Assessing the Geotourism Potential of the Niš City Area (Southeast Serbia)

Miloš Marjanović[1] · Nemanja Tomić[1] · Aleksandar R. Radivojević[2] · Slobodan B. Marković[1]

Abstract

The turbulent geological past of the southeastern part of Serbia, along with the influence of the Nišava River, has created a rich and complex geodiversity. However, the geotourism potential of this area remains fully unrevealed. This paper proposes an inventory of geosites in the Niš City area (southeast Serbia) and analyses them to reveal which geosite possesses the greatest geotourism potential. The selected sites were evaluated by applying the Modified Geosite Assessment Model (M-GAM) to discover the most suitable geosites for future geotourism development. The main goal of this study is to emphasize the geotourism potential of the Niš City area and establish the current state and geotourism potential of geosites located there. The results point out that further geotourism development should primarily be focused on Cerjanska cave and Sićevo gorge. The results reveal information about the key fields of improvement for each evaluated geosite. Also, results identify which areas require more attention and better management in the upcoming period for this area to become a geotourism destination that would attract a larger number of tourists in the future.

Keywords Geotourism · Assessment · Geoheritage · M-GAM · Niš · Serbia

Introduction

Special geological formations have long attracted visitors worldwide (Ólafsdóttir and Tverijonaite 2018). Geotourism is a form of sustainable tourism (Newsome et al. 2012; Filocamo et al. 2019) and nature-based tourism that focuses explicitly on geology and landscape (Carrión-Mero et al. 2020). It has rapidly expanded over the last decades all around the world (Reynard 2008; Dowling 2013; Ruban 2015). One of its tasks is to promote tourism to geosites

✉ Miloš Marjanović
milos.marjanovic@mail.com

Nemanja Tomić
airtomic@gmail.com

Aleksandar R. Radivojević
a.radivojevic@yahoo.com

Slobodan B. Marković
baca.markovic@gmail.com

[1] Department of Geography, Tourism and Hotel Management, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovića 3, 21000 Novi Sad, Serbia

[2] Department of Geography, Faculty of Sciences, University of Niš, Višegradska 33, 18000 Niš, Serbia

and an understanding of earth sciences through valuing and learning (Herrera-Franco et al. 2020) and represents the spectrum of abiotic elements appreciation (Williams et al. 2020). Geotourism studies are gaining big interest worldwide because of their scientific, academic, historical, societal, cultural, and aesthetic values (Bentivenga et al. 2019; Štrba et al. 2020; Shekhar et al. 2019; Rozenkiewicz et al. 2020). This form of tourism allows the discovery of geological peculiarities of the visited areas, in combination with other natural and human resources (Bentivenga et al. 2019). According to Necheş and Erdeli (2015), geotourism is seen as a way to mitigate the human pressure on a landscape by engaging tourists in outdoor activities and educational activities. Geotourism must follow five fundamental principles such as geological base (geoheritage), sustainability (geoconservation), education (geointerpretation), benefits at the local level, and tourist satisfaction (Herrera-Franco et al. 2020).

There are many geotourism definitions (Sadry 2009; Hose 1996, 2000, 2008; Joyce 2006; Gray 2008), but the widely accepted one is the definition given by Dowling and Newsome (2018) where geotourism represents a form of tourism that focuses on an area's geology and landscape, as the basis of fostering sustainable tourism development

to generate benefits for conservation, communities, and the economy. Another widely accepted definition of modern geotourism was provided by Hose and Vasiljević (2012): "Provision of interpretative content and services on geosites, geomorphosites, and surrounding topography, together with related in situ and ex situ artifacts, to enhance appreciation, education and scientific work for the present and future generations to preserve them." According to this definition, the main focus of geotourism is on interpretation, promotion, and conservation, as vital parts for the sustainable development of geotourism.

The main geotourism attractions are various geological and geomorphological sites called geosites. They represent landforms that have acquired scientific, aesthetic, cultural, historical, and socio-economic value because of their perception or exploitation by humans (Panizza and Piacente 1993, 2003; Panizza 2001; Reynard 2004; Reynard and Panizza 2005; Sellier 2010; Portal 2012; Bétard et al. 2017; Hobléa et al. 2018). The presence of geosites in any area may significantly contribute to the overall tourism attractiveness and development potential (Štrba et al. 2020; Tičar et al. 2018; Božić and Tomić 2015; Tomić et al. 2020).

One of the ways to promote and conserve places that possess distinctive geological heritage and landscape are geoparks (Brown 2006), where geotourism stands as an integral and essential part of their development (Dowling 2011). Farsani et al. (2011) state that geoparks represent an innovative approach to the protection of the natural and geological heritage. A geopark is a well-defined area with one or more geoheritage sites, singled out according to their scientific importance, rarity, scenic quality, or relation to geological history, events, and processes (Eder and Patzak 2004). According to McKeever and Zouros (2005), a geopark is a unified area that advances the protection and the use of geological heritage in a sustainable way and promotes the economic well-being of the people who live there. According to the List of UNESCO Global Geopark Network (UGGp), there are 161 geoparks in 44 countries that have achieved official recognition (http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/list-of-unesco-global-geoparks/).

The main goal of this article is to analyse the potential for geotourism development in the Niš City area. This research was carried out by applying the modified geosite assessment model (M-GAM) created by Tomić and Božić (2014). In this article, five geosites were singled out based on the degree of their attractiveness for geotourism development. These geosites potentially have the largest opportunity to attract the attention of a larger number of tourists. The results of the analysis should provide information about the major fields of improvement and identify which geosite requires more attention and better management in the time ahead (https://www.zzps.rs/wp/suva-planina Retrieved on 20.11.2020).

A short review of geoheritage assessment methods

Many types of research of geoheritage and geotourism potential generate the need for the development of geoheritage assessment models (Ólafsdóttir and Tverijonaite 2018). Geoheritage assessment represents an important step in the process of geotourism development (Reynard 2008). These procedures enable identifying areas of interest, like geological heritage (Reynard and Panizza 2005; da Silva 2019), proposing conservation plans, like geoparks (Carrión Mero et al. 2018), and regulation of their sustainable use, like geotourism (Herrera-Franco et al. 2020). According to Suzuki and Takagi (2018) assessing the value of geosites is widely recognised as a useful tool for the effective development, management, and protection of geological heritage. The methodology of evaluation of geosites has been continuously developing in the last three decades. The process of assessment of geodiversity is implemented through both qualitative (Gray 2004; Brilha 2016; Brilha et al. 2018) and quantitative assessment methods (Kot 2015; Ruban 2010; Melelli 2014; Forte et al. 2018). Early assessment models focus only on the scientific values (Rivas et al. 1997; Coratza and Giusti 2005). Some other models focus the attention on protection needs (Bruschi and Cendrero 2005), scenic or cultural interests (Panizza 2001). There are different models that assess scientific, aesthetic, tourist, intangible, cultural, social, and other values (Tomić 2011; Suzuki and Takagi 2018; Reynard 2008; Pralong 2005; Serrano and González-Trueba 2005; Pereira et al. 2007; Zouros 2007; Reynard et al. 2007; Erhartič 2010; Kubalíková and Kirchner 2016; Rybár 2010; Mikhailenko et al. 2017). Vujičić et al. (2011) presented a more complex model, which measures scientific/educational, scenic/aesthetic, protection, functional, and touristic values. One more interesting method of assessment of geoheritage was applied in research of Carrión-Mero et al. (2020) where a combination of Inventario Español de Lugares de Interés Geológico (IELIG) method and SWOT analysis was used to present the geoheritage of Ecuador.

As the tourists are the ones who decide whether to visit a certain geosite, their opinions and tendencies are very important, in particular when evaluating the tourism potential of a site (Tomić 2011). Tomić and Božić (2014) developed an assessment method entitled M-GAM (modified geosite assessment model), which is a combination of the GAM model created by Vujičić et al. (2011) and the importance factor (Im) first introduced by Tomić (2011) in his research. In that research, the opinion of visitors was included in the assessment process through a survey. Besides the assessment criteria from Vujičić et al.

(2011), the importance factor (Im) was introduced in the assessment process. This factor allowed visitors and tourists to reveal their opinion about the importance of each subindicator in the assessment model. The advantage of this model is that it combines the opinion of both experts and tourists.

This method has been effectively applied in many studies for the assessment of numerous geosites in Serbia, Slovenia, the USA, Iran, and Hungary. Some authors applied this model in evaluating karst geosites in eastern Serbia (Antić et al. 2019), other authors used it for the assessment of tourist potential of gorges and canyons in Serbia (Božić and Tomić 2015; Božić et al. 2014), the USA (Jonić 2018), Iran (Tomić et al. 2021) tourism potential of show-caves (Tičar et al. 2018; Tomić et al. 2019; Vuković and Antić 2019; Antić and Tomić 2019; Antić et al. 2020a), Miljković et al. (2018) applied it for evaluating hydrological heritage in eastern Serbia (Krupaj and Žagubica springs), and other authors applied it for assessing various geological heritage (Pál and Albert 2018, 2021; Antić and Tomić 2017; Antić et al. 2020b; Tomić et al. 2015, 2020; Vukoičić et al. 2018; Bratić et al. 2020).

Furthermore, the Importance factor which is the basis of the M-GAM model has been successfully used for the creation of two new assessment models. One of them is the Cultural Route Evaluation Model (CREM) developed by Božić and Tomić (2016) and later tested by Antić et al. (2021), while the other is the Spa Assessment Model (SAM) developed by Tomić and Košić (2020) who successfully applied it on the Kopaonik-Jastrebac spa zone in Serbia.

Study area

For this research, the Niš City area is defined as the territory of the City of Niš, located in the southeastern part of Serbia (Fig. 1). It consists of 5 municipalities (Medijana, Palilula, Crveni Krst, Pantelej and Niška Banja) and covers an area of 593.7 km². For most of its part, the City of Niš is located in the Niš valley. This valley is one of the largest in Serbia. It is about 44-km long and 22-km wide and occupies more than 70% of the administrative area of Niš (Manić et al. 2019). The territory of the City of Niš lies on the geo-tectonic border of the crystalline, Rhodope mass, and limestone mountains of eastern Serbia (Ršumović 1967). The Niš valley is surrounded by the limestone massifs of Kalafat Mt. (837 m), Batalovac Mt. (707 m), Crni Vrh Mt. (683 m), and the crystalline mass of Popova Glava

Fig. 1 Position of researched geosites within the Niš City area (Source: Authors)

Mt. (534 m). The eastern rim is lying on the limestone ridge of the Svrljiške Mt. (1334 m). The southern rim consists of the limestone ridge of Suva Mt. (1810 m) and the crystalline ridge of Seličevica Mt. (902 m). The western rim of the valley is lying on the crystalline ridge of Mali Jastrebac Mt. (1491 m). The main hydrological object is the Nišava river. It is 218-km long, and it flows through Serbia in the length of 151 km (Gavrilović and Dukić 2002).

The City of Niš has a very favourable position often called the crossroads of Europe. Because of this, it was the target of many conquerors during the past which is one of the reasons why it is rich in cultural heritage. One of the main European roads, the E-75 (A1), which connects the north and the south part of Europe, passes by the city. Another important road in Europe, E-80 (A4), which connects western Europe with Asia, also passes by Niš. In addition, Constantine the Great Airport is also located in Niš making this region well connected with the rest of Europe by air.

The geological past of this area caused the occurrence of natural values with an emphasis on geological and geomorphological features. In this article, the most representative forms of geoheritage will be singled out. Five geosites were chosen (Fig. 1) based on the degree of their attractiveness for geotourism and their potential to attract a larger number of tourists.

Cerjanska Cave system (Cerjanska Cave – GS 1) is located 12 km NE from Niš, in the limestone massif of Kalafat Mt. It consists of several geomorphological objects. The most famous one is the Cerjanska Cave, also known as Cerjanska Provalija. The Provalija Ponor is the main cave of the Cerjanska Cave system. It represents a large subterranean fluviokarst system, which has been explored to the length of 6131 m. It is one of the longest caves in Serbia. Cerjanska Provalija is a classic ponor cave at the contact of limestone and red sandstone. It consists of one main river passage with a total length of 4903 m, and several lateral passages with a total length of 1228 m. The river passage is the main morphological unit of the cave, and there are a lot of larger and smaller cave halls, connected with narrow canals. The water is constantly flowing through the cave, creating waterfalls and cascades in some places. There are also the vertical cave Cerjanska Propast (-97 m), Kravljanska pit, karst cave beyond the spring at Kravlje (-130 m) and a short cave Pećurina (30 m) at Gornjekravljansko spring (Žolnaj 1980). The first explorations of the cave were conducted between 1970 and 1976. It is extremely rich in cave ornaments (helictites, speleothems, columns, petrified waterfalls), and the main attractions are bat colonies. The first form of protection of this cave system was in 1955. During the period, the form of protection was often changed, and in 1988 it was declared as a Monument of Nature. The cave is still not fully equipped for regular tourist visits, so it is not open for mass tourism. Tourist visits are allowed only with
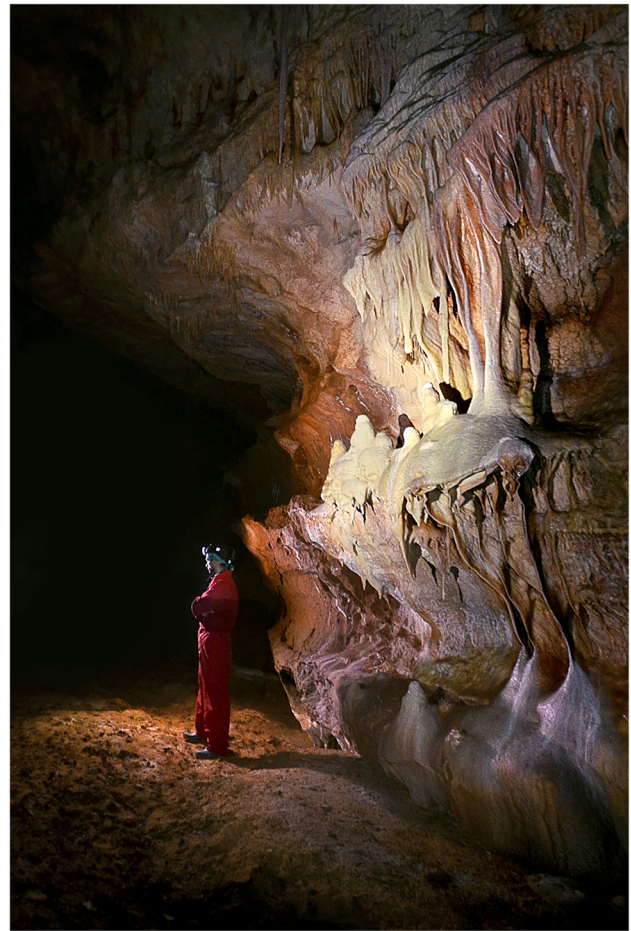
Fig. 2 Cerjanska cave – petrified waterfall (photo: Jovana Mladenović)

expert guides under full speleo equipment in small groups (Nešić et al. 2016). This type of visit to speleological objects is also known as "Wild Caving" (Figs. 2 and 3).

The Jelašnička gorge (GS 2) is located about 10 km east of the city of Niš. It has the protection status of a Special Nature Reserve (SNR) and it occupies 115.73 ha. It was put under protection in 1995 by the National Institute for Nature Conservation. The gorge stretches in the NW–SE direction. It is about 1.5-km long and on some points even 8 m wide (Began et al. 2017). The gorge was created by the intense vertical cutting of the Jelašnica river into limestone rocks of Suva Planina Mt., resulting in a narrow valley of steep slopes, with the highest point of 580 m. The gorge is cut through Upper Jurassic dolomites and reef limestones, with Paleozoic siliciclastic sediments below, and Neogene lacustrine sediments above the Jurassic sequence (Radović et al. 2019). Sections of the gorge eroded by water into rocky promontories, solitary ridges, and columns. The rich morphology, which gives the gorge a very attractive appearance, is complemented by specific forms

Fig. 3 Cerjanska cave – interior (cave jewelry) (photo: Jovana Mladenović)

of karst erosion: holes in the rocks, rock shelters, stone bridges, cavities, and caverns in the rocks (Kostić 1954). The Kulina stone bridge stands out with its size, beauty, and bizarre position on the left bank of the river Jelašnica, and the Sveti Ilija stone bridge, formed in the final, thinned part of the limestone cape Carevo Korito, on the right bank are landmarks of the Jelašnička gorge (Began 2019). There is also one attractive hydrological object, a small waterfall Ripaljka with a height of 8 m, which often runs out of water in the summer period (Fig. 4).

In addition, the Pešturina cave is a very important Paleolithic site in the area. It is located NW of the village of Jelašnica, 20 km from the city of Niš. Pešturina Cave is the only site in the Central Balkans that records both Middle Palaeolithic (Neanderthal) and Upper Palaeolithic (modern human) occupation levels with associated human remains (Lindal et al. 2020), including the first Neanderthal fossil identified in Serbia, a well-preserved maxillary first molar (Radović et al. 2019).

Nature Park Sićevačka (Sićevo) gorge (GS 3) is named after the village of Sićevo. It represents the breakthrough

Fig. 4 The Jelašnica gorge – stone bridge (photo: Jovana Mladenović)

Fig. 5 Nature Park Sićevačka gorge (photo: Jovana Mladenović)

gorge of the Nišava river. It is located between Svrljiške Mt. and Suva Mt. It spreads from the village Dolac to the village Prosek (Fig. 5). The gorge is 17-km long and more than 350 m deep. This composite, grandiose and heterogeneous gorge presents one of the most impressive and valuable limestone valleys of the gorge and canyon type in Serbia (Began et al. 2017). According to Djokić (2015), there are two narrow parts built mainly in carbonate rocks and an expansion at the mouth of the Ostrovički creek. The lower gorge was formed in the Permian and Devonian sandstones, and upstream, it was formed in Jurassic carbonate rocks, mostly stratified and banked limestone and dolomites. The most attractive part of the gorge is the grandiose Gradištanski canyon (7-km long) with closely folded sides, almost vertical (80⁻90°), with the heighest point of 400 m, and at some places just 10 m wide. It was formed in the Cretaceous banked and stratified limestone and dolomites. There are many caves and rock shelters in the Sićevo gorge, but very few of them are explored. The most famous one is Svinjska Rupa Cave, located on the right bank of Nišava River, at an altitude of almost 200 m above the international road. This is a dry cave without cave jewelry, but with a big bat colony. The cave is accessible for 50 m, and after that, a small corridor (1-m wide and 50-cm high) is disappearing in the rock. There are also Ogorelička cave, about 130-m long which the main canal ends with dangerous abysses, and Šuplja Dupka cave, about 60-m long (Jakšić and Momirović 2010). Mala Balanica cave in the Sićevo gorge is one of the most significant paleoanthropological and archeological sites of this area. During the recent excavation of the cave, the well-preserved dentition of the Middle Pleistocene human was found (Roksandić et al. 2011; Skinner et al. 2016). The special

marks of the gorge are also pits, sinkholes, hummocks, and imposing limestone escarpments, closely folded sides, and almost vertical and terraced stone cliffs. The Nature park Sićevo covers an area of 7.746 ha. The first act of protection was conducted in 1977, and in 2000 it was declared as a Nature Park (https://www.zzps.rs/wp/pp-sicevacka-klisura/).

Special Nature Reserve "Suva Planina" (Suva Mt. – GS 4) belongs to the southwest part of the Carpathian-Balkan mountain system, with a total length of 45 km and maximum width of 15 km (Trajković et al. 2013). The highest peak is Trem, with an altitude of 1810 m. Suva Mt. is a massif with remarkable phenomena and forms of karst relief, and a treasury of sediments of different ages rich in fossil flora and fauna. The core is composed of Permian red sandstone, clay, conglomerates, and Paleozoic shale. The basic geological structure consists of limestone (Milenković 2018). The relief of Suva Mt. is characterized by many Karst-based features such as sinkholes, caves, and pit caves. It is a curiosity that in such a small area there are a large number of sinkholes (over 100 sinkholes per 1 km^2), some of them are over 200 m wide and 50 m deep. Several pit caves have snow for most of the year. The pit cave "Ledenica pod Tremom" is the only permanent glacier pit in eastern Serbia, and it is located at an altitude of 1780 m. The pit cave "Jama u Konjskom" is the deepest one in this area (62 m), and it is a typical abyssal pit located at an altitude of 1100 m. There are also many underground geomorphological forms including cave residues and over 500 caverns (Nešić 2015). The most famous one is Peć Cave in the area of the village Bežište. It is 30-m long and has a ceiling height of 8 m. Vertical rock sections with a height of 200–300 m and a length of 1 km have a special aesthetic value (Randjelović et al. 2012). The first form of

Fig. 6 Special Nature Reserve "Suva planina" (photo: Jovana Mladenović)

protection was applied in 2015, and this area was declared as Special Nature Reserve "Suva Planina" (Fig. 6). It covers an area of 18.116 ha (https://www.zzps.rs/wp/suva-planina).

Inland salt area "*Lalinačka Slatina*" (GS 5) includes several smaller salt-affected sites in the vicinity of villages Lalinac, Oblačina, and Lepaja. It is situated close to Južna Morava River, on a substrate based on Mio-Pliocene conglomerates, gravel, sand, and coal-containing clay. It is located 10 km NW of Niš, at the foot of the Mali Jastrebac Mt., and it covers an area of 251 ha. On several locations, from the depth of the substrate, water erupts which is characterised by an increased content of mineral salts, especially sodium chloride (Zlatković et al. 2019). Salt-affected soils are a fragile and very endangered habitat (Zlatković et al. 2014). In addition to fragility, another feature is fragmentation of their appearance in Serbia. The occurrence of salt-affected soils outside of the Pannonian Plain in Serbia has an extremely local character and they are very rare. There are several localities in the vicinity of Niš City, Prokuplje City, and Vranje City. The salt concentration in the Lalinačka Slatina area is uneven, some fragments are highly salted, while others are less salted (Randjelović et al. 2007).This area is declared as the Monument of Nature since 2015 (Fig. 7).

Methodology

The methodology applied in this paper is based on the M-GAM model (Modified Geosite Assessment Model) developed by Tomić and Božić (2014). This method stands on previous geosite assessment methods developed by different researchers (Coratza and Giusti 2005; Bruschi and Cendrero 2005; Pralong 2005; Serrano and González-Trueba 2005; Pereira et al. 2007; Zouros 2007; Reynard et al. 2007; Erhartič 2010; Reynard 2008; Tomić 2011) and represents a combination of the GAM model created by Vujičić et al. (2011) and the Importance factor (*Im*) first introduced by Tomić (2011) in his research. The method combines the opinion of both tourists and experts, and neither side is favoured in the assessment process.

The M-GAM model consists of two key indicators: Main Values (MV) and Additional Values (AV), which are divided into 12 and 15 indicators, each of them individually marked from 0 to 1. The division is made due to two general types of values: main values — which are mostly generated by geosite's natural attributes, and additional values — which are mostly human-induced. The Main Values comprise three groups of indicators: scientific/educational (VSE), scenic/aesthetical values (VSA), and protection (VPr) while the Additional Values are divided into two groups of indicators, functional (VFn) and touristic values (VTr). The Main and Additional Values are presented in more details in Table 2. In total, there are 12 sub-indicators of MV, and 15 sub-indicators of AV which are graded from 0 to 1 that define M-GAM as a simple equation:

$$M - GAM = MV + AV \qquad (1)$$

where MV and AV represent symbols for Main and Additional Values. Since MV and AV consist of three or two groups of sub-indicators, we can derive these two equations:

$$MV = VSE + VSA + VPr \qquad (2)$$

Fig. 7 Inland salt area „Lalinačka slatina " (photo: Institute for nature conservation of Serbia)

$$AV = VFn + VTr \tag{3}$$

Each group of indicators consists of several sub-indicators, Eqs. (2) and (3) can be written as follows:

$$MV = VSE + VSA + VPr \equiv \sum_{i=1}^{12} SIMV_i, \text{where} 0 \leq SIMV_i \leq 1 \tag{4}$$

$$AV = VFn + VTr \equiv \sum_{j=1}^{15} SIAV_j, \text{where } 0 \leq SIAV_j \leq 1 \tag{5}$$

Values $SIMV_i$ and $SIAV_j$ represent 12 sub-indicators of Main Values (i = 1, ..., 12) and 15 sub-indicators (j = 1, ..., 15) of Additional Values. The main characteristic of M-GAM is that its focus is on the expert's opinion and the opinion of visitors and tourists regarding the importance of each indicator in the assessment process. Visitors' and tourists' involvement in the assessment process is made through a survey where each respondent is asked to rate the importance (Im) of all 27 sub-indicators (from 0.00 to 1.00) in the M-GAM model (Table 1). The importance factor (Im) allows visitors and tourists to express their opinion about each sub-indicator in the model and to show how important it is for them when choosing and deciding between several geosites that they wish to visit. After each respondent rates the importance of every sub-indicator, the average value of each sub-indicator is calculated and the final value of that sub-indicator is the importance factor. Afterward, the importance factor (Im) value is multiplied with the value that was given by experts (also from 0.00

to 1.00) who assessed the current state and value of each sub-indicator (Table 1).

This is done for each sub-indicator in the M-GAM model after which the values are added up according to the M-GAM equation, but this time with more objective and accurate final results due to the addition of the importance factor (Im). This parameter is determined by visitors and tourists who rate it in the same way as experts rate the sub-indicators for Main and Additional Values by giving them one of the following numerical values: 0.00, 0.25, 0.50, 0.75, and 1.00, marked as points. According to this, the importance factor (Im) is defined as:

$$Im = \frac{\sum_{k=1}^{k} Iv_k}{K} \tag{6}$$

where Iv_k is the assessment/score of one visitor for each sub-indicator and K is the total number of visitors. Note that the Im parameter can have any value in the range from 0.00 to 1.00. Finally, the M-GAM equation is defined and presented in the following form:

$$M - GAM = MV + AV \tag{7}$$

$$MV = \sum_{i=1}^{n} Im_i * MV_i \tag{8}$$

$$AV = \sum_{i=1}^{n} Im_j * AV_j \tag{9}$$

As it can be seen from the M-GAM equation, the importance factor (Im) value, which is rated by visitors, for each

Table 1 Structure of M-GAM model values

Indicators/subindicators	Description
Main values (MV)	
Scientific/Educational value (VSE)	
1. Rarity	Number of closest identical sites
2. Representativeness	Didactic and exemplary characteristics of the site due to its own quality and general configuration
3. Knowledge on geoscientific issues	Number of written papers in acknowledged journals, thesis, presentations and other publications
4. Level of interpretation	Level of interpretive possibilities on geological and geomorphologic processes, phenomena and shapes and level of scientific knowledge
Scenic/aesthetic (VSA)	
5. Viewpoints	Number of viewpoints accessible by a pedestrian pathway. Each must present a particular angle of view and be situated less than 1 km from the site
6. Surface	Whole surface of the site. Each site is considered in quantitative relation to other sites
7. Surrounding landscape and nature	Panoramic view quality, presence of water and vegetation, absence of human-induced deterioration, vicinity of urban area, etc
8. Environmental fitting of sites	Level of contrast to the nature, contrast of colors, appearance of shapes, etc
Protection (VPr)	
9. Current condition	Current state of geosite
10. Protection level	Protection by local or regional groups, national government, international organizations, etc
11. Vulnerability	Vulnerability level of geosite
12. Suitable number of visitors	Proposed number of visitors on the site at the same time, according to surface area, vulnerability and current state of geosite
Additional values (AV)	
Functional values (VFn)	
13. Accessibility	Possibilities of approaching to the site
14. Additional natural values	Number of additional natural values in the radius of 5 km (geosites also included)
15. Additional anthropogenic values	Number of additional anthropogenic values in the radius of 5 km
16. Vicinity of emissive centres	Closeness of emissive centers
17. Vicinity of important road network	Closeness of important road networks in the in radius of 20 km
18. Additional functional values	Parking lots, gas stations, mechanics, etc
Touristic values (VTr)	
19. Promotion	Level and number of promotional resources
20. Organized visits	Annual number of organized visits to the geosite
21. Vicinity of visitors centres	Closeness of visitor center to the geosite
22. Interpretative panels	Interpretative characteristics of text and graphics, material quality, size, fitting to surroundings, etc
23. Number of visitors	Annual number of visitors
24. Tourism infrastructure	Level of additional infrastructure for tourist (pedestrian pathways, resting places, garbage cans, toilets etc.)
25. Tour guide service	If exists, expertise level, knowledge of foreign language(s), interpretative skills, etc
26. Hostelry service	Hostelry service close to geosite
27. Restaurant service	Restaurant service close to geosite

Table 1 (continued)

Indicators/subindicators	Description				
Grades (0.00–1.00)	0.00	0.25	0.50	0.75	1
1. Rarity	Common	Regional	National	International	The only occurrence
2. Representativeness	None	Low	Moderate	High	Utmost
3. Knowledge on geoscientific issues	None	Local publications	Regional publications	National publications	International publications
4. Level of interpretation	None	Moderate level of processes but hard to explain to non-experts	Good example of processes but hard to explain to non-experts	Moderate level of processes but easy to explain to common visitor	Good example of processes and easy to explain to common visitor
5. Viewpoints	None	1	2 to 3	4 to 6	More than 6
6. Surface	Small	-	Medium	-	Large
7. Surrounding landscape and nature	-	Low	Medium	High	Utmost
8. Environmental fitting of sites	Unfitting	-	Neutral	-	Fitting
9. Current condition	Totally damaged (as a result of human activities)	Highly damaged (as a result of natural processes)	Medium damaged (with essential geomorphologic features preserved)	Slightly damaged	No damage
10. Protection level	None	Local	Regional	National	International
11. Vulnerability	Irreversible (with possibility of total loss)	High (could be easily damaged)	Medium (could be damaged by natural processes or human activities)	Low (could be damaged only by human activities)	None
12. Suitable number of visitors	0	0 to 10	10 to 20	20 to 50	More than 50
13. Accessibility	Inaccessible	Low (on foot with special equipment and expert guide tours)	Medium (by bicycle and other means of man-powered transport)	High (by car)	Utmost (by bus)
14. Additional natural values	None	1	2 to 3	4 to 6	More than 6
15. Additional anthropogenic values	None	1	2 to 3	4 to 6	More than 6
16. Vicinity of emissive centres	More than 100 km	100 to 50 km	50 to 25 km	25 to 5 km	Less than 5 km
17. Vicinity of important road network	None	Local	Regional	National	International
18. Additional functional values	None	Low	Medium	High	Utmost
19. Promotion	None	Local	Regional	National	International
20. Organized visits	None	Less than 12 per year	12 to 24 per year	24 to 48 per year	More than 48 per year
21. Vicinity of visitors centres	More than 50 km	50 to 20 km	20 to 5 km	5 to 1 km	Less than 1 km

Table 1 (continued)

Indicators/subindicators	Description				
22. Interpretative panels	None	Low quality	Medium quality	High quality	Utmost quality
23. Number of visitors	None	Low (less than 5000)	Medium (5001 to 10,000)	High (10,001 to 100,000)	Utmost (more than 100,000)
24. Tourism infrastructure	None	Low	Medium	High	Utmost
25. Tour guide service	None	Low	Medium	High	Utmost
26. Hostelry service	More than 50 km	25–50 km	10–25 km	5–10 km	Less than 5 km
27. Restaurant service	More than 25 km	10–25 km	10–5 km	1–5 km	Less than 1 km

Source: adapted from Vujičić et al. (2011)

sub-indicator separately, is multiplied with the value given by experts, individually for each sub-indicator. This is done for each sub-indicator in the model.

Authors Božić and Tomić (2015) conducted a survey in their research about different geotouristic segments and calculated the importance factor (Im) for each sub-indicator in the M-GAM model related to Serbian tourists. For this research, the importance factor values have been adopted from the mentioned paper.

Based on the results obtained, a matrix of Main Values (X-axes) and Additional Values (Y axes) is created (Fig. 8). The matrix is divided into nine fields represented with $Z(i,j)$, $(i,j = 1,2,3)$. Depending on the final score, each geosite will fit into a certain field. For example, if a geosite's Main Values are 6 and additional are 8, the geosite will fit into the field Z_{22}.

Results and discussion

For this study, five previously described geosites in the Niš City area were assessed by using the M-GAM methodology. The paper aims to compare their current state and geotourism potential and reveal the most suitable geosites for the initial geotourism development of the Niš City area. The final results of the assessment are shown in Tables 2 and 3, and Fig. 8.

Results presented in Table 2 show that the Main Values have a higher score than the Additional Values. It indicates a great potential for geotourism development, but these potentials are not fully utilised. Geosites with the highest Main Values are Sićevo gorge (7.70), Cerjanska cave (6.84), and Suva Mt. (6.84). Cerjanska cave and Sićevo gorge possess very high scientific values (VSE), especially in the case of rarity, representativeness, and level of interpretation, while Jelašnička gorge has a slightly lower score. However, geosites Suva Mt. and Sićevo gorge have the highest aesthetic values (VSA), especially regarding viewpoints, surface, and surrounding landscape and nature. These geosites have the biggest surface among all evaluated geosites. Geosites Cerjanska cave and Jelašnička gorge have a slightly lower score due to a smaller surface. Due to the high values of the importance factor of rarity, level of interpretation, and surrounding landscape and nature, geosites Sićevo gorge, Cerjanska cave, and Suva Mt. have the highest Main Values. Jelašnička gorge has a slightly lower score of Main Values. It possesses exceptional curiosity and aesthetic values. Specifically, the picturesque mountain environment, the Studena river, and numerous picnic sites attract a large number of visitors during the year. On the other side, the geosite with the lowest score of Main Values is the Lalinac salt area. This geosite covers a small area and has a low level of knowledge on geoscientific issues and viewpoints. All of the evaluated

Fig. 8 Position of analyzed geosites in the M-GAM matrix (Source: Authors)
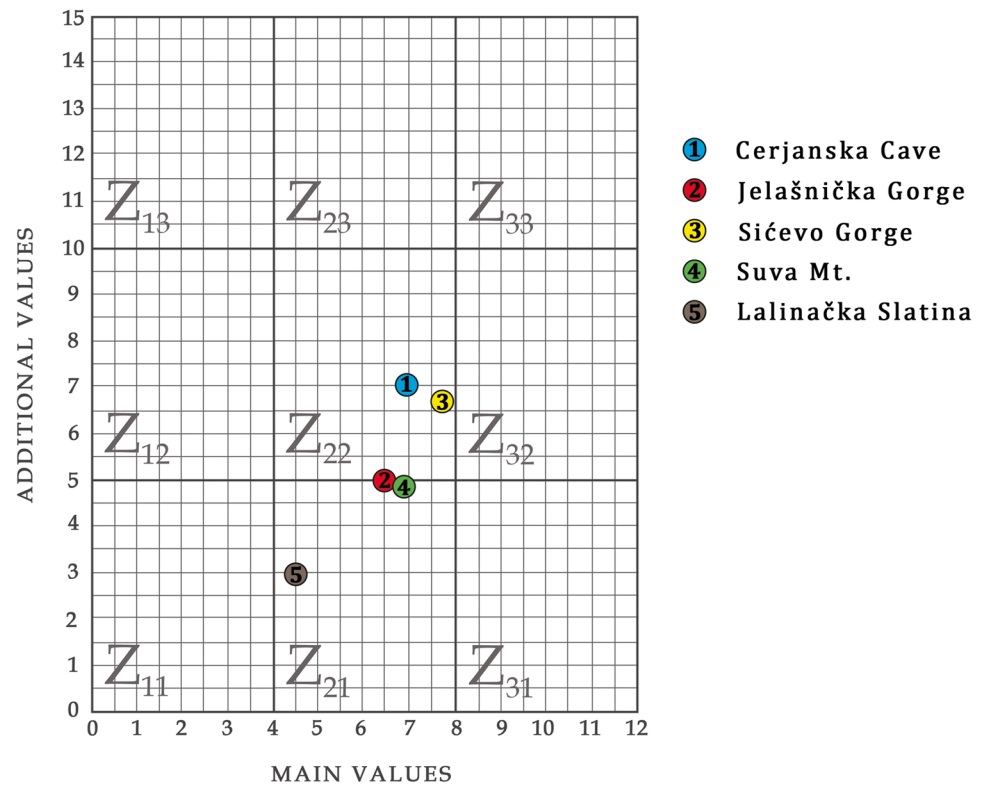
geosites are protected on a national level, and they are on the list of protected areas of the Institute for Nature Conservation of Serbia (INCS). Sićevo gorge, Jelašnička gorge, and Suva Mt. have the highest score of Protection values. These three geosites cover a huge area, which enables visits of large tourist groups without causing significant damage to the ecosystem. The geosite Cerjanska cave has a slightly lower score because it covers a smaller area and a big group of tourists can harm the ecosystem. Cerjanska cave represents speleological heritage, and due to its physical characteristics, only smaller tourist groups are allowed, in order not to harm biotic and abiotic values.

Additional Values are added values to a geosite for visitors' use. These values are very important for geotourism development. In Table 3, the overall score of Additional Values is presented for each evaluated geosite. Geosites Cerjanska cave (7.03) and Sićevo gorge (6.70) have the highest score of Additional Values, which means that these geosites are currently the most suitable for tourism activities.

In the case of functional values (VFn), the geosite Sićevo gorge has the highest score. This is mostly because an international road passes through the Sićevo gorge, connecting Europe and Asia. This area has numerous additional natural and anthropogenic values such as one of the oldest hydroelectric power plants in Serbia, dating from 1908, and several churches and monasteries. The Niš City area is lying on the crossroads of Europe and Asia, so it is easily accessible from all sides. However, the road network leading from the

city centre of Niš to the assessed geosites (except Sićevo gorge) has local character and low quality. Geosites Lalinac salt area and Suva Mt. have the lowest score according to accessibility because these geosites are connected to the main road by a narrow forest road limiting access, especially during rainy periods. For geotourism development, it is necessary to build up a quality road network due to the high score of the importance factor for accessibility. The city of Niš has a population of over 200,000 so this could be a potential tourist and visitor base for geotourism. This is the main reason for the high score of all assessed geosites regarding the vicinity of emissive centers.

The natural surroundings of Niš are very attractive for tourists and visitors. Numerous natural values such as surface and underground karst relief forms, thermo-mineral springs, numerous endemic herbs, and animal species, as well as local architecture and cultural heritage, increase the attractiveness of this area. Regarding additional functional values, the biggest problem of further tourism development is the lack of parking spaces. Apart from the geosite Cerjanska cave, none of them have a parking space for buses. There are few stops in Sićevo gorge, but none of them are equipped with bus parking spaces.

Tourism values are very important for the geotourism development and promotion. Analysing the touristic values (VTr) of evaluated geosites, it can be noticed that the geosite Cerjanska cave has the highest score (4.15). The main reason for such high touristic values is related to the vicinity of a

Table 2 Subindicator values given by experts for each analyzed geosite

	Values given by experts (0–1)					Im	Total value				
	GS1	GS2	GS3	GS4	GS5		GS1	GS2	GS3	GS4	GS5
Main Values (MV)											
Scientific/educational values (VSE											
1. Rarity ($SIMV_1$)	0.50	0.25	0.5	0.25	0.5	**0.89**	0.45	0.22	0.45	0.22	0.45
2. Representativeness ($SIMV_2$)	0.75	0.5	0.75	0.5	0.5	**0.79**	0.59	0.40	0.59	0.40	0.40
3. Knowledge on geoscientific issues ($SIMV_3$)	0.75	0.25	1	0.5	0	**0.45**	0.34	0.11	045	0.23	0.00
4. Level of interpretation ($SIMV_4$)	1	1	1	0.75	0.75	**0.85**	0.85	0.85	0.85	0.64	0.64
Scenic/aesthetic (VSA)											
5. Viewpoints ($SIMV_5$)	0.5	0.75	1	1	0.5	**0.79**	0.40	0.59	0.79	0.79	0.40
6. Surface ($SIMV_6$)	1	0.5	1	1	0	**0.54**	0.54	0.27	0.54	0.54	0.00
7. Surrounding landscape and nature ($SIMV_7$)	1	1	1	1	0.5	**0.95**	0.95	0.95	0.95	0.95	0.48
8. Environmental fitting of sites ($SIMV_8$)	1	1	1	1	1	**0.68**	0.68	0.68	0.68	0.68	0.68
Protection (VPr)											
9. Current condition (SIMV9)	1	1	1	1	0.5	**0.83**	0.83	0.83	0.83	0.83	0.42
10. Protection level(SIMV10)	0.75	0.75	0.75	0.75	0.75	**0.76**	0.57	0.57	0.57	0.57	0.57
11. Vulnerability (SIMV11)	0.75	1	1	1	0.5	**0.58**	0.44	0.58	0.58	0.58	0.29
12. Suitable number of visitors (SIMV12)	0.5	1	1	1	0.5	**0.42**	0.21	0.42	0.42	0.42	0.21
Additional values (AV)											
Functional values (VFn)											
13. Accessibility ($SIAV_1$)	1	1	1	1	0.75	**0.75**	0.75	0.75	0.75	0.75	0.56
14. Additional natural values ($SIAV_2$)	0.5	0.5	0.75	0.75	0	**0.71**	0.36	0.36	0.53	0.53	0.00
15. Additional anthropogenic values ($SIAV_3$)	0.5	0.5	0.75	0.5	0	**0.70**	0.35	0.35	0.53	0.35	0.00
16. Vicinity of emissive centers ($SIAV_4$)	0.75	0.75	0.75	0.75	0.75	**0.48**	0.36	0.36	0.36	0.36	0.36
17. Vicinity of important road network ($SIAV_5$)	1	1	1	1	1	**0.62**	0.62	0.62	0.62	0.62	0.62
18. Additional functional values ($SIAV_6$)	0.75	0.5	0.75	0.25	0.25	**0.59**	0.44	0.30	0.44	0.15	0.15
Touristic values (VTr)											
19. Promotion ($SIAV_7$)	0.5	0.25	0.75	0.25	0	**0.85**	0.43	0.21	0.64	0.21	0.00
20. Organized visits ($SIAV_8$)	0.75	0	0.5	0.5	0	**0.56**	0.42	0.00	0.28	0.28	0.00
21. Vicinity of visitors centers ($SIAV_9$)	1	0.5	0.5	0.25	0.5	**0.87**	0.87	0.44	0.44	0.22	0.44
22. Interpretative panels ($SIAV_{10}$)	0.5	0.25	0.5	0.25	0	**0.81**	0.41	0.20	0.41	0.20	0.00
23. Number of visitors ($SIAV_{11}$)	0.25	0.25	0.5	0.5	0	**0.43**	0.11	0.11	0.22	0.22	0.00
24. Tourism infrastructure ($SIAV_{12}$)	0.75	0.5	0.5	0.25	0	**0.73**	0.55	0.37	0.37	0.18	0.00
25. Tour guide service ($SIAV_{13}$)	0.5	0	0	0.25	0	**0.87**	0.44	0.00	0.00	0.22	0.00
26. Hostelry service ($SIAV_{14}$)	0.75	0.75	0.75	0.5	0.5	**0.73**	0.55	0.55	0.55	0.37	0.37
27. Restaurant service ($SIAV_{15}$)	0.5	0.5	0.75	0.25	0.5	**0.78**	0.39	0.39	0.59	0.20	0.39

Table 3 Overall ranking of the analyzed geosites by M-GAM

Geosite	Main values (MV)				Additional values (AV)			Field
	VSE	VSA	VPr	Σ	VFn	VTr	Σ	
GS 1	2.23	2.57	2.05	**6.84**	2.88	4.15	**7.03**	Z_{22}
GS 2	1.58	2.49	2.40	**6.47**	2.73	2.26	**4.99**	Z_{21}
GS 3	2.34	2.96	2.40	**7.70**	3.23	3.47	**6.70**	Z_{22}
GS 4	1.48	2.96	2.40	**6.84**	2.76	2.09	**4.85**	Z_{21}
GS 5	1.48	1.55	1.49	**4.51**	1.69	1.19	**2.88**	Z_{21}

visitor centre, tour guide service, and organised visits. The Sićevo gorge has a slightly lower score (3.47) due to the lack of high-quality interpretative boards. Geosites Lalinac salt area (1.19) and Suva Mt. (2.09) have the lowest score of touristic values. The main reason for such low tourist values is related to the low level of tourism infrastructure, interpretive panels, and promotional activities which are non-existent. Due to the high Importance factor for these sub-indicators, these elements should be the primary focus of future tourism development to attract more visitors to the sites.

Promotional activities of all geosites are on local and regional levels within the promotional activities of the Tourist Organization of the City of Niš. The official Tourist Organization website of the City of Niš (www.visitnis.org) promotes all of the evaluated geosites except the Lalinac salt area, but the information about the geoheritage of these geosites is insufficient. The funds assigned to promotional activities are very limited, so it is necessary to take advantage of the popularity, wide coverage area, and low cost of advertising via electronic media. This primarily refers to the use of internet marketing and promotional activities that represent one of the key trends in marketing strategies (Bratić et al. 2020). When it comes to organised tourist visits, it can be observed that only the geosite Cerjanska cave has 24–48 organized visits per year, as the only way of visiting this geosite is with organised tours. Geosites Sićevo gorge and Suva Mt. have less than 24 organised visits during the year. These geosites are often visited by hikers, adventurers, rock climbers, and nature lovers. If we look at the number of visitors, geosites Sićevo gorge and Suva Mt. have the highest number of visitors, between 10,000 and 100,000 visitors during the year because they are the main excursion sites of Niš.

Info boards, signs, and panels should provide visitors valuable information and many important and interesting facts that supplement the total interpretation impression. They should help visitors understand the processes and geology phenomena they are unable to see for themselves, and therefore, they will understand the site's surroundings. When it comes to interpretive boards, the geosite Cerjanska cave has a medium quality of interpretive panels (description of geosite and its meaning; bilingual interpretation; colour images; explanations of processes and phenomena; the level of protection). Other geosites have a poor quality of interpretative panels (serbian language only; there is no detailed description of geosite, its meaning, and level of protection; only the name of the geosite) or these elements are non-existent. Usually, they provide information on the length and duration of the walking path, difficulty, and other special features, but not on processes and geology phenomena. Interpretive panels, in the absence of a guide, simplify complex natural processes and provide meaningful information about the geosite, the length of the tourist trail, rules and

warnings, and facilitate the movement of visitors. Therefore, it is necessary to significantly improve the number and quality of interpretive panels, to increase the overall tourist experience. The other problem is that all interpretive boards are written only in Serbian, so it is impossible to be understood by anyone who does not speak, read, or understand Serbian language. The tourist organisation of the City of Niš has an organised guide service, but they are not trained well for geotourism. Quality and multi-lingual guide service is a very important factor in the geotourism development. Geotourists are often people who know little about geological and geomorphological processes, so a good interpretation is required to understand complex processes (Crane and Fletcher 2016). Niš has one visitor centre and it is located in the vicinity of Cerjanska cave. The role of visitor centres is multifaceted. In them, tourists can get information, hire guides, buy brochures, books and enjoy exhibitions. Given the fact that the importance factor for promotion, vicinity of visitor centres, interpretive panels, and tour guide service are among the highest in the M-GAM model for Serbian tourists, these elements should be the primary focus of future tourism development to attract more visitors to the site.

According to the overall score of MV and AV of evaluated geosites, each of them will fit into a certain field in a two-dimensional M-GAM matrix. Only two geosites (Cerjanska cave and Sićevo gorge) are located in the field Z_{22}. This indicates that these sites have the most potential for geotourism development among the evaluated geosites. All other evaluated geosites are located in the field Z_{21}. This means that their natural values (Main Values) are sufficient for the development of geotourism, but their additional values are poorly developed and require more intensive preparation of geosite to attract more tourists. The main purpose of the matrix is to compare one site in relation to another, according to their position in the matrix. Each of the matrix fields represents the level of Main and Additional Values. The higher the Values, the higher the position of the geosite on the X and Y axes in the matrix. Future geotourism development should be primarily focused on geosites Cerjanska cave and Sićevo gorge, which have a very good balance of Main and Additional Values but still plenty of room for improvement. Even so, more improvement of tourist values is necessary to attract more tourists and visitors in the future period. This refers to tour guide service, interpretive panels, and promotion.

Further geotourism development should be based on the use of Geographical Information System (GIS) (Marinoni 2004) and mobile applications which represents one of the smartest and the most efficient ways to bring geotourism closer to a wide audience (Filocamo et al. 2020). A Geographical Information System (GIS) is a valuable tool for quick management and complex processing of spatial data. The utilisation of GIS should help in better land use and

assessment procedure for geotourism (Marinoni 2004). Geotourism promotion through a mobile application is successfully applied in Piemont Region (NW Italy), in Sesia Val Grande UNESCO Global Geopark with PROGEO Piemonte app (Perotti et al. 2020). Mobile application PROGEO Piemonte App presents geotrail, geosites, off-site geoheritage elements to promote fieldtrips and virtual tours in the perspective of enhanced geotourism. Gambino et al. (2019) presented the mobile application TOURinSTONE for promoting geological heritage in the city of Torino in Italy, so this application combines urban tourism with geotourism. Reynard et al. (2015) presented the mobile application GeoGuide Lausanne. Pica et al. (2016a; b) proposed GeoGuide Rome a mobile application to link cultural and geological heritage. Filocamo et al. (2020) proposed the creation of a mobile application (called MoGeo App) for geoturism promotion of the Molise Region in Italy. This application aims to provide diverse geotourism information (combining geological attractions with other tourist attractions) to respond to various preferences of a wide audience.

Conclusion

The main focus of this study was to assess and compare the current state and geotourism potential of the five analysed geosites in the Niš City area by applying the M-GAM. The results obtained showed that all five geosites have a significant geotourism potential, which is based on natural resources, especially aesthetic and scenic values. It is an impressive fact that in such a small area there are as many as 5 areas that are under protection by the law of the Republic of Serbia as valuable natural heritage. The favourable traffic position of the Niš city region can influence the further development of geotourism. It is located at the crossroads of important European roads (one of them passes through SRP Sićevo), which can positively affect the arrival of foreign tourists (and tourists in transit) and enable this area to be a well-recognized geotourism destination out of Serbian borders. The next big advantage is that all geosites are located less than 30 km from the city centre and they are easily accessible from it. All geosites are located outside the city centre, on the peripheral area, which can affect the equal development of tourism in this area. Involvement of the local community in the geotourism development (interpretive activities, placement of domestic products, production of souvenirs, accommodation facilities) can bring positive economic effects for the population outside the city center. The city of Niš is popular as a destination of cultural tourism (music festivals, film festivals, wine festival), transit tourism, and MICE tourism, so geotourism can enrich the tourist offer of this area and more evenly distribute tourist activities to the entire region (not only in the city centre).

However, as our results show, there is a lack of necessary services and facilities for major geotourism development. Also, there is a lot of room for improvement of additional values. It is indisputable that the Niš city area possesses the resources for the development of geotourism, but better management of geosites and tourist destinations as a whole is necessary. A big problem for geotourism development is the lack of quality and multilingual guide service. This segment of the tourism market requires guided tours, so good quality tour guide service should be available. Geotourism is mostly based on self-guided tours, thus on site interpretation and geosite signage and signalization should be on a higher level. This is not the situation among the evaluated geosites, which is of low quality or non-existent. Lack of promotion activities is another problem for geotourism development, therefore usage of the Internet, GIS, virtual tours, better presentation at tourism fares, creative and informative brochures, maps for self-guided tours, and mobile applications is one of the smartest and the most efficient ways to bring geotourism closer to a wider audience. The promotion of geotourism can significantly affect the tourist's awareness of sustainable development and the importance of these geosites. Promotional activities can influence the education of (geo)tourists, which can result in responsible tourist behaviour.

Further development of geotourism research in this area can identify some new geosites and expand the geotourism offer even further in the future. Niš city region is less than 70 km away from the area of Nature Park Stara Planina. This area has numerous attractive geosites and it is supposed to be a new Serbian geopark in near future (Spatial plan of the Republic of Serbia 2021–2035 2021), so connecting Niš city region and Mt. Stara region in a georoute of the SE Serbia will positively affect the development of geotourism in this region. However, the full potential of this route remains to be fully revealed through further research of its geosites and their attraction for geotourism development.

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