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IMPLEMENTATION OF GIS TECHNOLOGIES IN ASSESSMENT AND PROTECTION OF NATURAL VALUES OF TARA NATIONAL PARK

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Abstract - Mount Tara is among the most important centers of Balkan and European ecosystem and species biodiversity. It is characterized by diversified and well-maintained communities of old deciduous and mixed coniferous forests (beech/fir/spruce). They represent a unique example of well preserved forests in SE Europe with numerous endemic and relict species of indigenous flora and fauna. The geographical information system (GIS) that we have created has proved an excellent tool for valorization and protection of all natural values and potentials of Tara National Park.

Key words: Tara National Park, geographical information system, biodiversity

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INTRODUCTION

Mount Tara represents a unique example of well preserved forests in SE Europe with numerous endemic and relict species of flora and fauna. The territory of Mt.Tara is on the list of Important Bird Areas of Europe (IBA) and Prime Butterfly Areas in Europe (PBA). There is an initiative to include Mt. Tara on the list of Important Plant Areas (IPA). These characteristics justify the inclusion of Mt. Tara in the Pan-European Ecological Network. Specific geomorphological, hydrological, geological, soil, and climatic features are also present on Mt. Tara.

Tara NP is one of the most thoroughly researched national parks in Serbia and Montenegro. During the last 60 years, many scientists and managers of the park have collected a large amount of data dealing with natural values of the area. The first study to declare Mt. Tara suitable for the status of a national park was performed in 1951, but Tara NP was not established until until the 1981. The Physical Plan of Tara National Park was accepted in 1989. In order to manage Tara NP effectively, it is divided into five managing units with a total of 751 parcels and subparcels.

The management and direction of practically all natural potentials of Tara NP are now primarily based on well-known principles of forestry, technology and management. The present study represents an effort to incorporate modern knowledge from the fields of biodiversity protection, conservation ecology, and geography into the mechanism of management of national natural resources, primarily to ensure their effective protection and sustainable exploitation.

It was our ambition to combine all of this data and create a modern database regarding the environmental (in the first step) and socioeconomic (in the final phase) potentials of Mt. Tara and the territory of Tara National Park as a future MAB reserve (A s h d o w n and S c h a l l e r, 1990; R a d o v i ć, 2004b).

Because environmental systems are highly complex, we most often tend to focus on small, discrete, and simplified aspects in studying them. But most problems of the environment are multi-factorial and demand analysis of a wide spectrum of information resources, questions and interests. This is where geographic information systems (GIS) as a computer-based approach entailing input, storage, manipulation, analysis and output of spatially referenced data play their role. For ecologists, GIS have

opened many new possibilities for research and application of gathered information. The GIS which we have created for Tara NP has themes similar to those of GIS projects (in ecology, environmental management, forestry, etc.) in Europe and the rest of the world.

This type of research is fully in keeping with world wide programs of investigation, preservation, and protection of mountain ecosystems undertaken because they are centers (hot spots) of great species and ecosystem diversity (Wadsworth and Treweek, 1999; Convis, 2001; Longley *et al.* 2001).

MATERIAL AND METHODS

Study Site

Tara NP (whitch encompasses the largest part of the Mt.Tara) is located in the southwestern part of the Republic of Serbia between 43°52'30'' and 44°01' North latitude and 19°14'30'' and 19°41'30'' East latitude (180 km from Belgrade) (Fig. 1). The park itself has an area of 19,175 ha, while the protected buffer zone around it has an area of 37,584 ha. There are two characheristic spatially-functional areas within Tara NP: High Tara (11,562 ha) and Flat Tara (7,613 ha) (Zeremski, 1956). The average altitude is from 1000 to 1200 m. The highest point of Tara NP is Kozji Rid (1 591 m), while the lowest point is at 300 m (where the reservoir of the Perućac hydroelectric power plant is located). Based on these characteristics, Mt. Tara is classified as one of the medium-high mountains of Serbia and Montenegro.The national park is completely within the territory of the Bajina Bašta municipality.

Study Procedure

Data sources

One of the major factors in creation of a successful GIS project is reliability of the data. In keeping with the requirements of the project, a large number of various types of data sources were used in its realization. Only data from authorized governmental institutions were taken into account here:

A topographic map on a scale of 1:50 000 (Military Geographical Institute, Belgrade, status as of 1984);

A topographic map on a scale of 1:50 000 (in digital raster form) (Military Geographical Institute, Belgrade, status as of 1984);

A map of relief and hydrology on a scale of 1:50 000 (Military Geographical Institute, Belgrade, status as of

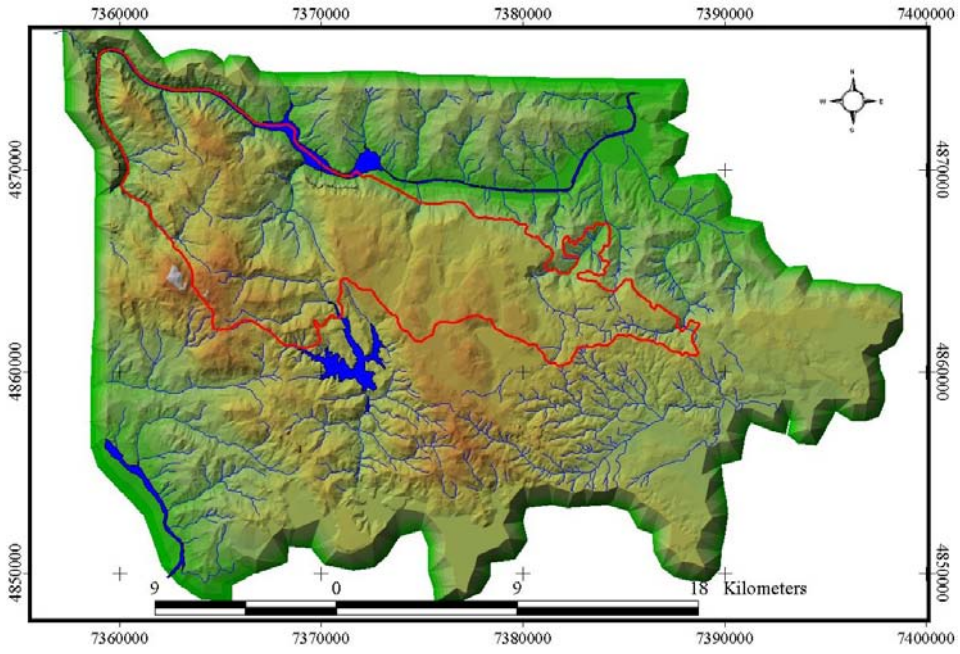

Fig. 1. Borders of Tara NP on DEM

1984);

A geological map on a scale of 1:100 000 (National Geological Institute, Belgrade, 1986 and 1977);

A soil map on a scale of 1:50 000 (Institute for Soil Research, Belgrade, 1963);

Aerial photographs (Military Geographical Institute, Belgrade, 1959);

A vegetation map of Tara NP on a scale of 1: 50 000 (Physical Plan of Tara NP, 1988);

A map of the five units of Tara NP on a scale of 1: 50 000 (Tara NP, 2003);

A map of the five units of Tara NP (with 751 parcels) Zvijezda, Crni Vrh, Rača, Tara, and Kaludjerske Bare, scale of 1:10 000 (Tara NP, 2003);

Data consisting of nine kinds of information for each parcel in the unit (name of the unit, number of parcels and sub-parcels, type of woodland, vegetation communities that occur, ecological affiliation of vegetation according to the type of soil, percentage of every vegetation species that occurs, purpose for witch the parcel is used, and the level of protection - zoning (Tara NP, 2003);

Data on representatives of the fauna and flora (source quoted for each processed group); and

A tourist map of Tara NP on a scale of 1: 25 000 (Geokarta, Belgrade, 2003).

Methodology of work and Content of Tara NP GIS

We appiled the procedures used in most GIS projects: scanning, georeferencing, digitizing (manual and semiautomatic), creation of a database, and integration of data (R a d o v i ć , 2004a). The Tara NP GIS is divided (by type and format) into various data forms: raster data, vector data, digital elevation model, and database. Raster data include all maps and aerial photographs cited in data sources after having been georeferenced.The following entities are represented in vector form: geology (polygon), soil (polygon), hydrology (line/polygon), vegetation communities (polygon), locations of important floristic and faunistic species (point), borders of Tara NP (polygon), management units (polygon), departments - parcels (polygon), settlements (polygon), roads (line), mountaineer trails (line), and other objects such as hotels, scenic points, waterfalls, caves, and groceries (point).

To achieve the maximum effect, 3D analyses were anticipated throughout the project. These analyses demand that certain phenomena be correlated with relief characteristics (elevation, aspect, and slope). To accomplish the appointed requirements, a digital elevation model (resolution 20 m pixel) was created. The DEM covered an area of about 1000 km^2 and for each pixel provides: coordinates (in meters), elevation (in meters), aspect (in degrees), and slope (in percentages). The elevation value in all of the following figures and 3D models is authentic (Z factor is 1,00 and H=100 %), so the images of relief are absolutely realistic and appear as in nature. The 3D model lies on a rectangle which represents sea level (altitude is zero meters).

The material used to process aerial photographs included a series of 19 photos of Tara NP (scale R= 1: 30 000; Wild RC-5 camera, year of production 1959). By using photographs almost 50 years old, we were able to discern some changes in vegetation and human influences that led to them. Processing of these photographs included scanning (resolution 750 dpi grayscale), georeferencing, and combining them with other data (vector and DEM).

RESULTS AND DISCUSSION

Geomorphological characteristics of Mt. Tara

The GIS analyses of geomorphological characteristics of the park included elevation zones, aspect and slope of relief. As for elevation zones these analyses show that most of the park's area lies at altitudes of from 800 to 1200 m (12,571 ha or 65,56 %) (Fig. 2). The GIS analyses of relief aspect show that north (2,853 ha; 14.9 %), northeast (3,604 ha; 18.8 %) and northwest (2,199 ha; 11.5 %) aspects take up most of the park. The GIS analyses of relief slope show that slope between 0-9.1 % encompasses 4,964.2 ha or 25.9 % of the park's territory; slope between 9.2- 18.3 % encompasses 5,363.4 ha or 28 %; and slope between 18.4-27.4 % encompasses 3,895.4 ha or 20.32 %; and slope between 27.5- 36.5 % encompasses 2,768.2 ha or 14.44 %.

Geological characteristics of Mt. Tara

The complex of Mt. Tara is characterized by high

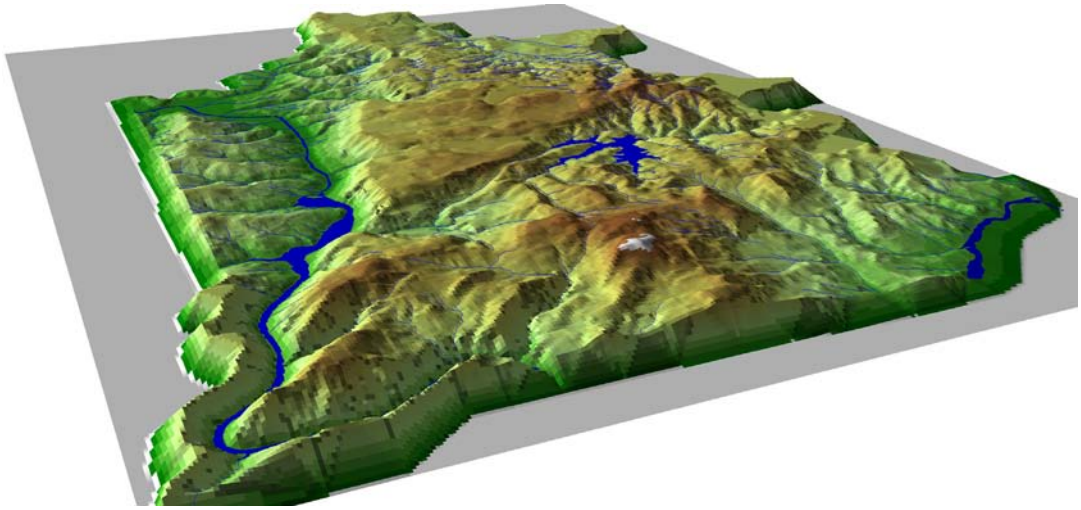

Fig. 2. Elevation zones on 3D model (NW view)

geological diversity with respect to age, origin and composition. There are rocks from the Carboniferous, Triassic, Jurassic, Cretaceous, Tertiary and Quaternary.

The GIS analyses of geology covered a total area of 34,351 ha. Authentic content was classified into 35 types of geological cover. To be able to make adequate correlations (with vegetation primarily, a generalization into six basic and seven combined types was performed (Tab. 1). Inside the park, limestone represents 77% of the rocks. In areas of Mt. Tara outside the park, limestone accounts for about 60 % of the rocks.

Table 1 Distribution of geology (absolute and proportional) within Tara NP

Geology	Area	
	(ha)	(%)
Limestone	14778.13	77.07
Mostly clastites	1381.11	7.20
Clastites	328.66	1.71
Mostly clastites with carbonates	95.53	0.50
Serpentinites- ofiolites (peridotites)	736.50	3.84
Ofiolites	700.82	3.65
Metamorphite	941.49	4.91
Free fluvial	130.58	0.68
Serpentinites- ofiolites	6.24	0.03
Mostly clastites (meta sediments)	24.90	0.13
Decomposed substrate	43.77	0.23
Mostly metamorphite	6.83	0.04
total	19174.56	100.00

Soil characteristics of Mt. Tara

The soil cover was digitized for an area of 55,024 ha, with ten types of cover: skeletal-rocky ground, chernozem on serpentines (humus silicate soil), alluvial deposit, deluvium, brown reddish soil on limestone, calcareous-skeletal soil on firm limestone, brown skeletoid soil on schist, parapodsol-gleized soil, eroded smonitza (shallow), and skeleton soil on serpentines.There are five types of soil cover inside the park (Tab. 2).

Hydrologic characteristics of Mt. Tara

Table 2. Distribution of soil type within Tara NP

Soil type	P (ha)	%
chernozem on serpentines (humus silicate soil)	2413.53	12.90
brown reddish soil on limestone	6529.85	34.00
calcareous - skeletal soil on firm limestone	9119.02	47.60
deluvium	44.55	0.23
brown skeletoid soil on schits	1067.61	5.57
total	19174.56	100.00

The most conspiciuos hydrological characteristic of the park is the Drina River (total length of 346 km; 22,7 km running around the park) and its canyon. The Drina forms a canyon over 1,000 m high on the park's boundary line. Most of the streams on Mt. Tara belong to the Drina River basin. The Drina is the biggest tributary (in terms of length, drainage area, and flow of water) of the Sava River and represents the base of the hydroelectric energy potentials of Serbia and Montenegro (G a v r i l o v i ć and D u k i ć , 2002).

There are three reservoirs in the region of Tara NP: Perućac, Zaovinsko Jezero and Kruščica. The Perućac

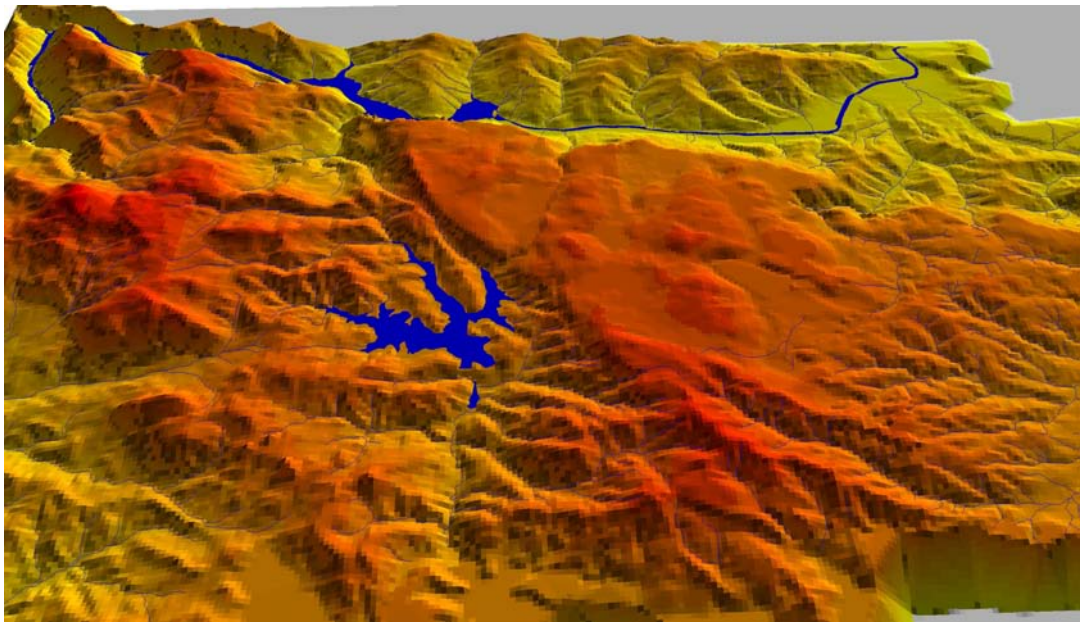

Fig.3. Hydrology on 3D model (S view)

Reservoir (50 km long, area of 12.4 km^2, max. depth of 85 m) was created when a dam (93 m high and 461 m long) was built in 1962 to provide hydroelectric energy for Bajina Bašta. The Zaovinsko Jezero (at an elevation of 600 m above the Perućac Reservoir) has five branches and about 150 million m^3 of water. It was created when a dam (125 m high) was built on the Beli Rzav River. It belongs to the reversible type. During the rainy season (and when the Drina has a high water level), water from the Drina is pumped through a pipeline 8 km long to Zaovine. When there is a shortage of electric energy, water runs back to the Drina and produces electric energy in pipeline turbines. Kruščica is just below Zaovine and is used only as a drinking water supply for the whole region.

The GIS theme Hydrology includes all hydroelements on Mt. Tara: streams, rivers, and lakes. It is possible to get information about the length of every watercourse or segment. The data model allows us to input information about the ichtyofauna present (Fig. 3).

Climate of Mt. Tara

The climate of Mt. Tara is characterized by fresh to cool summers and quite cold winter. Average annual temperature is 7.9^{0}C. Annual temperature variation is small: January -4.5^{0}C, August 16.7^{0}C. Nice weather continues into the first part of autumn, and October is warmer than April. Compared with other mountains of Serbia, Mt. Tara has a more pronounced mountain climate. Average annual precipitation is 977 mm. Snow starts to fall at the beginning of November and is present until the first part of May. Average thickness of the snow cover is about 100 cm (Tara Biosphere Reserve 2003). A particular characteristic of the climate of Mt. Tara is very high average annual humidity (83.4%) (Fig.4).

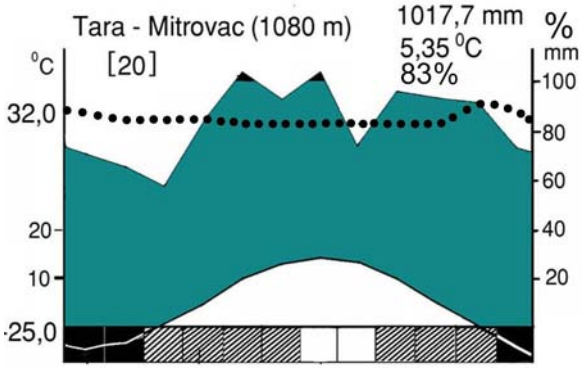

Fig.4. Climatic diagram of Mt. Tara (according to S t e v a n o v i ć , 2002)

Complexity of the climate is readily evident from the distribution of vegetation. Within the spacious area of Mt. Tara from 900 m to 1200 m, almost all species of the boreal dendroflora of Europe and their communities exist.

It is especially interesting that species like *Picea abies, Pinus sylvestris, Vaccinium myrtillus, Eriophorum latifolium, Listera cordata, Goodyera repens,* etc. live at low altitudes. This phenomenon is correlated with specific mesoclimate conditions. All communities that include mixed (deciduous-coniferous) forests and coniferous forests are spread like a mosaic, depending on the aspect and slope of the relief. This mosaic represents the basic ecological and biogeographical characteristic of Mt. Tara.

Analyses of floristic and vegetation diversity of Tara NP

Up to now, 1013 plant species have been recognized on Mt. Tara. That represents almost 1/3 of the entire flora of Serbia (G a j i ć , 1988; J o v a n o v i ć and O s t o j i ć , 2001). The large number of relict and endemic species confirms the opinion of botanists that Mt. Tara is one of the centers of floristic and vegetation diversity in Serbia and this part of the Balkan Peninsula. Some of the most important endemic and relict species are: *Picea omorika, Centaurea derventana, Potentilla visianii, Aquilegia grata, Edraianthus graminifolius aggr., Gypsophila sperguliifolia, Onosma stellulatum, Halacsya sendtneri, Cephalaria pastricensis, Haplophyllum boisserianum, Daphne blagayana, Hieracium waldsteinii, and Acer heldreichii* (S t e v a n o v i ć , 2002a).

At the center of floristic diversity of Mt. Tara is certainly the Serbian (Pančić's) spruce, *Picea omorika,* a unique paleo–endemic species and a living fossil of the European dendroflora with a range confined to the middle course of the Drina River in Western Serbia and Eastern Bosnia and Herzegovina (P a n č i ć , 1874, 1887; G a j i ć *et al.* 1994).

Mapping of some locations of characteristic and specific plant species (*Picea omorika, Micromeria croatica, Centaurea derventana, Euphorbia glabriflora, Acer heldreichii, Spirea cana, Daphne malyana, Leontopodium alpinum, and Aquilegia grata nikolicii*) for the Tara NP was completed with GPS after field research in July of 2003.

Within GIS analyses, the theme "Vegetation" was digitized from a vegetation map on a scale of R = 1: 50000 (M i š i ć , 1988). The vegetation map covers a total area of 28,244.5 ha. Vegetation is differentiated into 35 vegetation communities in a total of 354 polygons. Attribute data are in Serbian and Latin names. Inquiries addressed to the database allow us to get answers about the size of every polygon and all other statistical indices regarding the spread of vegetation communities. Parameters of vegetation can be easily correlated with all other themes. For instance, how the distribution of some vegetation corresponds with the type of geology, soil, elevation zones, and slope and aspect of relief (M i š i ć , 1988; G a j i ć *et al.*, 1992) (Tab. 3).

Table 3. Distribution of vegetation (absolute and proportional)

Latin name	Area (ha)	Area (%)
Carpino orientalis-Quercetum confertae cerris	61.18	0.22
Quercetum cerris carpinetosum orientalis	33.16	0.12
Quercetum cerris juglandetosum	24.85	0.09
Parietario-Juglandetum cerretosum calcicolum	16.73	0.06
Orno ostryetum carpinifoliae	2291.34	8.11
Orno ostryetum juglandetosum	85.79	0.30
Ostryo pinetum nigrae	867.94	3.07
Quercetum montanum	5.75	0.02
Alnetum glutinosae	9.85	0.03
Aceri-Ostryo-Fagetum	585.50	2.07
Fagetum submontanum	130.44	0.46
Fagetum submontanum juglandetosum	57.51	0.20
Erico-Pinetum	131.47	0.47
Fagetum montanum	352.53	1.25
Abieti-Fagetum	327.76	1.16
Piceeto-Abieto-Fagetum	2656.65	9.41
Piceeto-Abieto-Fagetum oxalidetosum	8922.71	31.59
Piceeto-Abieto-Fagetum myrtilletosum	108.74	0.38
Piceeto-Abieto-Fagetum pinetosum	1210.80	4.29
Piceeto-Abieto-Fagetum ostryetosum	21.30	0.08
Piceeto-Abieto-Fagetum ilicetosum	7192.42	25.46
Piceeto-Abieto-Fagetum taxacetosum	25.54	0.09
Piceeto-Abieto-Fagetum – Pinetum nigrae ostryetosum	53.03	0.19
Omoriko-Piceeto-Abieto-Fagetum	56.64	0.20
Omoriko-Piceeto-Abieto-Fagetum-Alnetum mixtum	574.47	2.03
Brometum erecti	47.17	0.17
Alectorolopho-Cynosuretum cristati	1831.14	6.48
Danthonietum calicinae	9.15	0.03
Nardetun strictae s.l.	148.65	0.53
Magnocaricion	43.04	0.15
Danthonietum calicinae	133.54	0.47
Poo molineri-Plantaginetum carinatae	99.37	0.35
Fagetum submontanum mixtum	24.48	0.09
Future reserve in beech forest	82.61	0.29
Reserve of Picea omorika	21.16	0.07
Total	28244.42	100.00

Analyses of faunal diversity of Tara np

Besides floristic and vegetation diversity, one of the most important characteristics of the natural potentials of Mt. Tara is the high diversity of its fauna.

The following animals have been recorded to date on Mt. Tara: 115 species of butterflies (60 % of the fauna of Serbia and Montenegro); 27 species of fish (25%); 12 species of amphibians (46 %); 12 species of reptiles (27

%); about 170 species of birds (45 %); and 51 species of mammals (48 %) (Radović, 2004a).

Special value to the fauna of Mt. Tara is lent by the presence of the grasshopper *Pyrgomorphulla serbica*, an endemorelict from the Pliocene (Matvejev, 1978; Pavićević, 2001).

Among other insect species, the presence of three species of butterflies (*Euphydryas maturna, Maculinea arion, and Parnassius apollo*) is very important. They qualify Mt. Tara as one of the Prime Butterfly Areas in Europe (YU-14) (Jakšić, 2003a, 2003b). Since October of 2003, Mt. Tara has been listed as one of the Prime Butterfly Areas in Europe (PBA) and a priority site for conservation (Swaay and Warren, 2003; De Vlinderstichting, Butterfly Conservation, Insect Life International). There are three important fish species on Mt. Tara that contribute highly to diversity of the ichthyofauna: *Hucho hucho* (Danubian salmon), *Salmo trutta* (brown trout), and *Thymallus thymallus* (grayling) (Simonović, 2001).

Some important species of amphibians and reptiles in the area of the park are: *Salamandra salamandra, Rana graeca, Zootoca (Lacerta) vivipara, Vipera ammodytes* (Džukić, 1973, 1995).

There are over 170 bird species on Mt. Tara (Matvejev, 1951; Vasić, 1977). Our ornithologists have proposed that this area be listed as one of the Important Bird Areas of Europe based on the presence of 46 particular bird species. The nomination was accepted for six bird species (whose population on Mt. Tara is larger than 1% of the total population): *Aquila chrysaetos, Falco peregrinus, Otus scops, Picus canus, Picus viridis, and Phoenicurus phoenicurus*). Accordingly, the region of Mt. Tara (36,000 ha) marked as 019 was included in the IBA list (Puzović and Gruбač, 2000). Among other important bird species of Tara NP are *Picoides tridactylus and Tetrao urogallus*.

The most valuable localities of birds are the canyon of the Rača, Zvijezda, the canyon of the Drina, and the gorge of the Beli Rzav.

The mammal fauna of Mt. Tara is characterized by the presence of the following representatives of large species: *Ursus arctos, Canis lupus, Rupicapra rupicapra, Sus scrofa, Felis sylvestris, Capreolus capreolus, Martes martes, Martes foina, Meles meles,* and (recently) *Lynx lynx* (Savić *et al.* 1995; Puzović, 2001; Paunović, 2003, *in voce viva*).`

The bear, *Ursus arctos*, is the symbol of Mt. Tara and is a characteristic resident of the western part of the muontain (Zvijezda, Crni Vrh, and the canyons of the Drina, Brusnica, Derventa, and Rača). Based on intensive tracking of the bear population, the estimated number today is about 30 individuals.

The chamois, *Rupicapra rupicapra*, represents a second important and protected species of large mammals on Mt. Tara. It is especially present on steep limestone peaks, cliffs, and hillsides within the canyons of the Drina, Brusnica, Derventa, and Rača. Today's number is about 100 individuals.

It is very important to mention the presence of the great vole (*Microtus multiplex*) in the area of Kameno Brdo, elevation of about 1100 m, and region of the Beli Rzav at 900 m. Its habitat on Mt. Tara is the only one in Serbia (Petrov, 1992; Puzović, 2001) and at the same time the eastern-most point of its range in the Balkans and Europe (Mitchell-Jones *et al.* 1999).

The distribution of all of these species in Tara NP is managed and mapped within the GIS.

Diversity of species on Mt.Tara

The region of Mt. Tara is characterized by high species diversity and high indices of species densities of the analyzed taxa. Living in this area, which represents 0,0039 % of the territory of Europe, are 10 % of all species of vascular plants, 26 % of all species of butterflies, 32 % of all species of birds, and 39 % of all species of mammals of Europe (Tab. 4).

Mount Tara also represents a center of ecosystem diversity. The vegetation of Mt. Tara includes more than 35 different communities of deciduous forests, mixed (deciduous-coniferous) forests, and coniferous forests as well as 19 meadow communities. Many of them, especially those with *Picea omorika* have a relict or endemorelict character.

The initiative on the inclusion of Mt. Tara to international list of areas important for preservation of the world flora – Important Plant Areas (IPA) – is therefore justified (Stevanović, 2002b).

Table 4. Comparative numerical synopsis of biological diversity for some groups in the region of Mt. Tara, Serbia and Montenegro, and Europe (according to S t e v a n o v i ć and V a s i ć , 1995).

Region / Taxa	Europe 4900000 km²	SCG 102.173 km² SCG/Eu=2.1%	Tara 192 km² Tara/SCG=0.19% Tara/Eu=0.0039%	%			Id=logS/logA		
				SCG/ Europe	Tara/ SCG	Tara/ Europe	Europe	SCG	Tara
Fungi Macromicetes	6.500	650	251	10	38.61	3.86	0.570	0.562	1.051
Vascular plants	10.000	4.282	1.013	38.93	23.66	10.13	0.598	0.725	1.316
Lepidoptera (Hesperioidea, Papilionoidea)	441	192	115	43.53	59.90	26.08	0.395	0.456	0.903
Pisces (Osteichties)	251	110	27	51.16	24.54	12.56	0.349	0.408	0.627
Amphibia	74	26	12	35.14	46.15	16.21	0.279	0.282	0.473
Reptilia	203	44	12	21.67	27.27	5.91	0.345	0.328	0.473
Aves	516	382	170	74.03	44.50	32.94	0.405	0.515	0.977
Mammalia	194	107	51	55.15	47.66	26.29	0.342	0.405	0.748

As a PBA, IBA, and IPA, Mt. Tara has all characteristics necessary for joining the Pan-European Ecological Network.

GIS analyses of the content of Tara NP

All quantitative indices obtained as a result of the analyses were derived from material covering the area of five managing units (Zvijezda, Crni Vrh, Tara, Rača, and Kaludjerske Bare) and 751 parcels. All 751 parcels of these five managing units were digitized (R= 1:10 000).

For each parcel, following eight characteristics were combined in the relational database: name of unit, number of parcel and sub-parcel, type of woodland, vegetation communities that occur, ecological affiliation of vegetation to soil type, percentage of every vegetation species that occurs, type and purpose of land use, and level of protection (Figs. 5 and 6).

The GIS of Tara NP also includes information about nature reserves, settlements, roads and transportation, tourist facilities, line of visibility, and details revealed by aerial photography.

Nature reserves

There are ten nature reserves established within Tara NP: the canyon of the Brusnica, Zvijezda, the gorge of the derventa, Bilo, Ljuti Breg, Crvene Stene, Pod Gorušicom, Crveni Potok, Račanska Šljivovica, and the Gorge of the Rača. The data model enables us to acquire information about area, zoning, and the presence of specific plant and animal species.

Settlements

The settlements theme was digitized from a topographic map on a scale of 1:50 000 (in digital raster form). All urban and rural settlements within the national park and its neighborhood are included. The biggest settlement is Bajina Bašta, the administrative center of the municipality.

Roads and transportations

The roads theme was digitized from a topographic map on a scale of 1:50 000 (in a digital raster form) and represents all types of roads.

Roads were divided into three categories: asphalt, macadam, and dirt roads. Horse trails were also digitized, but they have been omitted for the sake of clarity.

All of the rules of digitalization have been respected, so queries enable us to get precise information about length of every segment and the shortest road distance between any two points or crossroads on Mt. Tara.

Tourist contents

A tourist map of Tara NP on a scale of 1; 25 000 (Geokarta, Belgrade) was the basis for digitizing the following features: hotels, mountain trails, scenic points, buildings of the national park, and monuments of culture.

Line of visibility

This GIS enables us to show the line of visibility

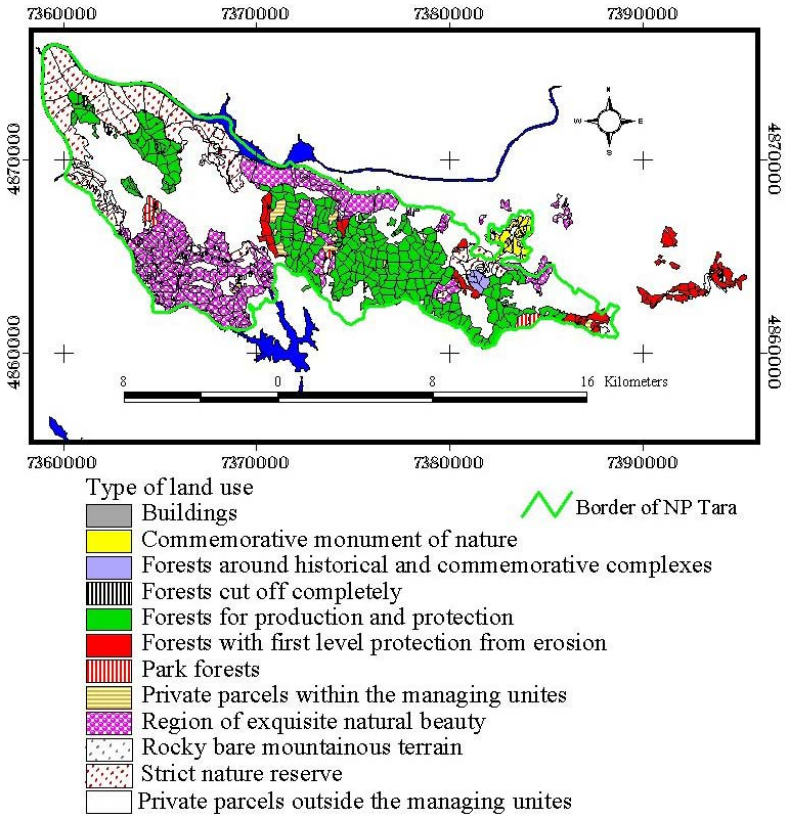

Fig. 5. Type of land use in Tara NP

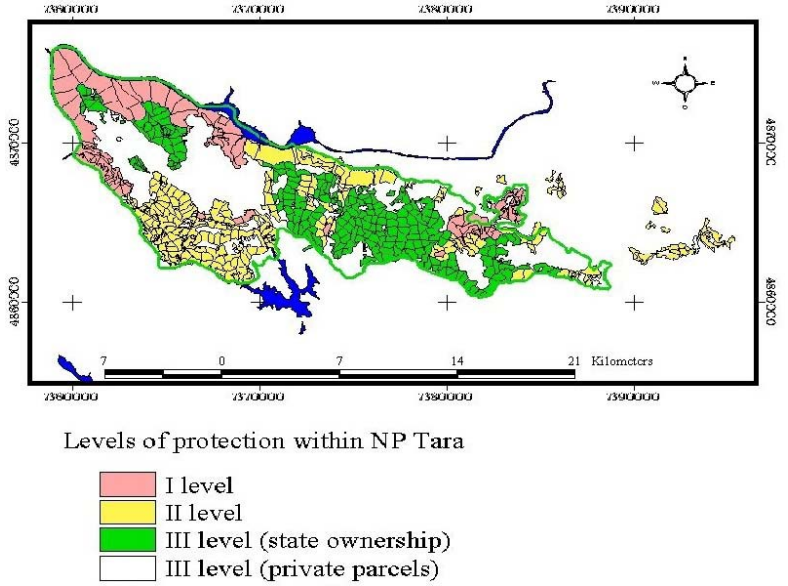

Fig. 6. Level of protection in Tara NP

from any point on the DEM, giving information about visibility, relief profile, elevation of starting and finishing points, and the distance between these two points. This is of direct value from the standpoints of tourism, mountaineering, research, telecommunications, and defense.

Aerial photographs

Aerial photographs combined with field research offer outstanding possibilities for ecological research, especially when vegetation is of interest. By managing aerial photographs produced over a longer period of time, we are able to conduct historical monitoring.

The processed material to process included a series of 19 aerial photographs of Tara NP (scale R= 1: 30 000, F= 114.60, Wild RC-5 camera, year of production 1959). Managing of these photographs included scanning (resolution of 750 dpi Grayscale), georeferencing and combining with other data (vector and DEM) using the ER – Mapper and PCI programs (Fig.7).

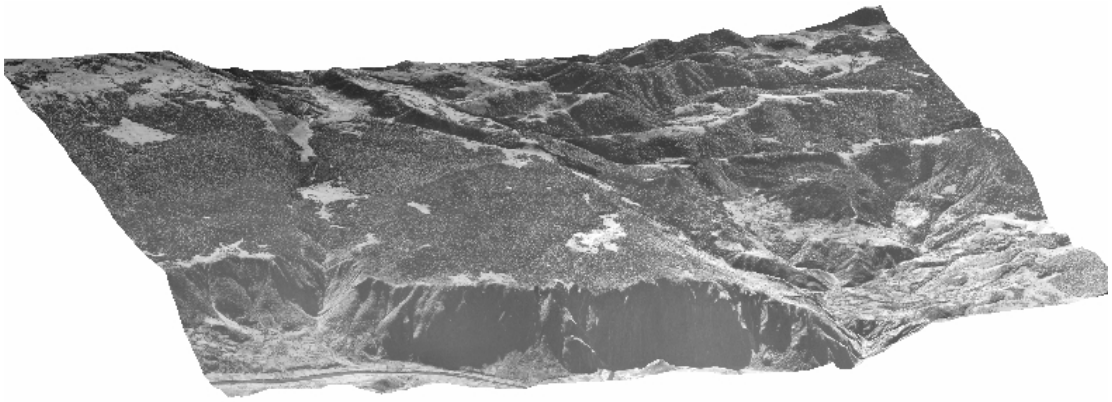

Fig. 7. Aerial photo (of part of Tara NP) georeferenced and joined to DEM (N view)

CONCLUSIONS

Tara NP represents an area with natural values of worldwide importance, most of which has retained the character of autochthonous natural environment.

The present work is a contribution to application of GIS technologies in the areas of conservation geography, biogeography, environmental ecology, biodiversity protection, physical geography and physical planning, and their implementation in protection and managing of natural resources in Tara NP. This information will be helpful to a wide circle of users in the areas of natural, biotechnical, technical, economic, and social sciences, as well as in tourism, sports, and recreation.

The virtues of the Tara NP GIS stem from the following characteristics: highly sophisticated computer solutions (hardware and software); standardization of the production process (input and storage of data); standardization of data (they can be used with any other GIS software now and in the future); openness of the system (the system is open to input of new themes and modification of existing ones); clear visualization; thoroughness of analyses (interactive, with more systematic, thematic, and topographic pharameters); and system decision support. all of these qualities make possible the efficient managing and protection of natural resources.

The GIS of Tara NP provides a basis for adequate preparation of documentation supporting the nomination of Mt. Tara for MAB "Biosphere Reserve" status within the worldwide network of the UNESCO MAB Biosphere Reserve Program. The GIS of Tara NP can easily be used as a multilateral model applicable to all other national parks, scientific reserves, natural monuments or Protected Landscapes on the territory of Serbia and Montenegro.

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ПРИМЕНА GIS ТЕХНОЛОГИЈА У ВРЕДНОВАЊУ И ЗАШТИТИ ПРИРОДНИХ ВРЕДНОСТИ НАЦИОНАЛНОГ ПАРКА ТАРА

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Географски информациони систем је: организован скуп рачунарског хардвера, софтвера, географских података и кадра, дизајниран да ефикасно прикупља, смешта, надграђује, манипулише, анализира и приказује све форме географски референциране информације. За екологе GIS је отворио нове могућности за истраживања и апликацију сакупљених информација.

Због саме комплексности система животне средине ми најчешће настојимо да их проучавамо користећи редукционистички приступ, фокусирајући се на мале, дискретне поједностављене аспекте. Међутим већина проблема у животној средини су вишефакторијални и захтевају разматрање широког спектра извора информација, питања и интереса.

За већину еколошких студија потребне су нам експлицитније и квалификованије теренске информације везане за факторе који би могли да објасне посматрану екосистемску, фаунистичку и флористичку разноврсност у димензији просторне и временске дистрибуције укључујући и податке о геологији, клими, педологији, дистрибуцији и понашању истрживаних врста. Овде своју улогу проналазе географски информациони системи (GIS).

Национални парк Тара обухвата највећи део планине Таре у западној Србији, просечне надморске висине 1000-1200 m на 180 km од Београда. Укупна површина заштићеног подручја Националног парка је 19.175 ha, а 37.584 ha представља заштитну зону око Националног парка. Припада општини Бајина Башта. Планина Тара представља једну од врућих тачака специјског и екосистемског диверзитета са 35 различитих шумских заједница лишћарског, мешовито четинарског типа, као и 19 описаних ливадских заједница. Многе од њих, посебно оне са Панчићевом омориком, имају реликтан или ендемо-реликтан карактер.

У том смислу сасвим је оправдано што се Тара данас нашла на листи подручја значајних за очување птичијег света (IBA) и дневних лептира Европе (PBA), а у току је њено укључивање у међународну листу подручја значајног за очување светске флоре (IPA).

Како се газдовање и управљање практично свим природним потенцијалима НП Тара, до сада, доминантно заснивало на принципима шумарске технологије и инжењеринга овај рад има своју пуну научну оправданост у покушају имплементације савремених научних сазнања из области заштите биодиверзитета, конзервационе екологије, географије и просторног планирања у механизам управљања природним националним ресурсима. Овај тип вредновања и заштите отвара могућност примене одрживог/усклађеног коришћења ресурса НП Тара.

Током 2002. и 2003. године формиране су теме GIS НП Тара које обухватају природне (геоморфологија, геологија, педологија, хидрологија, вегетација, флора, фауна), коришћене (експлоатација шума) и вештачке (антропогене) садржаје (путеве, бране, насеља, туристичке садржаје и границе).

Географски информациони систем који је формиран за НП Тару са темама које га чине да прати оквире сличних пројеката рађених у Европи и свету и један је од типичних географских информационих система (из области екологије, заштите животне средине, шумарства, итд.), који садржи готово све врсте података (изузев сателитских снимака) у GIS (растерске, векторске, DEM, база података и аерофотограметријске снимке).