

GEOHERITAGE SITES IN THE TERRITORIAL UNIT “NORTH OF THE AUTONOMOUS PROVINCE OF KOSOVO AND METOHIJA”

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ABSTRACT

This paper presents an assessment of geoh heritage sites in the territorial unit “North of the Autonomous Province of Kosovo and Metohija”, with the objective of identifying their scientific, educational, landscape–aesthetic, conservation, functional, and tourism values. The assessment of geoh heritage sites was carried out using the Geosite Assessment Model (GAM), which enables an integrated, quantitative evaluation. The analysis encompassed five representative geoh heritage sites and was based on data obtained from relevant scientific literature and field investigations. The results demonstrate that all analyzed sites exhibit medium to high values for the main indicators, confirming their considerable geoh heritage potential. In contrast, the additional values are predominantly moderate, primarily due to insufficient protection measures, limited promotion, and underdeveloped tourism infrastructure. The identified imbalance between the main values and the level of their valorization underscores the need for a systematic and integrated approach to geoh heritage management.

Keywords: Geoh heritage, Quantitative analysis, Geoconservation, Geotourism, Territorial unit “North of the Autonomous Province of Kosovo and Metohija”, Serbia.

INTRODUCTION

Human activities have a significant impact on the state of the environment and its transformation (Li et al., 2017; Vukočić et al., 2020). Direct and indirect interactions between human activities and natural processes have influenced the formation of different landscapes (Crutzen & Stoermer, 2021). Anthropogenic activities significantly modify landscapes and, when properly managed, contribute to the sustainable management and preservation of geomorphological heritage (Kubalíková et al., 2020).

Until the late 20th and early 21st centuries, nature conservation was primarily focused on the living world, namely biodiversity (McNeely & Miller, 1984; Nelson & Serafin, 1997; Pemberton, 2001; Brilha, 2002). More recent global trends have demonstrated a growing recognition of non-living natural resources, i.e., geodiversity. It was only from that period onward that the terms geodiversity, geoh heritage, geoconservation, and geotourism gained broad acceptance in scientific theory and literature.

The time and place of the pioneering use of the term geodiversity are not clearly defined. In Australia, Sharples (1995) defined geodiversity as “the diversity of geological and geomorphological processes and features on Earth.” In Europe, the concept has been defined and redefined on several occasions (Ivanović, 2024). The most comprehensive and most frequently used definition was provided by Stanley (2001). Geodiversity represents the relationship between people, the

landscape, and culture; it encompasses the diversity of the geological environment, features, and processes that constitute the landscape (relief), as well as rocks, minerals, fossils, and soils that have formed the framework for life on Earth (Stanley, 2001).

In the Republic of Serbia, geodiversity is defined as a set of geological formations and structures, features and forms of geological composition, and geomorphological characteristics of varying composition and genesis, as well as diverse paleoecosystems, which have been spatially modified under the influence of internal and external geodynamic factors throughout geological time (“Official Gazette of the Republic of Serbia,” No. 36/09, 88/10, corr., and 14/16).

As a representative concept derived from geodiversity, the term geoh heritage emerged (Petrović et al., 2023). In defining this term, confusion often arises, and the two concepts are frequently treated as equivalent. The first author to emphasize the importance of distinguishing between these concepts was Sharples (2002), who defined them as follows:

- Geodiversity—an intrinsic quality requiring conservation;
- Geoh heritage—the tangible manifestations of geodiversity (geobjects).

When selecting geoh heritage sites for protection, problems often arise regarding the selection of methods, the optimal size of the protected area of the site and its surroundings, and related issues. Geoh heritage consists of exceptional examples that represent major phases of Earth's history, including significant ongoing geological processes in the development of landforms, such as volcanic eruptions, erosion, or significant

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geomorphological or physiographic features (Wimbledon, 1996).

Geoconservation emerged from the need to protect the non-living component of nature, namely geodiversity. A considerable number of authors have addressed its definition (Sharples, 1995, 2002; Prosser, 2002, 2006; Gray, 2004; Burek & Prosser, 2008). To successfully preserve a natural entity, the integration of geoconservation with bioconservation is necessary. Geoconservation aims to prevent or minimize degradation in order to protect the natural and intrinsic values of rocks, landforms, and soils, not merely to maintain their value to people (Sharples, 2002).

The recognized importance of geodiversity, the need to protect it, and the potential to promote it for tourism purposes have necessitated the development of both qualitative and quantitative methods for its evaluation. The study area was selected due to its unique geological composition, diverse hydrological system, and representative examples of geoheritage. The objective of this research is to identify and inventory geoheritage sites and to conduct an individual evaluation of each geoheritage site within the territorial unit “North of the Autonomous Province of Kosovo and Metohija”.

The evaluation of geoheritage sites was carried out using the Geosite Assessment Model (GAM) developed by Vujičić et al. (2011) and subsequently validated by Hrnjak et al. (2013) and Vukočić et al. (2020). The principal contribution of this study lies in applying this methodology to obtain both qualitative and quantitative assessments of the geoheritage of the investigated area. The resulting data have practical applications and may serve as a tool for the protection, management, and sustainable planning of the study area.

Although several studies have addressed the geological characteristics (Borojević Šoštarić et al., 2012), hydrological features (Ivanović et al., 2020), and the overall geodiversity of the investigated area (Petrović et al., 2023), a systematic, quantitative assessment of its geoheritage remains lacking. Previous research has primarily focused on geological structure and mineral resources, while the geoheritage values of this area have remained insufficiently explored. Therefore, the application of the Geosite Assessment Model (GAM) provides an appropriate methodological framework for identifying and evaluating the scientific, educational, and tourism potential, as well as the need for protection, of geoheritage sites within the territorial unit “North of the Autonomous Province of Kosovo and Metohija”.

STUDY AREA

The territorial unit “North of the Autonomous Province of Kosovo and Metohija” covers an area of 1,750 km². It extends across the territory of four municipalities: Leposavić, Zvečan, Zubin Potok, and the northern part of Kosovska Mitrovica (the smallest municipality within this area) (Figure 1).

One of the most important geographical characteristics of this area is its position as a contact zone between the Kosovo Plain and the slopes of three mountain ranges (Rogozna, Kopaonik, and Mokra Gora). The territorial unit is characterized by substantial reserves of natural resources. The presence of numerous renewable and non-renewable resources is associated with the area's diverse morphological units. The Kosovo Basin is distinguished by abundant coal (lignite) deposits; Kopaonik is characterized by lead and zinc ore deposits; the Upper Ibar region, likewise, is characterized by significant ore reserves; and Rogozna by proven reserves of precious metals and a significant resource base for the timber industry.

The territorial unit “North of the Autonomous Province of Kosovo and Metohija” represents a spatial unit characterized by a complex geological composition and an even more complex geotectonic framework. The oldest rocks are metamorphic in origin, primarily amphibolites and mica schists (Borojević Šoštarić et al., 2012). Mélange formations are widely distributed (Ivanović et al., 2020). The territorial unit is predominantly composed of igneous rocks, including andesites, dacites, rhyolites, and their associated tuffs, while the northeastern part is dominated by Upper Carboniferous crystalline schists and rocks of the diabase–chert formation.

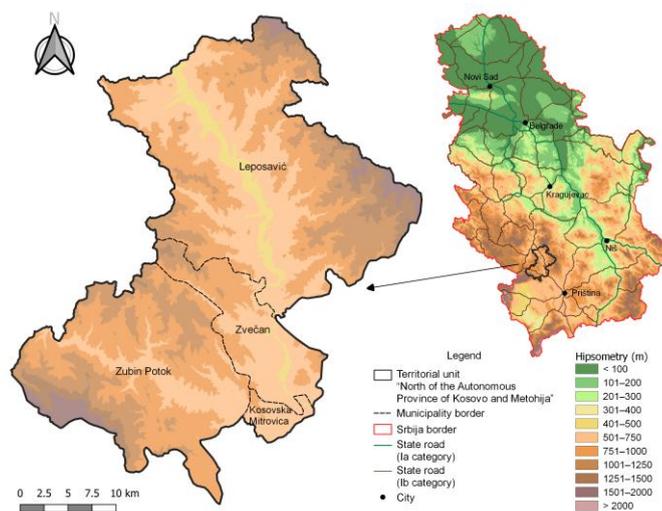


Figure 1. Geographical setting of the Territorial unit “North of the Autonomous Province of Kosovo and Metohija”.

This area was subjected to predominantly explosive magmatic activity, with frequent eruptions characterized by pronounced pyroclastic activity (Srećković-Batočanin et al., 1992).

This area has a high hydropower potential. More than 1,200 permanent and intermittent watercourses flow along the steep slopes of Rogozna, Kopaonik, and Mokra Gora. Of particular significance are the Ibar River basin and the

artificial Lake Gazivode. In addition to the aforementioned watercourses, the area is characterized by more than 600 springs. Intense volcanic activity also gave rise to several thermal springs, including Banjska and Vuča (Ivanović et al., 2020).

The territorial unit “North of the Autonomous Province of Kosovo and Metohija” remains poorly studied. Previous research in the area has primarily focused on geology (Borojević Šoštarić et al., 2012; Srećković-Batočanin et al., 1992) and hydrology (Ivanović et al., 2020). Regarding geodiversity studies, a notable contribution is the work by Petrović et al. (2023), which quantified geodiversity using a geodiversity index.

The study includes five representative geoheritage sites that are listed in the Inventory of Geoheritage of Serbia (Mijović, 2005). The Zvečan dome is classified as a paleovolcanic geomorphological heritage site (Gavrilović et al., 2005). The thermal-mineral springs of Banjska and Vuča are included among the hydrological heritage sites of Serbia (Institute for Nature Conservation of Serbia, 2022). The Banjska adaptation meander and bend are classified as elements of fluvial relief within geomorphological heritage (Gavrilović et al., 2005). The Upper Cretaceous reef formations near Leposavić, representing a Cretaceous geological formation, are classified as a site of historical, geological, and stratigraphic heritage (Banjac, 2005).

METHODOLOGY

This study evaluates geoheritage sites using the Geosite Assessment Model (GAM) developed by Vujičić et al. (2011), building on prior research on site assessment (Reynard et al., 2007; Zouros, 2007; Serrano & González-Trueba, 2005). The criteria for numerical evaluation were adopted from the existing literature, with minor modifications depending on the size and characteristics of the study area. The GAM model comprises two groups of values: main values (MV) and additional values (AV), and their calculation begins with the summation of these values for each geoheritage site (Equation 1) (Vujičić et al., 2011).

$$GAM = MV + AV. \quad (1)$$

The group (MV) comprises three sets of indicators: scientific–educational, landscape–aesthetic, and conservation. The overall score for the main values is obtained by summing the results of these three indicator categories (Equation 2).

$$MV = VSE + VSA + VPr. \quad (2)$$

where: MV–main values, VSE–scientific–educational values, VSA–landscape–aesthetic values, VPr–conservation values.

Each indicator group is composed of sub-indicators:

Scientific–educational values (VSE)=Rarity (I)+Representativeness (II)+Knowledge of geoscientific issues (III)+Level of interpretation (IV).

Landscape–aesthetic values (VSA)=Viewpoints (V)+Surface (VI)+Surrounding landscape and nature (VII)+Environmental fitting of the sites (VIII).

Conservation values (VPr)=Current condition (IX)+Protection level (X)+Vulnerability (XI)+Suitable number of visitors (XII).

The value of each indicator is obtained by summing the sub-indicators within each group, and based on that, Equation 2 can be presented as follows:

$$\sum_{i=1}^{12} SIMVi; \quad \text{where } 0 \leq SIMVi \leq 1.$$

SIMVi represents the 12 sub-indicators of the main values (i=1,...,12). A five-point scale was established to calculate sub-indicators. In order for the evaluation process to follow the methodology, these values have the following range (0.00–very low, 0.25–low, 0.50–moderate, 0.75–high, and 1.00–very high).

Using the same principle, sub-indicators are summed to obtain the additional values (AV). The second group, AV, consists of two indicator categories: functional and tourism values (Hrnjak et al., 2013). The sum of these two categories yields the overall additional value for a site (Equation 3) (Vujičić et al., 2011).

$$AV = VF_n + VTr. \quad (3)$$

where: AV–additional values, VF_n–functional values, VTr–tourism values.

Functional values=Accessibility (XIII)+Additional natural values (XIV)+Additional anthropogenic values (XV)+Vicinity of emissive centers (XVI)+Vicinity of important road network (XVII)+Additional functional values (XVIII).

Tourism values = Promotion (XIX)+Organized visits (XX)+Vicinity of visitor centers (XXI)+Interpretive panels (XXII)+Number of visitors (XXIII)+Tourism infrastructure (XXIV)+Tour guide service (XXV)+Hospitality services (XXVI)+Restaurant service (XXVII).

Equation 3 can be written in the following form:

$$\sum_{i=1}^{15} SIMVi; \quad \text{where } 0 \leq SIMVi \leq 1.$$

SI_{AVi} represents the 15 sub-indicators of the additional values (i=1,...,15) (Vujičić et al., 2011).

The scoring of indicators and sub-indicators was conducted by the author, based on field investigations and the analysis of relevant scientific literature. Fieldwork was conducted from July 2024 to September 2025 to assess geomorphological characteristics, accessibility, conservation

status, and tourism infrastructure. The evaluation criteria defined within the GAM methodology were consistently applied to all analyzed geoheritage sites in order to ensure comparability of the results. The scoring process followed the standardized scale proposed by Vujičić et al. (2011), which has been widely applied in geoheritage assessment studies. To reduce subjectivity, the evaluation was based on clearly defined indicators and previously validated methodological procedures.

RESULTS AND DISCUSSION

The territorial unit “North of the Autonomous Province of Kosovo and Metohija” contains numerous geoheritage sites, only a few of which have been evaluated and protected by the Institute for Nature Conservation of Serbia. Several are included in the Inventory of Geoheritage Sites of Serbia (Mijović, 2005). This study focuses on five representative geoheritage sites (Figure 2).

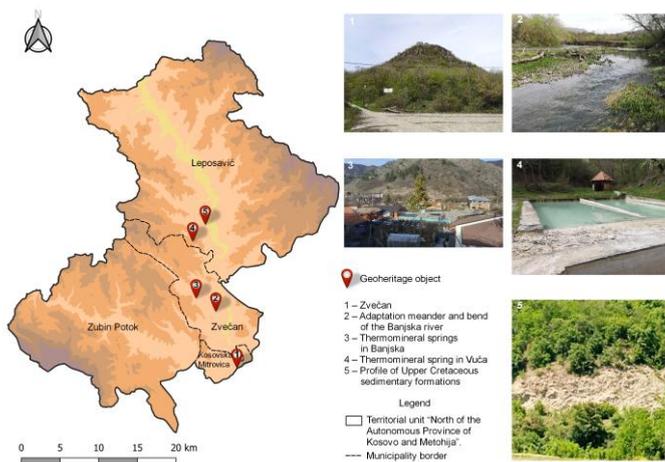


Figure 2. Geoheritage objects within the research area (Zvečan, 2–Adaptation meander and bend of the Banjska river, 3–Thermal mineral springs in Banjska, 4–Thermal mineral spring in Vuča, 5–Profile of Upper Cretaceous sedimentary formations).

The evaluation process begins by assigning scores to each sub-indicator of the main and additional values for individual geoheritage sites. Scores range from 0 to 1 (0.00, 0.25, 0.50, 0.75, 1.00), with higher values contributing to a greater overall site rating (Vujičić et al., 2011). Once all sub-indicators are scored, their values are summed to obtain the total score for each site (Table 1).

Table 1 highlights significant differences between the main and additional values, as well as within each group, reflecting variations in scientific significance, preservation status, spatial attractiveness, and the functional and tourism potential of the assessed geoheritage sites.

Among the main values, the Zvečan paleovolcanic dome achieved the highest score (MV=8.50). This geoheritage site stands out for its representativeness and high scientific, educational, and landscape–aesthetic values. Elevated sub-indicator scores for research potential, viewpoints, and integration into the surrounding environment confirm its outstanding natural significance, offering broad opportunities for further valorization.

Table 1. Sub-indicator and indicator values for geoheritage sites in the study area.

Object of geoheritage	1	2	3	4	5
Subindicators	0.50	0.25	0.50	0.25	0.25
I	0.75	0.50	0.75	0.50	0.50
II	1.00	0.75	0.50	0.50	1.00
III	0.75	0.75	0.75	0.75	0.50
IV	1.00	0.50	0.75	0.25	0.75
V	0.75	0.50	0.50	0.25	0.50
VI	0.75	0.75	0.50	0.25	0.50
VII	0.75	1.00	0.50	0.75	0.75
VIII	0.50	0.75	0.75	0.75	0.50
IX	0.50	0.00	0.50	0.50	0.00
X	0.50	0.50	0.75	0.75	0.50
XI	0.75	0.50	0.75	0.50	0.75
XII	8.50	6.25	7.50	6.00	6.50
Total Value (MV)	0.50	0.25	0.50	0.25	0.25
XIII	0.50	1.00	1.00	0.75	0.50
XIV	0.75	0.50	0.50	0.25	0.25
XV	0.50	0.50	0.75	0.25	0.25
XVI	1.00	0.75	0.75	0.75	0.75
XVII	0.75	0.75	0.75	0.75	0.75
XVIII	0.75	0.25	0.75	0.25	0.00
XIX	0.50	0.00	0.50	0.25	0.00
XX	0.50	0.00	0.75	0.25	0.00
XXI	0.25	0.25	0.25	0.25	0.25
XXII	0.50	0.00	0.50	0.00	0.00
XXIII	0.50	0.25	0.75	0.25	0.25
XXIV	0.50	0.25	0.75	0.25	0.00
XXV	0.00	0.00	0.00	0.00	0.00
XXVI	0.75	0.75	1.00	0.50	0.75
XXVII	0.75	0.75	1.00	0.50	0.75
Total value (AV)	8.50	6.00	10.00	5.25	4.50

The thermal-mineral springs of Banjska also rank highly in terms of main values (MV=7.50). Their representativeness and scientific importance result from past tectonic and volcanic activity in the Rogozna area, positioning the site as a

geoheritage site with significant potential for further valorization.

The Upper Cretaceous reef formations near Leposavić recorded moderate main values (MV=6.50). This site exhibits high scientific–educational value due to its stratigraphic and paleogeographic significance. However, the absence of official protection considerably reduces its overall score and limits its potential for further development.

The Banjska adaptation meander and bend, notable for its scientific significance and landscape–aesthetic appeal but lacking official protection, recorded moderate main values (MV=6.25).

The lowest main value score was observed at the Vuča thermal-mineral spring (MV=6.00). Its limited area, low visitor numbers, lack of viewpoints, and minimal surrounding natural features contributed to the site's overall lower rating.

In contrast to the main values, additional values exhibit considerably greater variation and generally lower scores. The highest additional value score was recorded for the Banjska thermal-mineral springs (AV=10.00). Their historical and cultural significance, combined with their therapeutic function, good accessibility, and the presence of hospitality and accommodation facilities, distinguish this site as one of the primary tourism centers in northern Kosovo and Metohija. However, the unfavorable political situation has hindered its further development and utilization.

The Zvečan paleovolcanic dome also achieved high additional values (AV=8.50). Although access is somewhat limited and no guide service is available, its high aesthetic, historical, and religious significance, combined with maintained walking trails, supporting facilities, and proximity to population centers, contributed to its overall score.

As with the main values, the Banjska adaptation meander and bend recorded moderate additional values (AV=6.00). The absence of promotion, interpretive signage, guide services, and supporting tourism infrastructure lowered the score, despite good accessibility and proximity to nearby population centers.

The Vuča thermal-mineral spring, although developed, lacks tourism facilities, promotion, interpretive panels, and guide services, resulting in a lower additional value score (AV=5.25).

The lowest additional value score was recorded for the Upper Cretaceous reef formations near Leposavić (AV=4.50). Despite their high scientific, educational, and geological significance, the site is neglected and damaged by railway excavation, with no visitors, promotion, protection, or supporting tourism infrastructure, resulting in limited potential for further tourism development.

The final scores for all analyzed geoheritage sites are presented in Table 2.

The final GAM evaluation results enable an integrated assessment of the relationships between the main values

(VSE+VSA+VPr) and the additional values (VF_n+VTr) of the geoheritage sites studied. The results clearly indicate a disparity between the main and additional values, reflecting a gap between the inherent potential of these sites and their current level of development and utilization.

Table 2. Final main and additional values of geoheritage sites in the study area (1–Zvečan, 2–Adaptation meander and bend of the Banjska river, 3–Thermal mineral springs in Banjska, 4–Thermal mineral spring in Vuča, 5–Profile of Upper Cretaceous sedimentary formations).

Object of geoheritage	VSE+VSA+VPr	Σ	VF _n +VTr	Σ	Field
1	3.00+3.25+2.25	8.50	4.25+4.25	8.50	Z32
2	2.25+2.25+1.75	6.25	3.75+2.25	6.00	Z22
3	2.50+2.25+2.75	7.50	4.50+5.50	10.00	Z23
4	2.00+1.50+2.50	6.00	3.00+2.25	5.25	Z22
5	2.25+2.50+1.75	6.50	2.50+2.00	4.50	Z21

The Zvečan paleovolcanic dome stands out as a site with high main values (ΣMV=8.50), driven by its scientific–educational significance, pronounced landscape–aesthetic features, and a relatively high degree of formal protection. Combined with high additional values (ΣAV=8.50), the site occupies field Z32, indicating a favorable balance between intrinsic values and functional tourism potential. These results suggest that, alongside the Banjska thermal-mineral springs, Zvečan could serve as a key driver of future tourism development and overall regional development within the territorial unit “North of the Autonomous Province of Kosovo and Metohija.”

The Banjska thermal-mineral springs achieved slightly lower main values (ΣMV=7.50) but the highest additional values (ΣAV=10.00), placing the site in field Z23. This disparity indicates that functional and tourism infrastructure are more developed than the intrinsic values represented by the main indicators. From a management perspective, this positioning carries certain risks, as intensified site use is not always accompanied by adequate protection measures, potentially compromising the integrity of the geoheritage site.

In contrast, the Banjska adaptation meander and bend, and the Vuča thermal-mineral spring exhibit moderate main values (6.25 and 6.00) and additional values (6.00 and 5.25), positioning them in field Z22. These sites are characterized by relatively balanced values, with no clearly dominant aspect. Such results indicate a stable foundation for further development, while highlighting the need for targeted interventions, particularly in protection, interpretation, and controlled tourism development.

The lowest overall score was recorded for the Upper Cretaceous reef formations near Leposavić, with a main value of 6.50 and an additional value of 4.50, placing the site in field

Z21. This result clearly reflects a pronounced imbalance between the site's high scientific–educational potential and its very poorly developed functional and tourism components.

The results indicate that none of the assessed geoheritage sites achieved high scores in both main and additional values, highlighting a structural issue in the management of geoheritage within the study area. The study clearly demonstrates that the scientific, educational, and landscape potential of Rogozna's geoheritage sites is not matched by adequate institutional, interpretive, or tourism mechanisms, substantially limiting the overall functionality and development of these geoheritage sites.

CONCLUSION

At the beginning of the 21st century, the global scientific community recognized that nature conservation is a highly complex process, requiring equal consideration of both biodiversity and geodiversity to achieve effective outcomes. Although geodiversity is theoretically treated as an integral part of nature, its conservation in the Republic of Serbia faces numerous challenges, among which the lack of quantitative data is particularly significant. Building on this context, the present study aimed to inventory and evaluate the geoheritage sites in the territorial unit “North of the Autonomous Province of Kosovo and Metohija,” providing a foundation for more effective protection and management of geoheritage in the region.

The study results demonstrate that the geoheritage of the investigated area possesses significant scientific, educational, landscape, aesthetic, archaeological, and historical values. The application of the GAM methodology enabled a systematic and comparable evaluation of five representative geoheritage sites, revealing a predominance of main values over additional (functional and tourism) values. Medium to high scores of the main indicators across all analyzed sites confirm the high intrinsic potential of the geoheritage in this area. In contrast, low to moderate additional values indicate underdeveloped systems for protection, interpretation, promotion, and tourism valorization, representing a key limitation to their practical use and sustainable management. Such patterns are characteristic of marginal areas with limited institutional support.

The results further validate the GAM methodology as a tool not only for assessment but also for identifying priority interventions in geoheritage protection, management, and sustainable utilization. The quantitative results obtained can serve as a basis for defining conservation priorities, planning, and developing strategies for sustainable spatial development. To adequately protect and subsequently valorize the geoheritage sites in the study area, in addition to the quantitative data obtained, close cooperation among relevant institutions at the national, provincial, and local levels is required.

ACKNOWLEDGMENTS

This study was carried out with the support of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract No. 451-03-33/2026-03/200091).

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