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Lucija Magaš[1], Dubravko Gajski[2], Katarzyna Dzięgielewska-Gajski[3]

SPATIAL MULTI-CRITERIA APPROACH TO THE EVALUATION OF ARCHAEOLOGICAL SITES

Abstract: One of the most demanding and challenging tasks for an archaeologist is discovering new archaeological deposits. The archaeologist considers many historical facts and explores their interconnectedness and impact on ancient life. The surrounding has the most significant impact on the life of the human community. Therefore ancient communities inhabit such places that provide them with favorable conditions for life and development, i.e., adequate climate, proximity to water, food and raw materials, and the possibility of protection from enemies. To draw the attention of the archaeologists to the areas where spatial conditions are fulfilled until some level, the spatial multi-criteria analysis of landscape features can be of great help. This paper aims to evaluate the landscape by the several predefined criteria using the multi-criteria analysis supported by Analytical Hierarchical Process (AHP). Finally, the evaluation result is visualized in GIS, showing the places where it is to expect an archaeological deposit. As a study area, the Požega valley was chosen because it represents many archaeological sites dating from the Iron Age. According to the personal preferences, five criteria were selected and ranked: proximity to water, altitude, terrain, slope, proximity to mineral resources, and land use. Five potential sites for archaeological research were identified using multi-criteria analysis in GIS and AHP. Finally, the possibilities of multi-criteria analysis in GIS in archaeological research are presented and discussed.

Keywords: GIS, AHP, multi-criteria analyses, archaeology, Požega valley

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[1] Podbrežje V., 32a, Zagreb, Croatia, lucija.magas@gmail.com
[2] University of Zagreb, Faculty of Geodesy, Department of Photgrammetry and Remote Sensing, Zagreb, Croatia, ORCID ID: 0000-0002-0237-647X, dgajski@geof.hr
[3] State Geodetic Administration of the Republic of Croatia, Regional Cadastre Office Zagreb, Real Estate Cadastre Department Samobor, Samobor, Croatia, e-mail: kdzgajski@gmail.com

Introduction

This paper's main task is to use multi-criteria analysis to find the most favorable locations of archeological sites of the Iron Age in the Požega valley.

Požega valley stands out for its diversity. This geomorphologically closed territory is rich in water, fertile soil, and quality sources of raw materials. Also, it provided shelter to the prehistoric inhabitants from the enemy army. The Požega valley offered favorable living conditions for communities during prehistory. During the Early Iron Age in the Požega Valley, there was a network of smaller and larger settlements connected into more complex systems with the main center. Most of the settlements were located near the water, mostly rivers. In addition, this area was characterized by a wealth of mineral resources, among which the most important is granite – an important building material. (Potrebica, 2003).

On the basis of the study of existing archaeological sites, it is possible to conduct further analyzes and locate future archaeological sites of a certain period. This paper will focus on the Iron Age period.

From the above, the research goals of this paper are defined:

- determine the historical value of the Požega valley,
- theoretically determine the concept of GIS and its role in spatial analysis,
- analyze the archeological sites of the Požega valley found so far,
- define the criteria responsible for the accommodation of individual prehistoric settlements,
- to define potential archeological sites of the Požega valley by the method of multi-criteria analysis.

This area is rich in archaeological sites. One of the most important is undoubtedly the area of Kaptol, which is located on the slopes of Papuk. Also, a group of tumuli were found in the area of Gradac, which is another important site of the Iron Age. The findings were of great importance at the European level as well. It is one of the most important sites for the overall picture of the cultural and historical development of Central Europe (Potrebica, 2012).

The location and characteristics of these settlements and many more will be used to select criteria for determining future sites of archaeological sites..

Research approach

This paper will highlight the most characteristic features of a prehistoric settlement and use them to obtain potential future sites for archaeological research. Each potential area will be evaluated separately.

The coordinates of the settlements were taken from the map of the Second Military Survey, which was published online on the Arcanum website. The relief was taken from the European Digital Elevation Model (EU-DEM) page, version 1.0 and cut to the borders of Požeško-slavonska County. Land use data is taken from the Corine Land Cover and clipped to county boundaries. Data on mineral resources (more precisely: granite) are taken from the OneGeology page. Water data are taken from the Open Street Map.

For the practical part of the paper, i.e. for visualization and spatial analysis of data, the program Quantum GIS version 3.4.7-Madeira was used.

The selection of potential locations for archaeological sites is complex and requires knowledge from several scientific fields, especially archeology. Multi-criteria analysis was used in order to obtain an appropriate location based on several different knowledge about the topic.

Iron Age in North Croatia

Although the primitive processing of iron began as early as 6000 BC in the Middle East, it is believed that the Iron Age began around 1000 BC because then the knowledge of iron melting spread to Greece and the Middle East. The Hittites are considered the greatest masters in ironworking, and they lived in the area of Turkey around 1500 BC. The Celts were the first people to process iron in Europe. The Early Iron Age in Central and Western Europe lasted from approximately 750 to 300 BC and is also called the Hallstatt culture, according to the Hallstatt site in Austria. This culture manifested itself in various areas of people's lives at the time. The appearance and use of iron is primarily seen in warrior equipment, riding equipment, the making of pottery and, and as an ornament on costumes. Mining and trade developed, and warriors and merchants became the ruling classes. The shape of the settlement is also changing. Settlements spread around fortified centers ruled by the ruler. Differences in social layers can also be seen in the rich equipment in graves with jewelry, pots, weapons, and other equipment. The strength of individual communities depended on the control of trade routes, natural resources and warrior power. The horse was a highly esteemed animal, a status symbol of a warrior. Trade routes moved to Greece and Italy. Several cultural groups have developed in Croatia.

Around 400 BC, the Late Iron Age began, also called the La Tène culture, according to a site in Switzerland. It is most significant for the Celtic conquests and colonization of Europe. The areas of northern Croatia and Srijem found themselves on the way of Celtic troops towards Greece. Traditional settlements and customs of the Early Iron Age were suppressed and replaced by a culture characterized by more intensive agriculture, crafts and new communications. Settlements have become smaller and more open. La Tène culture left strong influences on the settlements between rivers Sava, Danube and Drava.

Natural characteristics of the research area

The mountains that surround the valley form a special whole among the mountains of the Sava-Drava rivers area. From a distance, it seems like a complete massif, but it hides an elliptical valley - the Požega valley. The mountains resemble horseshoes, which is the highest in the west – Psunj (989 m). Orljava gorge separates Psunj from the largest Papuk (953 m). It follows Krndija (792 m) in the direction of the east and ends in the low Dilj mountain (471 m) (Fig. 1). To the south is Bablja mountain, or Požega mountain (616 m). The Požega mountains make up the heart of Slavonia. It is closed on all sides by a plain (from the north by Podravina, from the south by Posavina, in the west by the

valleys of Ilova and Pakra, and in the east by the Danube). Between Dilj-mountain and Požega mountain there is a narrow valley through which the river Orljava flows. The valley of the river Orljava, especially the part where the Lonđa flows, is very fertile but also prone to floods due to the overflow of the river from its bed. Regarding the richness of the soil and mineral raw materials, the lowland part of the Požega valley has in the past been exposed to significant floods of the Orljava and Londža and the soil is alluvial. The land has an impermeable base and a thick layer formed by deposition and floods. The bottom of the Požega valley is not entirely flat, but it is wavy and intersected by streams that flow from Papuk and Krndija to the south. The last century was marked by sudden deforestation, and this left a mark on the ground. Once wooded areas, today they are fertile soils, the basis of agricultural production. The soil consists mainly of loam, clay and peat rich in nitrogen and deficient in limestone and phosphorus. Mountains are the remnants of once much larger mountains. They were built of tertiary rocks, with traces of Paleozoic rocks, granite, crystalline shales...

The most common minerals and ores in the Požega valley are Iron ores, coal, marl and granite. The primary and largest waterway in this area is Orljava, which springs between Papuk and Psunj, and flows into the Sava near Kobas. Today it is not so rich in water, but it is believed that throughout history, when the entire valley was forested, it was even navigable.

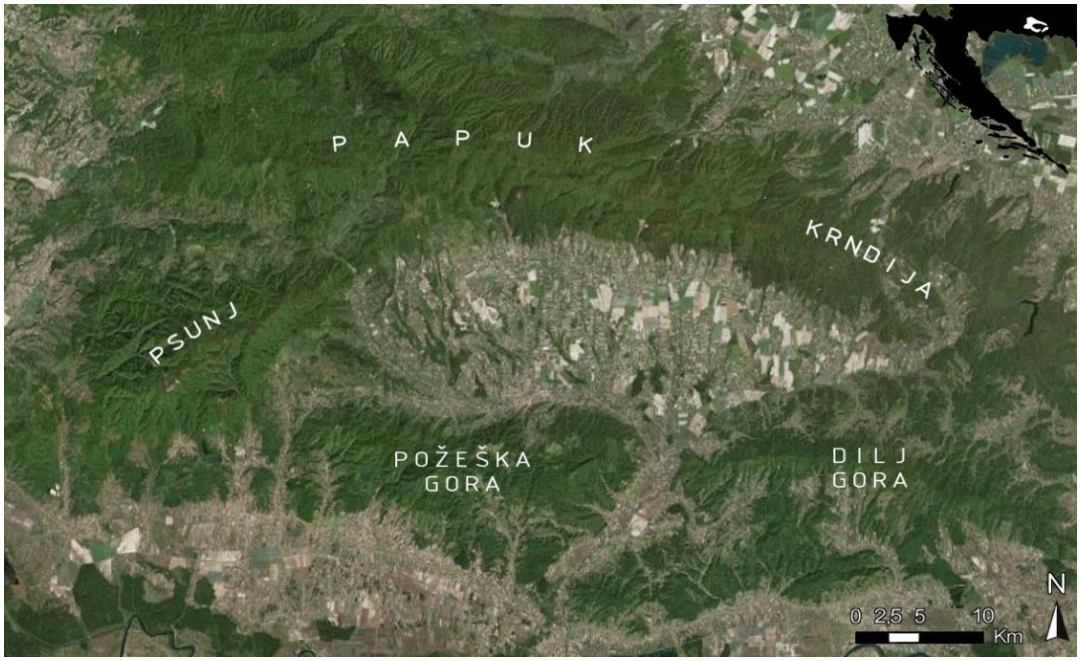

Fig. 1. Position of the Požega Valley
Source: Lichter, 2015

Multi-criteria analysis

Multicriteria analysis is a mathematical tool that is an integral part of multi-criteria decision-making. The main feature of multi-criteria decision-making is that it is used in solving complex decision-making problems. Based on the previously set goals, appropriate criteria will be defined and evaluated. The AHP method was used to investigate the problems in this paper.

The AHP method or the method of analytical hierarchical process is one of the most commonly used methods. The method was founded by prof. Thomas L. Saaty in 1971-1975 (Saaty, 1987). Once the criteria have been defined on the basis of certain purposes, the decision-maker attaches to each criterion its relative importance on the basis of his own decision. That is, criteria of varying importance will have corresponding weight in defining results. The AHP method is based on comparing alternatives in pairs. This method solves complex problems by breaking them down into simpler components: goal, criteria, and alternatives.

AHP method

The AHP method is based on a well-defined mathematical structure of a consistent matrix and the ability to generate appropriate weights. The AHP methodology compares criteria in pairs based on individual preference. Based on this, the weight ratios of each alternative are obtained. A decision is made based on the ranking of alternatives (Fig. 2).

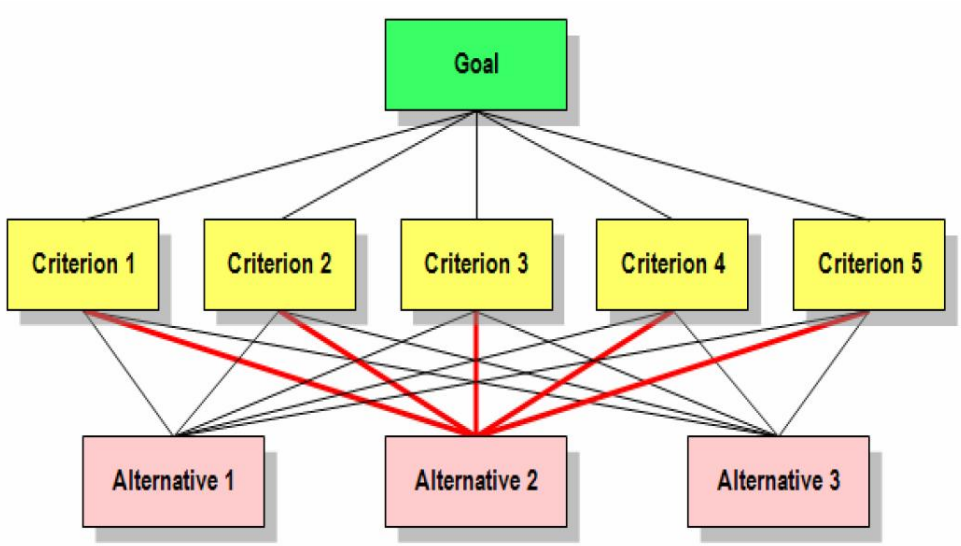

Fig. 2. Hierarchical threshold levels
Source: Pogarčić et. al., 2008

Metodology of the AHP method

The decision-maker must judge the relative importance of the two criteria; he has to compare the importance of all possible pairs of criteria. The idea of this method assumes that it is easier to assess the relative importance for each pair of criteria than to

determine the weights of it at once or rank all the criteria together. In order to determine the weights of the criteria, it is necessary to assess the relative importance for each pair (X_i, X_j). The decision-maker should opt for one of the following statements:

- both criteria are equally important,
- criterion X_i is more important than criterion X_j,
- Criterion X_j is more important than criterion X_i.

Each individual statement has a certain weight ratio of these criteria (w_i, w_j):

1. it is assumed that $a_{ij} = w_i / w_j = 1$,
2. it is assumed that $a_{ij} = w_i / w_j > 1$,
3. it is assumed that $a_{ij} = w_i / w_j < 1$.

By selecting proposition 2 or 3, the intensity of preference can be expressed in multiple degrees using the Saaty scale. The Saaty scale is a scale consisting of five degrees and four intermediate levels of verbally described intensities and the corresponding numerical values for them ranging from 1 to 9. The following figure (Fig. 3) shows the values of the Saaty scale.

The fundamental scale for pairwise comparisons		
Intensity of importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
2	Equally to moderately	*
3	Moderate importance	Experience and judgment slightly favour one element over another
4	Moderately to strongly	*
5	Strong importance	Experience and judgment strongly favour one element over another
6	Strongly to very strongly	*
7	Very strong importance	One element is favoured very strongly over another; its dominance is demonstrated in practice
8	Very strongly to extremely	*
9	Extreme importance	The evidence favouring one element over another is of the highest possible order of affirmation
Intensities of 2, 4, 6, and 8 can be used to express intermediate values. Intensities 1.1, 1.2, 1.3 (at sublayer level) can be used for elements that are very close in importance.		

Fig. 3. Saatys scale
Source: Pogarčić et. al., 2008

The use of the AHP method

The AHP method can also be used in individual decision-making processes, but it is still more useful in solving more complex problems, especially those that involve a high level of risk and is based on human judgment and perception and far-reaching effects. The unique advantage of the AHP method is that it provides a simple solution to seemingly complex issues. This method can be used to answer a number of questions in decision making, transportation, prioritization, and choosing the right alternatives.

Some of the better-known cases of using this method are the following:

- Decision on how to reduce the impact of global warming (Fondazione Eni Enrico Mattei)
- Select a university (Bloomsburg University of Pennsylvania)
- Quantification of the overall quality of software systems (Microsoft Corporation)
- Deciding on the location of production facilities at sea (University of Cambridge)
- Risk assessment in the business of petroleum products (American Society of Civil Engineers)
- Decision on how to best manage US catchment areas (US Department of Agriculture)

In short, the AHP method is based on a well-defined mathematical structure of a consistent matrix and the ability to generate appropriate weights. The AHP methodology compares the criteria in pairs based on individual preference. Based on this, the weight ratios of each alternative are obtained. A decision is made based on the ranking of alternatives.

Criteria selection

There are many criteria that can have a greater or lesser influence on the discovery of new prehistoric sites. In this research the following five criteria were used:

- Proximity to water
- Elevation
- Terrain slope
- Granite deposit
- Land use

Proximity to water

The two most important rivers of this area are certainly Sava and Orljava, which together form an extensive network and are one of the main factors in shaping today's area of the Požega valley. The proximity of the river not only meant fertile land but also represented the possibility of communication. The proximity of the water marked the foundation of the population's prosperity. (Potrebica, 2003.)

The following figure shows the rivers of Požega-Slavonia County together with the already established archeological sites from the Iron Age. From the attached, it can be seen that all the settlements are in the river valleys (Fig. 4.). From which it can be

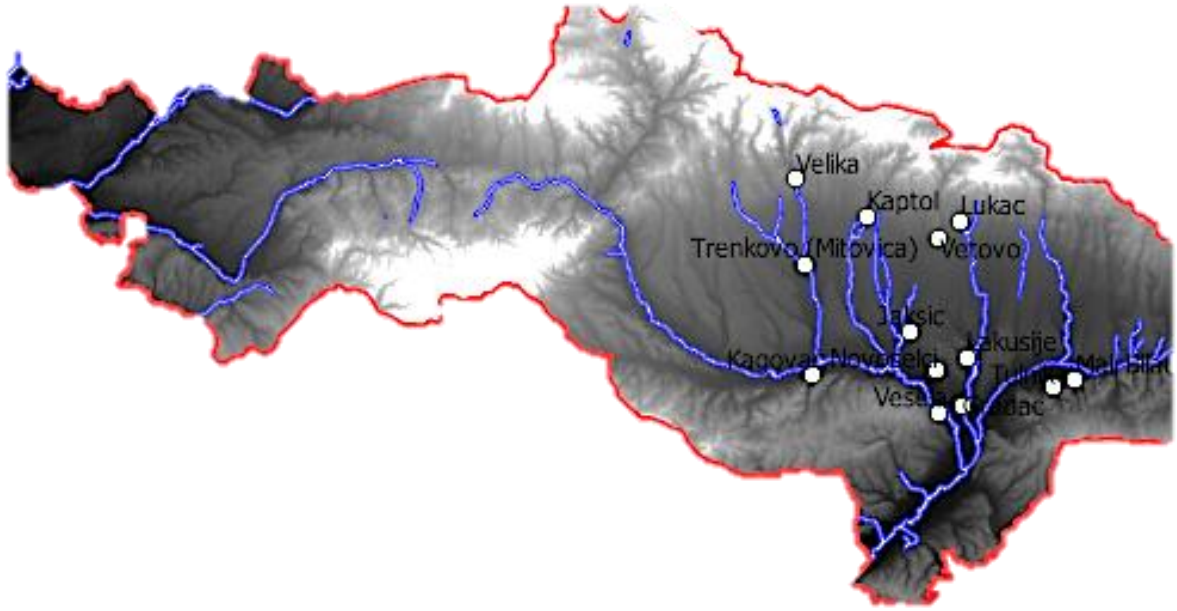

Fig. 4. Connection between settlement locations and water proximity
Source: Own study

concluded that the proximity of water is an excellent indicator of future locations.

In order to categorize the area of Požega – slavonska county with regard to the distance from rivers, the QGIS Raster Distance tool was used. The result is the euclidean distance of the Požega – slavonska county from the rivers (Fig. 5). Each pixel in the resulting raster has a corresponding value depending on the distance from the target raster. The result is divided into five categories. The first or brightest are the areas closest to the target raster, in this case the rivers. The darkest areas are the ones that are furthest away.

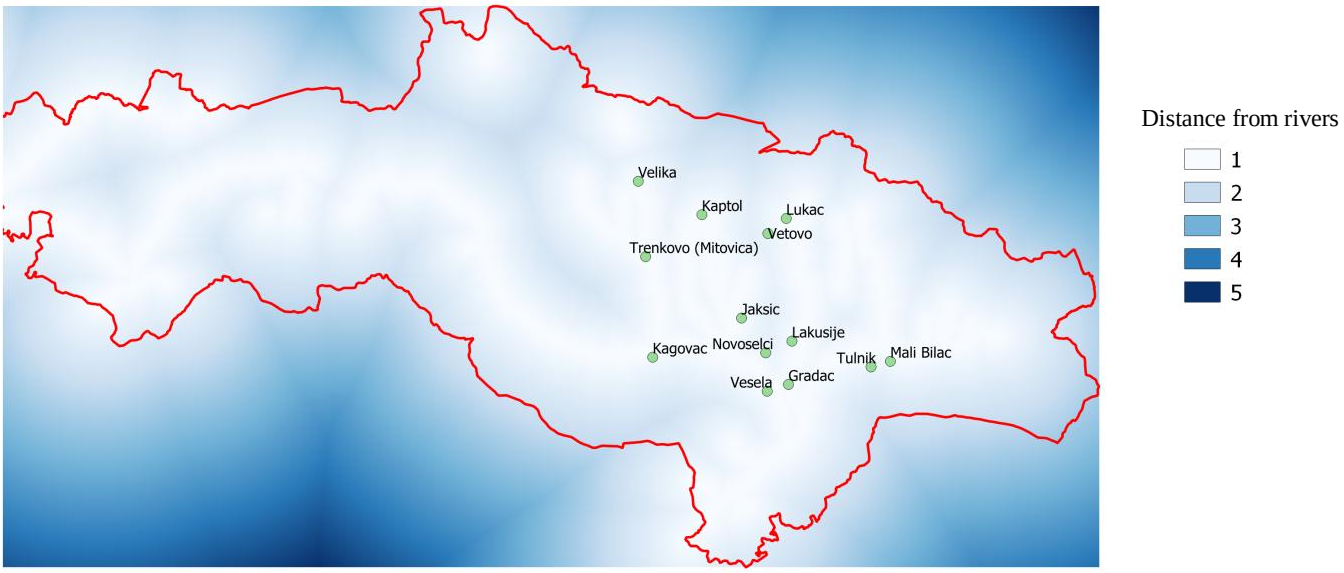

Fig. 5. Categorization of a given area with respect to distance from rivers
Source: Own study

Elevation

The study of a site or broader area always involves the question of its visual correlation with another specific site or wider area. (Glavaš, 2017) Prehistoric settlements were connected in complexes around larger fortified settlements. The larger settlements in the center were the dominant settlements located on the relatively larger slopes. The best examples are Kaptol and Gradac. These high-altitude settlements are placed in strategic positions that serve to monitor the entire valley, but also the communication roads that pass through Papuk. The analysis of previous archaeological sites resulted in the average altitude of the site being 194 m. For the purpose of this paper, the obtained average height was assumed as the ideal height for locating potential sites of future archaeological sites (Potrebica, 2003).

This altitude is set as the target altitude. Using the QGIS Raster Distance tool, the areas that most closely correspond to the target height are selected (Fig. 6).

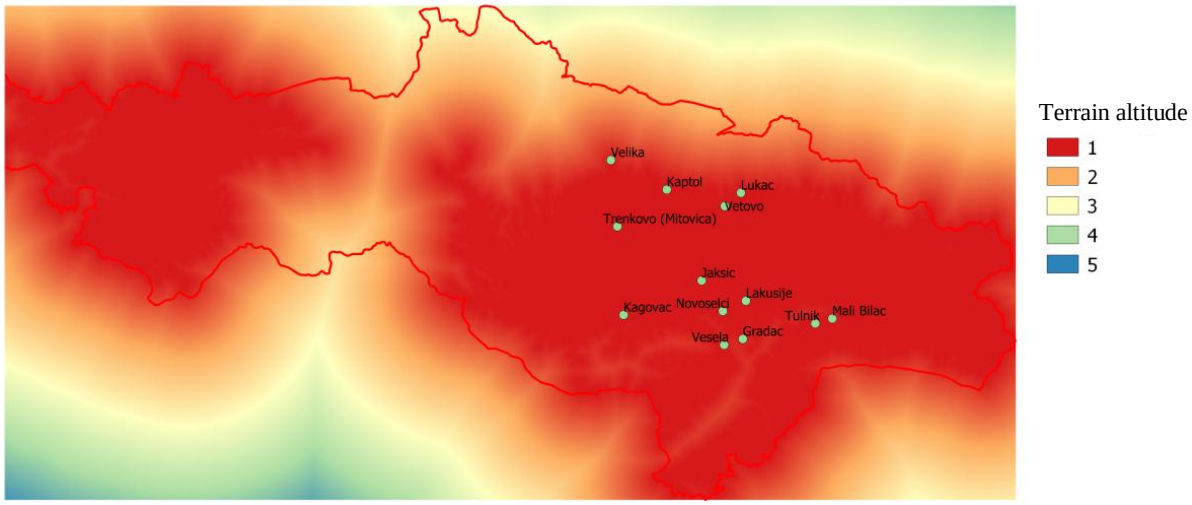

Fig. 6. Categorization according to altitude
Source: Own study

Terrain slope

Different types of slopes cause different types of geomorphological processes and have different socio-economic evaluation (eg for construction, agriculture, roads ...). The inclination of the slopes in the Požega valley ranges from 0 to 20 degrees, ie. from the plain to a significantly inclined slope. Analyzing the positions of the previous locations, most of the sites are settled in the interval of 5 to 10 degrees (from slightly inclined to inclined slope). All settlements of the previous archeological sites are located at the base of large slopes, with a slope of no more than 5 degrees. Knowing this fact a slope of up to 5 degrees will be taken as ideal.

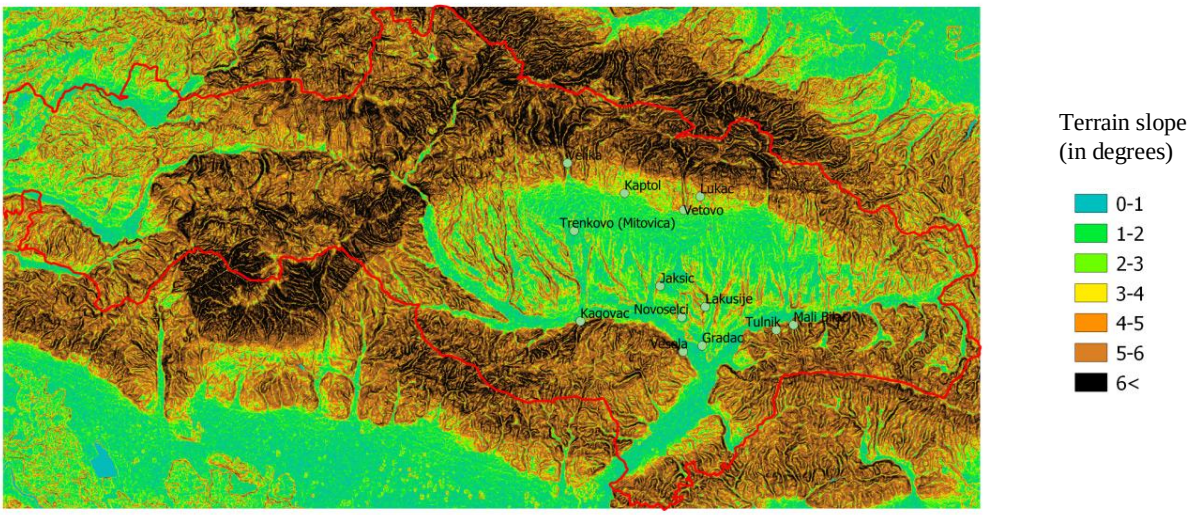

Fig. 7. Slope categorization
Source: Own study

Granite deposit

Granitoid rocks are frequent igneous rocks of the continental crust and have received a lot of attention in the past. It is one of the most important natural building materials. It was first used in the Stone Age. Its main usage was making tools and weapons. Ancient peoples used granite because of its exceptional strength. Granite deposits are thought to have played an important role to ancient settlements. The location of the granite site was taken from the OneGeology Portal. From the determined location, it can be seen that five archeological settlements are located in a narrower zone, where they are closer to the location of the granite site (zone 1), and the rest of the settlement is located in zone 2, as it shows Fig. 8.

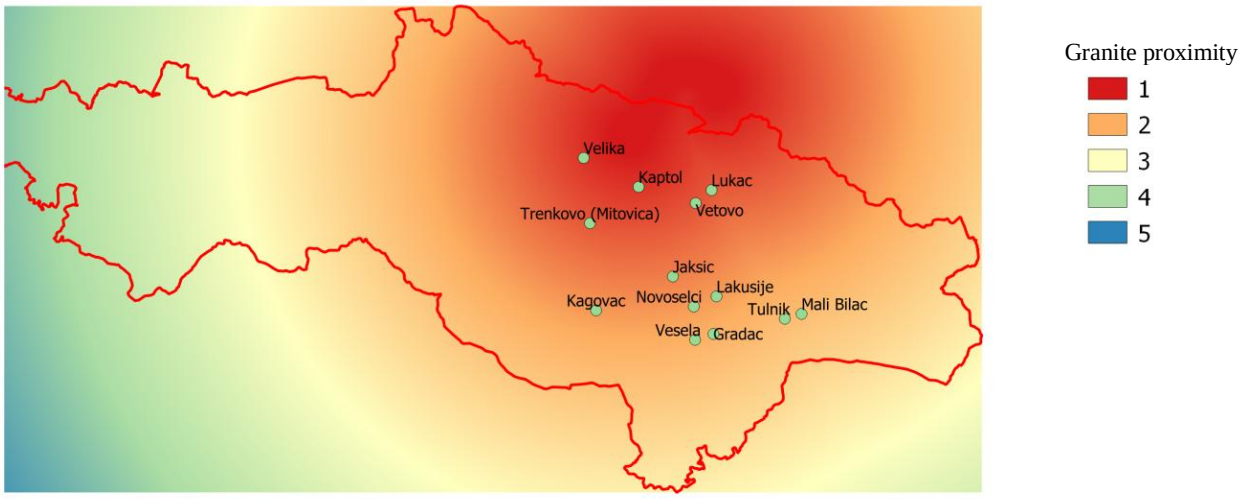

Fig. 8. Raster of granite deposits distance
Source: Own study

Land use

Previous locations of prehistoric sites have shown that their locations in most cases appear in urbanized locations, mostly near larger cities and in areas of developed agricultural production. Corine Land Cover (CLC) data were used to analyze land use. CLC provides data on land cover for the territory of the Republic of Croatia in 44 different classes distributed in 3 levels for the reference year 2018. For the purpose of preparing this paper, it is necessary to single out agricultural areas, urban areas and non-irrigated arable land. Using the Raster Distance tool, a distance raster was obtained with respect to the areas indicated by 1 (agricultural areas, urban areas, non-irrigated arable land). The following figure (Fig. 9) shows the distance raster, and the areas closest to the area of mark 1 are highlighted with the lightest shade of green.

Fig. 9. Land use
Source: Own study

AHP data processing

After defining the criteria, they are processed using the Analytical Hierarchical Process. For the purposes of this paper, the AHP Priority Calculator was used, in which it is first necessary to enter the defined criteria. After entering the name of the criteria, the decision-maker compares the importance between each alternative pair. Two criteria can be equally important, or one of them is more important. If one of them is of greater importance, the user can opt for a value of 2 to 9 degrees (Saaty scale). Using the defined parameters, the program defines the weight matrix. The criteria are ranked according to importance. The highest priority condition has the highest weight, and the lowest priority condition has the lowest weight. The criterion of proximity to water greatly exceeds the importance of other criteria, while the criterion of land use is almost negligible.

Results

We add the obtained weights to each corresponding criterion and use the Raster Calculator tool to get the result. Figure 11 presents the resultant raster in which the areas are divided into five categories. Categories are defined with respect to the probability of containing archaeological sites. The area marked in red is the area of the highest potential to contain Iron Age archaeological sites. The following figure highlights some of the potential locations.

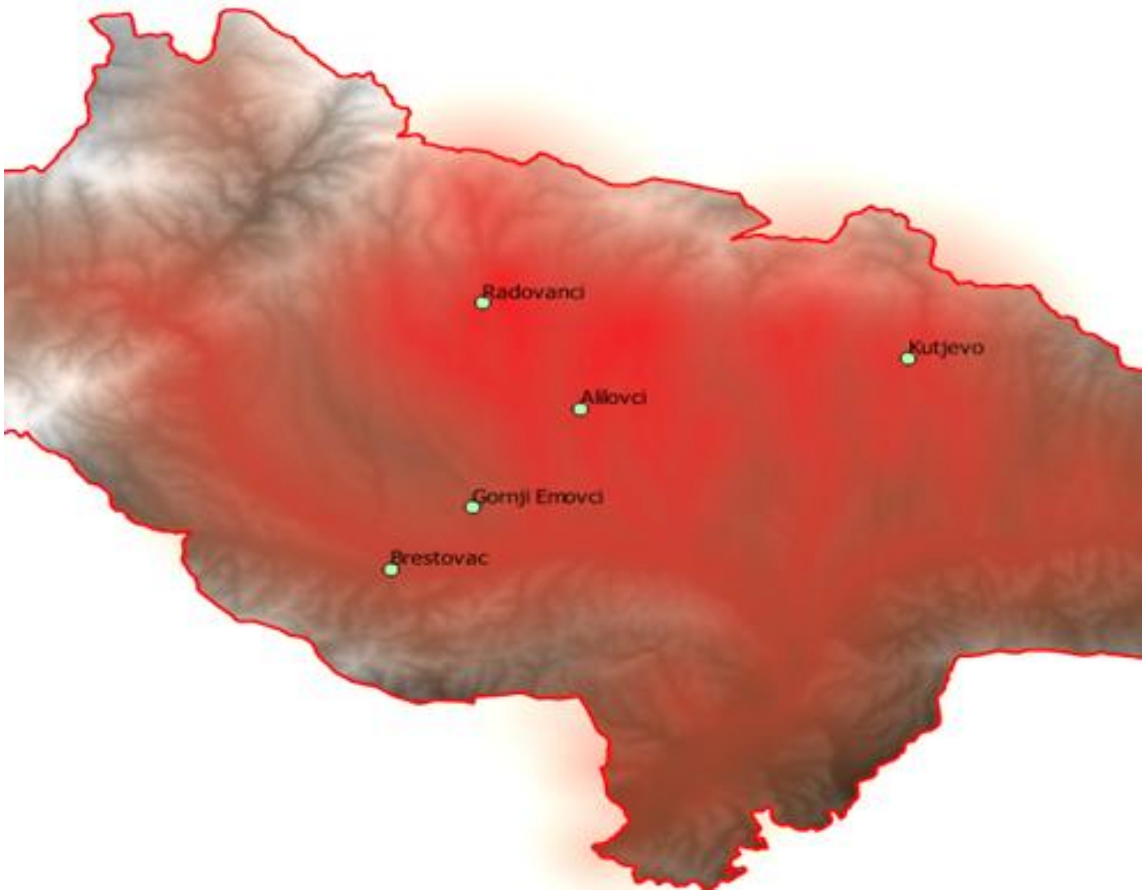

Fig. 10. Potential locations of archaeological sites
Source: Own study

Of these settlements, the village of Radovanci, which is located on the northern edge of the Požega valley, should certainly be highlighted. Remains of an ancient necropolis i.e., two ancient masonry tombs, were discovered there during the 1920s. Also, in 1976, during the cultivation of vineyards, three more ancient tombs without masonry architecture were discovered. The finds date from the 4th century. These discoveries speak of the possible existence of a larger ancient necropolis in the area of the Požega valley. Also worth mentioning is the town of Kutjevo, which in the Middle Ages stood out for its position along important communication networks and is known for its medieval monasteries. In addition, Kutjevo, along with Kaptol and Požega, was one of the most important urban settlements in the Požega Valley in Turkish times. The city was an important trading center for the European and Turkish sides. (Andrić, 2010) Although it stood out as an important fortified urban settlement, there are not many records about it before the Middle Ages. Remains of prehistoric and medieval pottery have been found north of Alilovac, in the central part of the Požega valley, on an elevated part. The site extends in the length of 500 m and in the width of 200 m. These findings indicate the existence of a small prehistoric medieval settlement. A prehistoric settlement was also discovered on the southern slopes on the west of Brestovac. Here the river Orljava enters the Požega valley, and the mountain Papuk ends. The oldest settlements have always been located along natural communication networks and along river valleys, so it

is not surprising to find a prehistoric settlement along the road Požega – Našice. Remains of a prehistoric and medieval settlement were found north of Gornji Emovci. Remains of Stone Age pottery and remains of medieval pottery were found. It is believed that the settlements were built on an elevated elongated hill near Emovac river. Also, the settlement was connected by water with the rest of the valley by the river Orljava. (Minichreiter, 2005) Prominent settlements certainly have a rich history and certainly meet the set criteria as potential locations for prehistoric research, more precisely, the Iron Age.

Conclusion

The geoinformation system has had multiple applications in archeology since ancient times. People have always looked for ways to archive historical events and locations. The ways in which that can be achieved are numerous.

The aim of this paper is to show how, based on previous experience, i.e. on the basis of already established sites, we can locate new archaeological sites. Based on the collected knowledge and available literature, the following conditions were selected and then ranked according to personal preference and knowledge: proximity to water, altitude, the slope of the land, proximity to mineral resources and land use. By overlapping the conditioned areas, a separate area of the Požega valley was obtained, with the greatest possibility of the appearance of new sites. A more detailed study of that area singled out five locations: Kutjevo, Brestovac, Alilovci, Gornji Emovci and Radanovci. A deeper analysis of the history and culture of these settlements reveals that they have an interesting past, that they can already stand out with numerous archaeological sites and that their history has not yet been fully told.

This paper certainly confirmed the benefit and role of GIS in archeology and the obtained results are interesting. Further research should look at the results from another angle, i.e. from other scientific fields. In other words, some more criteria should be considered. In particular, the results should be viewed from an archaeological point of view. We should take into account the socio-economic picture of the Iron Age, also analyze the older and younger periods separately. It would be necessary to determine which settlements existed in the same period and in what relation they were. It would also be interesting to discover the communication routes between the settlements and the height control points of each individual settlement. In addition to archeology, the results should be analyzed from the point of view of geologists. In the field of geology, one could gain knowledge about how different the landscape was three millennia ago, how the relief changed, which rivers were navigable and where there is still the possibility of finding granite and other minerals.

This paper can serve as a basis for future, more detailed research. In cooperation with other scientific fields, a much broader picture of the life of the people of the Iron Age Požega Valley can be obtained.

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