

GEOSPATIAL ANALYSIS OF THE PROTECTED AREAS OF NIŠAVA DISTRICT

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Abstract

Geographical areas, that have been declared protected, represent key resources in the preservation of biodiversity and natural ecosystems. The Nishava district, with its diverse geography and wealth of natural resources, includes numerous protected areas that have significant ecological value. Geospatial analysis of these areas allows a better understanding of their distribution, physical characteristics and potential for further protection and management. The aim of this analysis is to look at the spatial distribution of protected areas in the Nišava District, as well as to identify the key factors that affect their protection. By studying these areas through geographic information systems (GIS), it is possible to more accurately map borders, monitor changes in ecosystems, and analyze the impact of human activities and climate change on their preservation. Geospatial analysis also contributes to the identification of potential areas that could be included in future conservation plans, as well as better strategies for integrating protected areas into the broader framework of sustainable development. This analysis plays a key role in improving the management of protected areas and contributes to the preservation of the natural resources of the Nishava District.

1. Introduction

Protected areas represent key elements of preserving biological and ecological balance, with the aim of protecting natural resources, preserving biodiversity and sustainable land use. Within the Republic of Serbia, the Nishava district is characterized by a wealth of natural resources and a specific geographical-ecological structure, which makes it extremely relevant for the analysis of ecological and geospatial characteristics.

Geospatial analysis of protected areas of the Nišava District includes the use of modern technologies, such as GIS (Geographic Information Systems), for identification, mapping and assessment of the state of these areas. Through a detailed analysis, this paper aims to collect and analyze spatial data that will contribute to a better understanding of the layout of protected areas, their ecological values, as well as the challenges in their preservation.

This work focuses on understanding the role of protected areas in the preservation of biodiversity and opportunities for implementing sustainable nature conservation practices. Also, through mapping and analysis of existing data, an effort is made to identify key areas that require additional attention in the context of protection and preservation of natural resources.

Considering the strategic importance of preserving natural values and protecting biodiversity, this paper deals with the question of how spatial information can contribute to more efficient management and planning of protected areas in the Nishava District.

The goal of this research is to conduct a detailed geospatial analysis of the protected areas of the Nishava district, in order to obtain precise and relevant information about the spatial characteristics, biodiversity and ecological value of these areas.

2. Materials and methods

GIS (Geographic Information System) was used to analyze the spatial distribution, which enables the following:

- **Spatial mapping:** Creation of maps showing the boundaries of protected areas in the Nishava District, including municipal boundaries and natural barriers (mountains, rivers, lakes);
- **Distance analysis:** Analyzing the distance between protected areas and other important points, such as urbanized zones, roads, and commercial areas;
- **Analysis of ecological corridors:** GIS can help in the identification of ecological corridors, ie. connections between protected areas, which enable migration and preservation of biological diversity;
- **Identification of the impact of human activities:** Monitoring the impact of urbanization, industry, agriculture and infrastructure on protected areas through space.

Using GIS tools, thematic maps can be generated that shows:

- Boundaries of protected areas in relation to administrative boundaries of municipalities;
- Ecosystem types present in each protected area (eg. forest, mountain, wetland);
- Topographic features, such as mountain areas and water resources, which explain the importance of these areas for biodiversity conservation.

2.1. Research Area

The Nishava district is located in the southeastern part of the Republic of Serbia and covers an area of approximately 2,729 km² (Republic Institute of Statistics, 2020). Administratively, it is divided into six municipalities: Aleksinac, Razanj, Svrljig, Doljevac, Merosina and the City of Nish, which represents the economic, administrative and cultural center of the district. (Lukic, Filipovic, 2018).

The geographical position of the Nishava District determines its natural characteristics. It is located between mountain massifs such as Suva planina, Svrljiske mountains and Jastrebac, while the river Nishava, which gives the area its

name, flows through the central part (Djordjevic, 2015). The relief of the district is predominantly hilly and mountainous with the presence of valley parts such as the Nishka valley (Marjanovic, 2017).

The climate is moderate-continental, with a pronounced influence of the Mediterranean climate along the Nishava valley, which creates favorable conditions for the diversity of ecosystems and plant life (Jovanovic, Petrovic, Nikolic, 2016). These features contribute to the creation of unique natural landscapes, some of which have been declared protected areas for their geological, ecological and landscape value (Miljkovic, 2019).

The hydrographic network of the Nishava district consists of the rivers Nishava, South Morava, Moravica and their tributaries, as well as numerous springs and karst springs, especially famous in mountainous areas (Vasiljevic, 2014).

The flora and fauna of this area are extremely rich, with a significant number of endemic and relict species that contribute to biological diversity and represent an important segment of nature protection (Stevanovic & Vasic, 2005).

2.1.1. Natural features of the Nishava district

The Nishava district is characterized by an exceptional diversity of ecosystems that results from its geomorphological, climatic and hydrological specificities. Mountain, forest, river and steppe ecosystems are represented in this area, as well as specific ecosystems of karst areas (Lazarevic, Stankovic, Djordjevic, 2016). Each of these ecosystems has a significant role in preserving biological diversity. The forests of the Nishava district constitute the dominant ecosystem, and the most abundant are oak-hornbeam (*Quercus-Carpinus*) and beech (*Fagus sylvatica*) forests at higher altitudes. Pines (*Pinus nigra*) and endemic species such as pine (*Pinus heldreichii*) can be found in the area of Suva mountain and Svrljiske mountains (Jovanovic, Petrovic, Nikolic, 2017). River ecosystems are connected with watercourses such as Nishava, South Morava and their tributaries. These ecosystems support a rich fish life, including species such as smolt (*Hucho hucho*) and flounder (*Chondrostoma nasus*). There are also significant wetland habitats that support a variety of amphibians and wading birds (Milosevic, 2019). On the southern edges of the Nishava district, in areas with a drier climate, steppe ecosystems have developed with specific species such as kosinin's sasa (*Halacysa sendtneri*) and steppe autumn frost (*Colchicum autumnale*) (Pavlovic, Tomovic, 2015). The Nishava district is home to a rich fauna that includes many endemics and relicts (Stevanovic, 2015).

Species such as the Balkan lynx and the bald eagle live in the mountainous areas. Speleological habitats, such as Cerjanska Cave, provide shelter for numerous species of bats.

The preservation of these ecosystems is of crucial importance for the protection of biological diversity. Protected areas such as Sicevacka gorge, Suva planina and Jelasnicka gorge play a key role in preserving the natural values of this region (Lukic, 2018).

In addition to national categories, protected areas in Serbia can also be classified according to the international standards of the International Union for Conservation of Nature (IUCN), which recognizes the following six categories (Dudley, 2008):

- Ia Strict Nature Reserve;
- Ib Wilderness;
- II National Park;
- III Natural monument;
- IV Area of species management;
- V Protected landscape;
- VI Area of sustainable use of natural resources.

Alignment of national categories with the IUCN classification enables more effective international recognition and protection of natural assets.

This categorization is crucial for planning, implementation of protection and management of protected areas, and contributes to the preservation of biological diversity at the local and global level.

3. Results and discussion

Protected areas in the Republic of Serbia, including the Nishava District, are governed by legal frameworks defined through the Law on Nature Protection (Sluzbeni glasnik RS). This law is harmonized with international standards and defines the types of protected areas, their classification, protection regimes, as well as measures for their preservation.

According to the current law, protected areas are classified into the following categories (Miljkovic, 2018):

1. National parks – Large natural areas of exceptional importance with preserved ecosystems, intended for the protection of natural and cultural values and sustainable tourism. An example of a national park near the Nishava District is the Kopaonik National Park.
2. Nature parks – Vast areas with preserved natural ecosystems and landscapes, such as the Sicevacka gorge. These areas are intended for the preservation of biological diversity, education and recreation.
3. Special Nature Reserves – Smaller areas with specific ecosystems or species of exceptional importance for protection, such as Jelasnicka Gorge and Cerjanska Cave.
4. Protected habitats – Areas that include natural habitats of endangered plant and animal species. Examples are individual habitats on Suva mountain.
5. Natural monuments – Individual elements of nature such as geological, hydrological or geomorphological phenomena. An example is the stalactite and stalagmite formation in Cerjanska Cave.

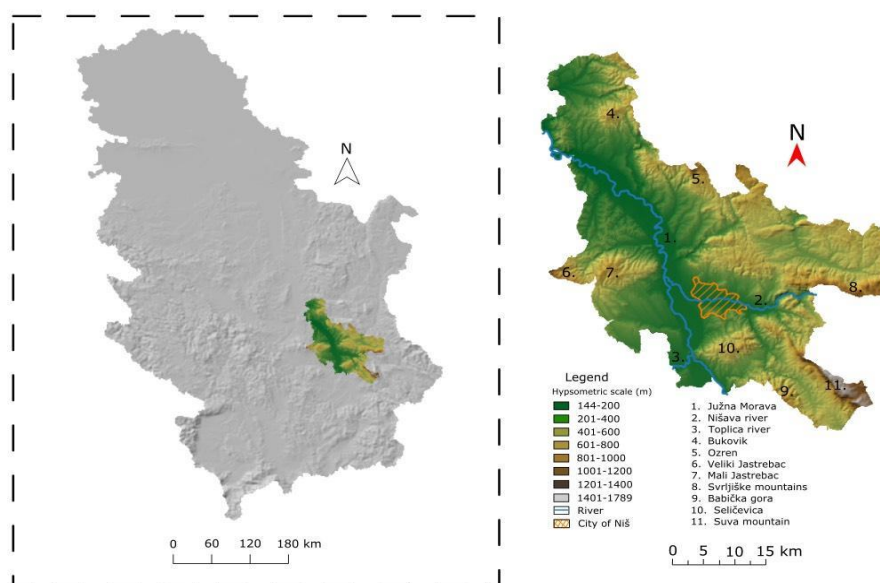


Figure 1. Nishava district

3.1. Sicevacka Gorge

The Sicevo gorge is located in the southeast of Serbia, between the Suva mountains in the south and the Svrljske mountains in the north. It stretches for a length of approximately 17 kilometers, along the course of the river Nishava, between the villages of Prosek and Sicevo (Djordjevic, 2015). This gorge represents one of the most beautiful and significant geomorphological phenomena in the Nishava district. The Sicevo Gorge was created by the erosive action of the Nishava River, which cut its course through limestone formations. The high cliffs, which reach up to 400 meters in height, are a spectacular sight, while the gorge itself includes numerous caves and karst phenomena (Nikolic, 2015).

The river Nishava is fast in this part of its course, with many whirlpools and waterfalls, which makes the gorge attractive for rafting and other forms of adventure tourism. Due to the specific geomorphological and microclimatic conditions, the Sicevo gorge is home to a large number of plant and animal species. Endemic and relict plants such as *Ramonda serbica* (Serbian ramonda) and *Ramonda nathaliae* (Natalia's Ramonda) can be found here.

Sicevo Gorge was declared a protected area in 1977 due to its geological, biological and landscape values. This area is protected as the "Sicevo Gorge Nature Park" and has significant educational, scientific and touristic value. The objectives of protection include the preservation of natural ecosystems, rare plant and animal species, as well as the development of sustainable tourism (Stojanovic, 2016).

The gorge is also known for its rich cultural and historical heritage, including the remains of Roman roads and monasteries such as the Monastery of the Holy Virgin in Sicevo (Petrovic, 2017).

3.2. Suva mountain

Suva mountain is a mountain massif that extends in southeastern Serbia, within the Nishava district. It is located between the Nishava river in the north and the Toplica river in the south, while its ridge stretches in the west-east direction for a length of about 45 kilometers. The highest peak is Trem, which reaches a height of 1,810 meters above sea level. The mountain is known for its specific bare, rocky top, which is why it got the name "Dry Mountain" (Jovanovic, 2015).

Suva mountain is predominantly built of limestone and dolomite, with pronounced karst landforms such as sinkholes, coves, caves and gorges (Miljkovic, Petrovic, Nikolic,

2016). It is characterized by a harsh morphology with steep slopes, cuts and ridges that provide a spectacular landscape (Stevanovic, 2015). Due to its geomorphological specifics, Suva planina is popular among mountaineers and speleologists.

Suva planina was declared a protected area in 2002 as "Dry Mountain Nature Park". This status enables the preservation of natural ecosystems, specific flora and fauna, as well as cultural and historical heritage. The mountain is also important for the development of mountain tourism, mountaineering, speleology and scientific research.

As part of protection, special attention is paid to the preservation of rare plant species, prevention of illegal logging and suppression of soil erosion.

3.3. Jelasnicka Gorge

The Jelasnica gorge is located in the southeastern part of Serbia, in the Nishava district, about 15 kilometers southeast of Nish. It stretches for about 2 kilometers, between the village of Jelasnica and the foot of Suva mountain. The gorge was cut by the river Jelasnica, which, through erosive action, created a dramatic relief with steep cliffs, high rocks and numerous geomorphological forms (Nikolic, Petrovic, Markovic, 2018). The Jelasnica gorge represents a typical karst relief, built of Mesozoic limestones with pronounced shapes such as sinkholes, caves and smaller canyons. The cliffs of the gorge reach a height of up to 200 meters and abound with rock formations that are attractive for climbing and speleology.

The Jelasnica Gorge was declared a Natural Monument in 1995 due to its geological, biological and landscape value (Miljković, 2019). The objectives of protection include the preservation of rare plant and animal species, as well as geomorphological formations that are of scientific and educational importance. The gorge is a popular destination for climbing, hiking and scientific expeditions, and is especially attractive in spring when a large number of plant species bloom.

3.4. Oblacinsko Lake

Oblacinsko lake is located in the southeastern part of Serbia, near the city of Nis, and has great ecological, geological and touristic importance (Kostic, 2013).

The protection of this area involves several aspects. First, in order to preserve biological diversity, access is regulated to prevent overuse of natural resources and pollution. Other

national and international organizations, including WWF and UNESCO, encourage the preservation of the lake as part of cultural and natural heritage, which includes educational programs and conservation projects (Markovic, 2016).

Additionally, Oblacinsko lake plays a significant role in ecotourism, as it attracts numerous visitors who come to enjoy recreation, sport fishing, guided tours and bird watching. Due to its beautiful nature and specific ecosystem value, the lake is becoming an important destination for nature and ecology lovers.

3.5. Bovan lake

Lake Bovan is located in the southeastern part of Serbia, near the village of Bovan, in the municipality of Aleksinac, and is one of the most beautiful natural resources of this region. The lake was created artificially, as a result of the construction of the Bovansko Jezero hydroelectric plant, which regulated the water flow of the Moravica River. Due to its ecological, hydrological and recreational values, Lake Bovan has become a significant protected area (Nikolic, 2016). The protection of Lake Bovan involves several key aspects. First, biodiversity conservation measures have been established for the lake, including monitoring of fish and bird populations, as well as preventive action aimed at reducing water pollution and improper use of resources. Also, the area around the lake is part of local ecological corridors, which enables the preservation of waterfowl and fish migrations. In addition, Lake Bovan is important for its recreational potential and opportunities for the development of ecotourism. Visitors come for opportunities for fishing, water sports, and walking and enjoying nature. Due to its beauty and preserved nature, the lake is a popular destination for tourists who want to get to know the natural beauty of southeastern Serbia.

3.6. Kamenica Vis

Kamenica Vis is a geomorphological form located in the southeastern part of Serbia, near the city of Nish. This natural phenomenon is a high rock formation, which is geologically and ecologically significant due to its specific geological characteristics and biodiversity. Kamenica Vis was declared a protected area due to its unique geological structure and biological diversity (Petrovic, 2017).

The protection of Kamenica Vis includes the preservation of its geological and ecological values. Local authorities recognize its importance as a natural monument, and various

measures are implemented, including the education of visitors and the prohibition of overexploitation of resources and the construction of infrastructure that could threaten this natural heritage. Kamenica Vis is also important for ecotourism, as it provides conditions for hiking, bird watching and other activities that help promote natural heritage and raise awareness of the importance of nature protection (Lukic, 2019).

3.7. Lake Krajkovac

Lake Krajkovac, located near the town of Prokuplje, is one of the most important water bodies in southeastern Serbia. This lake is created artificially, and during the last decades it has become important both as an ecological resource and as a destination for tourism. Due to its specific biodiversity and ecological importance, lake Krajkovac was declared a protected area within the framework of national ecological initiatives (Nikolic, 2016).

The protection of this area includes preventive measures to preserve its biological diversity, as well as the introduction of restrictions for commercial activities that may threaten the ecosystem. It is also important to preserve water quality and protect against pollution, because the lake is a key element of the local hydrological network. Legislative initiatives and local protection aim to preserve not only biodiversity, but also to provide conditions for the further development of ecotourism.

In addition, Lake Krajkovac is a popular destination for tourists and recreational activities, such as fishing, swimming, and nature walks, thus contributing to local economic development (Stojanovic, 2017). The activities carried out in the lake and its surroundings should be aimed at preserving the natural state, and in the future, the development of ecotourism is expected with strict control of ecosystem preservation.

3.8. Cerjan Cave

The Cerjan Cave is located in southeastern Serbia, near the village of Cerje, about 14 kilometers north of Nish. This cave extends over a length of about 7,000 meters, which makes it one of the longest caves in Serbia. Cerjan cave is known for its rich speleological and geomorphological complex, with impressive halls, channels, stalactites, stalagmites and rare cave decorations. Cerjanska Pećina was declared a protected natural asset in 1998 as "Cerjanska Cave Nature

Monument". This status ensures the preservation of its unique speleological formations and cave ecosystem.

The cave is important for scientific research, speleology, ecotourism and educational activities. Research was organized and conducted, but access to the cave was controlled to prevent degradation of the cave decorations (Stojanovic, 2016).

3.9. Popsica cave

Popsica Cave was declared a protected natural asset due to its unique speleological formations, rich fauna and flora, as well as its importance for scientific research and education. Due to its specific geological structure, the cave is recognized as an important object that should be preserved for future generations.

The cave is important for the protection of endemic and relict species of fauna, such as bats, which often inhabit it, as well as for the preservation of specific cave ecosystems (Nikolic, 2015). Due to its ecological values, the cave is prohibited from carrying out any activities that could threaten its biological and geological integrity, such as unauthorized entrances, damage to speleological formations and pollution.

As part of the protection, the cave is placed under a special conservation regime, which includes controlled access. This allows experts to explore the cave, but also protects it from the potential harmful effects of tourists. Due to its natural value, Popšica cave has become an attractive destination for speleologists, mountaineers and all nature lovers, with an emphasis on ecotourism (Lukic, 2018).

At the same time, the cave is important for the local community as it contributes to the development of ecotourism and increasing awareness of the importance of preserving natural values. Educational programs and guided tours allow tourists and visitors to learn more about the speleological and ecological values of this cave, thus contributing to the promotion of natural heritage protection.

3.10. Samar cave

Samar Cave is one of the natural treasures of the Nishava District and has been declared a protected natural asset due to its exceptional speleological, geological and biological characteristics. The cave is located near the village of Samar, in the southeastern part of Serbia, and due to its importance, it is protected in order to preserve its geological structure, as well as the endemic species of fauna that inhabit the interior of the cave (Nikolic, 2016).

The protection of Samar Cave has several key aspects. First, due to its geological value, the cave is an important speleological site, which is used in the research of speleogenesis and geological processes. Another, and no less important, reason for protection is its role as a habitat for several species of bats, which are of key importance for the ecosystem of the cave, but also for the ecological balance in the wider area (Marinković, 2015). Also, specific cave fauna were found in the cave, including troglobiont species adapted to life in underground conditions, as well as a wealth of minerals and speleological formations such as stalactites, stalagmites and cave decorations (Stojanovic, 2017).

Cave protection includes strict access control measures. Visitors can only enter accompanied by licensed guides, and all activities inside the cave are strictly regulated in order to preserve its natural heritage. Also, Samar Cave has great potential for the development of ecotourism and education, considering its attractiveness for nature lovers and speleologists. Organized visits and research allow the public to learn about the importance of protecting underground ecosystems and their role in preserving biological diversity (Jovanovic, 2018).

3.11. Prekonoska cave

The Prekonoska Cave, located in the southeastern part of Serbia, is considered one of the important natural objects due to its speleological, geological and biological values. It has been declared a protected natural asset in order to preserve its specific geological and biological heritage. The cave is home to numerous endemic species of fauna, especially bats, which make up a significant part of its underground ecosystem (Nikolic, 2016).

The protection of this cave implies strict control of access, with a special emphasis on the preservation of the ecosystem and the prevention of any harmful activities that could threaten the natural balance. The cave is under constant surveillance to ensure its preservation in its natural state, and all activities related to its visit or research are strictly regulated.

Also, Prekonoška cave has potential for the development of ecotourism and scientific research, providing visitors with a unique insight into the underground world and the importance of protecting underground ecosystems. Educational activities and guided tours play a key role in raising awareness about the preservation of natural heritage.

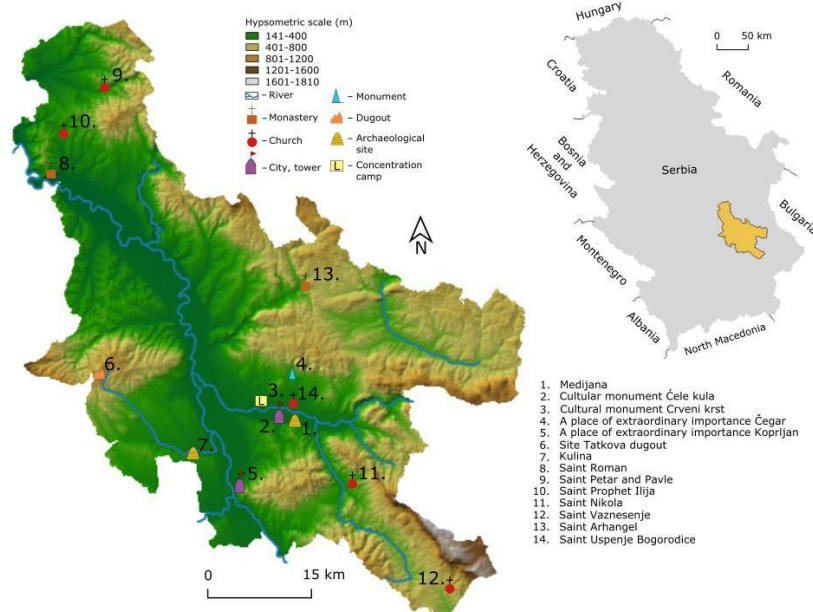


Figure 2. Map of anthropogenic values

Protected areas in the Nishava district are distributed in different geographical units, and their spatial distribution plays a key role in the preservation of the ecosystem:

- Sicevo Gorge, which is located in the southeastern part of Nishava District, connects with Suva Planina and Jelasnica Gorge, which enables the migration of fauna through this region;

- Kamenicki vis, located near the river Nishava, has a significant connection with Bovansko lake and Oblacinsko lake, because it is located in the same hydrological area;

- Oblacinsko lake and Bovansko lake are located nearby, making this region significant for hydrological and ecological studies.

Various factors affect the distribution of protected areas in the Nishava District:

- Geological factors: Mountain areas such as Suva Mountain and Kamenicki Vis provide specific conditions for plant and animal life;

- Water resources: Lakes such as Bovansko lake and Oblacinsko lake constitute important hydrological points in the region, connected to the river Nishava;

- Climatic factors: Classification of areas according to climatic conditions (eg continental climate in lower areas and mountain climate in higher areas);

- Human activities: The expansion of settlements, agriculture, and industry in the vicinity of these protected areas can affect their spatial connectivity and natural balance.

The analysis of the spatial distribution of protected areas in the Nishava District is important for several reasons:

- Effective management of natural resources: Helps identify threatened ecosystems and species, which allows for better management of protected areas.

- Ecotourism planning: Spatial analysis can help develop sustainable ecotourism and better access for visitors, while preserving the natural state.

- Preservation of biodiversity: By analyzing the connectivity of protected areas in the Nishava district, a network of ecological corridors can be created, which enables better preservation of habitats for species that are at risk.

The protected areas of the Nishava district face numerous challenges that threaten their effective protection. The main problems include human activities, such as urbanization and agriculture, which cause habitat fragmentation, as well as water and air pollution, especially in areas such as Lake Bovan and Lake Oblacinsko. Also, the lack of financial resources, weak coordination between institutions and climate change further complicate the preservation of these natural resources.

Climate change can lead to changes in ecosystems, thereby endangering habitats and species that inhabit protected areas, while inadequate coordination between local and national institutions leads to inefficient management. The lack of education among local residents and visitors also contributes to the negative impact on nature, as there is not enough awareness of the importance of protecting natural heritage.

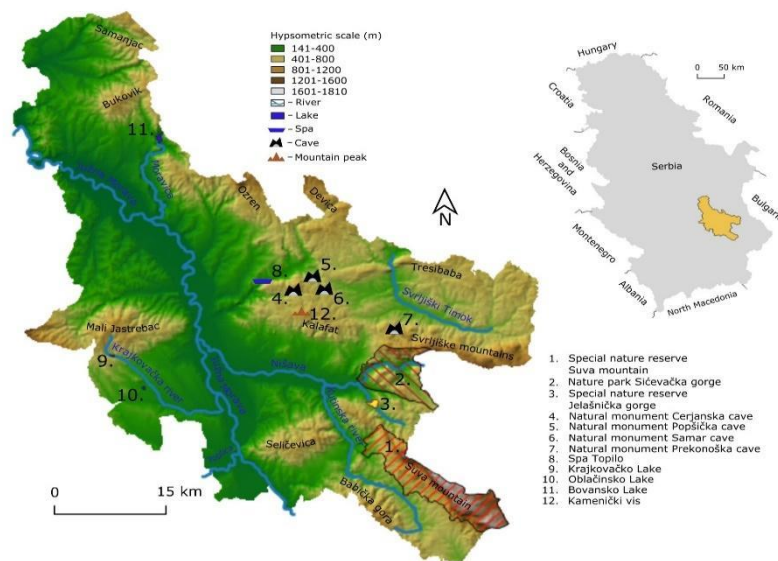


Figure 3. Map of natural values

However, there are also opportunities for improving the management of protected areas. The development of sustainable tourism, such as ecotourism, can bring additional funds for nature protection, while at the same time reducing the negative impact on the environment. Education and raising awareness among local communities and tourists are key to preserving natural resources.

For effective protection, it is necessary to develop strategic plans that take into account the specifics of each area, as well as apply new technologies, such as GIS systems and drones, to monitor the state of the ecosystem. Increasing cooperation between institutions and implementing sustainable strategies can contribute to the preservation of protected areas in the Nišava district in the long term.

4. Conclusion

Geospatial analysis of protected areas of the Nishava District provides important insights into the spatial distribution and ecological characteristics of these areas, enabling more efficient management and conservation of natural resources. Using geographic information systems (GIS) it is possible to precisely monitor the boundaries of protected areas, analyze changes in ecosystems and identify potential threats, such as urbanization, agricultural activities and climate change.

This analysis also enables better coordination between institutions and the improvement of protection strategies, as

well as the development of sustainable plans for the conservation of biodiversity and natural resources. Understanding the spatial distribution of protected areas in the Nishava District is the foundation for making informed decisions regarding their future preservation. In the future, these analyzes may be useful for expanding the network of protected areas, which will contribute to the sustainable development and preservation of the natural values of this region.

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