Research Article

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Geotourism and geoethics as support for rural development in the Knjaževac municipality, Serbia

https://doi.org/10.1515/geo-2022-0388
received January 16, 2022; accepted June 23, 2022

Abstract: The main goal of this study is to emphasise the geotourism potential and the values of geoethics as drivers of rural development in the territory of the Knjaževac municipality, which is one of the richest areas in Serbia in terms of geoheritage. Numerous objects of geomorphological and hydrological heritage stand out in an area of 1,202 km^2. Despite this richness in geoheritage, the potential of geotourism development has been ignored by many stakeholders, and the geoheritage of this area has not been sufficiently explored and proposed for tourism purposes. This study makes an inventory of geosites in the municipality of Knjaževac. The selected sites were evaluated by applying the Modified Geosite Assessment Model to discover the most suitable geosites for future geotourism development, in order to select the geosite that possesses the greatest geotourism potential to support rural development. The results uncover information about the major areas of improvement for each evaluated geosite. Moreover, areas that demand more attention and better management in the upcoming period to become recognisable geotourism destinations were identified. It is pointed out that geoethical implications in geosite management can contribute to sustainable geoconservation in Eastern Serbia.

Keywords: geoheritage management, East Serbia, modified geosite assessment model, sustainability, geodiversity protection, regional development

1 Introduction

Geotourism, as a new niche market segment within tourism, puts focus on the promotion and conservation of diverse geological and geomorphological features of the landscape [1,2]. The occurrence of geoheritage elements in a specific area may remarkably contribute to the overall tourism attractiveness and its development potential [3–5]. Even though geotourism promotes geoheritage features, many authors have recently initiated the connection between geodiversity, biodiversity, archaeological and cultural values, gastronomy, and architecture to widen the quality of the geotouristic experience [6,7]. The definition of modern geotourism is presented by Hose and Vasiljević [8].

Geotourism has shown considerable growth all over the world [9–11], and the rapid increase in the number of geoparks worldwide is closely linked to it [1]. According to the List of UNESCO Global Geopark Network, there are 177 geoparks in 46 countries that have achieved official recognition (https://en.unesco.org/global-geoparks/list, accessed 12 Jun 2022). Geoparks are usually located in

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rural areas, typically distant and underdeveloped [12], and tourism is seen as one of the primary tools to develop an area [13]. Furthermore, geotourism is an important source of income in many rural and underdeveloped areas [14,15]. Geoparks create opportunities for local economic growth and employment [16] and enable market access for many stakeholders [17]. Residents' involvement in geotourism planning is the key to the sustainable geotourism development process [18]. The geotourism planning process needs to follow the attitudes of local communities and it should not decrease residents' sense of belonging to the local environment [16].

In addition, geotourism planning should include certain values of geoethics. Geoethics is a relatively new term in geosciences focused on the responsible implementation of knowledge in areas related to the anthropogenic impact on geoheritage. Therefore, the involvement of organisations and institutions that promote this type of ethically-responsible behaviour towards the Earth system, is a crucial indicator for the sustainability and conservation of georesources used for the development of geotourism destinations. By applying the appropriate principles and values of geoethics, scientists can establish long-term sustainability of destinations, which could not only be passed on to future generations of scientists but also managers and tourists.

The municipality of Knjaževac is located in the eastern part of Serbia (Figure 1). Geomorphological processes in the past period created interesting features for geotourism development in this area. In fact, there are various geo-objects such as gorges, caves, cracks, waterfalls, pits, and springs, showing a great geodiversity in the area. Unfortunately, the potential of geotourism development in the area has been ignored by many stakeholders, and the geoheritage has not been sufficiently explored and used for tourism purposes. The main goal of this study is to emphasise the geotourism potential and the values of geoethics as drivers of rural development in the territory of the Knjaževac municipality, as well as to make a preliminary list of geosites. This research was carried out by applying the modified geosite assessment model (M-GAM) created by Tomić and Božić [19]. The geotourism development in the municipality of Knjaževac could be beneficial for the improvement of the social level of the local community, as well as to raise the economical level through a well-founded geotourism action plan. A geoethical approach to the geotourism planning of the area is needed to maximise social and cultural benefits and minimise environmental impacts on touristic destinations.

2 Methods

2.1 Study area: geographical and geological features

The territory of the Knjaževac municipality (Figure 2) is one of the areas in Serbia with the most valuable geoheritage. Numerous geomorphological and hydrological "objects," such as waterfalls, caves, pits, and gorges, stand out on an area of 1,202 km^2. Its geological, pedological, and geomorphological features represent a potential for the geotourism development. Local geosites have great scientific, environmental, educational, economic, and cultural value. For that reason, they should be protected, promoted, and managed as an important asset for the sustainable, ecological, touristic, and economic development of the Eastern Serbia region.

The municipality of Knjaževac is located along the border of the Republic of Bulgaria. It spreads along the entire basin of the Trgoviški Timok river, the lower basin of the Svrljiški Timok river, and the upper basin of the Beli Timok river. To the east, it is bordered by the Mountain (Mt.) Stara Planina massif. The southwestern border consists of the hills of Mt. Tresibaba and Mt. Jalovik. The north border is the Mt. Tupižnica and the Tumba and Zdravac hills, and the west border is the Mt. Slemen and Mt. Krstatac.

The geographical position of the city of Knjaževac can be considered relatively favourable, due to the proximity of the city of Zaječar, and the regional centre, the city of Niš.

The municipality of Knjaževac has a peripheral position concerning the main direction of tourists' flow in Serbia. It is located more than 70 km from highway E-75, which is the main tourist corridor. However, Knjaževac has an extremely favourable position to secondary tourist routes of Eastern Serbia, which connects the Djerdap region with other Serbian tourist regions. Part of the Nature park Mt. Stara Planina, a famous Serbian ski-resort, is included in the territory of the Knjaževac municipality, attracting numerous domestic and foreign tourists.

The territory of Knjaževac, with its specific and diverse geological features, represents an interesting area of the Carpathian–Balkan orogenic structure that connects the Romanian Southern Carpathians and the Bulgarian Eastern Balkans. Cambrian green shales and metapelite rocks have been identified in the southwestern part of the municipality. In the southern parts, there are Permian red sandstone formations that include conglomerates. Jurassic sediments are most widespread in the north-eastern part and lie over green shales. The Lower Jurassic period is represented by sandstones and conglomerates of Gresten facies that turn into

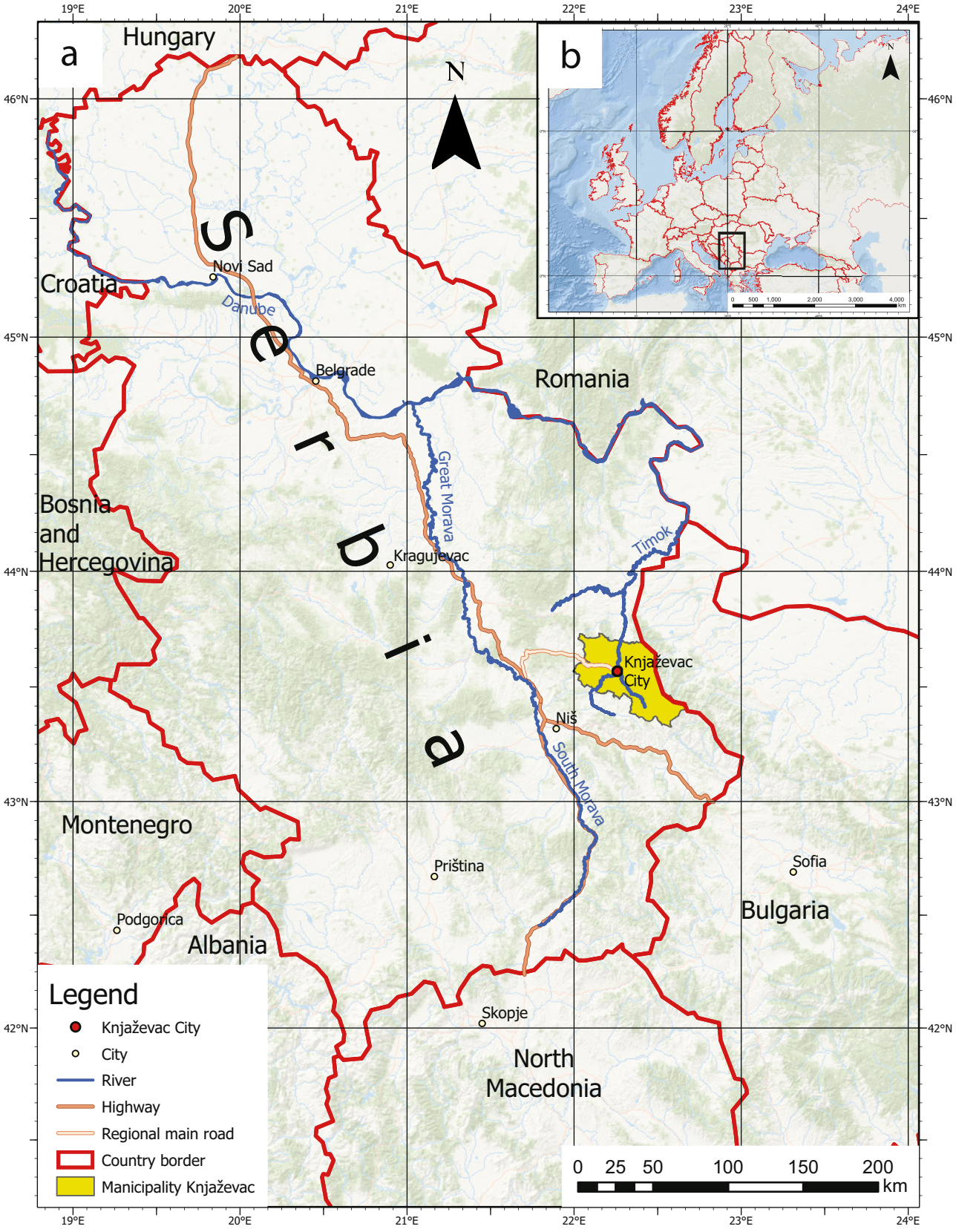

Figure 1: (a) Position of the Knjaževac municipality within the borders of the Republic of Serbia and (b) position of the Republic of Serbia within the Europe.

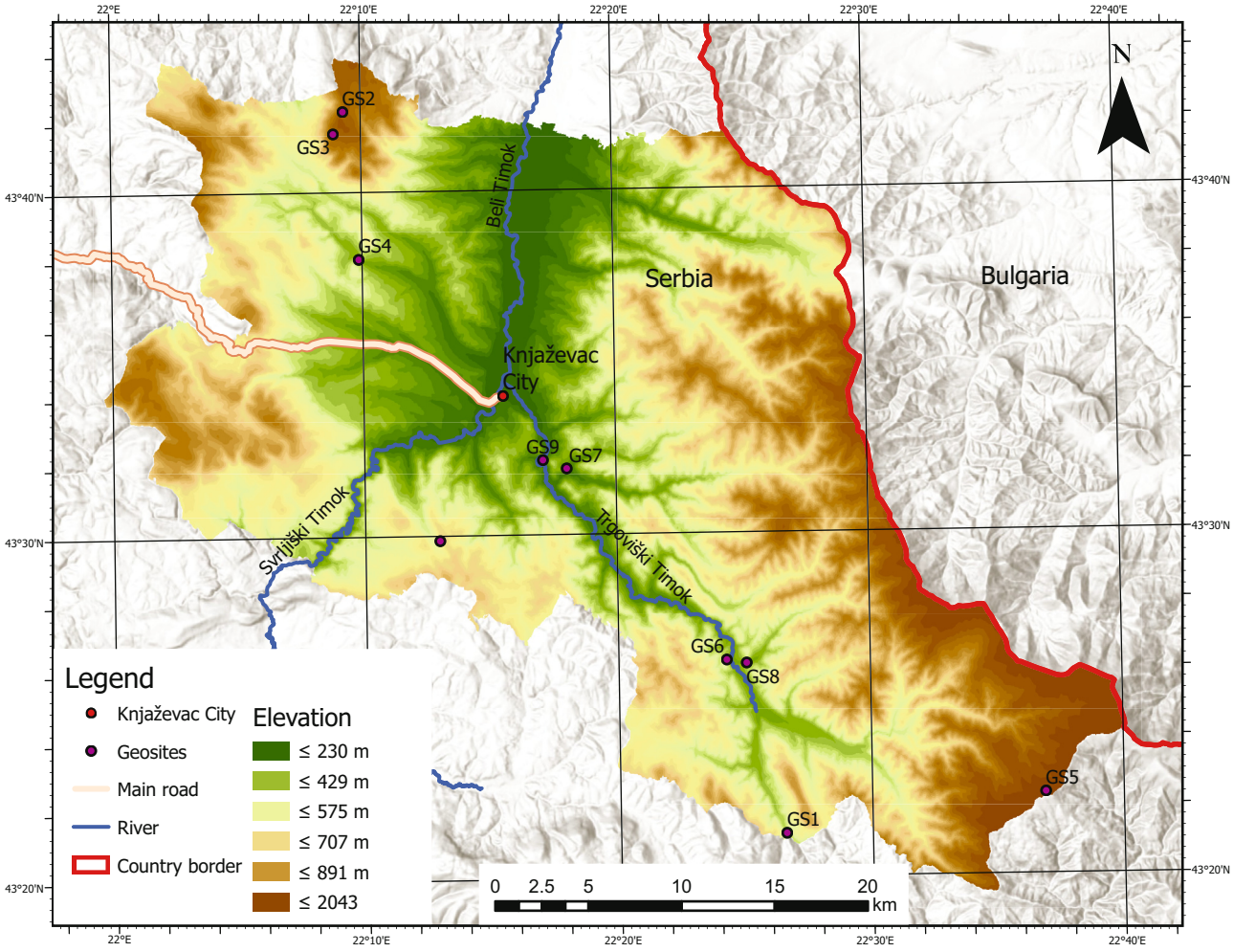

Figure 2: Position of the evaluated geosites within the Knjaževac municipality: GS1-The Bigar waterfall, GS2-The Tupižnička Ledenica pit, GS3-The Davidov propast pit, GS4-The Ždrelo gorge, GS5-The Babin Zub, GS6-The Korenatac gorge, GS7-The Žukovac, GS8-The Gabrovnica cave, GS9-The Baranica cave.

Middle Jurassic sandy limestones. Quaternary sediments outcrop in the valley of the Beli Timok river and the Trgoviški Timok river. They are represented by Pleistocene and Holocene formations, the river terraces, and alluvial deposits of the Beli Timok river are formed of gravel, sand, and clay [20].

The Knjaževac municipality is located in the eastern part of Central Serbia where three types of climates are recognised: continental, moderate continental, and modified Mediterranean type [21]. The valley of the Beli Timok river has lower annual precipitation than mean annual precipitation (MAP) in Central Serbia (685.3 mm). On the other hand, this valley has higher annual temperatures than the mean annual temperature (MAT) in Central Serbia (10.7°C) [22]

The geological evolution of this area created peculiar geological, geomorphological, and hydrological features that can have in some cases geotouristic relevance. To this aim, nine geosites were selected based on their attractiveness for geotourism purposes and their potential to attract a larger number of tourists.

2.1.1 The Bigar waterfall (GS1)

This geosite is known for a 35 m-high waterfall, created by the deposition of tufa (Serbian "Bigar"), which created a section over which the water of the Bigar stream falls at the river mouth of the Stanjinska river. Upstream from the river mouth, there are two small waterfalls and a series of smaller waterfalls that overflow from cascading lakes. Vegetation barriers and calcium carbonate play a significant role in the formation of waterfalls. Throughout its course, from the source to the river mouth, the valley is filled with tufa. Due to the representative appearance of tufa terraces and waterfalls, and in order to preserve the geomorphological and hydrological features of the karst spring Bigar stream, in whose valley is

the largest accumulation of tufa in Serbia, as well as the impressive waterfall, the valley of Bigar stream has been declared a Monument of Nature [23] (Figure 3).

2.1.2 The Tupižnička ledenica pit (GS2)

The most famous speleological object of the Mt. Tupižnica is located in its southern area, at the foot of the Ledenički peak 1,160 m above mean sea level (AMSL). It represents a karst pit of complex morphological, genetic, and evolutionary characteristics. The cave entrance is located on a horizontal surface covered with vegetation. The pit consists of an oblique, vertically stepped channel and a large hall 20 m wide, 6 m high, and the deepest point is 26 m below the entrance. There are two entrances to the pit, which are interconnected by a stone bridge about 2 m wide. The total length of the explored channels is 63 m [24]. The population of this area knows this geosite and perceives it as a rarity and natural landmark. In 2018, the Tupižnička ledenica pit was declared Monument of Nature, and its total surface is now placed under protection [25].

2.1.3 The Davidov propast pit (GS3)

This is the deepest known pit on the Tupižnica Mt. The pit has a vertical entrance of about 20 m depth; at its end, there is a sloping shelf with the hatch leading to another part of the pit, with a depth of over 40 m, and width of 20 m. At the bottom of the pit, there is a large amount of collapsed rocks, which descend to the lowest point of the pit – 81 m from the entrance. There are also speleothems, smaller columns, and a large floor formation, resembling a round altar [26].

Figure 3: Geosite of the Bigar waterfall; Photo: Miloš Marjanović (Date: 27 Jun 2021).

2.1.4 The Ždrelo gorge (GS4)

This is also known as the "Meteors of Knjaževac." The gorge is located 10 km northwest of Knjaževac, in the area of the Stogazovac village. It is cut for a length of 300 m in the Kulinje hill (540 m AMSL) on the right side, and the Rudina hill (460 m AMSL) on the left side of the Zubetinačka river, which flows through the gorge. In its narrowest part at the bottom, the width of the gorge is just 2–3 m. The Ždrelo gorge is cut into Upper Cretaceous limestones. These rocks were formed, approximately estimated, about 120 million years ago [27]. Later tectonic movements uplifted mountains and the work of exogenous forces created the contours of modern reliefs. At the bottom of the gorge, there are many collapsed rocky blocks that contributed to the creation of large whirlpools. The Zubetinačka river flows over these blocks in the form of waterfalls. The limestone terrains of the

Figure 4: Geosite of the Ždrelo gorge (Meteors of Knjaževac); Photo: Ivica Mišić (Date: 16 January 2022).

Ždrelo gorge are characterised by specific forms of relief that are created by the process of limestone dissolution, like pavements on limestone sections and small caves. The length of the pavements is about 10 m, the width is about 50 cm, and the depth does not exceeding 1 m [27] (Figure 4).

2.1.5 The rocky peak Babin Zub (GS5)

It is a group of quartz sandstones. This is one of the peaks of the Mt. Stara Planina massif and is located at an altitude of 1,758 m. There are characteristic vertical sections of rocks on it, one of which has a tooth-like shape that gave the name to this peak. Climbing the rocky peak is possible only with mountaineering equipment. In the area of the Babin Zub, there is also the spring of the Trgoviški Timok river, with a temperature of 4°C, which makes it the coldest spring in Serbia [25] (Figure 5).

2.1.6 The Korenatac gorge (GS6)

This is a deep gorge that was cut into limestone deposits by the Trgoviški Timok river. The gorge is 5.5 km long with a depth of 100–150 m. It started to be formed by the erosive stage of the Trgoviški Timok river. The Korenatac gorge is cut between the limestone hill Vrtača and Vrla Čuka (662 m AMSL) on the right valley side, and Crkvište (538 m AMSL) and Sinjovrška Čuka (692 m AMSL) on the left valley side of the Trgoviški Timok river. The geological structure of the gorge is very complex. The right side of the Trgoviški Timok basin is made of Paleozoic shales and Permian sandstones, with andesitic rocks and granites. Downstream, there is a narrow zone of limestones on the right and left valley sides [28].

The channels of the Korenatac cave were cut into limestone rocks on the right side of the valley of the Trgoviški Timok river. The cave in the Korenatac gorge is located near the village of Gornja Kamenica in the municipality of Knjaževac. A permanent underground

Figure 5: Geosite of rocky peak Babin Zub; Photo: Danilo Penić (Date: 15 August 2021).

stream flows out of the cave. The latest research on the Korenatac cave began in 2018 by the Sports Speleological Society Knjaževac, with the help and support of other speleological organisations. New cave channels were discovered, and the measured length of the cave was 1,441 m. The latest research has established that the cave is developed in, at least, three levels of channels. Upperparts of the cave are rich in speleothems, and one of the symbols of the cave is a pillar 8.5 m high, called "Gorostas" [29] (Figure 6).

2.1.7 The Žukovac stratigraphic geosite (GS7)

About 6.5 km SE of Knjaževac, in the valley of the Ukovačka river, on the local road Knjaževac-Žukovac, facies of Lower Cretaceous (Barremian–Aptian) bioclastic limestones, dated back to 125 million years, outcrop [28]. This facies consists of massive blue biosparites with shells, brachiopods, snails, and hedgehogs. Deposits contain numerous microfossils, especially foraminifera miliolite, green algae, and a lot of organogenic detritus mollusks. Further down the road, towards the village of Žukovac, biosparites replace biomicrites with corals and foraminifera that contain a terrigenous component [28].

2.1.8 The Gabrovnica cave with prehistoric cave art (GS8)

The cave in the Gabrovnica village is located on the left side of the old road Kalna – Gornja Kamenica. The cave entrance, 2 m wide and 1.5 m high, is located about 30 m above the Trgoviški Timok river. The entrance narrows towards the interior, where the corridor of undetermined length begins. The cave is well known for its prehistoric paintings. Cave art is visible at the cave entrance, and it represents the first discovery of its kind in Serbia. Five

Figure 6: Entrance of the Korenatac cave; Photo: Miloš Marjanović (Date: 16 January 2022).

paintings can be observed, and one of the most representative is a horse with a blade, in black colour. The cave and the paintings were discovered in 1997 during research activities conducted by the Faculty of Philosophy in Belgrade and the local museum. This cave art is dated back to the end of the Bronze Age and the beginning of the Iron Age [30,31] (Figure 7).

Figure 7: (a) Entrance of the Gabrovnica cave; Photo: Miloš Marjanović (Date: 16 January 2022). (b) Drawing in the Gabrovnica cave; Photo: Miloš Marjanović (Date: 16 January 2022).

2.1.9 The Baranica cave – paleontological site (GS9)

It represents a composite cave system located 4 km south of Knjaževac [32]. It was formed in the so-called Urgonian rocks of the Lower Cretaceous, which are represented by limestones, bioclastic limestones, sandstones, and marls [33]. Baranica is a dry karst cave with two entrances, a larger one in the south and a smaller one in the east. The cave is not rich in speleothems, but it is of great importance because it represents a site where the excavations revealed the remains of large mammals and various rodents from the late Pleistocene [34,35]. In addition to the numerous paleontological findings that are of exceptional importance for the study of Pleistocene mammal fauna in Serbia, Upper Paleolithic artefacts of flint and other tools were discovered, which indicates the presence of humans [30]. The proposal for the study of this site for protection purposes and its classification as a natural monument has been submitted to the Institute for Nature Conservation of Serbia (INCS) (Figure 8).

Figure 8: Geosite of the Baranica cave; Photo: Ivica Mišić (Date: 16 January 2022).

2.2 (Geo)tourism and rural development in the Knjaževac municipality

Tourism and rural areas are interconnected due to their nature. Geotourism is a nature-based type of tourism and most of the geoheritage sites are located within the rural areas, where human impact is lower than in urban areas and geosites and landscape can be more easily visible and appreciated.

Two decades ago, the municipality of Knjaževac was mainly a rural area. Tourism was developed mostly in the city centre, near Ravna village (archaeological site of Ravna) and in two wineries. During the 2000s, the depopulation trend of this rural area was significant and agrarian production declined. Recently, the local government points out tourism as the major element of local development. An extensive tourism development started a decade ago, when the 4 star hotel "Stara Planina" was built on Jabučko Ravnište plateau on Mt. Stara Planina, near the peak of Babin Zub, to support winter-sport tourism. This hotel brought many more investments in infrastructures, so Knjaževac municipality started its way from a mainly agricultural area to recognisable tourist destination. In such a short period, a significant increase in the number of beds mainly in rural tourism (Table 1), tourists, and overnight stays, especially of foreign tourists, was observed (Table 2). Foreign visitors were a rare presence in the Knjaževac municipality. However, the number of foreign visitors and their overnight stays was almost tripled in a period of 7 years. The number of domestic tourists arrival and overnight stays is doubled, and they have a tendency to stay longer. The increased number of tourists led to an increase in the income of people living in the area. If this trend continues, the number of tourists will grow significantly in the very near future.

Moreover, an increasing number of beds in rural areas, especially in the villages of Crni Vrh, Kalna, and Balta Berilovac, which are located near Jabučko Ravnište led to the improvement of the accommodation capacity (over 80% of the accommodation in rural tourism is located in those 3 villages). Many small hotels, hostels, lodgings, rooms within private households, and restaurants were built in the past few years. However, other areas of the municipality did not have notable tourism infrastructure development.

Rapid tourism development brought many benefits to residents. Hundreds of new jobs have been created indirectly. Old crafts were restored, organic food production was increased, and other local products got trademarked. Furthermore, this would stimulate locals to open new economic activities.

Winter sports attract tourists only for a few months, and during the rest of the year, Knjaževac municipality is visited by a lower number of tourists. Moreover, winter-sport tourism is located only in one part of the

Table 1: Bed capacity from 2013–2021

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021
Beds	230	320	480	518	600	610	612	614	626

Source: www.toknjazevac.org.rs.

Table 2: Tourist traffic in Knjaževac municipality

Year	Tourist arrival			Tourists staying overnight		
	Total	Domestic	Foreign	Total	Domestic	Foreign
2013	12.742	10.603	2.139	35.335	29.940	5.935
2014	11.853	9.335	2.518	42.641	34.334	8.307
2015	17.262	13.262	4.000	58.875	47.027	11.848
2016	15.439	10.922	4.517	55.014	41.611	13.403
2017	16.850	13.339	3.511	57.584	46.727	10.857
2018	22.667	17.201	5.466	73.885	58.880	15.005
2019	24.286	18.548	5.738	81.347	65.516	15.831
2020	27.035	24.061	2.973	95.096	85.796	9.300

Source: www.toknjazevac.org.rs.

municipality and the rest of the territory is not included in the tourism offer, so it continues to remain underdeveloped. As the unique natural landscape is by far the major factor attracting tourists to the Knjaževac municipality, geotourism may be the driving factor of equal rural development, and the factor that could attract tourists during the whole year. Geotourism can highlight harmony between the natural environment, agriculture, and rural culture [39]. According to several authors [36–40], geotourism is a tool for acquiring sustainable rural development, as it promotes nature protection, education, and culture. Furthermore, it creates employment opportunities, stimulates local entrepreneurship, and raises local income, as well as contributes to the overall economy and encourages residents to promote touristic activities in rural areas.

2.3 Geoethics: values and responsibilities

Geoethics is important to become more aware of the need to develop geoconservation measures. Geoethics highlights the ethical, social, and cultural implications of geoscience knowledge, as well as the responsibilities of anthropogenic activities in producing impacts that can have disastrous consequences on Earth's ecosystems [41–43]. Geoethics promote principles, values, and behaviours for developing an inclusive and ecological-oriented society. The human agent is at the centre of an ethical framework in which the principle of responsibility drives choices and practices "wherever human activities interact with the Earth system" [43,44].

Geoscience knowledge is pivotal in developing responsible practices to reduce anthropogenic impacts on the Earth system. This implies that geoscientists hold a crucial role in modern society to define and apply the geoethical framework [44]. Geoscientists possess adequate knowledge, abilities, and expertise, professional and cultural awareness of georesources, and can feel a great responsibility towards the Earth's geological heritage. These responsibilities can be reflected in many aspects of their professional activity, such as assisting and advising the management of protected natural areas on the prudent use of natural resources, on activities for preventing or reducing georisks, and on designing and carrying out educational activities to increase people's awareness on geo-environmental problems [45,46].

Geotourism, as a growing global trend in the fields of nature-based tourism [36], encompasses many areas where tourism activities must be carried out with maximum protection measures due to the vulnerability of geosites. In addition, geotourism implies interpretive elements of destinations, making geoeducation and the promotion of the importance of georesources to tourists as its fundamental activities [47]. For these reasons, it is necessary to establish a close link between geotourism and geoethics, thereby, making the geotourism destinations achieve a guaranteed status of sustainable and responsible-managed places in the tourism market. Only by creating a balance between protection and economic gain, geotouristic sites can be conserved for future generations [44].

The Eastern Serbia region is facing various challenges in terms of preserving local geoheritage, both for the common good and for geotourism affirmation. The biggest challenge is the problem related to the exploitation of copper and gold, which determines numerous consequences on the nature and population of Eastern Serbia [48]. Moreover, hydrological geoheritage has been endangered for a long time in the protected Nature park of Mt. Stara Planina, due to private investors who have been trying to implement small hydropower plants in recent years, the construction of which would have significantly affected geodiversity and biodiversity [49]. In addition, illegal afforestation is very common [50], which degrade forest and river ecosystems. Therefore, a geoethical code of conduct would be needed to manage those problems and favour the development of inclusive, sustainable, and geoconservation policies. Affirmation of geoethics in Eastern Serbia would develop more favourable conditions for understanding and recognising the values of geodiversity and geoheritage, and create a responsible geotourism development.

Knjaževac is located in the area at the junction of the Carpathian and the Balkan Mountains. This is an area with marked geodiversity and numerous potential geotourism destinations. Due to such a favourable position, Knjaževac can become a centre to put into practice geoethics in land management, by implementing responsible solutions to local environmental problems.

2.4 Methodology

Studies associated with the assessment of geoheritage are relatively young and fast-growing [51]. The assessment of geoheritage is an important step in the process of geotourism development [52], and it is widely accepted as a tool for the effective protection, development, and management of geological heritage [53]. The evaluation methodology has been constantly developing in the last two decades. The methodology applied in this study is based on the Modified Geosite Assessment Model (M-GAM model) developed by Tomić & Božić [54]. This method represents a

mix of previous geosite assessment methods [52–58] and the Importance factor (Im) introduced by Tomić [59]. The method provides the opinion of both tourists and experts, and neither is favoured in the assessment process. The M-GAM was successfully applied numerous times for the evaluation of geoheritage in Serbia, Hungary, Iran, India, Slovenia, and USA [3,60–69]. Software ArcGIS Pro, QGIS, and SAGA GIS are used for the cartographic presentation of geosites (Figures 1 and 2).

The Im is calculated for each sub-indicator in the M-GAM model related to Serbian tourists by Božić and Tomić [62]. For the purposes of this research, the values of the Im have been adopted from the mentioned paper.

3 Results and discussion

This research evaluated nine geosites in the Knjaževac municipality described in the previous section, by using the M-GAM methodology. The presentation of the current state and geotourism potential of those geosites, as well as detection of the most suitable of them for the initial geotourism development, are the principal aim of this study. The final results of the assessment process are shown in Tables 3 and 4 and Figure 9.

Looking at Table 3, it is evident that the Main Values (MV) have much higher scores than the Additional Values (AV). The geosites of "Babin Zub" (7.50), "Bigar waterfall" (6.76), and "Korenatac gorge" (6.54) have the highest MV. Furthermore, scientific values (VSE) of the geosites "Babin Zub" and "Bigar waterfall" are highly-rated, especially in the case of representativeness, knowledge on geoscientific issues, and level of interpretation. The geosites of "Tupižnička ledenica pit" and "Gabrovnica cave" have a slightly lower score. However, the geosites of "Korenatac gorge," "Babin Zub," and "Ždrelo gorge" have the highest aesthetic values (VSA), in particular viewpoints, surface, and surrounding landscape and nature. This is mostly due to the biggest surface among evaluated geosites and picturesque mountain environment. Geosites "Bigar waterfall" and "Žukovac" have smaller surfaces and fewer viewpoints, so they gain slightly lower scores. All the evaluated geosites have utmost surrounding landscape and nature, and the environmental fitting because of the unspoiled nature and vivid environment. Geosites "Babin Zub," "Tupižnička ledenica pit," and "Bigar waterfall" are the only ones protected on a national level, and they are on the list of protected areas of the INCS. In addition, protection of geosite "Baranica cave" on a national level is in progress, and soon it will be on the list of protected areas of INCS. "Babin Zub" and "Bigar waterfall" have the highest score of Protection values. These two geosites cover a huge area, which validates more visitors without damaging the environment. The geosite "Babin Zub" is located in the picturesque mountain environment of the highly attractive Nature Park Mt. Stara Planina. Geosite "Korenatac gorge" and "Ždrelo gorge" have a slightly lower score because they are not protected by the law. The "Baranica cave" and "Gabrovnica cave" have the lowest score because they cover a smaller area, they do not have the protected status and a big group of tourists can cause damage to the geosite. According to the Serbian visitors and tourists in the M-GAM model, sub-indicators of the level of interpretation, surrounding landscape and nature, and current condition, are highly-rated, thus geosites "Babin Zub" and "Bigar waterfall" have the highest MV. The geosite "Korenatac gorge" has a somewhat lower score of MV, but it possesses exceptional curiosity and aesthetic values. Specifically, the picturesque mountain environment, the Trgoviški Timok 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 MV is "Davidov propast pit." This geosite covers a small area, has a low level of knowledge on geoscientific issues and none of the protection status.

Additional Values are particularly significant for geotourism development. In Table 4, the final evaluation result of AV is presented for each of the geosites. Geosites "Babin Zub" (5.71) and "Bigar waterfall" (5.65) have highly-rated additional values, so these geosites are instantly the most convenient for tourism activities.

When it comes to functional values (VFn), the geosite "Bigar waterfall" has the highest score. This is mostly because it is easily accessible by bus, and this area has numerous additional natural and anthropogenic values such as several watermills and St. Onuphrius the Great monastery, dating from the 16th century. The municipality of Knjaževac is a little bit off the main traffic roads and tourist directions; however, it is easily accessible from all over the way. Nearby Nature park Mt. Stara Planina, which is partly within the territory of the municipality of Knjaževac, can attract a larger number of tourists and support geotourism development.

The road network leading from the centre of Knjaževac to the evaluated geosites has local character and low quality, except "Babin Zub" geosite, where the famous ski resort of Serbia is located, which has new and high-quality road with great signalisation. Geosites "Tupižnička ledenica pit" and "Davidov propast pit" have the lowest

Table 3: Sub-indicator values given by experts for each analysed geosite

	Values given by experts									Im	Total value								
Indicators/Sub-indicators	**GS_1**	**GS_2**	**GS_3**	**GS_4**	**GS_5**	**GS_6**	**GS_7**	**GS_8**	**GS_9**		**GS_1**	**GS_2**	**GS_3**	**GS_4**	**GS_5**	**GS_6**	**GS_7**	**GS_8**	**GS_9**
Scientific/Educational values (VSE)																			
Rarity ($SIMV_1$)	0.25	0.25	0.25	0.25	0.500	0.25	0.25	0.75	0.25	0.89	0.22	0.22	0.22	0.22	0.45	0.22	0.22	0.67	0.22
Representativeness ($SIMV_2$)	1.00	0.50	0.50	0.50	1.00	0.75	0.50	0.50	0.50	0.79	0.79	0.40	0.40	0.40	0.79	0.59	0.40	0.40	0.40
Knowledge on geoscientific issues ($SIMV_3$)	1.00	0.75	0.25	0.25	0.75	0.50	0.50	1.00	1.00	0.45	0.45	0.34	0.11	0.11	0.34	0.23	0.23	0.45	0.45
Level of interpretation ($SIMV_4$)	1.00	0.75	0.50	0.75	1.00	1.00	0.75	0.75	0.75	0.85	0.85	0.64	0.43	0.64	0.85	0.85	0.64	0.64	0.64
Scenic/Aesthetic values (VSA)&&&																			
Viewpoints ($SIMV_5$)	0.50	0.25	0.25	0.75	1.00	1.00	0.50	0.25	0.25	0.79	0.40	0.20	0.20	0.59	0.79	0.79	0.40	0.20	0.20
Surface ($SIMV_6$)	0.50	0.25	0.25	0.75	0.75	1.00	0.25	0.00	0.00	0.54	0.27	0.14	0.14	0.41	0.41	0.54	0.14	0.00	0.00
Surrounding landscape and nature ($SIMV_7$)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Environmental fitting of sites ($SIMV_8$)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Protection (VPr)																			
Current condition ($SIMV_9$)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.75	0.50	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.62	0.42
Protection level ($SIMV_{10}$)	0.75	0.75	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.76	0.57	0.57	0.00	0.00	0.57	0.00	0.00	0.00	0.00
Vulnerability ($SIMV_{11}$)	0.75	0.75	0.75	0.75	0.75	0.75	0.5	0.75	0.5	0.58	0.44	0.44	0.44	0.44	0.44	0.44	0.29	0.44	0.29
Suitable number of visitors ($SIMV_{12}$)	0.75	0.50	0.50	0.75	1.00	1.00	0.50	0.25	0.25	0.42	0.32	0.21	0.21	0.32	0.42	0.42	0.21	0.11	0.11
Functional values (VFn)																			
Accessibility ($SIAV_1$)	1.00	0.25	0.25	0.75	1.00	0.75	0.75	0.75	1.00	0.75	0.75	0.19	0.19	0.56	0.75	0.56	0.56	0.56	0.75
Additional natural values ($SIAV_2$)	0.75	0.25	0.25	0.75	0.25	1.00	0.25	0.25	0.75	0.71	0.53	0.18	0.18	0.53	0.18	0.71	0.18	0.18	0.53
Additional anthropogenic values ($SIAV_3$)	0.50	0.25	0.00	0.00	0.00	0.25	0.25	0.25	0.50	0.70	0.35	0.18	0.00	0.00	0.00	0.18	0.18	0.18	0.35
Vicinity of emissive centres ($SIAV_4$)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.48	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Vicinity of important road network ($SIAV_5$)	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.62	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Additional functional values ($SIAV_6$)	0.25	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.50	0.59	0.15	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.30
Touristic values (VTr)																			
Promotion ($SIAV_7$)	0.50	0.25	0.00	0.50	0.75	0.25	0.00	0.00	0.25	0.85	0.43	0.21	0.00	0.43	0.64	0.21	0.00	0.00	0.21
Organised visits ($SIAV_8$)	1.00	0.50	0.25	0.50	1.00	0.50	0.00	0.00	0.00	0.56	0.56	0.28	0.14	0.28	0.56	0.28	0.00	0.00	0.00
Vicinity of visitor's centres ($SIAV_9$)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interpretative panels ($SIAV_{10}$)	0.75	0.00	0.00	0.00	0.50	0.25	0.00	0.25	0.25	0.81	0.61	0.00	0.00	0.00	0.41	0.20	0.00	0.20	0.20
Number of visitors ($SIAV_{11}$)	0.75	0.25	0.25	0.25	0.75	0.25	0.00	0.00	0.25	0.43	0.32	0.11	0.11	0.11	0.32	0.11	0.00	0.00	0.11
Tourism infrastructure ($SIAV_{12}$)	0.50	0.00	0.00	0.25	0.75	0.25	0.00	0.00	0.00	0.73	0.37	0.00	0.00	0.18	0.55	0.18	0.00	0.00	0.00
Tour guide service ($SIAV_{13}$)	0.25	0.25	0.25	0.25	0.25	0.25	0.00	0.00	0.00	0.87	0.22	0.22	0.22	0.22	0.22	0.22	0.00	0.00	0.00
Hostelry service ($SIAV_{14}$)	0.75	0.25	0.25	0.50	1.00	0.25	0.75	0.25	0.75	0.73	0.55	0.18	0.18	0.37	0.73	0.18	0.55	0.18	0.55
Restaurant service ($SIAV_{15}$)	0.50	0.00	0.00	0.25	1.00	0.00	0.50	0.00	0.50	0.78	0.39	0.00	0.00	0.20	0.78	0.00	0.39	0.00	0.39

GS_1 – Bigar Waterfall; GS_2 – Tupižnička ledenica pit; GS_3 – Davidov propast pit; GS_4 – Ždrelo gorge; GS_5 – Babin Zub; GS_6 – Korenatac gorge; GS_7 – Žukovac; GS_8 – Gabrovnica cave; GS_9 – Baranica cave.

Table 4: Overall ranking of the analysed geosites by M – GAM

Geosites	Values				
	Main values VSE + VSA + VPr	Overall	Additional values VFn + VTr	Overall	Field
GS_1 – Bigar Waterfall	2.31 + 2.30 + 2.15	6.76	2.21 + 3.44	5.65	Z_{22}
GS_2 – Tupižnička ledenica pit	1.59 + 1.96 + 2.05	5.60	0.97 + 1.00	1.97	Z_{21}
GS_3 – Davido propast pit	1.16 + 1.96 + 1.48	4.59	0.80 + 0.65	1.45	Z_{21}
GS_4 – Ždrelo gorge	1.37 + 2.63 + 1.58	5.58	1.53 + 1.77	3.30	Z_{21}
GS_5 – Babin Zub	2.42 + 2.83 + 2.26	7.50	1.51 + 4.20	5.71	Z_{22}
GS_6 – Korenatac gorge	1.89 + 2.96 + 1.69	6.54	1.88 + 1.39	3.26	Z_{21}
GS_7 – Žukovac	1.48 + 2.16 + 1.33	4.97	1.35 + 0.94	2.28	Z_{21}
GS_8 – Gabrovnica cave	2.15 + 1.83 + 1.16	5.14	1.35 + 0.39	1.73	Z_{21}
GS_9 – Baranica cave	1.71 + 1.83 + 1.81	4.34	2.36 + 1.46	3.82	Z_{21}

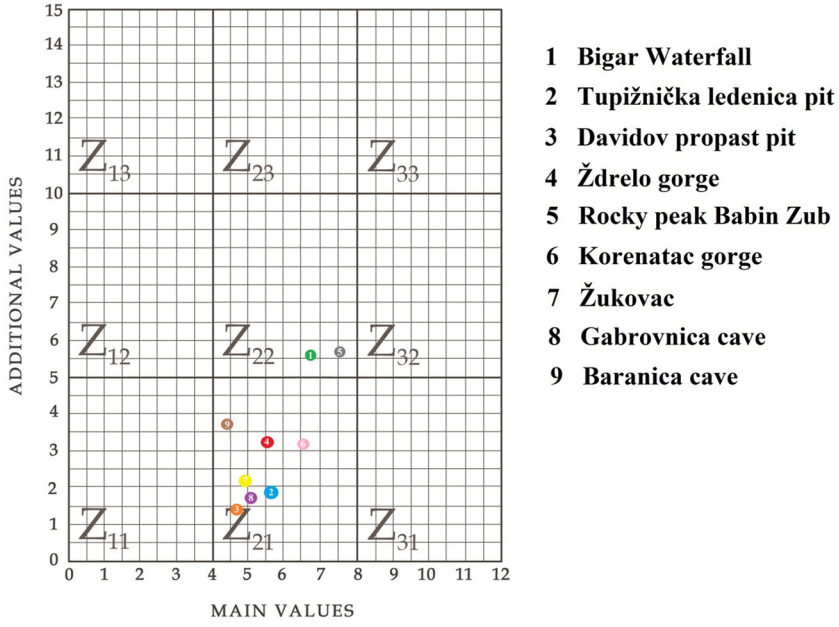

Figure 9: Position of the analysed geosites in the M-GAM matrix.

score according to accessibility because these geosites are connected to the main road by a track, and during the winter and rainy periods, the access is very limited. Due to the great significance of the geosite's accessibility for tourists, geotourism development requires a good quality road network. The city of Niš, which is 55 km southwest of Knjaževac, has a population of over 200,000, so this could represent a potential tourist and visitor base for geotourism.

The highly attractive natural surroundings of Knjaževac are visited by a large number of tourists. Various natural values such as underground and surface karst formations, thermo-mineral springs, gorges, waterfalls, numerous animal species and endemic herbs, and vicinity of the Nature park Mt. Stara Planina, together with cultural heritage local and architecture, expand the appeal of this area. The deficiency of parking lots is one of the crushing problems for further tourism development, regarding additional functional values. Except for the geosites "Babin Zub," "Bigar waterfall," and "Baranica cave," not one geosite has a parking lot for buses. There are few stops in "Korenatac gorge" and "Ždrelo gorge," but bus parking is not provided.

Tourism values are of great importance for tourists in M-GAM model, and they have a big impact on geotourism development and promotion. Looking at the touristic values (VTr) of evaluated geosites, it can be seen that the geosite "Babin Zub" is the highest rated (4.20). The

main reason for such high touristic values is because it is one of the most visited and popular ski resorts of Serbia; the only geosite among evaluated which is promoted on a national level; has the most significant number of organised visits and visitors; and as a ski resort, the "Babin Zub" has accommodation/restaurant facilities of the highest quality. The geosite "Bigar waterfall" (3.44) has somewhat lower result due to the lack of accommodation and restaurant facilities, and promotional activities. Geosites "Gabrovnica cave" (0.39) and "Davidov propast pit" (0.65) have the lowest score of touristic values for the low level of tourism infrastructure, interpretive panels, and promotion. Due to the high importance factor for these sub-indicators, the improvement of these elements is mandatory, so these sites could attract more visitors in upcoming times.

Promotional activities of evaluated geosites (except "Babin Zub" and "Bigar waterfall") are on a local level within the promotional activities of the Tourist Organisation of the municipality of Knjaževac. The official website (www.toknjazevac.org.rs) promotes all of the evaluated geosites except "Gabrovnica cave," "Korenatac gorge," and "Žukovac," but the information provided is inadequate. Geosites "Babin Zub" and "Bigar waterfall" are promoted within promotional activities of Nature park Mt. Stara Planina. Due to the restricted funds allocated to the promotion, it is of great importance to make use of the popularity and low cost of the announcement via the internet. Internet marketing and promotion are some of the tendencies in contemporary marketing [63]. On analysing organised tourist visits, it is noted that only geosites "Bigar waterfall" and "Babin Zub" have more than 48 organised visits per year, as these geosites are very popular among visitors of Nature park Mt. Stara Planina, adventurers, rock climbers, nature lovers, and hikers. Regarding the number of visitors, the mentioned geosites have the highest number of visitors, between 10,000 and 100,000 visitors during the year because "Bigar waterfall" is included usually in the student excursion program and the geosite "Babin Zub" is a famous ski resort.

Info boards, panels, and signs are very useful for visitors, as they provide information and many notable facts about the visited sites. These visual elements can complement the general tourists' experience. They represent a major component of the overall tourist experience (0.81). On analysing the interpretive boards and panels, the geosite "Bigar waterfall" has high-quality interpretive panels (information about geosite's location and processes; bilingual interpretation [Serbian and English]; colour illustrations; and the level of protection). The main reason why the interpretive panels of the geosite "Bigar waterfall" did not receive the highest values is related to the existence of limited information on the geology and geomorphology of the geosites. The quality of interpretive assets of other geosites is very low (only the name of the geosite is available; there is no detailed description of geosite or its meaning; only Serbian language is used; the lack of level of protection; unfitting in the environment) or these elements do not exist at all. Interpretive panels have a big significance in the self-guided tours, as they can explain complex processes, as well as provide information about the geosite's location, the direction of movement, the length of the tourist trail, rules, reminders, and caution signs. Hence, qualitative and quantitative improvements of the interpretive panels are needed, to provide a quality tourist experience.

The tourist organisation of the municipality of Knjaževac does not have an organised guide service. High-quality and multi-lingual guide service is a vital factor in the overall tourism development. High-quality verbal interpretation is required to explain complex processes, as geotourists are commonly visitors with insufficient knowledge about geological and geomorphological processes [70].

Knjaževac does not have a visitor centre. The visitor centre is very important in informing visitors and providing geoheritage interpretation. Visitor centres have diverse purposes. Tourists can get information about attractions, hire guides or audio guides, buy brochures or maps, or learn about geological forms and processes through description, animation, or demonstration.

In the M-GAM model, the importance factor for promotion, interpretive panels, vicinity of visitor centres, and tour guide service is highly-rated for Serbian tourists, thus, future tourism development should be directed towards setting or improving these elements to pull up a big number of visitors.

Looking at the final result of MV and AV of the geosites, each of them fits into a certain field in a two-dimensional M-GAM matrix. Two of the geosites ("Babin Zub" and "Bigar waterfall") are located in the field Z_{22}. This means that these geosites have greater potential for future geotourism development compared to others. All other geosites are located in the field Z_{21}. This indicates that geosites possess the potential for geotourism development, but they need significant improvement in their AV. Future geotourism development should be primarily focused on the geosites "Babin Zub" and "Bigar waterfall," which have a high score of both the Main and Additional Values, despite still plenty of room for improvement. Even though, significant enhancement of touristic values is

necessary to attract a larger number of tourists and visitors in the future.

It has been highlighted by many authors [16,37–40] that in geotourism, if proper plan and management is missing, it can lead to irreversible damage to the fragile geosites, which will further lead to a decrease in the visitor satisfaction and finally in the number of visitors. If carefully managed, geotourism activities can contribute to adopt conservation policies and practices for the defence of vulnerable environments, while developing them as geotouristic destinations [71]. Applying the principles and values of geoethics leads to the adoption of best strategies and practices to minimise negative impact on the environment, and to achieve positive outcome in terms of community's sense of place, local economy, and management of natural resources [31].

As for the geoethical challenges for the geosites considered in this study, it should be noted that some uncontrolled human activities and tourism development could induce heavy impacts on touristic destinations, their geosites, landscapes, and ecosystems.

For example, near the peak of Babin Zub, there are already three hotels and two restaurants. Further development of accommodation and restaurant facilities could decrease the aesthetic and scenic values of the geosite if not properly designed and managed. The villages of Crni Vrh, Balta Berilovac, and Kalna are several kilometres away from the Mt. Babin Zub, and these villages are suitable locations for new accommodation and restaurant facilities development; this would lead to a reduced tourism pressure on the protected area of the peak Babin Zub and would create a more diffused economic development in the territory around the geosite.

The Bigar waterfall is an attractive destination due to its spectacular tufa accumulation. Many visitors want to take rocks from this site as a souvenir, so they usually break part of the tufa accumulations. In this way, they are strongly damaging this geosite. Only by informing and educating tourists about the significance of these landforms and the geologic process for their creation and the need to conserve this geosite for other people's experience and to respect abiotic and biotic components of the local geoheritage can avoid irreversible damage to the environment. Surely, initial activities to protect the geosite should consider placing panels with warning signals, explanations about the geological process that create the geosite, and information about the local fauna and flora. These panels should also put in evidence reasons why it is important to protect the geosite, its importance for the local economic development, and the need and advantages to respect ecosystems.

Further geoethical challenges are related to speleotourism development in Gabrovnica cave, Baranica cave, and Korenatac cave, as well as in the Tupižnička ledenica pit and Davidov propast pit. Initiating sustainable and responsible speleotourism development is a big challenge. Appreciation of the conservation of the environment and the protection of the caves, as well as creating economic opportunities for the local population, requires complex activities [31]. Educating tourists and the local population on the fragility of the caves, their scientific, ecological, and cultural significance and economic potential can prevent irresponsible behaviours, like vandalism (the carving on cave paintings in the Gabrovnica cave) and abandon waste on-site (plastic bags and bottles, that were found on the bottom of Tupižnička ledenica pit and Davidov propast pit).

Finally, uncontrolled deforestation in the Ukovačka river valley can increase erosion of stratigraphic layers and induce landslides. Geoethics consider prevention activity on the basis of effective land management for reducing anthropogenic impacts on nature and minimising land degradation. This implies that forests, as fundamental ecosystem service for capturing atmospheric CO_2, have to be considered as a pillar of the strategies to create sustainable and responsible human communities through nature-based solutions.

4 Conclusion

This study aimed to make a preliminary list of geosites in the municipality of Knjaževac and to assess and compare the current state and geotourism potential of nine of them by applying the M-GAM matrix method. The results showed that all nine geosites have a notable geotourism potential, due to their particular scenic and aesthetic values. It is also interesting that in such a small area, there are relatively numerous valuable sites with great geotourism development potential. The favourable touristic position of the municipality of Knjaževac, the vicinity of Nature park Mt. Stara Planina and a popular ski-resort, can positively affect the flow of domestic and foreign tourists, and make this area a well-recognised geotourism destination. All geosites are located in rural areas. Local community involvement in geotourism development (interpretation of sites, selling domestic products, souvenir production, accommodation, and restaurant facilities) can bring positive economic effects for the population in this rural area. The Knjaževac municipality is already popular as a wine tourism and winter

sports destination, so geotourism can enrich the tourist offer and be a way to distribute tourist activities in the entire region (even in areas that currently are not considered for touristic purposes).

Even so, there are some shortcomings for the potential geotourism development, and there is a large scope for additional values' improvement. It is certain that the Knjaževac municipality has natural assets for geotourism development, but a much better management approach and strategy of tourist development, that also includes geoethical principles (responsibility) and values (respect for geodiversity and biodiversity, minimisation of human impact on environment, and inclusivity of local human communities in the decision-making process and economic development), are mandatory.

This article also proposes a plan for a geotourism development in Knjaževac municipality, which can be helpful to the local administration, regional government, local communities, and other interested parts:

- Mapping and inventorying geoheritage in a unique database (which is partly done in this study)
- Improvement of access roads for all evaluated geosites
- Installing high-quality signalisation
- Training and educating tour guides for quality geotourism experience
- Promoting geoheritage on a local, regional, national, and international levels
- Building of visitor's centre
- Connecting geosites and making a georoute
- Improvement of tourism infrastructure
- Involvement of local community in geotourism development
- Applying the values of geoethics and sustainability

The initial activity for geotourism development in the municipality of Knjaževac is to identify geoheritage and make a preliminary list of geosites, which is provided by this study. Connecting these geosites in a unique geotrail will lead to the making of a tourism product. Geotrails are the most widespread form of modern geotourism provision in many countries [72]. Geotrails are an emerging trend in the first part of the 21st century, linking geosites and natural and cultural features [73]. They can significantly enhance the appeal of a region to the visiting public [74,75].

Further geotourism research in the municipality of Knjaževac can identify some new geosites and expand the geotourism offer in the future. Part of the municipality of Knjaževac is located within the borders of the Nature park Mt. Stara Planina area. This area has numerous attractive geosites and it is supposed to be a new Serbian geopark, and National park in the near future [76], so connecting the municipality of Knjaževac and Nature park Mt. Stara Planina area in a georoute of southeast Serbia will positively affect the development of geotourism in the country. However, the full potential of this route remains to be fully revealed through further research about geosite destinations.

Acknowledgments: This article is the result of research on the project Development Programs for the Revitalisation of the Village of Serbia, funded by the Serbian Ministry of Education, Science and Technological development (Grant No. 451-03-68/2022-14/200124).

Conflict of interest: Authors state no conflict of interest.

Data availability statement: This manuscript (or one with substantially the same content, by any of the authors) has not been previously published in any language anywhere and that it is not under simultaneous consideration or in press by another journal.

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