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EVALUATION AND VALORIZATION OF GEOHERITAGE OF THE MOUNT ROGOZNA AREA (SERBIA)

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Abstract: Due to its unique geology, relief, and extensive hydrologic network, Mount Rogozna has been chosen as a case study for the quantification of geodiversity. The study consists of two interconnected parts. The first part demonstrates the application of the geodiversity evaluation method using the geodiversity index, whereas the second part deals with the evaluation of the geoheritage objects of the studied area. The methodology for calculating geodiversity index that was applied in this research was modified due to the size of the studied area. The geodiversity index is calculated based on the number of abiotic elements and the roughness of the relief within the studied area. Mount Rogozna, with an area of 818.26 km^2, has been studied and processed using a network of spatial polygons of 500 × 500 m and using different maps. The second part of the research deals with the evaluation of geoheritage objects, applying the Geosite Assessment Model. The obtained results demonstrate that geoheritage objects are not always located in places with high values of the geodiversity index. This is proven by the fact that 5 out of 7 geoheritage sites are located in areas with low geodiversity values. The obtained qualitative and quantitative data with maps showing the distribution of geodiversity can serve as a starting point for the development of a planning and management strategy, but also as the example of good practice for possible further application in the quantification of geodiversity in this part of Serbia, and beyond its borders as well.

Keywords: Geoheritage, quantitative analysis, Geodiversity index, Mount Rogozna, Serbia

1. INTRODUCTION

The terms geodiversity, geoheritage, geoconservation have been used in scientific and professional literature since the end of the 20th century. Many scientists have been engaged in the research and definition of geodiversity (Sharples, 1995; Prosser, 2002; Gray, 2004; Kozlowski, 2004; Serrano & Ruiz-Flaño, 2007). The first definitions of geodiversity were provided by Dixon (1996) and Sharples (2002) – "as a variety of geological and geomorphological processes and phenomena on Earth". Today, Gray (2004) definition is most often used: geodiversity is "The natural range of geological, geomorphological and pedological phenomena, which includes their compositions, connections, properties, interpretations and systems".

The term geoheritage derived from the term geodiversity. Defining the concept of geoheritage is not simple. There is often confusion, and the two terms – geoheritage and geodiversity are understood as equivalent. Sharples (2002) clearly emphasizes the importance of distinguishing between these two concepts:

- Geodiversity - a quality that should be conserved (protected);
- Geoheritage - contains specific examples of geodiversity (geoobjects) that have been identified as sites of importance for conservation.

Those components of natural geodiversity which are of significant value to humans for purposes which do not decrease their intrinsic or ecological values; such purposes may include scientific research, education, aesthetics and inspiration, cultural development and contribution to the sense of place experienced by human communities, constitute geoheritage (Dixon, 1996). This is one of the first and most frequently used definitions of geoheritage. For an object to be declared as a geoheritage object, it must meet certain criteria established by the relevant institutions (e.g. in the Republic of Serbia – Institute for Nature Conservation of Serbia). Geoheritage objects are rare, geologically representative, pedological and geomorphological formations, events and processes distinguished as special natural values of exceptional scientific, cultural, aesthetic, touristic and other importance ("Official Gazette of RS", no. 36/09, 88/10, 91/10, 14/16 and 95/18).

According to many authors, until the end of the last century, geodiversity was considered "the forgotten half of nature" (Sharples, 2002; Brilha, 2002; Pemberton, 2001; Nelson & Serafin, 1997; McNeely & Miller, 1984). Thus, the concept of geoconservation arises from the need to appreciate this "forgotten" part of nature. Many authors have dealt with defining the term geoconservation (Sharples, 1995, 2002; Prosser, 2002; Prosser et al., 2006; Gray, 2004; Burek & Prosser, 2008). In simple terms, geoconservation can be defined as action taken with the intent of conserving and enhancing geological and geomorphological features, processes, sites and specimens (Burek & Prosser, 2008). One of the main challenges facing geoconservation is the adequate selection of those elements that should be preserved for the benefit of present and future generations (Brilha et al., 2018; Micić Ponjiger et al., 2021).

This research aims to calculate the geodiversity index on the Rogozna mountain area, show the spatial distribution and location of geoheritage objects, and obtain quantitative data about them. This area was chosen for research because of its unique geology, morphology, pedology and hydrology. Quantification of geodiversity was carried out based on the methodology developed by Serrano & Ruiz-Flaño's (2007). Because of the size of the studied area, the methodology was partially modified based on the work of Micić Ponjiger et al., (2021). Accordingly, the quantitative assessment of geodiversity was obtained using a 500 × 500 m grid on maps (geological, geomorphological, topographic and pedological), and a digital elevation model for deriving subindices and topographic roughness. The main contribution of this research is the creation of maps, for the first time for this area, with the spatial distribution of geodiversity index, geoheritage objects and obtained quantitative data about them. The obtained results can be used as a useful tool in practice, providing information necessary in the process of protection, management and further development of this area.

2. AREA OF RESEARCH

Mount Rogozna (Figure 1.) is located in southwestern Serbia, and with an area of 818.26 km^2 covers parts of the territory of seven municipalities: Novi Pazar, Tutin, Raška, Zubin Potok, Kosovska Mitrovica, Zvečan and Leposavić.

The border of Mount Rogozna is spatially defined by hydrographic elements, primarily the Ibar river and its left tributary the Raška River. The Ibar forms the border in the northeast, east and southeast. On the southwest side (on the Ibar River), there is an artificial reservoir Gazivode. The west border is formed by the Raška River and its tributaries: the Jošanica, Cvrnjska and Paljevska rivers. Areas with a height of 800 m to 1500 m dominate and it extends in a northwest-southeast direction, with a length of about 20 km (Ivanović et al., 2020). Crni Vrh - Čukar (1504 m), in the southwestern part, is the highest point of Rogozna. The following peaks stand out for their height: Mliječnjak (1348 m), Šanac (1328 m), Bubski Šiljak (1284 m) and Jeleč (1262 m).

For Serbia, Mount Rogozna presents an example of a complex geological and geotectonic structure. Her main features are tertiary volcanic rocks, northwest-southeast direction, and polymetallic mineralization such as lead, zinc, copper, gold, silver, molybdenum, and others (Serafimovski et al., 2022). The oldest geological formations are metamorphic rocks – amphibolites and micaschists, with some marble in the deeper parts and sericite-chlorite slates, quartzite, marble, limestone, and diabase in the higher parts (Borojević Šoštarić et al., 2012; Ivanović et al., 2020). Mélange is more widespread, especially in the central parts (Ivanović et al., 2020). Mount Rogozna predominantly consists of volcanic rocks – andesite, dacite, rhyolite and their tuffs. In the northeastern part, prevailing formations are crystalline schists of Upper Carboniferous period and diabase-hornblende rocks. During the Tertiary Period, the territory of Mount Rogozna had been exposed to intense, explosive magmatic activity with frequent eruptions resulting in exceptional pyroclastic flows (Srećković-Batoćanin et al., 1992). Strong volcanic activity created the conditions for the appearance of polymetallic ore – galena, pyrite and sphalerite – minerals that were exploited during the ancient and medieval periods.

One of the characteristics of the Rogozna mountain is its branched hydrographic network with numerous permanent and periodic rivers (over 1000), which belong to the basins of the Ibar, Raška, and Gazivode. In addition to the branched river network, numerous permanent and periodic springs (over 400) also appear in this area. Also, there are two smaller natural lakes on the mountain (Crnovrško lake at the

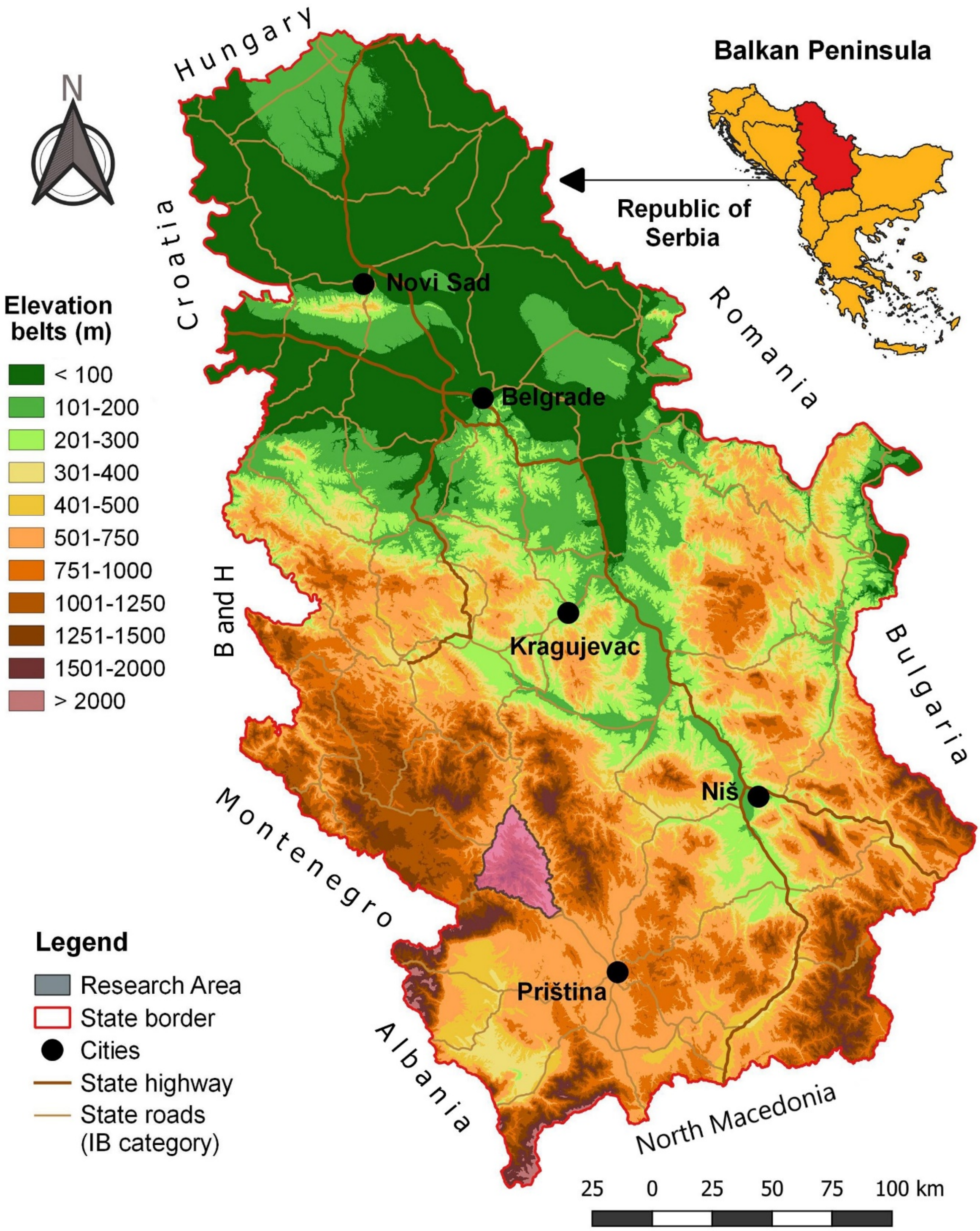

Figure 1. The geographic position of Rogozna mountain (https://earthexplorer.usgs.gov/)

foot of Crni Vrh and Vinorog lake on the territory of Odojeviće settlement). The consequence of intense volcanic activity during the Tertiary Period is the presence of several thermal and thermomineral springs at the foot of the mountain (Banjska, Vuča, Novopazarska Banja) (Ivanović et al., 2020).

The Mount Rogozna area has been only partially explored. More significant research was carried out in the field of geology (Mojsilović et al., 1978, Mojsilović et al., 1983; Bogdanović et al., 1981; Srećković-Batoćanin et al., 1992; Borojević Šoštarić et al., 2012) and hydrology (Ivanović et al., 2020). In regard to the quantification of geodiversity, this paper presents a pioneering work for this part of Serbia and can serve as a potential tool for managing the studied area.

3. MATERIAL AND METHODS

The research consists of two parts. The first part is based on the calculation of the geodiversity index, using the methodology developed by Serrano & Ruiz-Flano's (2007), which was applied for the first time in Serbia in a rural area by Micić Ponjiger et al., (2021), with minor modifications due to the size of the studied area. The methodology connects different physical elements (geological, geomorphological, hydrological, pedological) with topographic roughness and the surface of the studied area, represented by formula 1 (Serrano & Ruiz-Flano's, 2007)

$$Gd = Eg\ IR / Ln\ S \qquad (1)$$

explanation: Gd – geodiversity index, Eg – the number of different physical elements in the given unit, IR – the topographic roughness of the unit, S – size of the spatial unit (km^2) and Ln – is the Napierian logarithm.

The parameter Eg is obtained by summing geological, geomorphological, hydrological, and pedological elements. The sources of spatial data were created by digitizing geological (Urošević et al., 1970; Mojsilović et al., 1978; Bogdanović et al., 1981; Mojsilović et al., 1983), geomorphological (Menković et al., 2013), topographic (Military Geographical Institute, 1984; Military Geographical Institute, 1985) and pedological (Antonović & Nikačević, 1967; Antonović et al., 1967; Nikodijević & Antonović, 1967; Antonović & Nikodijević, 1967; Nikodijević & Aleksić, 1967; Institut za vodoprivredu „Jaroslav Černi", 1971); small scale maps from the available databases of the Republic of Serbia and by collecting data during the field research (Figure 2, 3).

The roughness coefficient includes different orientations and slopes that affect the topographic surface, geomorphological and hydrological processes. Geodiversity assessment was performed at the level of geological, geomorphological, pedological and hydrological elements. Relying on the results of Pellitero et al., (2010), microrelief forms, fossils and minerals were not included in the evaluation, because they would give too much weight to the final result (Micić Ponjiger et al., 2021).

Based on the size of the study area and the scale of the input data, the resolution for Gd was set to a 500 × 500 m grid (Hjort & Luoto, 2010). The collected data were homogenized in order to avoid duplication of polygons of the same value within each cell during addition (Micić Ponjiger et al., 2021). The value of geodiversity increases with the number of evaluated (included) elements and their presence in the studied area, and the final result is a semi-quantitative scale that enables the establishment of five values of geodiversity, for each homogeneous unit (Serrano & Ruiz-Flano's, 2007).

The GIS software package QGIS Version 3.16.10 LTR was used for entering, editing, analyzing, and creating vector spatial data.

The second part of the research deals with the evaluation of geoheritage objects through the application of the Geoheritage Assessment Model (GAM) developed by Vujičić et al., (2011), and later scientifically confirmed (Hrnjak et al., 2013). The proposed criteria for numerical evaluation were taken from the existing literature and were developed during field research. The GAM model consists of two groups of values: main value (MV) and additional value (AV), and the evaluation procedure is performed by adding the main and added values for each object (equation 2) (Vujičić et al., 2011):

$$GAM = MV + AV \qquad (2)$$

The first group (MV) contains three groups of indicators: scientific/educative, landscape/aesthetic and protection. The sum of these three groups of indicators gives the result for the main values (equation 3):

$$MV = VSE + VSA + VPr \qquad (3)$$

Where: (MV–Main values, VSE–Scientific/Educational values, VSA–Scenic/Aesthetic values, VPr–Protection values).

Each group of indicators consists of subindicators (see Table 3).

By summing the group of subindicators, the value of each indicator is obtained. In this regard, equation 2 can be presented in the following form:

$$\sum_{i=1}^{12} SIMVi; \text{ where } 0 \le SIMVi \le 1$$

SIMVi presents 12 subindicators of the main values (i = 1, ..., 12). In accordance with the definition of the GAM model (Vujičić et al., 2011), each of the sub-indicators can receive only one of the following numerical values: 0.00, 0.25, 0.50, 0.75 and 1.00 (Tomić & Božić, 2014).

Following the principle for the main values, the same summation procedure is conducted to obtain additional values. By adding two groups of indicators (functional and tourist), the result for additional values is obtained (Vujičić et al., 2011) (equation 4):

$$AV = VFn + VTr \qquad (4)$$

Where: (AV - Additional values, VFn - Functional values, VTr - Tourist values). Furthermore, functional values consist of 6 sub-indicators, and tourist values of 9 (see table 3).

By summing the group of subindicators, the value of each indicator is obtained. A formula equivalent to equation 3 is created:

$$\sum_{i=1}^{15} SIAVi; \text{ where } 0 \le SIAVi \le 1$$

SIAVi presents 15 subindicators of additional values (i = 1, ..., 15) (Vujičić et al., 2011; Vukoičić et al., 2018; Vukoičić et al., 2021).

To graphically display the results of the evaluation, a GAM matrix was created consisting of X and Y axes, which represent the main and additional values (Figure 7) (Vukoičić et al., 2020). Depending on the rating, the estimated geolocation occupies a corresponding field. Thus, its value is determined, and depending on the main value, the existence of the so-called "tourist value" is also established (Vukoičić et al., 2020; Petrović et al., 2020).

4. RESULTS AND DISCUSSION

The first part of the research involves the calculation of the parameter Eg, which is obtained by summing up various geological, geomorphological, hydrological and pedological elements, for the purposes of which new maps were created.

In the creation of the geological-stratigraphic map, sheets 1:100000 of the basic geological map of Serbia were used: Rožaje (Mojsilović et al., 1983), Titova Mitrovica (Bogdanović et al., 1981), Sjenica (Mojsilović et al., 1978), Novi Pazar (Urošević et al., 1970),

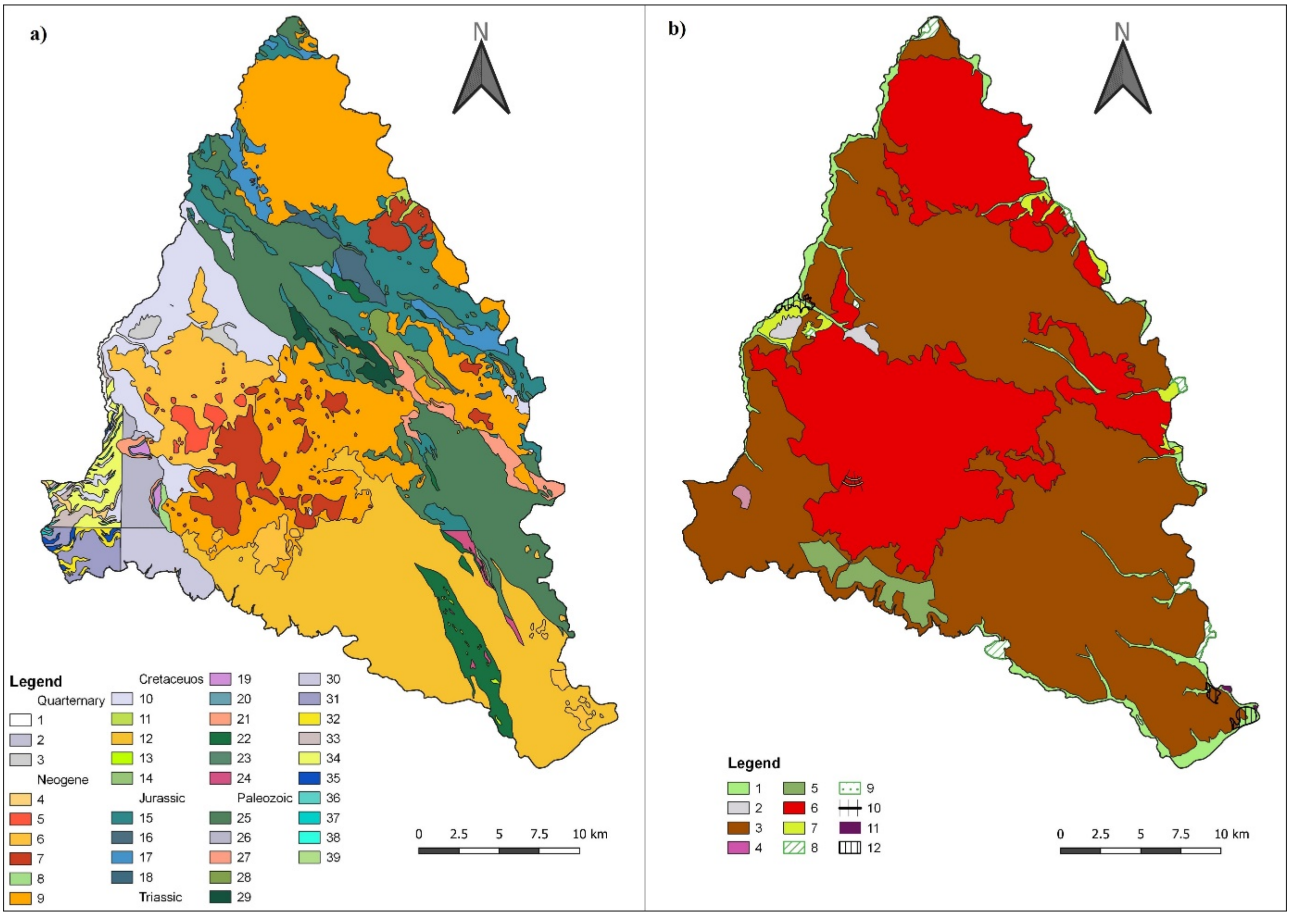

Figure 2. Spatial layout of:

a) Geology map*, Quaternary (1-alluvium, 2-sipar, 3-diluvium); Neogene (4-gravel, sand and clay, 5-andesite-basalt, trachyte-basalt and basalt, 6-quartz latite, 7-quartz latite and latite, 8-massive limestone sand beds, 9-dacite-andesite); Cretaceous (10-sandstones, 11-limestones and marls, 12- flysch: alevrolites, claystones, sandstones with olistoliths – "Vardar zone"; clays, sandstones, marls "Inner Dinarides", 13-mélange: olistoliths, blocks and clasts of ultrabasite, marble, schists and limestone, 14-banky and massive limestones (Cenomanian-Turonian)); Jurassic (15-clays, marls, sandstones, cherts and diabases; diabase-hornblende formations, 16-diabases and spilites, 17-gabbros and rodingites, 18-gabbros and amphibolites); Triassic (19-marble limestones and dolomites, 20-sandy and marly sediments and limestones, 21-quartz conglomerates, breccias and quartz sandstones, 22-serpentinites, 23-diabases, spilites and basalts, 24-volcanic and sedimentary formations: clays, sericite and chlorite schists, metasandstones, metadiabases, cherts); Paleozoic (25-harzburgites, 26-phyllites, metamorphosed sandstones and limestones, albite-chlorite and stilpnomelane schists, 27-gneisses, leptinolites and biolite schists, 28-sericite and chlorite schists, 29-amphibole and amphibolite schists, 30-green schists, argillophyllites, clays and cherts, 31-sandstones and shale rocks, 32-argillite schists and metasandstones, 33-argillite schists, phyllites and sandstones, 34-phyllites, 35-quartzites, 36-marbles, 37-marbles and calc-schists, 38-marble limestones and marbles, 39-albite-chlorite-actinolite schists)

b) geomorphology of the Mount Rogozna, 1-alluvial plain, 2-deluvio-proluvial pediment deposit, 3-area of intensive rill and gully erosion, 4-area of developed karstic forms, 5-area of development of cryo-nivelated processes, 6-area of Tertiary volcanism, 7-area of moderate rill and gully erosion, 8-river terraces, 9-sand bar-island, 10-caldera rim remnants, 11-waste dump, 12-settlement

(Source: authors based on basic geological and geomorphological map of Serbia)

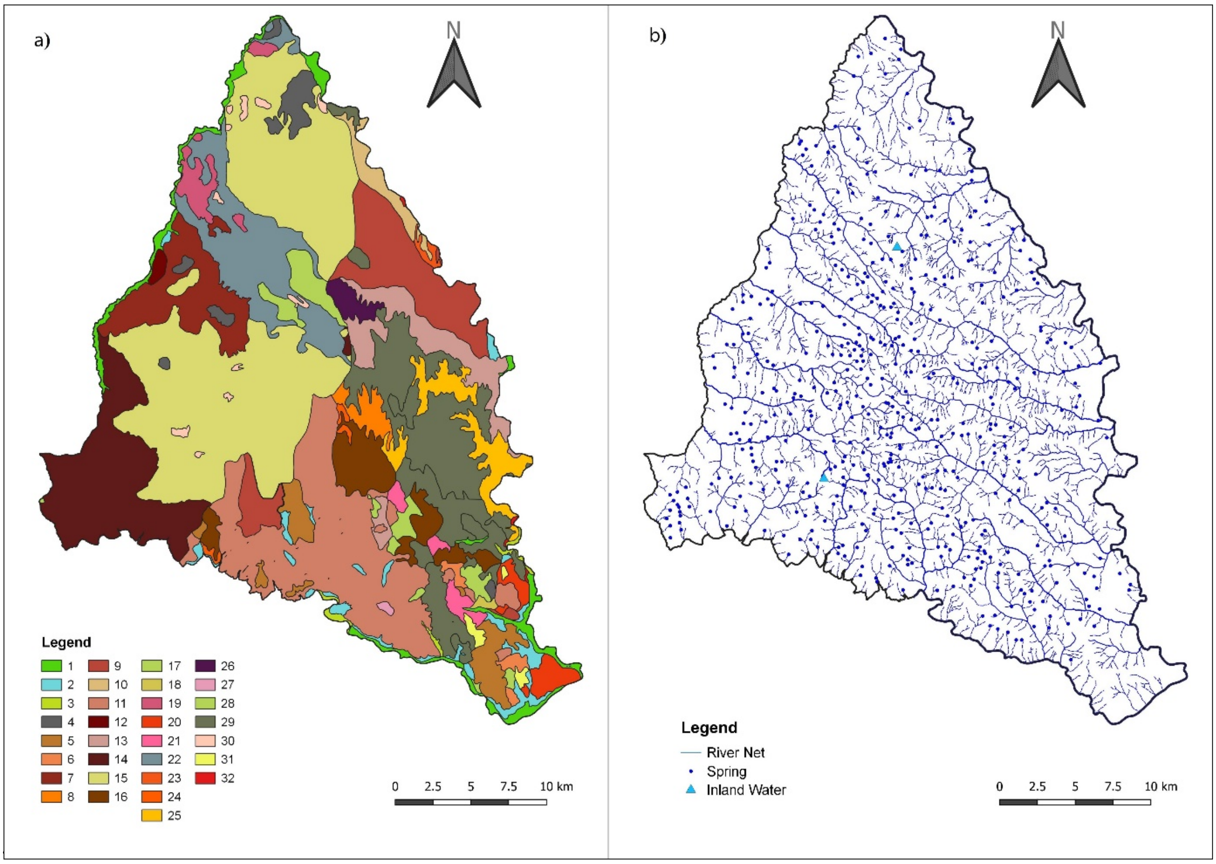

Figure 3. Spatial layout of:
a) Pedology map*, 1-alluvium, 2-deluvium, 3-alluvial-deluvial loamy soil, 4-smonitza, 5-brown soil on sandstone, 6-brown leached soil on sandstone, 7-gray brown acid soil on sandstone, 8-brown soil on basic rocks, 9-brown soil on neutral rocks, 10-brown soil on acid rocks, 11-brown soil on flysch, 12-brown skeletoidal soil on flysch, 13-brown soil on schists, 14-brown skeletoidal soil on schists, 15-gray brown soil on andesite, 16-brown soil on limestone, 17-brown soil on chert, 18-clayish brown soil on lacustrine clays, 19-gray brown skeletoidal soil on diabase, 20-Reddish-brown soil on sediments, 21-brownized red soil on limestone, 22-black Soil on serpentine rock, 23-lithosol on neutral rock, 24-lithosol on limestone, 25-lithosol on ultrabasic rocks (serpentine), 26-typical ranker on schists, 27-typical ranker on sandstone, 28-typical rendzina on limestone, 29-typical rendzina on serpentine, 30-skeletonstones, 31- Podzol-pseudogley, 32-bare rock
b) hydrology of the Mount Rogozna
(Source: authors based on basic pedological and topographic map of Serbia)

and the data from the collected literature. The data are grouped according to different geological formations and into different stratigraphic units (Figure 2a).

As a representative sub-index of the geological diversity of the Rogozna mountain, lithology has values ranging from 1 to 8 (Figure 4a). The greatest lithological diversity (6-8) is in the western part of the mountain, where formations from the Paleozoic to the Quaternary period are widespread. The core of Mount Rogozna consists of formations over 350 million years old, represented by various schists: amphibolite, green, sericite, chlorite, phyllite, marble, quartzite (Borojević Šoštarić et al., 2012). A smaller area (southern and central parts) is occupied by Mesozoic rocks, which are represented by quartz sandstones, sericite and chlorite schists, breccias, conglomerates and limestones from the Triassic period. The rocks of the Jurassic Period are composed of gabbro, diabase and clay formations, and they prevail in the eastern part. Formations from the Cretaceous Period, such as sandstones, flysch and mélange, cover the southern and western zones, where the geological diversity is the highest. High geological diversity also occurs in the central parts of the mountain, where formations from the Cenozoic period are present; andesites, dacites, latites and basalts (andesite-basalts, trachyte-basalts).

The morphogenetic system – erosive, accumulative and anthropogenic landforms, as representative subindices of geomorphological diversity, have values from 1 to 5 (Figure 4b). The greatest geomorphological diversity (4-5) is found in the eastern and western parts of the mountain. The geological structure of the areas of intense and moderate erosion on the western edge of the mountain consists of sandstone and phyllite, whereas the area in the eastern part is dominated by volcanic formations belonging to the Tertiary period.

The identified pedological subindices vary between 1 and 7 (Figure 4c). The greatest diversity is on the southern and southeastern edges of the mountain. Different types of brown soils prevail, in the same complexes with leached soils, whose mutual relations depend on the type of relief. These are relatively shallow soils of low quality. On the northern side, the pedological cover is made up of significantly higher quality soils – chernozem and smonitza. The main type of poorly developed soil is rendzina, and it occupies a large area in the eastern part of the mountain. Also, different subtypes of brown soils occupy considerable areas in the western part of Mount Rogozna.

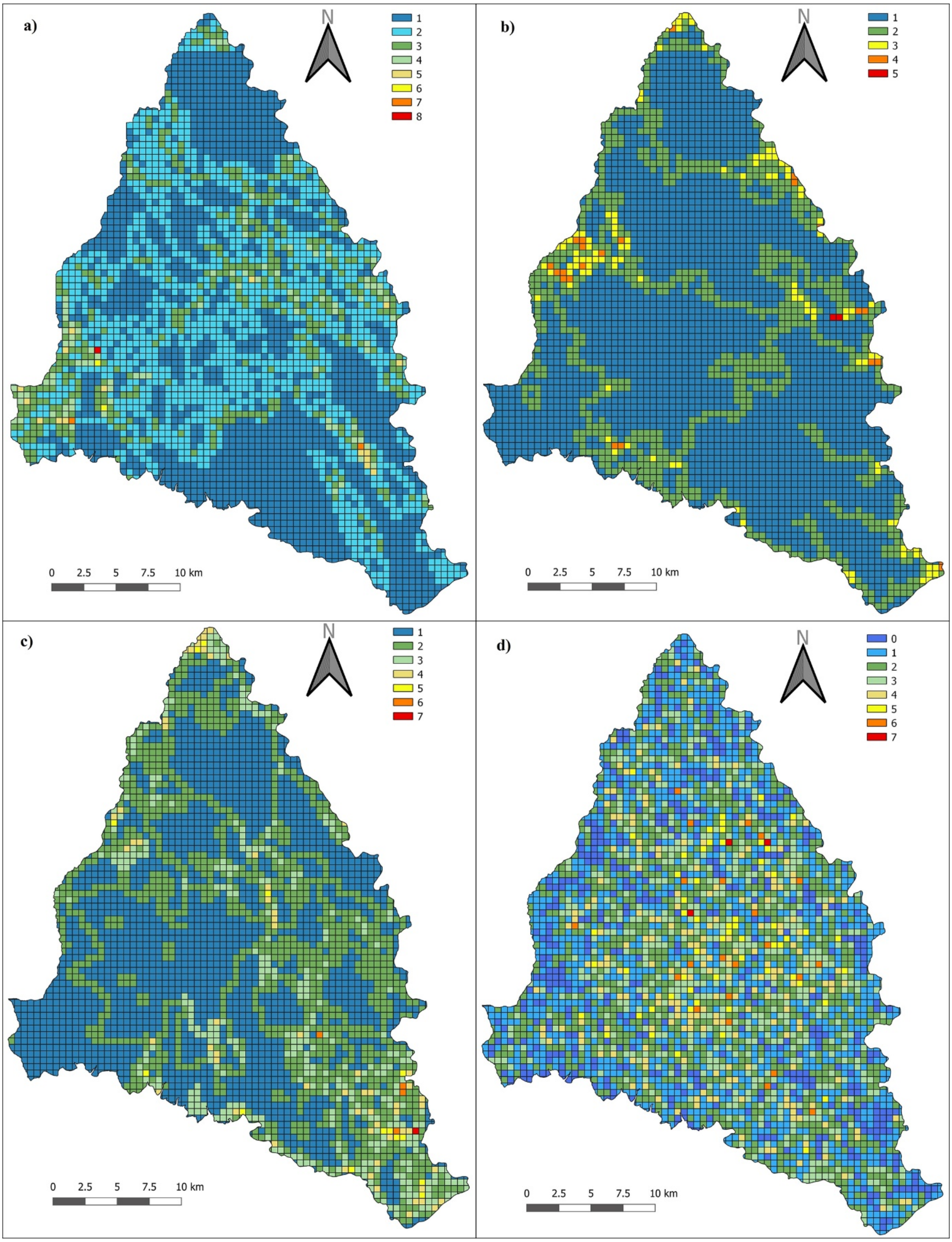

Figure 4. Spatial distribution subindices for: a) geology, b) geomorphology, c) pedology and d) hydrology

Numerous permanent and temporary watercourses and groundwater that shape the relief of Mount Rogozna are significant for geodiversity. The distribution of hydrological sub-indices ranges from 0 to 7 (Figure 4d). The central parts of the mountain have high values (5-7), primarily due to a large number of springs. Because of the slopes and extensive dissection of the terrain, water flows in all directions, with a slightly greater flow towards the south.

Geodiversity index scores can vary between 0 and ∞ (Pellitero et al., 2010; Micić Ponjiger et al., 2021), but in this case they vary from 0 to 16. The final score (Gd) is a semiquantitative scale that allows the establishment of five geodiversity values, from very low to very high for each homogeneous unit (Serrano & Ruiz-Flano's, 2007), and in this research the following ranges were determined: very low (0-3), low (3-6), moderate (6-10), high (10-15), very high (>15) (Figure 5).

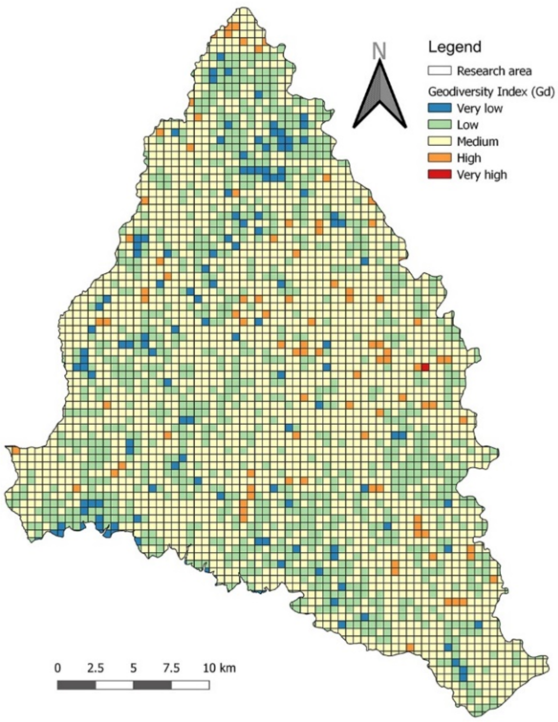

Figure 5. Geodiversity index map of the studied area

Very high (0.04%) and high (2.79%) values were observed in the eastern and central parts of the mountain. This can be explained by the specific geological structure and intensive geomorphological processes. It is noticeable that more than half of the territory (63.63%) has moderate values (table 2), which confirms that a greater part of the mountain is geologically heterogeneous, with a variety of pedological cover, a developed morphogenetic system, and a high hydro potential. The low (29.77%) and very low (3.77%) value of geodiversity (Gd), mostly in the north, can be explained primarily by the lower altitude, low roughness coefficient, but also by a somewhat more homogeneous pedological structure and less developed geomorphological system.

Table 2. Distribution of (geodiversity) Gd index in the studied area

Gd index	Research area [km^2]	Research area [%]
Very low	30.82	3.77
Low	243.63	29.77
Moderate	520.69	63.63
High	22.84	2.79
Very high	0.28	0.04

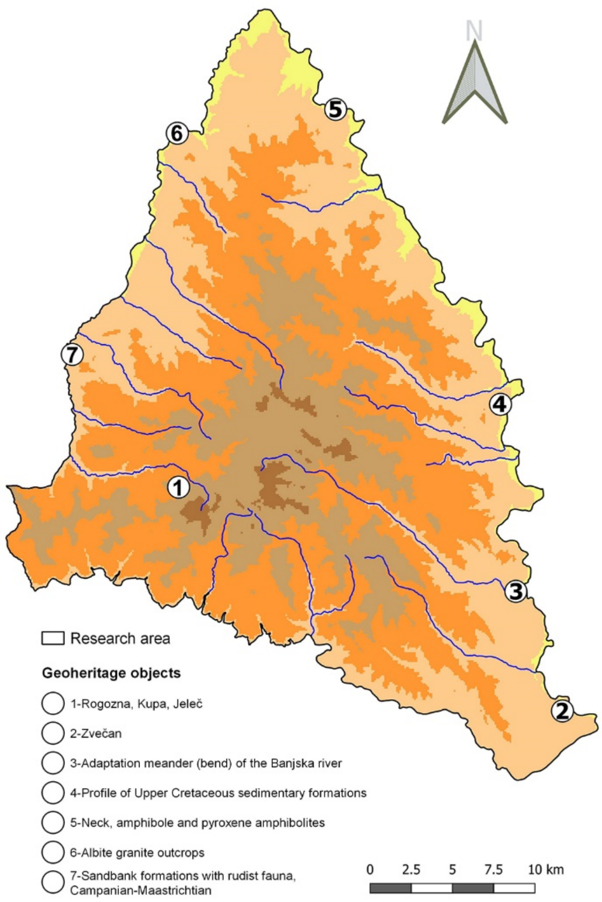

Figure 6. Territorial distribution of geoheritage objects in the studied area (source: The Inventory of Serbian geoheritage Sites*)*

Geodiversity and geoheritage are concepts that are believed not to be synonymous (Micić Ponjiger et al., 2021). In addition to the assessment of the geodiversity of Mount Rogozna (general values), the research is also based on individual abiotic elements (geolocalities – localities of conservation importance). Because geolocalities do not have the same value, there is a need to perform inventory and to evaluate the geolocalities individually (Figure 6).

Based on data from the Institute for Nature Conservation of Serbia, Archives of the National

Council for the Geoheritage of Serbia, seven geoheritage sites were processed on the territory of Mount Rogozna (The Inventory of Serbian Geoheritage Sites, 2005) (Figure 6).

Next, the results of the GAM method of evaluation of the existing objects of the geoheritage of Mount Rogozna are presented. The evaluation started by assigning values to sub-indicators for each object individually. The assigned values can range from 0 to 1 (0.00, 0.25, 0.50, 0.75, 1.00), where by a higher value of a subindicator results in a higher overall rating of the object (Vujičić et al., 2011; Valjarević et al., 2017). When each subindicator has been assigned its value, those values are summed (Table 3). The final results of the analyzed objects are shown in table 4, and graphically in Figure 7.

Based on the results obtained with the GAM method, a graphic matrix was formed, which shows that the processed geoheritage objects in the researched area have high and medium main values. These values show slight oscillations. All localities have high landscape/aesthetic values. Scientific/educational values are

Table 3. Assigning values to subindicators using the GAM method (according to Vujičić et al., 2011)

Object of geoheritage / Subindicators	1	2	3	4	5	6	7
Rarity	0.50	0.50	0.25	0.25	0.25	0.25	0.25
Representativeness	0.75	0.75	0.50	0.50	0.50	0.25	0.50
Knowledge on geoscientific issues	0.75	0.75	0.25	0.25	0.25	0.25	0.50
Level of interpretation	0.75	0.75	0.50	0.50	0.25	0.50	0.50
Viewpoints	0.75	0.75	0.25	0.50	0.25	0.50	0.50
Surface	0.50	0.75	0.50	0.50	0.50	0.25	0.25
Surrounding landscape and nature	1.00	1.00	0.50	0.50	0.50	0.75	0.75
Environmental fitting of sites	1.00	0.75	1.00	1.00	1.00	0.75	1.00
Current condition	0.50	0.75	0.50	0.75	0.75	0.75	0.75
Protection level	0.75	0.75	0.00	0.00	0.00	0.00	0.00
Vulnerability	0.50	0.75	0.75	0.50	0.75	0.50	0.75
Suitable number of visitors	0.75	0.75	0.50	0.50	0.50	0.25	0.25
Total Value (MV)	**8.50**	**9.00**	**5.75**	**5.75**	**5.50**	**5.00**	**6.00**
Accessibility	0.25	0.50	1.00	1.00	1.00	1.00	1.00
Additional natural values	0.75	0.75	0.25	0.25	0.50	0.25	0.50
Additional anthropogenic values	0.00	0.50	0.50	0.50	0.50	0.50	0.25
Vicinity of emissive centers	0.75	1.00	1.00	1.00	0.75	0.75	1.00
Vicinity of important road network	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Additional functional values	0.00	0.50	0.50	0.75	0.50	0.50	0.50
Promotion	0.25	0.50	0.00	0.00	0.00	0.00	0.00
Organized visits	0.25	0.50	0.00	0.00	0.00	0.00	0.00
Vicinity of visitors center	0.25	0.50	0.50	0.50	0.50	0.50	0.50
Interpretative panels	0.00	0.25	0.00	0.00	0.00	0.00	0.00
Number of visitors	0.25	0.50	0.25	0.25	0.25	0.25	0.25
Tourism infrastructure	0.25	0.75	0.25	0.25	0.25	0.25	0.25
Tour guide service	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hostelry service	0.50	0.75	0.75	0.75	0.50	0.50	0.50
Restaurant service	0.25	0.75	0.75	0.75	0.50	0.50	0.50
Total value (AV)	**4.50**	**8.50**	**6.50**	**6.75**	**6.00**	**5.75**	**6.25**

Table 4. Overall assessment of the analyzed objects using the GAM model

Geoheritage object	Main values	Additional values	Field
Rogozna, Kupa, Jeleč	8.50	4.50	**Z31**
Zvečan	9.00	8.50	**Z32**
Adaptation meander (bend) of the Banjska river	5.75	6.50	**Z22**
Profile of Upper Cretaceous sedimentary formations	5.75	6.75	**Z22**
Neck, amphibole and pyroxene amphibolites	5.50	6.00	**Z22**
Albite granite outcrops	5.00	5.75	**Z22**
Sandbank formations with rudist fauna, Campanian-Maastrichtian	6.00	6.25	**Z22**
Total	**6.39**	**6.32**	**Z22**

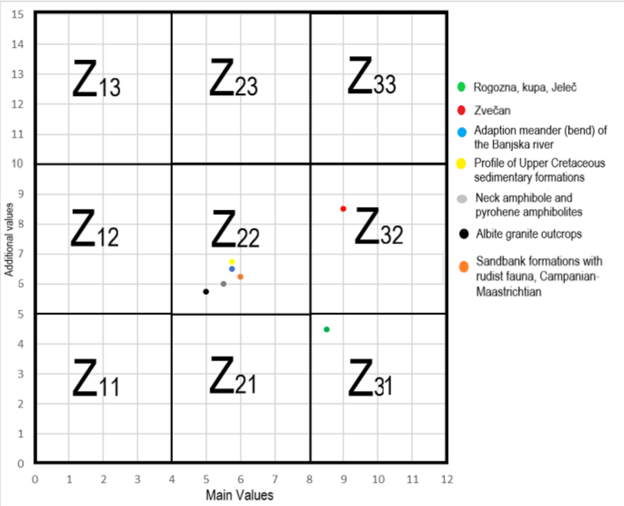

Figure 7. Distribution of the estimated values in the GAM matrix

moderate and high in some localities (Zvečan). The main disadvantage of the evaluated localities is the lack of adequate research and protection. Namely, inconsistency in policy-making of the republic, provincial and local bodies is a big problem. Regarding the assessment of main values, the following geolocalities stand out: Zvečan (9.00) and Mount Rogozna, Kupa, Jeleč (8.50).

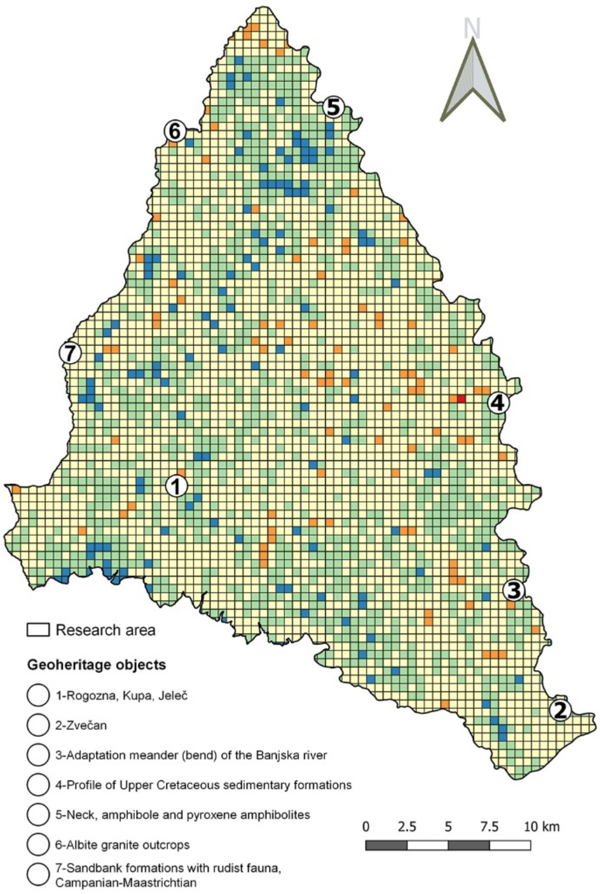

Figure 8. Territorial distribution of geoheritage objects in the studied area (source: The Inventory of Serbian Geoheritage Sites)

Unlike main values, additional values have lower ratings. The biggest problem is inadequate promotion, lack of guide services, information boards, and tourist infrastructure. Most geolocalities have good accessibility, are located near emitting areas and have moderate values of additional facilities (tourist, functional). Zvečan (8.50) has the highest rating of additional values, while Mount Rogozna, Kupa, and Jeleč (4.50) are extremely low on the scale.

By analyzing the geodiversity map (Gd) and the matrix obtained on the basis of the evaluation of the geoheritage objects of Mount Rogozna, we come to the conclusion that the area of high Gd is not necessarily a condition for the concentration of geolocalities of the greatest interest. Thus, 5 out of 7 geolocalities recognized by the Institute for Nature Protection of Serbia are concentrated in areas of low and the remaining 2 in areas of moderate geodiversity, whereas not a single object is situated in an area with high geodiversity (Figure 8). This shows that individual high-value geolocalities (Zvečan) may have minimal diversity, in contrast to many high-Gd areas that do not have specific geolocalities, especially the central part of the mountain.

The results obtained in the research confirm the statement (Pellitero et al., 2010) that "geodiversity is a quantitative value, whereas geoheritage is qualitative, sometimes assessed in a numerical way, but always open to interpretation" (Micić Ponjiger et al., 2021).

5. CONCLUSION

In the past several decades, international scientific and professional public has realized that the protection and preservation of nature presents a very complex set of measures and goals, and that in order to achieve effective results, an equal appreciation of biodiversity and geodiversity is necessary. Although in theory geodiversity is treated as an integral part of nature, numerous problems appear during geoconservation on the territory of the Republic of Serbia. One of the biggest is the lack of quantitative data. Namely, it is not possible to provide detailed information on geodiversity using only basic maps. Quantification of geodiversity creates the need to develop a methodology for data collection, criteria for evaluation and creation of a geodiversity map.

Starting from this fact, this research tries to create a map of geodiversity and take the first step in the evaluation of geoheritage at a local level, in the area of Mount Rogozna. A methodological approach in the research would be a starting point and an effective tool for creating a foundation for analysis, implementation of legal protection and management of this space.

Based on the results of the research, it was concluded that all protected geoheritage objects in this area, recognized by the Institute for Nature Protection of Serbia, are located in zones of moderate and low values of geodiversity. On the other hand, there is no legal protection of any kind for the area with the highest and high values of geodiversity. The obtained results presented on the maps provide valuable information, as they indicate areas where geodiversity is concentrated. The highest geodiversity index values can be an indicator of which areas should be protected.

Maps of the geodiversity index, maps of the distribution and evaluation of geoheritage objects, other quantitative and qualitative data obtained in the research, aim to create a planning strategy and establish territorial zones with different protection regimes, depending on their potential and capacity in terms of use.

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