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SPATIAL ANALYSES, FIELD SURVEY, TERRITORIES AND MENTAL MAPS ON THE ISLAND OF BRAČ

1. Introduction and project background

The principal subject of this paper is to discuss the use of geographic information systems (GIS) within archaeological landscape studies and to present some recent results of such work. Our study has been carried out in the central Adriatic where an international team of archaeologist, historians, geographers and other specialists has been studying the archaeology of the Central Dalmatian islands (Croatia) for more than 10 years (Fig. 1).

The research goals of the Adriatic Island Project was to study interaction between human and environment from prehistory to the present time with emphasis to settlement patterns, colonization, population trends, subsistence strategies, contacts, land use and economy of the prehistoric, protohistoric, Greek and Roman communities who lived in the area. The research was first focused on the island of Hvar (Gaffney, Stančič 1991) and then to other neighbor islands:Brač, Šolta, Vis and Palagruža. This region was incorporated in comparative analysis between the islands.

However, this paper will focus on the recent research carried out on the island of Brač. On the basis of archaeological data and the natural environment data we wanted to make some spatial models with GIS and analyse of the island of Brač. In 1994 extensive field survey of the island was completed, providing more than 600 records in the sites and monuments database. Simultaneously extensive archive research was completed providing useful data for our analysis. Since one of the goals of the research was to analyse the long term changes of the Mediterranean landscape of the island of Brač, natural environment data were gathered as well, and later on incorporated into GIS. Digital elevation model (DEM), soil and geology information layers were the most important data in further GIS analysis.

2. The island of Brač

The island of Brač is third largest island in the Adriatic Sea. It has an elliptical shape with maximum length of 36 kilometers measured from eastern tip to the western tip of the island (Fig. 2). Its maximum width is 12 kilometers. Total surface is 395 square kilometers. The orientation of the island is E-W and is different from the general orientation of the Adriatic coast which is NW-SE.

From the geologists perspective Brač is an anticline peak with an east-west strike surrounded by synclinals; Brač Channel on north and Hvar Chan-

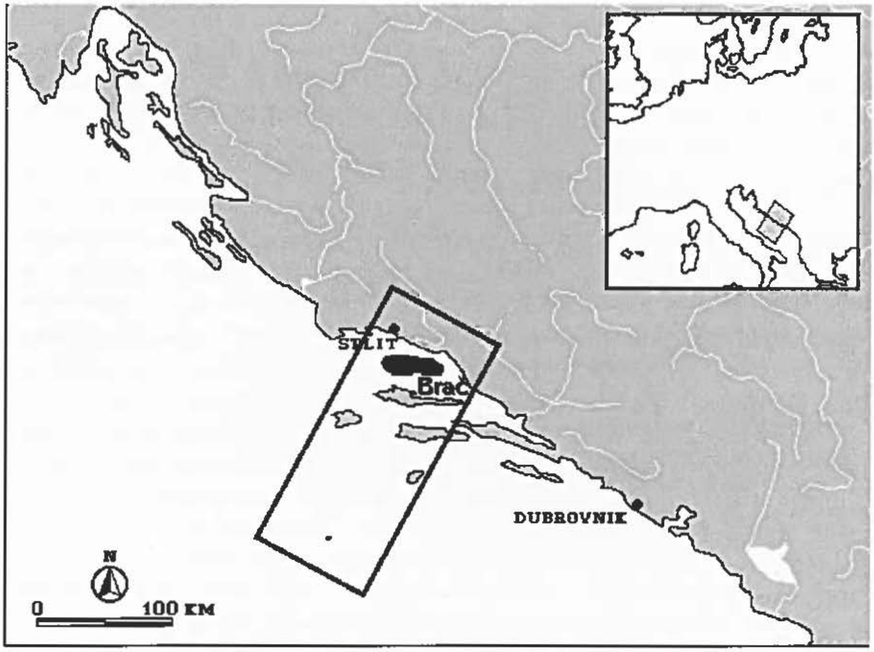

Fig. 1 – The study area.

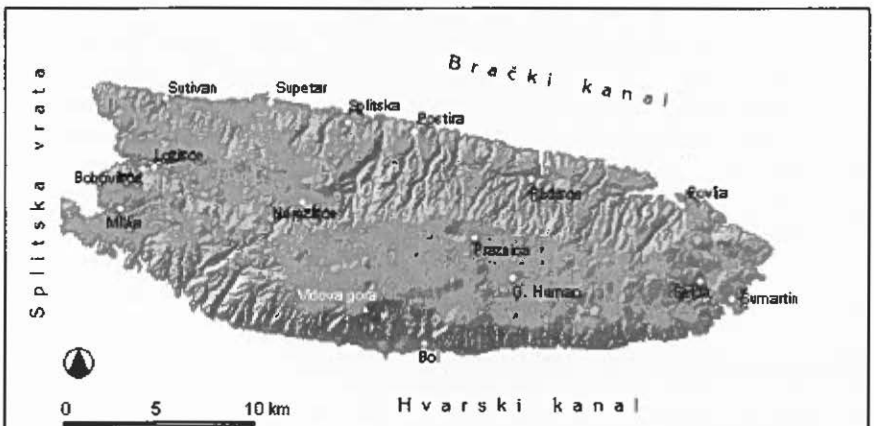

Fig. 2 – The island of Brač.

nel on south. Brač is also characterized by especially dramatic relief. The highest peak of the island Vidova gora raises 778 meters above sea level and is the highest peak on all Adriatic islands. The depth of the channels is on some locations over 80 meters. The anticline is asymmetrical and is much closer to the southern coast of the island. The relief is therefore asymmetrical. From the anticline the terrain drops dramatically to the southern coast. To the north three plateau can be distinguished. The highest one is from the peak up to the elevation of 700 meters, the second plateau is lower and its minimum elevation is 400 meters. Finally the lowland is from the coast to the elevation of c. 170 meters (DERADO 1984). Due to this asymmetrical shape of the island most of the slopes are north facing.

The island is also characterized by numerous dry valleys, especially in its lower parts. Most of these valleys are tectonic by its origin, however, some of them are fluvial origin. The valleys are often very deep and with very steep slopes. Most of the valleys on the northern coast have thick Pleistocene deposits and are very suitable for agriculture. Majority of these valleys were closely related to one of the major settlements on the island.

The climate of Brač is that of typical Mediterranean climate with relatively mild winters and hot summers (JURAS 1984). Despite the island is relatively small, there are significant differences between the coastal air temperatures and the air temperatures inland. Temperature is dropping 0.6 degrees Celsius every 100 metres of elevation. Therefore, average the air temperature on the coast is 16 degrees Celsius and 12 degrees Celsius inland. The hottest month is July while January is the coldest month in a year. The differences between the southern and northern coast in air temperature are relatively high in autumn and winter while in late spring and summer they do not seem to be significant.

The rainfall are extremely important in the Mediterranean climate. The rainfall varies from 799 mm in Ložišče to 1320 mm for Pražnice. The highest rainfall is on the highest plateaux of the island (Gornji Humac 1153 mm and Pražnice 1320 mm). North and north-eastern coasts have a bit less, even smaller is rainfall on the southern and south-eastern coast. The driest areas are on western and north-western coast. The rainfall is not regularly dispersed thorough the year. Most of rain is in winter and autumn, much less in spring. Summers are usually very dry, with July as the driest month with 25-30 mm of rainfall. Due to high evaporation and very little rainfall summer draughts are usual.

2.1 *The geology and hydrology of Brač*

The basic form of the island results from its origin as an anticline peak with similar orientation like the island of Hvar. The geology of the island is relatively monotonous (ČUBRAKOVIČ 1984) and the majority of the Brač lithology are limestone, dolomitesed limestone, dolomites, sandy limestone, sandstone, flysch, breccia and quaternary deposits.

During the Eocene, a series of flysch deposits were laid down in a syncline along the southern edge of the island. The most marked occurrences of flysch, a redeposited limestone sediment, occur above Bol. Quaternary deposits occur in many localised areas and include isolated colluvial layers on the steep southern slopes and the alluvial and brecchia deposits within the numerous north facing valleys. The distribution of lithological classes on the island is shown in Fig. 3. On the basis of this map, originally produced in scale 1:100 000, the data was incorporated into GIS.

The hydrology of the island is largely influenced by the permeable limestone which has led to an almost total absence of surface water. Due to relatively bad collector characteristics of dolomites compared to limestone, dolomites sometimes act like hydroisolators. However, the only real hydroisilator on the island are the Eocene flysch on the southern coast of the island close to Bol. This results in a series of seasonal or permanent streams occurring at the interface of the flysch and limestone.

Since the island of Brač has very few resources of sweet water, most of the water for animal consumption had to be collected in large ponds or *lokve*. Lokve were especially frequent in the upper two plateaux where pastoralism was traditional. Water for human consumption was collected in cisterns. In some cases watercaptures were built in stream valleys. The water supply changed dramatically when in 70s the pipeline brought fresh water from the Cetina river from the mainland.

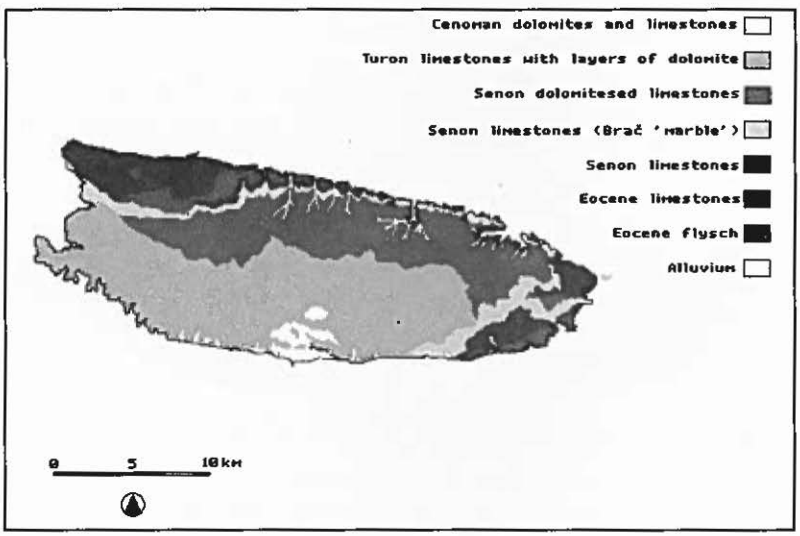

Fig. 3 – Lithology of the island of Brač.

2.2 *Soils on Brač*

The development of soils on Brač was influenced by similar factors like the soils on other islands of Central Dalmatia: climate, geological basis, relief, live organisms and humans. Since most of these factors can easily be compared with the case of island of Hvar, Vis and Šolta, only the differences and Brač characteristics will be stressed here. On Brač five different series of soils are represented:

- soils developed on limestone and dolomites,
- soils developed on crystallised dolomites,
- soils on Eocene flysch and carbonate sandstone,
- soils on colluvial and delluvial deposits,
- anthropogenic soils.

On the basis of relatively poor soil map of the island in scale 1:200 000 (Miloš 1984) a reclassified soil map was produced and incorporated into GIS (Fig. 4).

3. The island of Brač field survey and archaeological database

The island of Brač has been archaeologically studied for more than a century. In the case of the island of Brač there was no archaeological database available. Since the island of Brač seemed to be perfect for the study of changes of landuse and settlement patterns in prehistory, it was decided to collect the archaeological data. The island of Brač has an extensive plateau in the central part of the island with an elevation of 400 meters up to 778 meters. The initial study of the archaeological remains (Vrsalović 1957, 1968) indicated

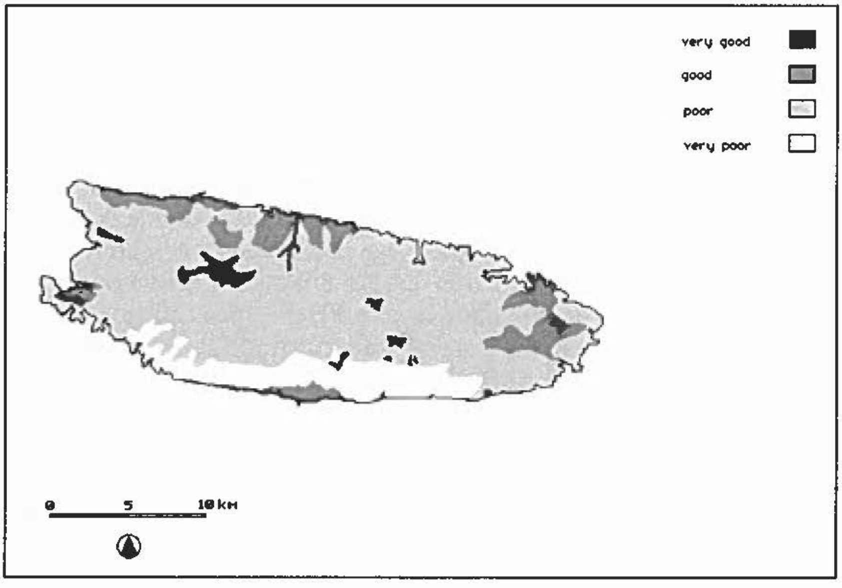

Fig. 4 – Soil classes on the island of Brač.

that this plateau might have been the focus of landuse during the Bronze age. The existence of the Iron age sites closer to the coast, most notably the hillfort of Rat near Ložišče (Marović, Nikolanci 1977) indicated that there might have been a shift in the settlement pattern from the Bronze age to the Iron age. On the island of Hvar this change was impossible to study due to its elongated shape. The territories of the Bronze and Iron age sites were all controlling southern as well as northern costs. The island of Brač is much wider and therefore perfect for these kinds of studies.

On the basis of the results of previous field campaigns it was assumed that a systematic survey would give us much better insight into the past occupation and human activities on the island. It was decided that the stratified sampling of the landscape should be applied in the field walking.

During a four months field campaign in 1994 all the sites were surveyed using an extensive survey sampling strategy. Most of the sites were discovered by systematic field survey; however, sometimes some additional information was used to find them. All previously known and new archaeological sites were recorded, as well as some natural resources, like flint, ponds and wells. Archaeological sites from periods ranging from earliest prehistory through to the early Middle Ages were the focus of our research; however, some ethnographic monuments and industrial archaeological sites had to be documented as well.

During the field work a total of more than 600 sites were recorded of which some 3/5 were not previously known. The necessity of the field work completed is demonstrated in the number of previously known sites is compared with the present data. Previously some 25 Roman sites were known; during the field work, nearly 90 Roman sites were documented, of which about 1/3 are major settlement sites with surviving structures. Even more dramatic are the results for the prehistoric settlements, with 7 sites known before and 10 new sites discovered. During the field work, a large amount of written and drawn data on new sites was recorded. The field team extensively recorded each site on the spot, while some variables (e.g. bibliography) were completed later on. During the course of the field work all the data was gathered and instantly stored in the database. Since it was hoped that the archaeological database will remain in use by the local authorities for the protection and management of natural and cultural heritage, the database was designed and all the data input in Croatian language.

4. Natural environment database

For the purpose of the analysis of the long term man/environment interaction an extensive natural environment data was needed. First the thematic data on soils, geology and digital elevation model had to be produced.

In all circumstances, when a thematic map with appropriate information on the subject concerned was available, the data was input into the geographic information system. Thematic maps with soil data and the geological map of the island of Brač were digitised. Both information layers were then integrated into the IDRISI geographic information system. For the purpose of this thematic data integration in geographic information system a spatial resolution of 30 meters was selected as the most suitable. This spatial resolution is accurate enough to provide detailed data on the environment and the information layers are still treatable by convenient GISs. The geology information layer was produced from the geology map on a scale of 1:100,000 (Derado 1984), while the soil map was on a scale of 1:200,000 (Miloš 1984).

Special attention was paid to the production of the digital elevation model (DEM), since it is a very important information layer in any natural environment analysis. All sorts of information can be derived from DEM, most notably slope, aspect, visibility, watersheds and much more. A 30 meter resolution was chosen for our purposes since the DEM would still represent the natural terrain with considerable accuracy despite the fact that many smaller features would be lost. Contour lines on eight 1:25,000 maps covering the island of Brač were digitised, including special features like karst dolinas and mountain peaks. After the process of digitising, editing, interpolation and filtering, DEM was produced and integrated into the natural environment database providing, together with information layer on the soil and geology data, a good basis for the further analysis.

5. Spatial analyses

In the research presented in this report there is no chance for us even attempt to consider the human/environment interface on the island of Brač as a whole, nor given the number of other specialists working on the subject, would it be particularly useful. What we can do is try to investigate and present some specific areas of the archaeology or landscape archaeology of Brač through the application of GIS techniques. We would also like to use these case studies to illustrate the type and resolution of data that archaeologists working in these regions or elsewhere must collect if they are to make good use of the potential of GIS. Following this line of thought, we have restricted ourselves to four particular problem areas:

– the definition of Bronze age, Iron age and Roman age site territories,
– aspects of the analysis of land use within site territories,
– to analyse transition and migration trends from the Bronze to Iron ages,
– to model perception of space and territories on selected sites from the Bronze age using mental maps approach.

5.1 *Analysing settlement patterns and territories of Bronze and Iron age sites*

Virtually all human groups produce boundaries and the history of archaeological research is littered with attempts to locate these problematic barriers (De Atley, Findlow 1984). Cultural boundaries, ethnic boundaries, property boundaries and the less tangible boundaries of personal space have all become the object of archaeological research at some point or another and a bewildering range of archaeological examples and ethnographic cautionary tales relating to their definition can be found in literature. Despite the perpetual dangers of «drawing lines that don't exist around areas that don't matter», in this chapter we intend to look how GIS can be applied to the problems of boundary identification.

Eleven hillfort sites on the island of Brač were dated on the basis of pottery detected in the Bronze age. The initial inspection of their distribution shows a strong concentration of these sites on the highest plateau. There seems to be only two sites which occur closer to the sea. The settlement pattern in the Iron age is dramatically different. Two of the Bronze age sites remain inhabited. The Gračišče site on the eastern coast of the island and Gradac in the higher plateau retain their position in this period, while all other Bronze age hillforts appear to be abandoned. However, five new sites appear and they are all positioned very close to the sea.

Most GIS include a module to calculate a relative cost surface across a landscape using the DEM. The cost surface shows the relative energy or time consumption expended when an individual crosses from one point to another. If the land crossed is steep in one direction the energy use and time consumption will be greater and the distance to the edge of the catchment shorter. If the land in another direction is relatively flatter this will be reflected by a longer distance to the edge of the catchment. In considering these results we should note that 1 hours walk catchment was suggested as a limit of the territory (Bintliff 1977, 112).

We can demonstrate the process of constructing a catchment using all Bronze age sites in Fig. 5. For example, the site on Vidova Gora above Zlati rat, which is observed, the territory to the north, which includes the high plateau, produces a greater distance to the edge of the catchment. The area to the south which is in the direction of the coast produces a far shorter distance to the catchment boundary. This is due to a very dramatic drop in elevation and extremely steep terrain.

We can assume that the territories calculated with the cost surface approach present a sufficient approximation to territories of the Bronze age hillforts. Using this model it can be clearly proved that even the site Gnjilac at the north-western part of the island did not include coast in its territory. All Bronze age societies on the island of Brač were definitely oriented towards the high plateau and Nerežiško polje. The proximity of sea did not play any important roll in the society.

However, in the Iron age, the situation is very different. If the cost surface approach is applied on Iron age hillforts one can clearly see very a different pattern of territories (Fig. 6).

Iron age communities definitely moved toward the sea. All seven sites include coast in their territories, with the exemption of Gračišče near Donji Humac and Gradac at the high Plateau. Gračišče near Donji Humac is positioned above Nereţiško polje and must have used the resources from this very fertile field extensively. This site is less than 1 kilometer away from the Bronze age site of Gnjilac and might represent some kind of continuity of the earlier settlement. The Gradac hillfort on the high plateau might have been

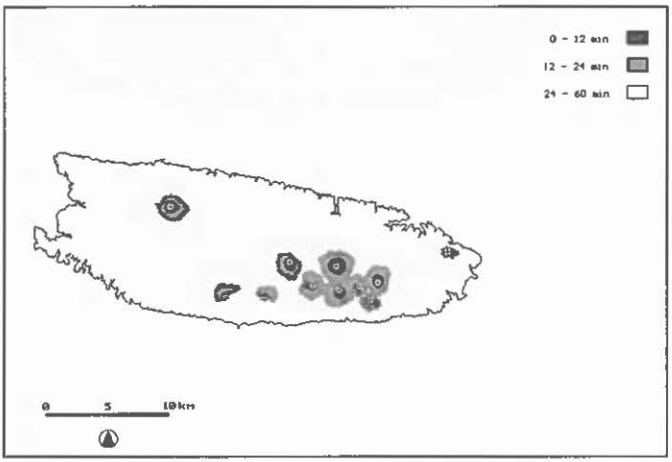

Fig. 5 – Cost surface territories of the Bronze age hillforts.

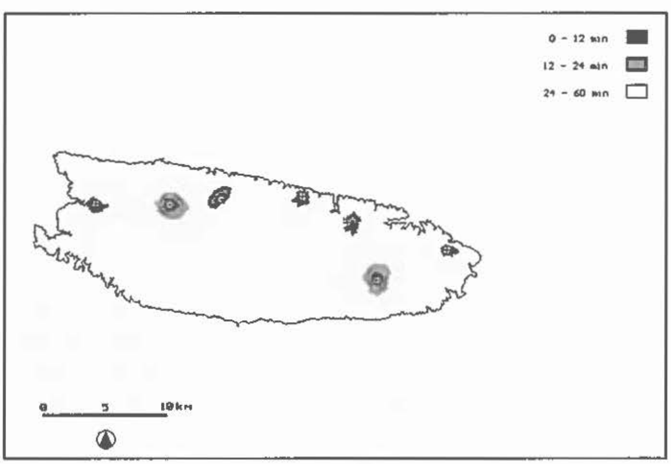

Fig. 6 – Cost surface territories of the Iron age hillforts.

in continuous use throughout the Bronze and Iron age. It has probably extensively used resources on *polje* which lies east from the site.

The change of geographical location of the hillforts is marked by the movement from the inland and higher plateau to locations closer to the coast. Hillforts now control sea resources and, most notably, safe anchorage. For example, the Vicja Luka bay is only a kilometer away from the Split gates, which can be very difficult to sail in the very frequently dangerous north-eastern and south-western winds, and together with the hillfort above, it contains important records on the trade and other contacts with the Greeks (Marović 1971; Marović, Nikolanci 1977). The location of the Iron Age hillforts is clearly a compromise between the wish to control sea resources, trade routs and fertile land.

5.2 *Perception of space in Bronze age*

Following the initial analysis of territories, landuse and migration trends in prehistory and the Roman age we were very tempted to try to move in other directions with GIS research. While most of the analysis performed was oriented towards the economy, and since we already criticised some aspects of this kind of research, we decided to try to model the perception of landscape of some past societies. During the field work on the island of Brač some 240 Bronze age barrows were documented. It was assumed that they might help us in modeling the perception of space and mental maps of the Bronze age population.

Our general hypothesis is that barrows are not distributed randomly over the landscape but are positioned very carefully. We think that they might be positioned on special points relatively close to individual hillfort settlements where they could simultaneously mark the territories of individual hillfort societies and inform the intruders that they are coming on someone else's land. In accordance with this assumption, several hypotheses were set. The first one is on the distribution of barrows considering the distance from the central settlement. We would like to see how far away from the settlement are the barrows which belonged to that individual settlement positioned. The second hypothesis is that the barrows act as some kind of landmark and therefore would have to be positioned in locations such that they would be intervisible from the hillfort. Finally, we would like to model the landscape in terms of which points on the landscape are the most visible from all barrows. By doing this we might be able to investigate some trends in the perception of space in the Bronze age. All the research described was carried out on the area around the hillfort Gradac on the eastern part of the island. Gradac is a very prominent hillfort lying close to the hillforts Hum and Smrcevik veli. In its close proximity there are 55 barrows which most probably belonged to the commune living on Gradac. The area under study is shown on Fig. 7

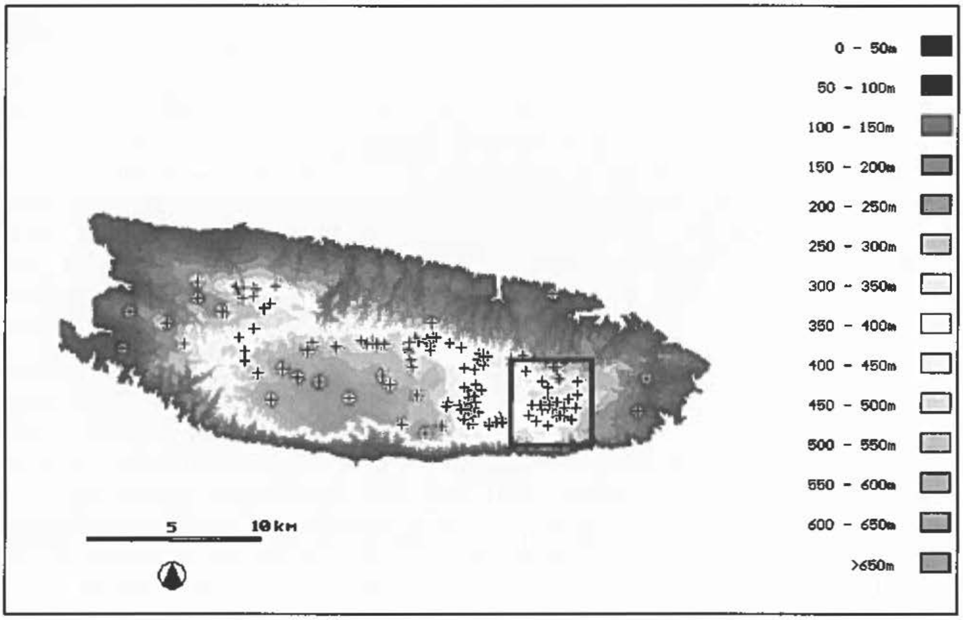

Fig. 7 – Location of the area under study with the distribution of Bronze age barrows.

together with the general distribution of all barrows documented.

The analyses began by testing the first two hypothesis which were questioning the distance from hillfort to the barrows belonging to it. A cost surface model was used to design a catchment within 30 minutes walking distance from the hillfort Gradac. If the catchment is compared to the distribution of sites, one can clearly see that all the barrows belonging to this hillfort are positioned within 30 minutes catchment. We continued the analysis by analysing which locations in the landscape are visible from the hillfort. In Fig. 8 the solid line represents 30 minutes catchment, while the shaded area represents all surfaces which are visible from the hillfort Gradac. The Gradac hillfort is represented with a black dot and barrows with crosses. In some cases a cross can represent more barrows if they are clustered in a smaller area.

The largest cluster in the area is composed of 7 barrows. One can clearly see that 41 barrows from total 55 analysed in the area fall within the area visible from the hillfort. There are a few exceptions in this pattern which are worth stressing. On the southwestern part of the study area there are two barrows lying in the valley going from the Gradac hillfort towards the hillforts Hum and Smrčevik veli. They are not visible from Gradac but they stand on the easiest route towards the two neighboring hillforts. We can assume that they mark some kind of crossing point in the landscape. It is worth noting how the 30 minutes catchment line follows the area visible from the Gradac

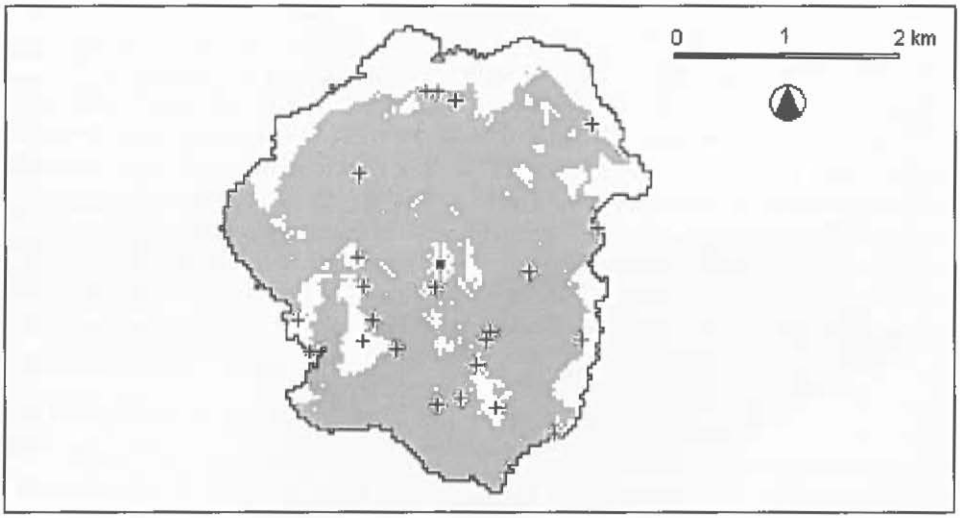

Fig. 8 – Surface visible from Gradac hillfort, Gradac 30 minutes catchment and barrows locations.

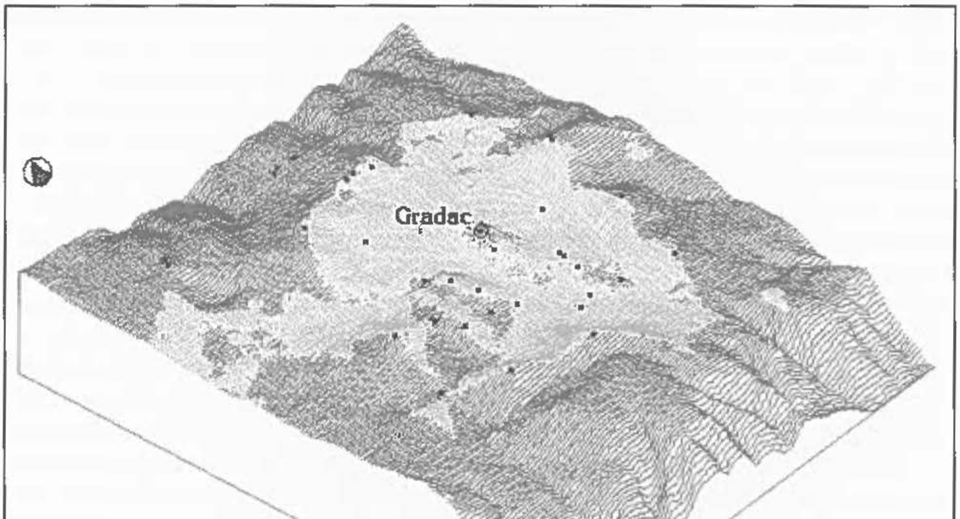

Fig. 9 – Perspective view on the landscape under study. Lighter grey colour presents the surface visible from the Gradac hillfort. Black dots are barrows.

hillfort. All these patterns are much easier to perceive on the perspective image of the landscape in Fig. 9. The lighter grey colour represents surfaces seen from the Gradac hillfort and black dots present the location of barrows or barrows clusters.

In further analysis we wanted to model the space as seen from all barrows in the area under study. The analysis of this data involved the calculation of the viewshed for each monument, that is the area which can be seen from an individual site. This information represents the area within which that monument is likely to communicate visual information. Monument viewsheds can overlap, producing zones in which an observer might be aware of many monuments, all of which may carry information. Presumably, the increasing density of such information can be interpreted in some circumstances as a measure of the importance of a particular area. In the context of this work, it is perhaps better to emphasise the ability of such a procedure to provide a mapable, spatially variable index of perception, which incorporates groups of monuments and plots their visual relationship with the surrounding landscape. Analysis of this data should give an insight into the cognitive landscape within which the monuments operated.

This procedure is called cumulative viewshed produced interesting results (Fig. 10). Within the cumulative viewshed the areas which are only visible to one monument have a value of one and the areas which are intervisible have a value of two. Analysis of these viewsheds provides a number of inter-

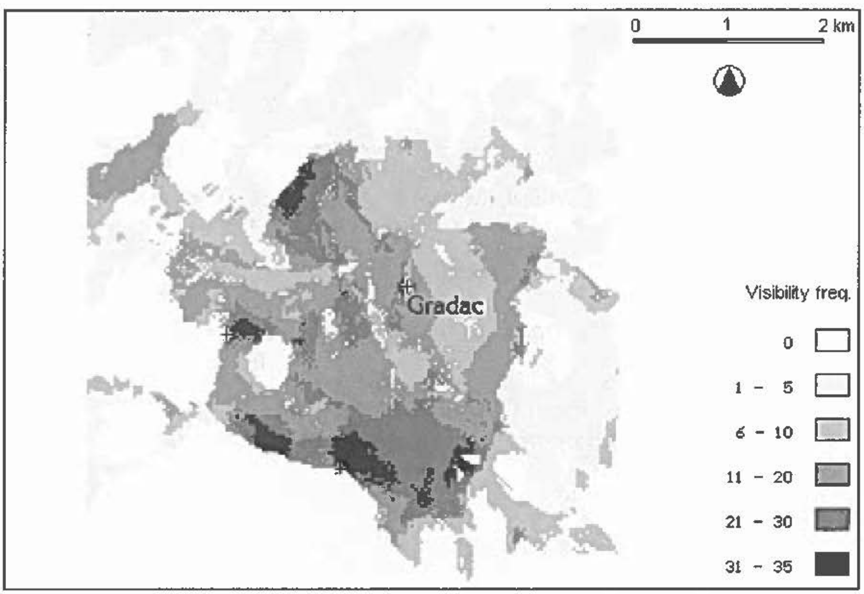

Fig. 10 – Cumulative viewshed from all barrows within Gradac catchment.

esting patterns. The highest cumulative viewshed values are on top of the hills around Gradac which dominate the landscape. On the locations which are seen from most barrows there are usually no archaeological features. However, the Gradac hillfort is seen from 34 barrows in the area out of which 41 have been interpreted to fall in its catchment.

6. CONCLUSIONS

The analysis of the Brač barrows and hillforts clearly illustrates the potential of GIS for the study of large-scale cognitive phenomena and its ability to utilise the full landscape for such purposes. This is new and we are only just beginning to explore the possibilities on offer (GAFFNEY *et al.* 1995). The future for innovative work in GIS will therefore lie in the development of more sophisticated mathematical modules explicitly for archaeological purposes and within the context of GIS technologies. The approaches presented here present the possibility to produce results on changes of landscape, settlement patterns, perception of space and environment.

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BIBLIOGRAPHY

BINTLIFF J.L. 1977, *Natural Environment and Human Settlement in Prehistoric Greece*, BAR Supplementary Series 28, Oxford.

BURROUGH P.A. 1986, *Principles of Geographical Information Systems for Land Resources Assesment*, Clarendon Press, Oxford.

ČEČUK B. 1981, *Kopacina, Otok Brač – vipeslojno prethistorijsko nalazište*, «Arheološki pregled», 22, 9-10.

ČUBRAKOVIČ V. 1984, *Uvod u geologiju i hidrogeologiju otoka Brača*, «Bračkі zbornik», 14, 17-22.

DE ATLEY S.P., FINDLEY F.J. 1984, *Exploring the Limits: Frontiers and Boundaries in prehistory*, BAR International Series 223, Oxford.

DERADO K. 1984, *Reljef otoka Brača*, «Bračkі zbornik», 14, 7-13.

GAFFNEY V., STANČIČ, Z. 1991, *GIS Approaches to Regional Analysis: A Case Study of The Island of Hvar*, Ljubljana, Znanstveni institut filozofske fakultete.

GAFFNEY V., STANČIČ Z., WATSON H. 1995, *The impact of GIS on archaeology: a personal perspective*, in *Arhaeology and Geographical Information Systems*, London, Taylor & Francis, 211-229.

JELASKA V. 1984, *Bituminozne stijene otoka Brača*, «Brački zbornik», 14, 39-42.

JURAS V. 1984, *Klimatski prikaz otoka Brača*, «Bracki zbornik», 14, 57-65.

MAROVIČ I. 1971, *Zeljeznodobni grobovi u Zaganj-docu (o. Brač)*, «Vjesnik za arheologiju i historiju dalmatinsku», 65-67, (1963-1965), 1-26.

MAROVIČ I., NIKOLANCI M. 1977, *Cetiri groba iz nekropole u Vičjoj Luci (o. Brač) u 1908 god*, «Vjesnik za arheologiju i historiju dalmatinsku», 70-71, (1968-1969), 5-55.

MILOŠ B. 1984, *Brača tla*, «Bracki zbornik», 14, 66-77.

VRSALOVIČ D. 1957, *Bilješke s reambulacije*, «Bracki zbornik», 3, Split, 88-97.

VRSALOVIČ D. 1968, *Povijest otoka Brača*, «Bracki zbornik» 6, Supetar.

ABSTRACT

An international team of scholars from Croatia, Canada, Britain and Slovenia is trying to analyse human adaptation of nature on the Central Dalmatian islands in Croatia. Archaeological data and various environmental information was integrated into GIS. GIS was ideal platform for a variety of analytical procedures: the economy of past societies was analysed, territories of larger communities were modelled, trade routes were predicted and the positioning of different sites was observed. In the paper special emphasis is paid to the GIS application of sites and monuments database in the analysis of the perception of space using the data from the Bronze age.