigmoidal one.

The altitude: The standardization of the altitude has been made by using a symmetric linear function, establishing four main points: 100 m (the 0 value), 155 m (the 155 value), 165 m (the 255 value) and 200 m (the 0 value) (see fig. 2).

Inclination (slope): The standardization of this factor has been made by using a sigmoid function with monotone decreasing (once the inclination increases, the favorability decreases), by establishing as main points the values of 0 degrees for 255 value and 5.5 degrees for 0 value (see fig. 3)

The exposure of the surfaces: It has been used a symmetric sigmoid function, by establishing as main points the values of 112 degrees and 247 degrees (the 0 value) and 135 degrees and 225 degrees (the 255 value) (see fig. 4).

The distance to the water sources: For the standardization of this factor has been used a symmetric and linear sigmoid function (as the distance to the water increases, the probability of the existence of a settlement is lower, but also contrarily, if the distance to the water is very short, there is a flood danger) by establishing the next critical values: 100 m (the 0 value), 180 m (the 255 value), 580 m (the 255 value) and 800 m (the 0 value) (fig. 5).

The evaluation based on the weighted multi-criteria and the realization of the pattern

It is obvious that not all the factors taken in consideration have the same importance in the favorability of placing a possible archeological site, which has a linear combination of these, in which each has the same „weight", would be, in our opinion, a wrong approach. This method permits establishing the areas with different levels of risk in a much better way, because before combining the factors that have been standardized previously, it is established, for each factor a level of relative importance.

The attribution of the weight is difficult and it is relative when all the factors are simultaneous taken in concern. The distribution of the information in simple comparisons in pairs, in which two criteria are taken in concern at once, may facilitate the weighting process and will provide a much more stabile set of criteria weight. This technique of pair comparison, implemented in the IDRISI program has been elaborated by Saaty, in 1977, in the context of a decision taking process, known as Analytical Hierarchy Process or AHP. The factors are compared two by two, by giving notes by using a continuous scale of nine values (fig.6). The inclination of the slopes and the distance to the water sources it is considered to be more important then exposure and altitude.

The determination of the weight attributed to each factor it is calculated with the scores from the matrix and will be used in the following step to make the final map. In the method of the multi-criteria evaluation using a linear weighted combination it is necessary that the sum of the weights to be 1 and the consistency ratio to be smaller than 0.1 (see fig. 7). The consistency ratio defines the probability that the matrix ratings were randomly generated.
Combining the factors by taking in concern ones weight, has led to the final pattern, which represents the probability of the identification of the new archeological sites. The probability level varies continuously in space, from high probability (the 255 value) to low probability (the 0 value), because of the way that the given factors are combined in a certain place and because of ones „weight".

Conclusions

Even if the factors taken in concern are not very precise, the results of the archeological field research have demonstrated the fact that these predictive patterns have an approx. 80% accuracy (for the post-roman sites in our examples), which satisfies us. Of course, not only the morphometrical factors are relevant, but also the military, economic, cultural and social ones. But we consider that this is a good start, especially because the field data confirms it. It remains as a future objective integrating these data in an interdisciplinary complex of information and data that can provide rapid and high quality evaluation of the archeological potential of a certain area (whatever that is and no matter to which period it belongs).

Acknowledgements

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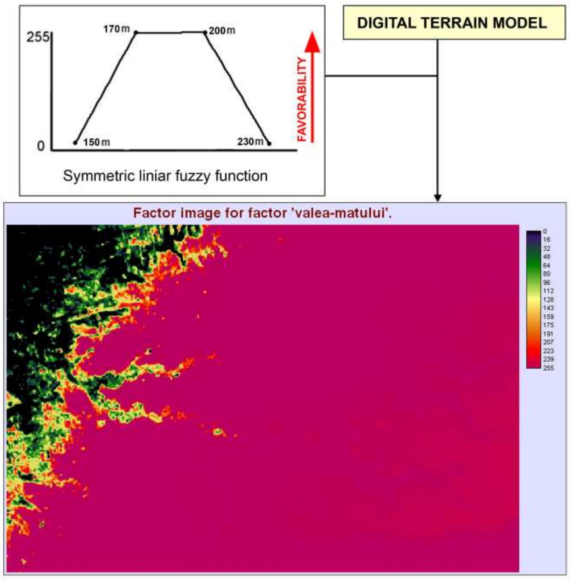


Fig. 2 - The standardization of the altitude values by using a linear symmetric membership fuzzy function.

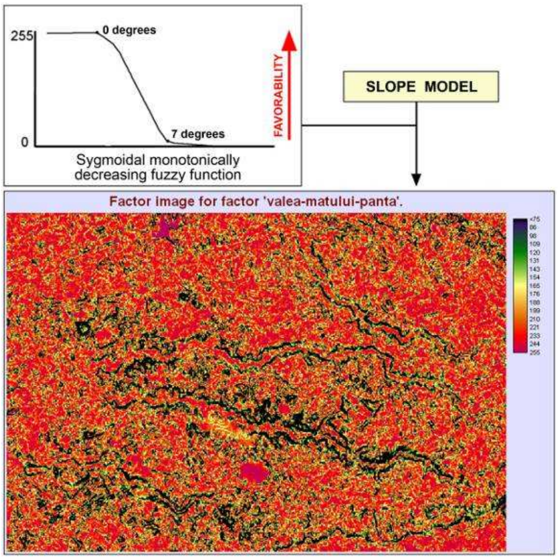


Fig. 3 - The standardization of the slope values by using a sigmoid membership fuzzy function, with monotone decreasing.

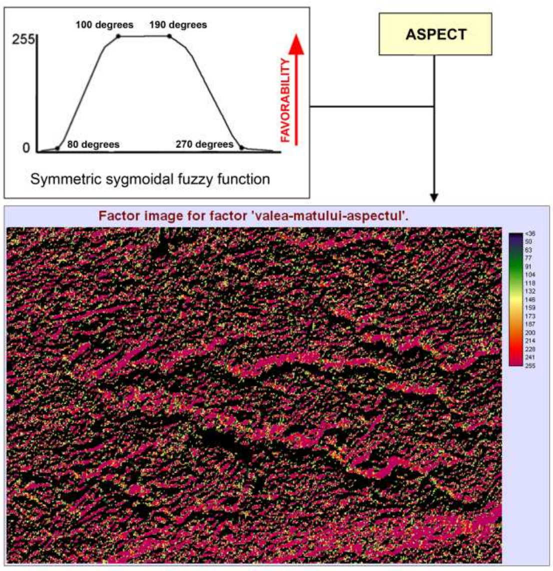


Fig. 4 - The standardization of the aspect values by using a sigmoid symmetric membership fuzzy function.

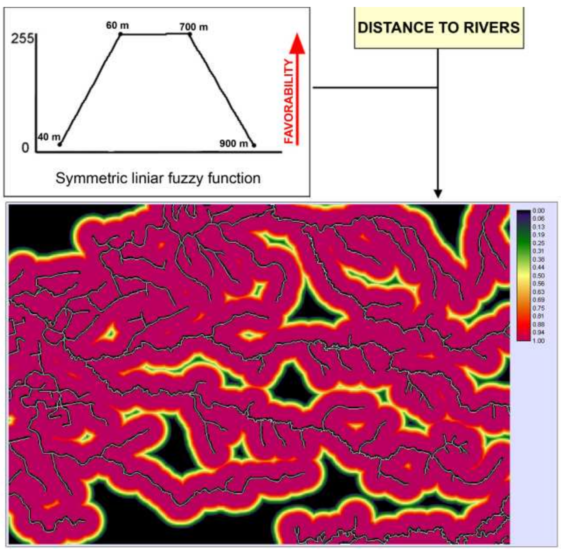


Fig. 5 - The standardization of the distances to the water by using a linear symmetric membership fuzzy function.

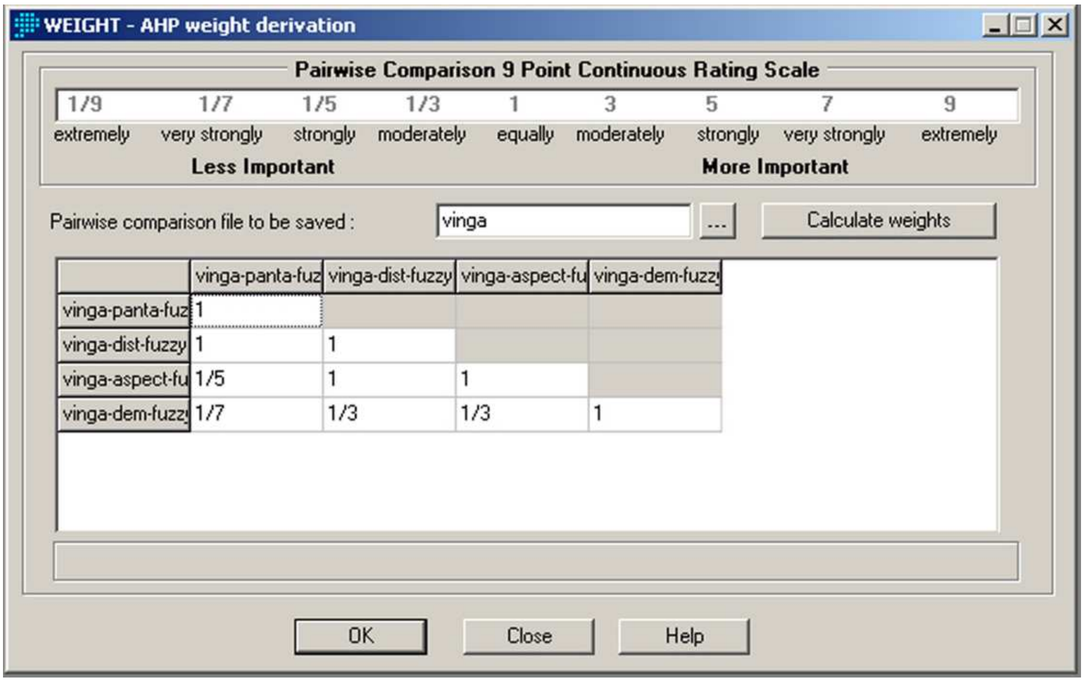


Fig. 6 - The WEIGHT module (IDRISI Andes): the nine values scale and the matrix of the scores given to the four factors, analyzed two by two.

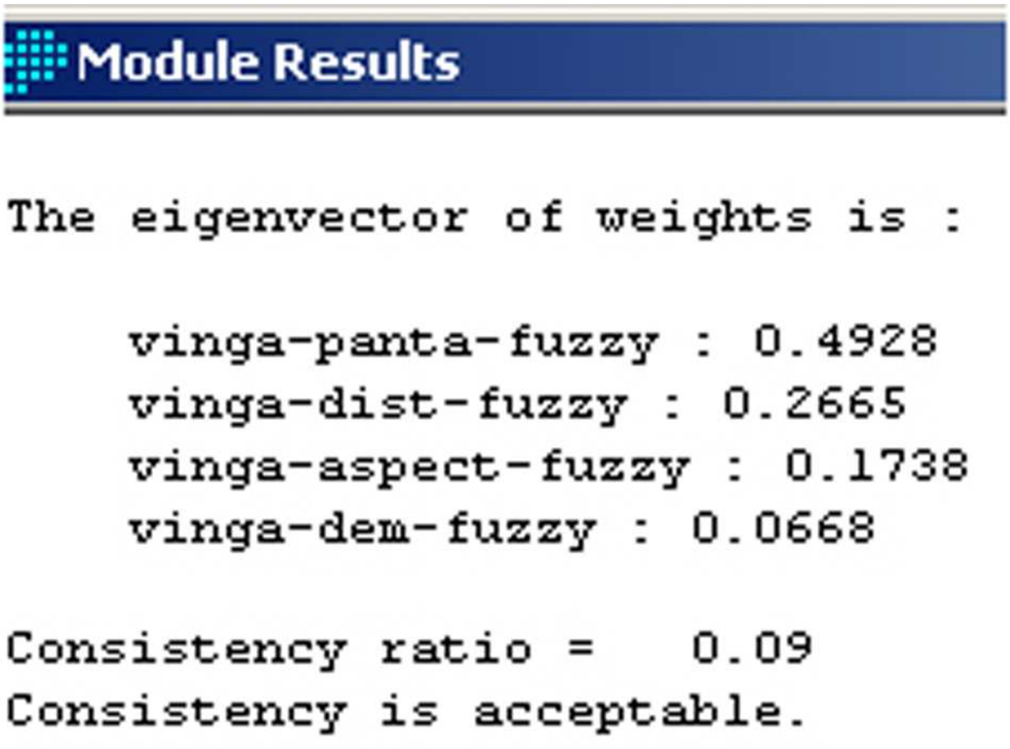
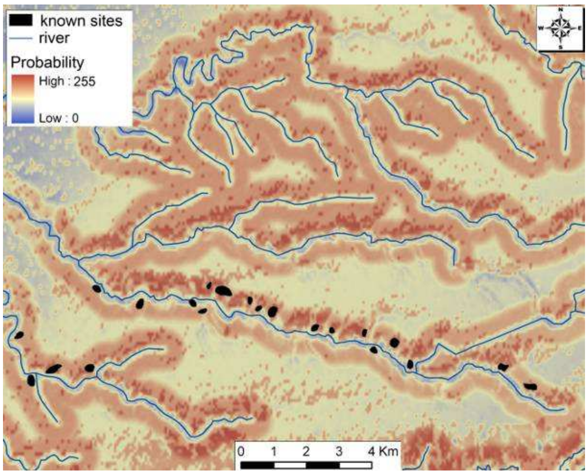


Fig. 7 - The weight calculated for each factor and the consistency ratio.



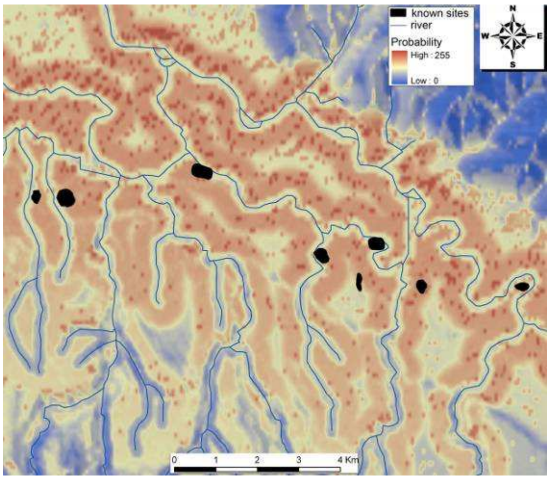


Fig. 8 - Case study: The Vinga High Plane, Timiş County.

Fig. 9 - Case study: The High Plane of Gătaia, Timiş County.

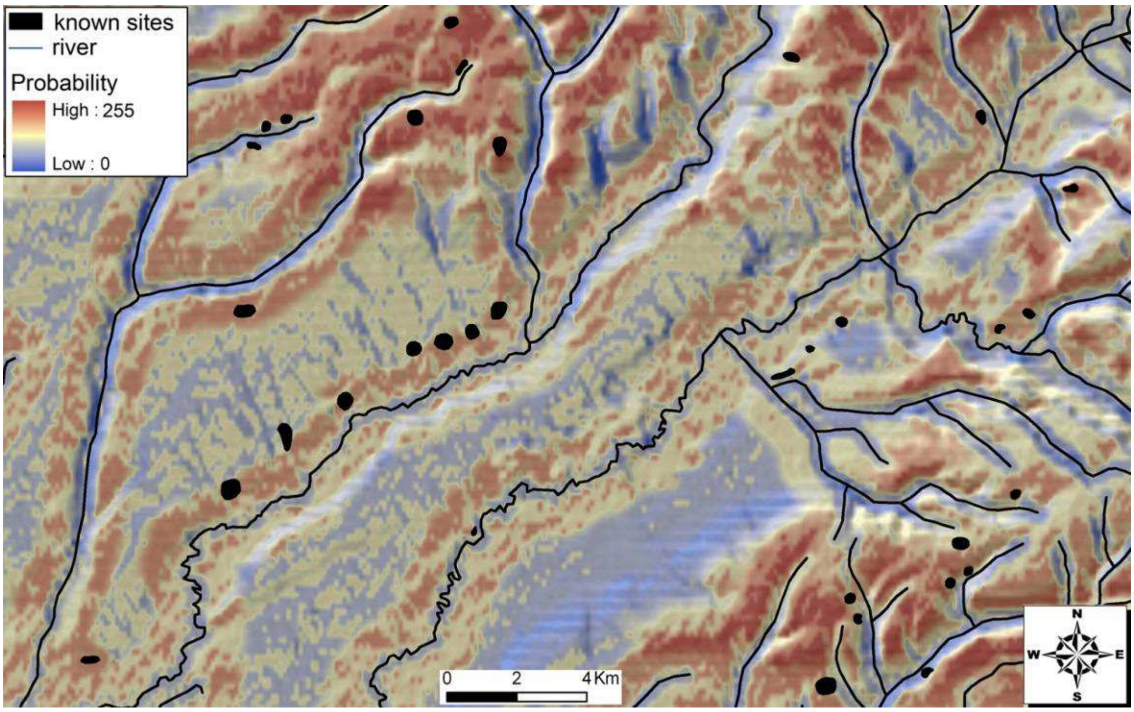


Fig. 10 - Case study: The bottom land of the Timis river.

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