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Inventory and Evaluation of Geosites: Case Studies of the Slovak Karst as a Potential Geopark in Slovakia

Miroslav Kudla [1], Miriama Javorská [2,*], Jana Vašková [3], Vladimír Čech [3] and Dana Tometzová [2]

1 State Nature Conservancy of the Slovak Republic, Slovak Caves Administration, 031 01 Liptovský Mikuláš, Slovakia; miroslav.kudla@ssj.sk
2 Department of Geo and Mining Tourism, Institute of Earth Resources, Faculty of Mining, Ecology, Process Control and Geotechnologies, Technical University of Košice, 042 00 Košice, Slovakia; dana.tometzova@tuke.sk
3 Department of Geography and Applied Geoinformatics, Faculty of Humanities and Natural Sciences, University of Prešov, 081 16 Prešov, Slovakia; jana.vaskova1@smail.unipo.sk (J.V.); vladimir.cech@unipo.sk (V.Č.)
* Correspondence: miriama.javorska@tuke.sk

Abstract: This study analyzes and evaluates natural and anthropogenic geosites within the potential Geopark Slovak Karst using a slightly modified Geosite Assessment Model (GAM). It focuses on three case studies from this area: Jasovská Cave, Gombasecká Cave, and Domica Cave, including their surroundings. The aforementioned caves represent the primary points of interest and draw in high concentrations of visitors. We aim to highlight opportunities for dispersing visitors to other nearby geosites and encouraging their extended stay in the region. Based on the research results, it can be concluded that the highest point values (from 22.5 to 23.5 points) are achieved by three UNESCO caves (Jasovská Cave, Domica Cave, and Baradla Cave). These caves have a high level of both main and additional values. Gombasecká Cave has a total point value of 20.5 points, with a high level of main values and a medium level of additional values. Other geosites reach total point values from 9 to 16 with different levels of main and additional values. The three accessible caves will continue to be the main object of interest for tourists. The networking of other nearby geosites with caves in the form of educational trails and their greater promotion could help visitors stay longer in the region and direct their attention to these geosites. The research methodology used in this study proved to be suitable and we can see its further use in the evaluation of geosites across the entire territory of the potential Geopark Slovak Karst.

Keywords: Slovak Karst geopark; geoheritage; geosite; cave; GAM

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1. Introduction

The term "geosite" is an often-reinterpreted term in the literature, dealing with geotourism [1–4], geodiversity [5,6], geoheritage [7,8], or geoparks [9,10]. Geosites represent the skeleton, the fundamental basis, of a particular region when such places are analyzed and evaluated in terms of the potential or use of the territory for geotourism. According to Goudie [11], geosites are parts of the geosphere that are particularly important for understanding the Earth's history. They are spatially limited and distinguishable from the surroundings from a scientific point of view. More precisely, geosites are defined as geological or geomorphological objects that have acquired scientific value (e.g., certain sedimentological stratotypes, such as relict moraine, representing the extension of a glacier), cultural–historical value (e.g., places with religious or mystical value), aesthetic value (e.g., some mountainous or coastal landscapes), and/or social/economic value (e.g., aesthetic landscapes as tourist destinations) due to human perception or use.

Groups of geosites are often distinguished and referred to as natural sites (e.g., hydrogeological, pedological, paleontological, and petrological sites) or anthropogenic (geohistorical) sites (e.g., mines and bunkers). Geosites, in terms of dimensions, represent territories from several m^2 (e.g., springs) up to several km^2 (e.g., glaciers) in size. In addition to the term geosite, the term "geomorphosite" is often used, but it is not easy to distinguish between the two terms. Some authors consider geomorphosites a subgroup of geosites, while others understand geomorphosites as the geomorphological equivalent of geosites. Geosite research often takes place in an area known as a geopark. UNESCO Global Geoparks (UGGps) are defined as unified geographical areas where the landscape and sites are of international geological significance and are managed with a holistic concept of protection, education, and sustainable development. A bottom-up approach combines nature conservation with sustainable development while involving local communities. There are currently 213 UNESCO Global Geoparks, spanning 48 countries [12]. A European Geopark is defined as a territory that includes a specific geological heritage with a sustainable territorial development strategy supported by a European development program. It must have clearly defined boundaries and a sufficient area for territorial economic development. A European Geopark must include a certain number of geological sites of exceptional importance in terms of their scientific quality, rarity, aesthetic value, or educational value. Most of the sites present in the territory of the European Geopark must be part of the geological heritage. However, they can also have archaeological, ecological, historical, or cultural significance [13]. The evaluation and inventorying of sites within geoparks, specially protected areas (i.e., national and natural parks) or other regions, is a frequent topic of research [14–40].

From the point of view of geotourism potential, the territory of the Slovak Republic can be characterized as relatively diverse, with several territories having a wide variety of suitable geosites. Despite its small area, thanks to the varied geological–geomorphological substrate and the centuries-old use of the land by humankind, the territory of the Slovak Republic is a suitable place for the location and creation of geoparks. To date, four geoparks are registered in the Slovak Republic, which are part of the European Geoparks Network: Banskoštiavnický Geopark, Banskobystrický Geopark, Malé Karpaty Geopark, and Novohrad–Nógrád Geopark. The last of these four is part of the UNESCO Global Geoparks Network.

Analyzing, evaluating, and establishing inventories of geosites are all essential in regions that represent the sites of potential or aspiring geoparks. From the point of view of geotourism, such potential geoparks represent a welcome addition and expansion of the network of existing geoparks at the national or international level [41–57].

The "Concept of Geopark Development in Slovakia" from 2008 envisages several other regions in the territory of the Slovak Republic that could become geoparks and thus expand the European Geoparks Network or the UNESCO Global Geoparks Network. Creating a geopark in terms of this concept must be preceded by an analysis of the geodiversity of the given region, the characteristics of its natural and anthropogenic geosites, the setting of adequate management of the area, and the involvement of local governments and organizations. In this paper, we refer to an area that meets the conditions related to this concept as a potential geopark.

Karst territories with surface and underground karst forms represent an ideal space for a potential geopark. In such areas, as a rule, caves represent the main object of interest for tourists and thus represent the dominant geosites of karst areas, which are so often the subject of research and evaluation [58–75].

One of the regions with potential geoparks in the Slovak Republic is the karst territory of the Slovak Karst, which, together with the neighboring Aggtelek Karst in Hungary, is the largest karst area in Central Europe. Favorable geological conditions (i.e., the occurrence of massive light Wetterstein limestones), together with the geological–tectonic development of the territory, created favorable conditions for the emergence and expansion of the karst phenomenon here. On a total area of approx. 800 km^2 (together with the Aggtelek Karst), a diverse range of forms of underground (endokarst) and surface (exokarst) karst was created to form this territory. From the view of the types of karst relief, it is plain karst with the occurrence of karst plains, which point to the midmountain leveling system. We can find several natural geosites in this area (caves, chasms, springs, sinkholes, limestone pavements, canyons, and gorges). Settlement and centuries–old use of this territory by humans has also caused the appearance of anthropogenic geosites (quarries, artificial lakes, monasteries, and mining works). Due to the area's valuable natural resources, there are two national parks in this karst area: in Slovakia, there is the Slovak Karst National Park (Figure 1), established in 2002; in Hungary, there is the Aggtelek National Park (established in 1985).

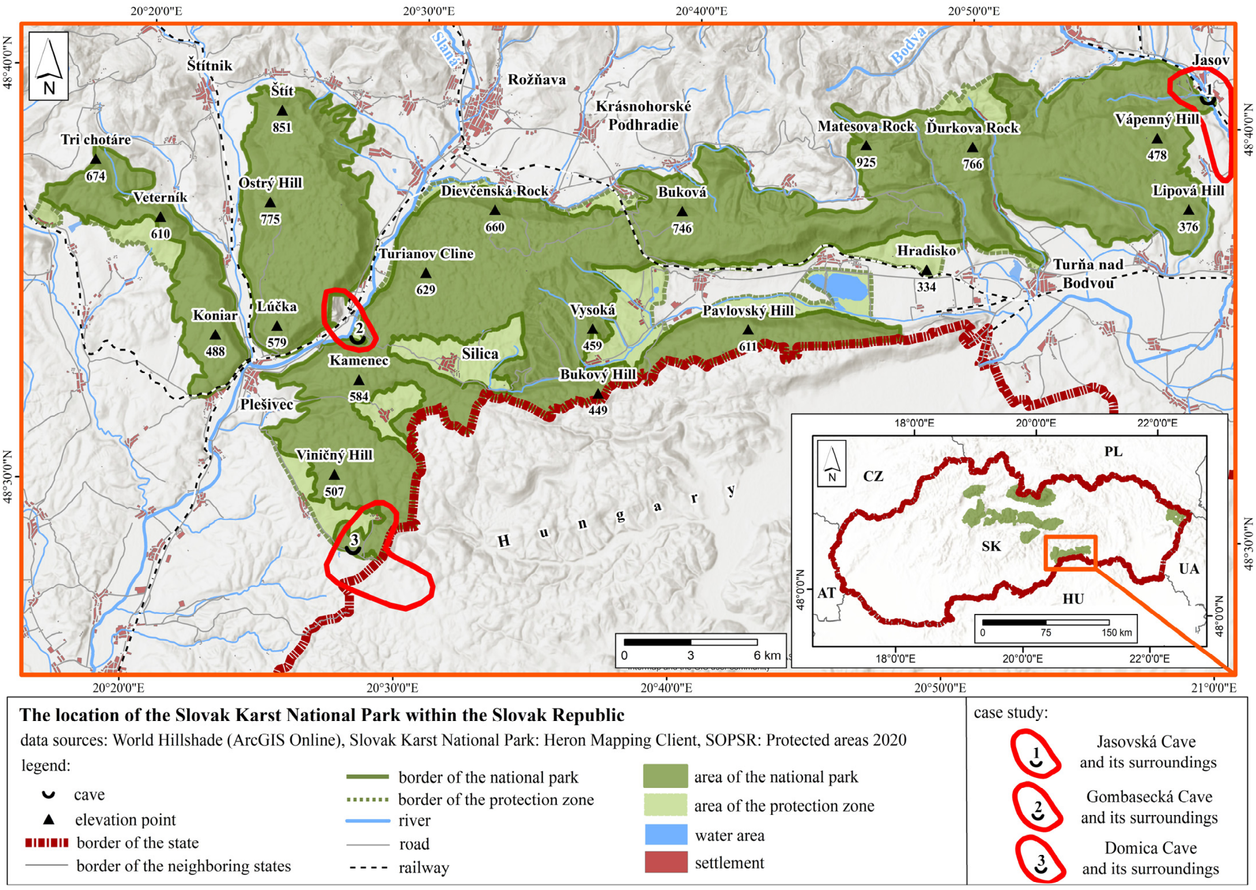

Figure 1. Location of the Slovak Karst National Park within the Slovak Republic.

As a contribution to the literature, this paper aims to inventory and assess natural and anthropogenic geosites on three case studies from the area of the potential Slovak Karst Geopark.

2. Study Area

2.1. The Slovak Karst

The Slovak Karst is located in the southern part of the Western Carpathians in the southeast of the Slovak Republic in the Slovak Ore Mountains. The territory, with an area of 361.65 km^2, covers four territorial administrative districts, namely Košice–Okolie, Gelnica, Rožňava, and Revúca. In the south, it stretches along the state border with the Republic of Hungary for a length of 57 km. The territory of the Slovak Karst is divided into nine subdivisions, namely Jelšavský kras, Koniarska planina, Plešivecká planina, Silická planina, Turnianska kotlina, Horný vrch, Dolný vrch, Zádielska planina, and Jasovská planina. The core zones of the territory are represented by the areas Silica–Jasov (27,299 ha), Plešivecká planina (5471 ha), and Koniarska planina (1595 ha). The territory's highest point is Dvorník Hill (932 m a.s.l.).

At the beginning of the Middle Triassic, limestone and dolomite layers began to form from the calcareous organisms of reefs on the subsided basins of the Late Permian. The sea retreated from the karst region, probably at the beginning of the Cretaceous. The uplift of the Gemer base caused the gravitational slide of limestone blocks in the form of mantels up to several tens of kilometers [76,77]—the first traces of karsting in Gombasek and Včeláre date from the Upper Cretaceous period. The flattening of the territory was caused by meandering surface flows from the Slovak Ore Mountains. The lifting and cutting of the area by the rivers Štítnik and Slaná occurred about 7 million years ago, while vertical caves and chasms such as Zvonivá jama, Malá Žomboj, Obrovská priepasť, and Brázda were created. More minor uplifts in the Pliocene about 3 million years ago were of great importance for the creation of the horizontal levels of several caves, such as Gombasecká, Ardovská and Hrušovská caves, or the Domica–Baradla cave system lP [78–80]. The territory of the Slovak Karst (Figure 2) is built mainly of light Triassic Wetterstein and Steinalm limestones with a lesser amount of dark-gray Gutenstein limestones [77,81,82].

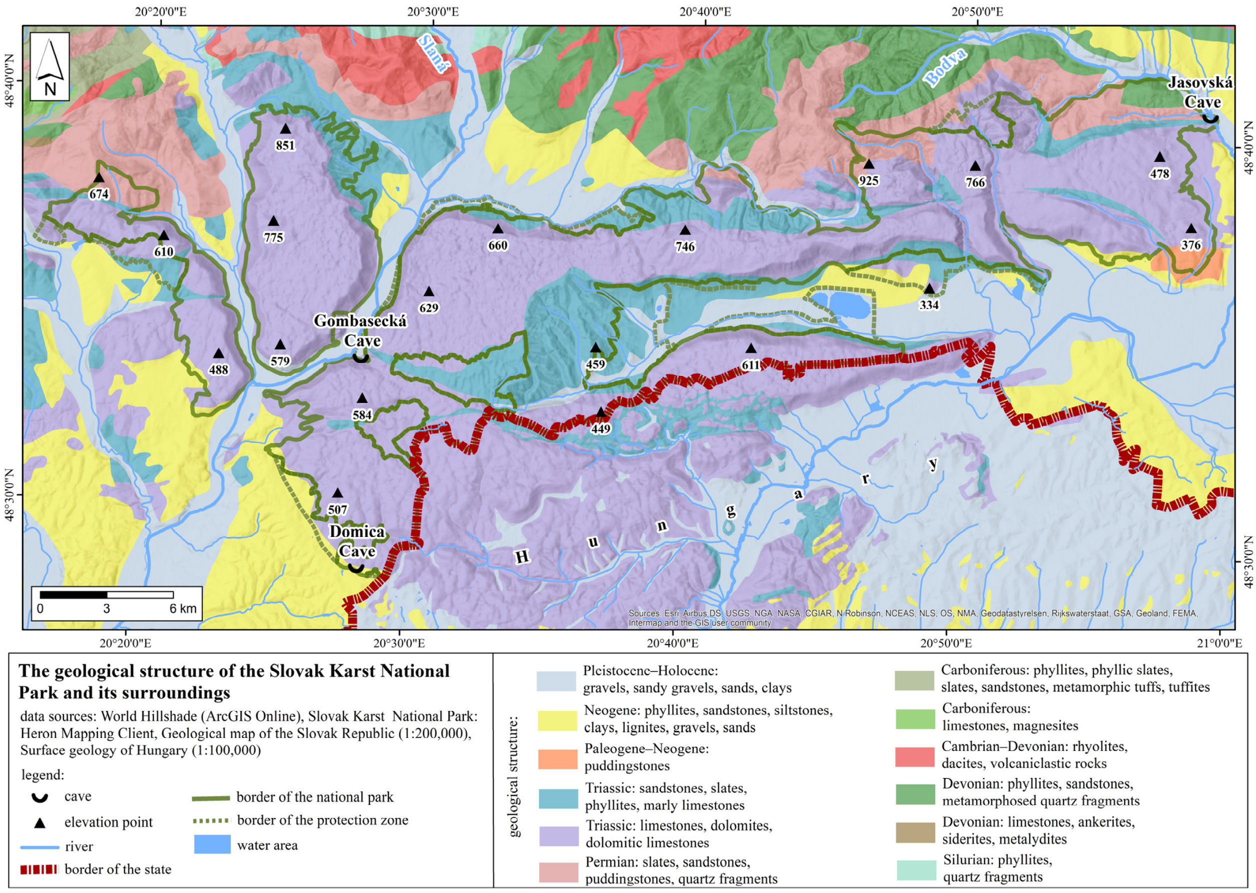

Figure 2. The geological structure of the Slovak Karst National Park and its surroundings.

The division of the initially uniform limestone territory into separate plateaus was caused by the uplift of the territory of the Slovak Karst and Aggtelek Karst in the late Tertiary, which was accompanied by an intensive deepening of the surface flows dividing this territory into plateaus. They are separated by the Štítnik and Slaná canyons, up to 400 m deep [83]. The plateaus of the Slovak Karst belong to the most fully developed karst plateaus in Europe and represent a typical Central European plateau karst of a temperate climate zone, with the perfect development of almost all surface and subsurface karst phenomena [84]. Limestone pavements are widespread on almost all plain surfaces, while the most representative area in terms of their occurrence is the Kečovské Karrens (Kečovské škrapy) [85]. Various types of sinkholes are abundantly represented; on the edges of the plateaus, there are also blind valleys ending in a limestone wall or dry valleys with sinkholes at the bottom [86–88].

The Slovak Karst finds itself in a mildly warm and humid climatic region with a cold winter, experiencing average winter temperatures of −2 to −5 °C and summer temperatures of 16 to 18 °C. The annual number of days with snow cover is around 60–80, and the number of summer days is between 30 and 50. The average annual temperature is around 8.8 °C. The annual average precipitation ranges from 630 to 780 mm. A significant seasonal change of weather is characteristic.

The territory of the Slovak Karst is drained by the rivers Slaná, Štítnik, and Bodva with their side tributaries. The territory is characterized by a general lack of water, which is most pronounced on the surface of the plateaus. Numerous karst lakes (Smradl'avé jazero, Jašteričie jazero, and Farárova jama) can be found on the edges of the plateaus near the junction of karst and non-karst rocks [89]. The lack of water on the surface is compensated for by the accumulation of groundwater inside the plateaus, drained by springs and springs of shallow circulation at their foothills with fluctuating yields, such as Čierna, Hučiaca, Brzotínska, or Pstružia vyvieračka. The regimes of springs connected with waters of deeper circulation, such as Veľká studňa, Teplá voda (Včeláre), or Kunová Teplica, are more constant. A particular type is represented by periodic springs based on the principle of an underground reservoir, which is gradually filled with water before compressed air pushes it to the surface at once [90,91].

The soil cover on the karst plateaus of this territory is significantly conditioned by the georelief, as well as the geological bedrock. Karst ridges and mounds are mainly covered by rubified rendzins, representing the most widespread soil type. In dry valleys and plateaus, characteristic cambisols are rubified. The territory is characterized by the frequent occurrence of terra rossa, either in an autochthonous form or, even more so, in a resedimented form [92].

The specific characteristics and peculiar conditions of the territory of the Slovak Karst are also reflected in the diversity of its flora and fauna [93]. Within Slovakia, several flora taxa occur only in the Slovak Karst, e.g., Sadler's fern (*Ferula sadleriana*), the pisiform grass-pea (*Latyhrus pisiformis),* or the short–necked sedge (*Carex brevicollis*). The peculiarities of the territory also create specific conditions for animals, predominantly of the steppe and forest–steppe zones, such as the predatory bush cricket (*Saga pedo*), the European ground squirrel (*Spermophillus cittelus*), the praying mantis (*Mantis religiosa*), or the mollusk *Pupilla triplicata*. The occurrence of 217 species of birds has also been confirmed. Bats, which find suitable living conditions in the caves of the Slovak Karst, are the most abundant cave fauna, some of which are endemics and troglobites, such as the shrew *Eukoenenia spelaea*, the cave shrew *Niphargus aggtelekiensis*, the beetle *Duvalius bokor*, the shrew *Neobisium slovacum*, and the springtail *Pseudosinella aggtelekiensis* [94–103].

Since 1995, the territory of the Slovak Karst has been included in the UNESCO World Natural Heritage List as part of the "Caves of the Slovak and Aggtelek Karst" project.

2.2. Geosites of the Territory

In the studied territory of the Slovak Karst, we focused on three case studies. At the center of these three areas is an accessible cave, listed as a UNESCO World Heritage Site. Thus, this cave represents the area's main geosite, with the largest concentration of visitors in the entire Slovak Karst. In its vicinity, we also selected other geosites. We evaluated their potential in order to point out other opportunities for the development of geotourism in the area, given that this would subsequently lead to more extended stays of visitors in the region and their broader dispersion.

2.3. Jasovská Cave and Its Surroundings (Figure 3)

GS_1, Jasovská Cave (Figure 4)—The cave itself is located in the easternmost part of the Jasovská Plateau on the edge of the Medzevská pahorkatina upland. In 1846, it was made available by the religious order of Premonstratensians. The entrance to the cave is under the Jasovská Rock near the village of Jasov. Since 1995, Jasovská Cave has been registered among the natural monuments in the UNESCO World Heritage List within the Slovak and

Aggtelek Karst caves. The upper and some lower parts, mostly oval–shaped corridors, were created by the action of the formerly submerged waters of the Bodva river. Stagnant waters also formed some parts of the cave spaces. It is an important wintering place for 19 species of bats out of the total 24 species that live in Slovakia. It is known for being the location of paleontological sites of cave bear (*Ursus spelaeus*) and cave hyena (*Crocuta spelaea*) bones, as well as for its archaeological sites and fascinating history. Since 1995, speleoclimatic stays have been carried out in the cave [104–107].

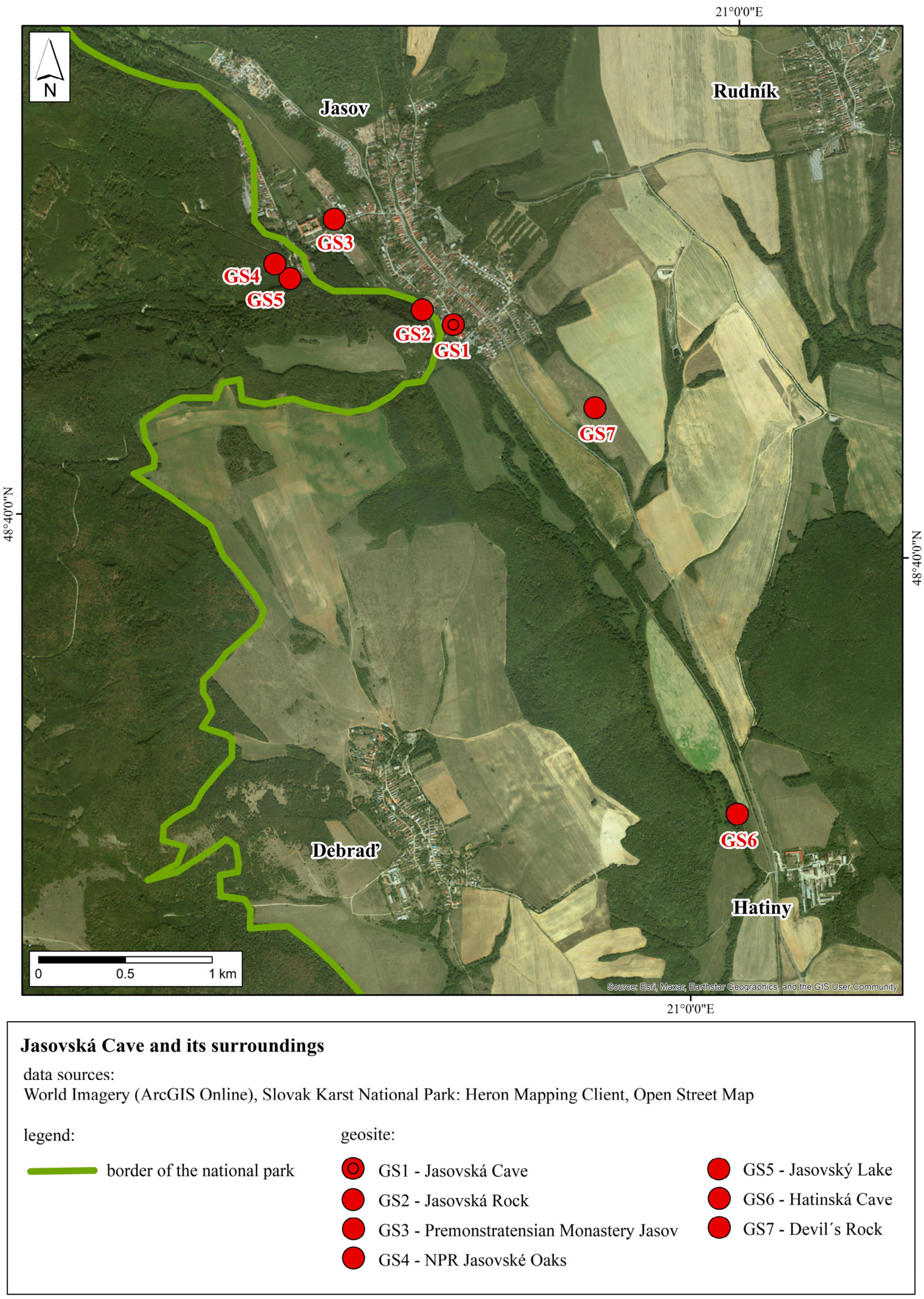

Figure 3. Geosites of Jasovská Cave and its surroundings.

Figure 4. Jasovská Cave (GS_1).

GS_2, Jasovská Rock (Jasovská skala)—In addition to Jasovská Cave, the Jasovská Rock also hides smaller caves. The massif is built mainly of Middle Triassic gray Gutenstein dolomites and light Steinalm limestones and dolomites of the siliceous mantle. At the top of the Jasovská Rock are the ruins of the Jasovský Castle from the beginning of the 14th century. An educational trail, Jasovská skala, has been built on the site, which leads from the bottom of Jasovská Cave to its top, then to the ruins of the castle, and from there through the Jasovské Oaks and to Jasovský Lake.

GS_3, Premonstratensian Monastery, Jasov (Figure 5)—The first definite mention of this monastery in Jasov dates from 1243. The building of the Premonstratensian Monastery itself underwent several reconstructions, the most significant of which took place in the middle of the 18th century, when the original complex was practically demolished and replaced by the current late-Baroque monastery complex. Even though it is not a geosite, it is closely related to the geosites of the surrounding area and has historically directly conditioned their use and anthropogenic changes [108].

GS_4, NNR Jasovské Oaks (Jasovské Dubiny)—In the northern part of Jasovská Rock, in the immediate distance from Jasovský Lake, there is the territory of the national nature reserve Jasovské Oaks (Dubiny), which has an area of 35 ha. This site is the oldest nature reserve in the territory of the Slovak Karst. It was declared a nature reserve in 1950 to protect preserved natural communities in places crossed by xerothermic biotopes [94].

GS_5, Jasovský Lake (Figure 6)—This lake is located near the monastery complex north of the Jasovská Rock. It was built in the first half of the 15th century thanks to the Premonstratensians from Jasov. The pond is fed by the Teplica karst spring. Part of the complex of the pond is also an extensive historic cellar [108].

GS_6, Hatinská Cave—Freely accessible to the public, Hatinská Cave is located 7.5 km south of Jasov and 1.3 km east of the village of Debraď. Since 2013, the cave has been freely accessible to the public, although there is no marked trail leading to it. This cave, which is 40 m long, is represented by an inactive fluviokarst passage [109].

GS_7, Devil's Rock—Devil's Rock is a lonely limestone rock massif located southeast of the village of Jasov, only 1.7 km from the entrance of Jasovská Cave. With a height of more than 2 m and a diameter of more than 5 m, the rock stands out from the practically flat terrain [108].

Figure 5. Premonstratensian Monastery, Jasov (GS_3).

Figure 6. Jasovský Lake (GS_5).

2.4. Gombasecká Cave and Its Surroundings (Figure 7)

GS_8, Gombasecká Cave (Figure 8)—The cave itself is located at the western foot of the Silická Plateau in the Slovak Karst National Park. It was officially opened to the public only in 1955. Since 1968, as the first cave in Slovakia, it has been used for speleoclimatic healing stays—i.e., speleotherapy. The cave was included as a natural monument in the UNESCO World Heritage List, as part of the Slovak and Aggtelek Karst caves, in 1995. The spaces, arranged in two levels, were created in the Middle Triassic limestones of the siliceous mantle along tectonic faults due to the corrosion and erosion activity of the Čierny stream and its tributaries. Several parts of the cave have a rich and varied sinter filling. Characteristic are the extremely long straws, which reach up to 3 m. The cave is known for hosting the discovery of the genuine cave animal of the Slovak caves and the largest troglobite, which is a centipede of the genus *Typhloiulus* sp. with a body length of 26 millimeters [110–112].

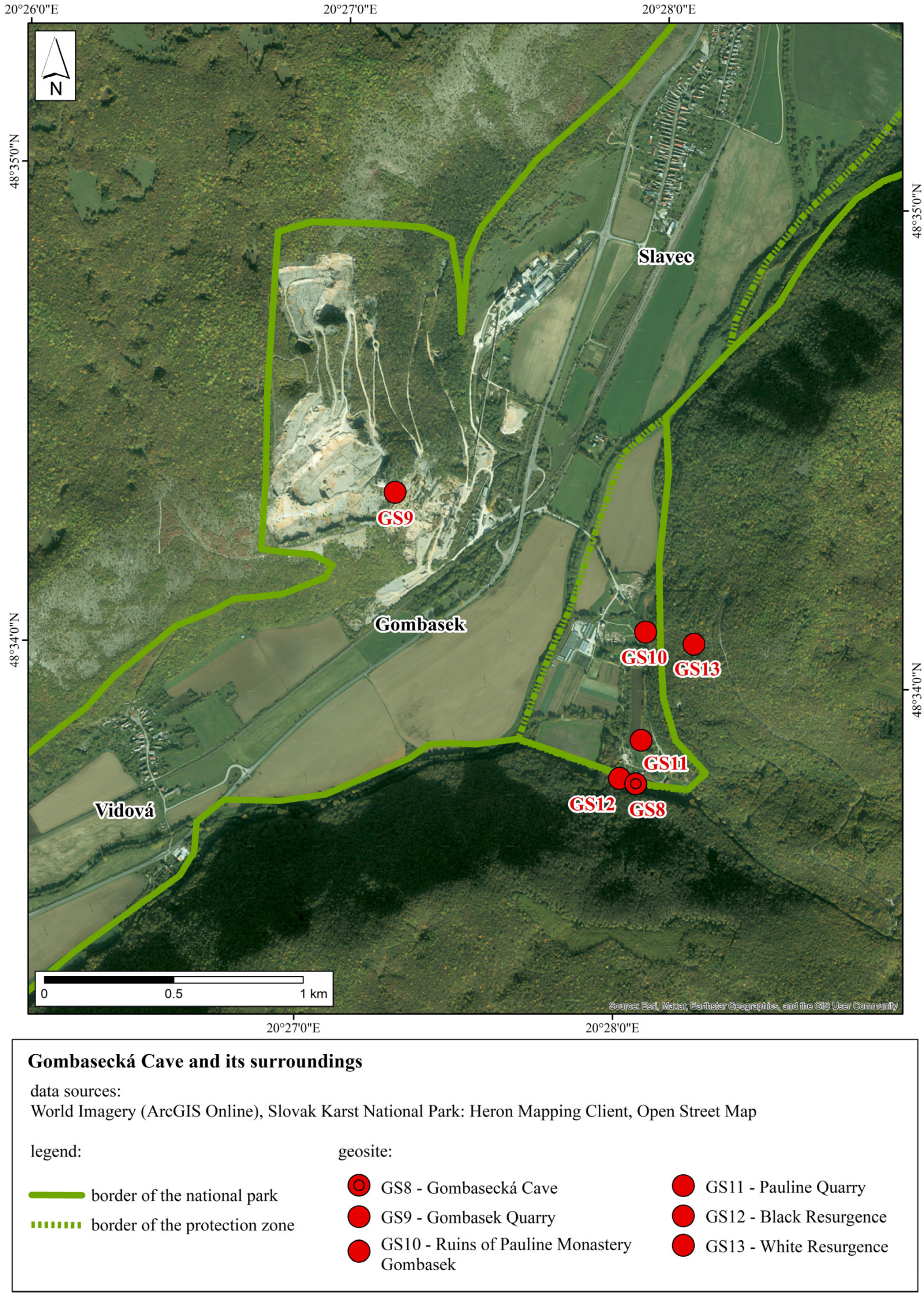

Figure 7. Geosites of Gombasecká Cave and its surroundings.

Figure 8. Gombasecká Cave with its unique thin-straw stalactites (GS_8).

GS_9, Gombasek Quarry (Figure 9)—This site is an active quarry on the southeastern slope of the Plešivecká Plateau on the western edge of the village of Slavec. In addition to limestone mining, it provides an ideal opportunity to learn about the geological values of the Plešivecká Plateau and the Slovak Karst. During mining, several cavities filled with Upper Cretaceous sediments were discovered in the quarry, the oldest evidence of karst processes in the Slovak Karst. The favorable location of the nearby Gombasecká Cave makes this quarry a potential destination for geotourism participants [113,114].

Figure 9. Ruins of the Pauline Monastery (GS_{10}) and, in the background, Gombasek Quarry (GS_9).

GS_{10}, Ruins of the Pauline Monastery, Gombasek (Figure 9)—The Ruins of the Pauline Monastery, a church built in 1371, are located only 700 m north of Gombasek Cave, from where an educational trail leads to them. Only a few walls, bare masonry, church walls, and fragmentary remains of interior plasters have been preserved. Similar to the case of the Premonstratensian Monastery in Jasov, here, we present the Ruins of the Pauline Monastery as a historical monument that, in the past, was directly related to the use and anthropic changes in the surrounding geosites [115].

GS_{11}, Pauline Quarry—During the activity of the Pauline monastic order in Gombasek, a quarry operated by the Pauline order was used to extract limestone for the construction of the monastery and other buildings in the vicinity, which no longer exist today. It is located between the cave and the Ruins of the Pauline Monastery. All of the aforementioned locations are connected by the educational trail through Gombasek [115].

GS_{12}, Black Resurgence (Čierna vyvieračka)—This karst spring is located near the entrance of Gombasecká Cave. The cave was discovered through a trench made directly in the spring of 1951. During the season of spring, the waters of the extensive underground hydrological system of the Plešivecká Plateau between Silická ľadnica Cave and Gombasecká Cave leave the underground [112].

GS_{13}, White Resurgence (Biela vyvieračka)—The White Resurgence is located at the western foot of the Silická Plateau, only 820 m northeast of Gombasecká Cave. This spring drains part of the Silická Plateau, and its waters flow from the massive accumulation of slope debris. A noteworthy feature of this site is the artificial historical retaining wall, which collects water from the karst spring [116].

2.5. Domica Cave and Its Surroundings (Figure 10)

GS_{14}, Domica Cave (Figure 11)—Domica Cave is located on the southwestern edge of the Silická Plateau. The Club of Czechoslovak Tourists opened this cave in 1932. In addition to making the cave accessible, they introduced electric lighting and dammed the underground river Styx, allowing an underground boat cruise that operates depending on the hydrological conditions. Since 1995, Domica has been included in the UNESCO World Heritage List within the Slovak and Aggtelek Karst caves. Together with the Čertova diera Cave, this cave is part of the Domica–Baradla cave system, which has a length of more than 30 km, with ¼ being located in Slovakia and ¾ in Hungary. The corrosive and erosive activity of the submerged waters of the Styx and the Domický stream created it. This cave's underground spaces are richly decorated with various forms of sinter decoration, including shields and drums. The cave represents a unique archaeological site, especially concerning Neolithic Bukovohora culture. At the same time, it is an essential chiropterological site. The presence of 160 species of animals has been confirmed here, including troglobiont and endemic fauna, such as the shrew Eukoenenia spelea and the hornbill *Niphargus aggtelekiensis* [116–125].

GS_{15}, Domické Karrens (Domické škrapy)—Near Domica Cave, there is a national nature reserve named Domické škrapy. It is a territory with an area of 24 ha and numerous occurrences of loose karrens. In 1973, it was declared a national nature reserve. At this site, surface karst phenomena are mainly represented by different types of karrens [112]. At the same time, this site is home to rare xerothermic communities of plants and animals typical of the Slovak Karst. An educational trail of the same name passes through this territory, dedicated to the presentation of the protected area [88,94,103].

GS_{16}, Baradla Cave, Aggtelek—Baradla Cave forms a more significant part of the cross-border Domica–Baradla cave system, with a length of more than 30 km, and just like Domica Cave, Baradla Cave, in the village of Aggtelek, is also accessible. It has eleven entrances, four of which are open to the public [126]. The submerged waters of the Styx and the Domický streams create the cave system. The underground spaces of the Baradla Cave are richly decorated, and it is a significant location in terms of the occurrence of sinter shields and drums. The cave system is a vital biosphere site and is included in the list of the Ramsar Convention [91]. It is also home to many species of troglobites and endemic invertebrates, such as the shrew *Eukoenenia spelaea* and the cave shrew *Niphargus aggtelekiensis* [88]. Speleotherapy is also implemented and developed in Baradla Cave [127,128].

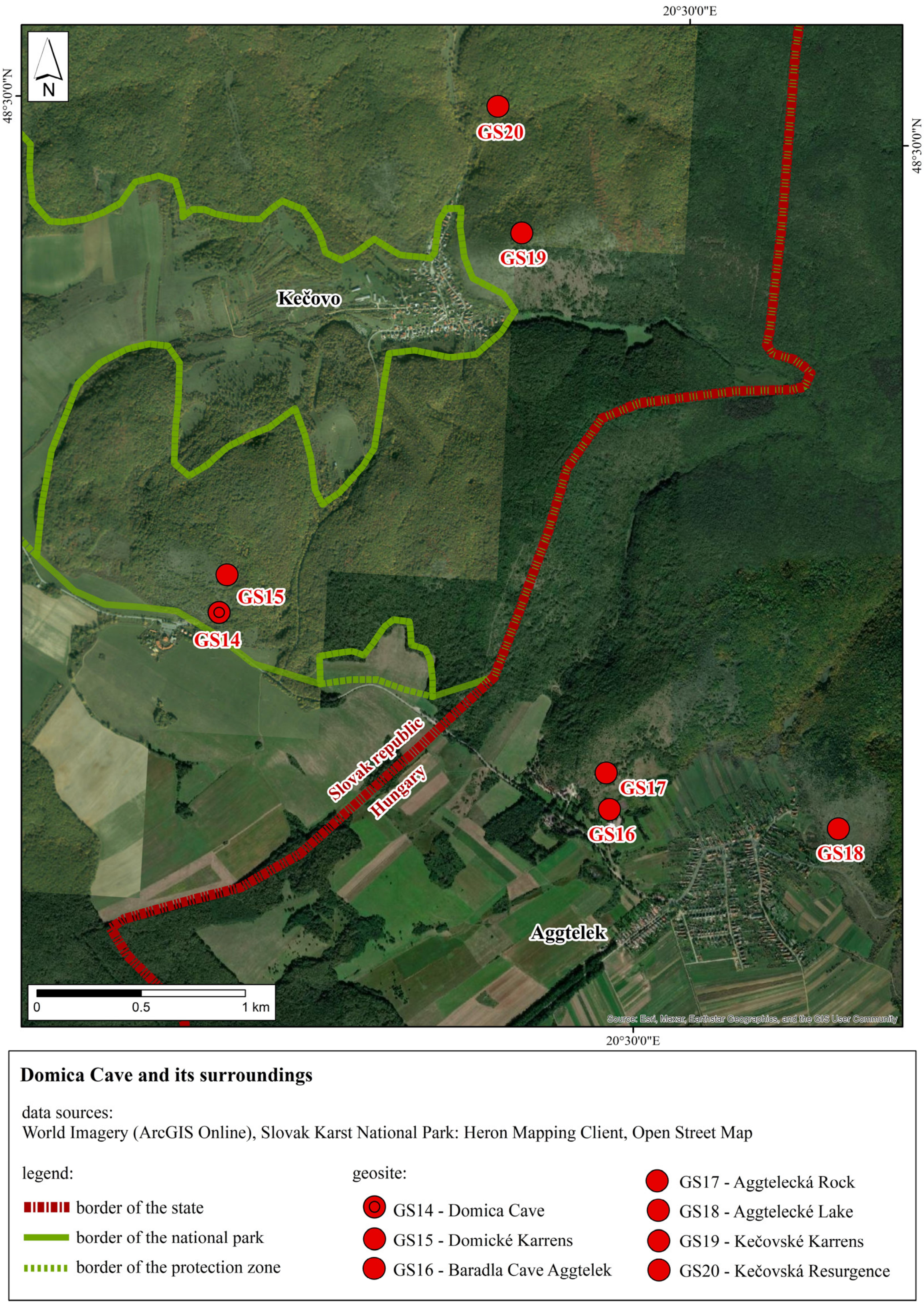

Figure 10. Geosites of Domica Cave and its surroundings.

Figure 11. Majko's Dome in Domica Cave, one of the most beautiful underground spaces in Slovakia (GS_{14}).

GS_{17}, Aggtelek Rock (Figure 12)—This site is a protruding limestone massif on the southwestern slope of the Silická Plateau with the entrance to the accessible Baradla Cave; it represents a significant dominant feature of the village of Aggtelek and, at the same time, a location frequently visited by tourists, with good tourist infrastructure and an information center. Visitors to the Aggtelek Karst and Baradla Cave are concentrated here. The surroundings of the Aggtelek Rock represent an ideal educational location regarding the prospect of redistributing visitors to other localities [88].

Figure 12. The Aggtelek Rock (GS_{17}).

GS_{18}, Aggtelek Lake—This lake is located east of the Hungarian village of Aggtelek, in the immediate vicinity, just one kilometer from the entrance of Baradla Cave. With an area of up to 1.13 ha, it is one of the most extensive karst lakes. It is formed at the interface of clayey gravels and Triassic limestones while representing the end of a blind valley. This lake is a geological curiosity and a great tourist attraction [84,88].

GS_{19}, Kečovské Karrens (Kečovské škrapy)—Just 3 km northeast of Domica Cave, 300 m northeast of the village of Kečovo on the southwestern slope of the Maliník hill (492 m above sea level), there is the protected site of Kečovské škrapy, declared in 1981. This territory, with an area of 7 ha, represents the largest karren field on a limestone hillside in Slovakia. Numerous occurrences of fissures and various rare types of karrens characterize it. It is also a remarkable example of the consequences of anthropic activity: due to the removal of original forest stands and long–term grazing by herds of goats and sheep, the shallow soil cover has been gradually erased, exposing the limestone bedrock [94].

GS_{20}, Kečovská Resurgence (Kečovská vyvieračka)—Just 700 m north of the village of Kečovo and the site of Kečovská škrapy, there is a karst spring (resurgence) named Kečovská vyvieračka. It drains part of the underground of the Silická Plateau. Its waters serve as a water source for the village of Kečovo and its surroundings. There are several smaller caves near this karst spring.

3. Methods

In our evaluation, we used the existing GAM (Geosite Assessment Model) first used by Vujicic et al. [129] and modified it slightly. When compiling the indicators and their groups, Vujicic et al. used methodological procedures and criteria for evaluating geosites presented in the works of several other authors [130–138]. The GAM is based on the division of indicators into two main groups: main values, with three subgroups (Scientific/Educational value—VSE; Scenic/Aesthetic value—VSA; Protection value—VPr), and additional values, with two subgroups (Functional value—VFn; Touristic value—VTr). Each subgroup contains a certain number of indicators, with five levels of point values, from 0 to 1.

On top of these indicators used by Vujičič et al. [129], we added one indicator for each subgroup within the group of main values. Regarding the Scientific/Educational value, we added the indicator I_5, "Research and education "in situ"", as we consider the possibility of conducting scientific research or education directly at the geolocation to be an essential indicator of the overall evaluation. With this indicator, we focused on whether the geosite is physically accessible for research and education, whether there is enough space for a more significant number of people, whether the location is fenced or locked, and whether special entry permits are required. In the Scenic/Aesthetic value subgroup, we added the indicator I_{10}, "Basic physiognomy of the site", where we assume that concave forms, convex forms, or combined concave–convex forms hold higher Aesthetic/Scenic value and are more attractive to visitors there. We also added the indicator I_{15}, "Protected biota", to the subgroup of Protection value, as we assume that the occurrence of rare or specially protected plant and animal species (e.g., bats) increases the attractiveness of the given geolocation.

After adding these three indicators, the group of main values contained 15 evaluation indicators; similarly, the group of additional values contains 15 evaluation indicators (Tables 1–5). Every single geosite was evaluated using 30 indicators, while for each indicator, a given geolocation was assigned a point value in the range of (0–0.25–0.5–0.75–1). The total resulting point value of the geolocation was thus calculated according to a simple formula:

$$GAM = \text{main values } (VSE+VSA+VPr) + \text{additional values } (VFn+VTr).$$

Table 1. The structure of the Geosite Assessment Model (GAM) used by Vujičič et al. [129], supplemented for this study.

Scientific/Educational Value (VSE)						
Indicators and Descriptions		**Grades (0–1)**				
Indicator	**Description**	**0**	**0.25**	**0.5**	**0.75**	**1**
I_1 Rarity	Number of closest identical sites	Common	Regional	National	International	The only occurrence
I_2 Representativeness	Didactic and exemplary characteristics of the site due to its own quality and general configuration	None	Low	Moderate	High	Utmost
I_3 Knowledge on geoscientific issues	Number of written papers in acknowledged journals, theses, presentations, and other publications	None	Local publications	Regional publications	National publications	International publications
I_4 Level of interpretation	Level of interpretive possibilities relating to geological and geomorphologic processes, phenomena, and shapes and level of scientific knowledge	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 visitors	Good example of processes and easy to explain to common visitors
I_5 Research and education "in situ"	Possibility of conducting scientific research or education directly at the geosite—suitability of the space, availability, need for permits, etc.	None	Low	Moderate	High	Utmost

Table 2. The structure of the Geosite Assessment Model (GAM) used by Vujičič et al. [129], supplemented for this study.

Scenic/Aesthetic Value (VSA)						
Indicators and Descriptions		**Grades (0–1)**				
Indicator	**Description**	**0**	**0.25**	**0.5**	**0.75**	**1**
I_6 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	None	1	2 to 3	4 to 6	More than 6
I_7 Surface	Whole surface of the site—each site is considered in quantitative relation to other sites	Small	-	Medium	-	Large
I_8 Surrounding landscape and nature	Panoramic view quality, presence of water and vegetation, absence of human–induced deterioration, vicinity of urban areas, etc.	-	Low	Medium	High	Utmost

Table 2. *Cont.*

Scenic/Aesthetic Value (VSA)						
Indicators and Descriptions		**Grades (0–1)**				
Indicator	**Description**	**0**	**0.25**	**0.5**	**0.75**	**1**
I_9 Environmental fitting of sites	Level of contrast to the surrounding nature, contrast of colors, appearance of shapes, etc.	Unfitting	-	Neutral	-	Fitting
I_{10} Basic physiognomy of the site	Predominant geometric shape of the geosite	Flat, linear	Concave	Convex	Linear–convex	Concave–convex

Table 3. The structure of the Geosite Assessment Model (GAM) used by Vujičič et al. [129], supplemented for this study.

Protection Value (VPr)						
Indicators and Descriptions		**Grades (0–1)**				
Indicator	**Description**	**0**	**0.25**	**0.5**	**0.75**	**1**
I_{11} Current condition	Current state of the geosite	Totally damaged (as a result of human activities)	Highly damaged (as a result of natural processes)	Moderately damaged (with essential geomorphologic features preserved)	Slightly damaged	No damage
I_{12} Protection level	Protection by local or regional groups, national government, international organizations, etc.	None	Local	Regional	National	International
I_{13} Vulnerability	Vulnerability level of the geosite	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
I_{14} Suitable number of visitors	Proposed number of visitors on the site at the same time, according to surface area, vulnerability, and current state of the geosite	0	0 to 10	10 to 20	20 to 50	More than 50
I_{15} Protected biota	Occurrence of specially protected and rare plant and animal species in the geosite	None	1	2 to 3	4 to 6	More than 6

Table 4. The structure of the Geosite Assessment Model (GAM) used by Vujičič et al. [129], supplemented for this study.

Functional Value (VFn)						
Indicators and Descriptions		**Grades (0–1)**				
Indicator	**Description**	**0**	**0.25**	**0.5**	**0.75**	**1**
I_{16} **Accessibility**	Possibility of approaching the site	None (inaccessible)	Low (accessible on foot with special equipment and expert-guided tours)	Medium (accessible by bicycle and other means of man-powered transport)	High (accessible by car)	Utmost (accessible by bus)
I_{17} **Additional natural values**	Number of additional natural values within a radius of 5 km (geosites also included)	None	1	2 to 3	4 to 6	More than 6
I_{18} **Additional anthropogenic values**	Number of additional anthropogenic values within a radius of 5 km	None	1	2 to 3	4 to 6	More than 6
I_{19} **Vicinity of emissive centers**	Closeness of emissive centers	More than 100 km	100 to 50 km	50 to 25 km	25 to 5 km	Less than 5 km
I_{20} **Vicinity of important road** networks	Closeness of important road networks within a radius of 20 km	None	Local	Regional	National	International
I_{21} **Additional functional values**	Presence of parking lots, gas stations, mechanics, etc.	None	Low	Moderate	High	Utmost

Table 5. The structure of the Geosite Assessment Model (GAM) used by Vujičič et al. [129], supplemented for this study.

Touristic Value (VTr)						
Indicators and Descriptions		**Grades (0–1)**				
Indicator	**Description**	**0**	**0.25**	**0.5**	**0.75**	**1**
I_{22} **Promotion**	Level and number of promotional resources	None	Local	Regional	National	International
I_{23} **Organized visits**	Annual number of organized visits to the geosite	None	Less than 12 per year	12 to 24 per year	24 to 48 per year	More than 48 per year
I_{24} **Vicinity of** visitor **center**	Closeness of visitor center to the geosite	More than 50 km	50 to 20 km	20 to 5 km	5 to 1 km	Less than 1 km
I_{25} **Interpretative panels**	Interpretative characteristics of informative panels' text and graphics, material quality, size, fitting to surroundings, etc.	None	Low quality	Medium quality	High quality	Utmost quality

Table 5. *Cont.*

Touristic Value (VTr)						
Indicators and Descriptions		**Grades (0–1)**				
Indicator	**Description**	**0**	**0.25**	**0.5**	**0.75**	**1**
I_{26} **Number of visitors**	Annual number of visitors	None	Low (less than 5000)	Medium (5001 to 10.000)	High (10.001 to 100.000)	Utmost (more than 100.000)
I_{27} **Tourism infrastructure**	Level of additional infrastructure for tourists (pedestrian pathways, resting places, garbage cans, toilets, wellsprings, etc.)	None	Low	Medium	High	Utmost
I_{28} **Tour guide** services	Tour guides' expertise level, knowledge of foreign language(s), interpretative skills, etc., if tour guides exist	None	Low	Medium	High	Utmost
I_{29} **Hostelry** services	Hostelry service(s) close to the geosite	More than 50 km	25–50 km	10–25 km	5–10 km	Less than 5 km
I_{30} **Restaurant** services	Restaurant service(s) close to the geosite	More than 25 km	10–25 km	10–5 km	1–5 km	Less than 1 km

These results allowed us to compile a matrix of main and additional values (Figure 13), similar to Vujicic et al.'s [129] procedure. In Figure 13, on the X-axis are the main values, and on the Y-axis are additional values. The matrix is divided into 9 fields (zones) labelled Z_1 to Z_9, while the main grid lines that form the fields have a value of 5 units for both the X-axis and the Y-axis. Thus, if a given geolocation has a sum of main values of 9 and a sum of additional values of 4, it is located in field Z_2, which means that it has an intermediate level of main values and a low level of additional values.

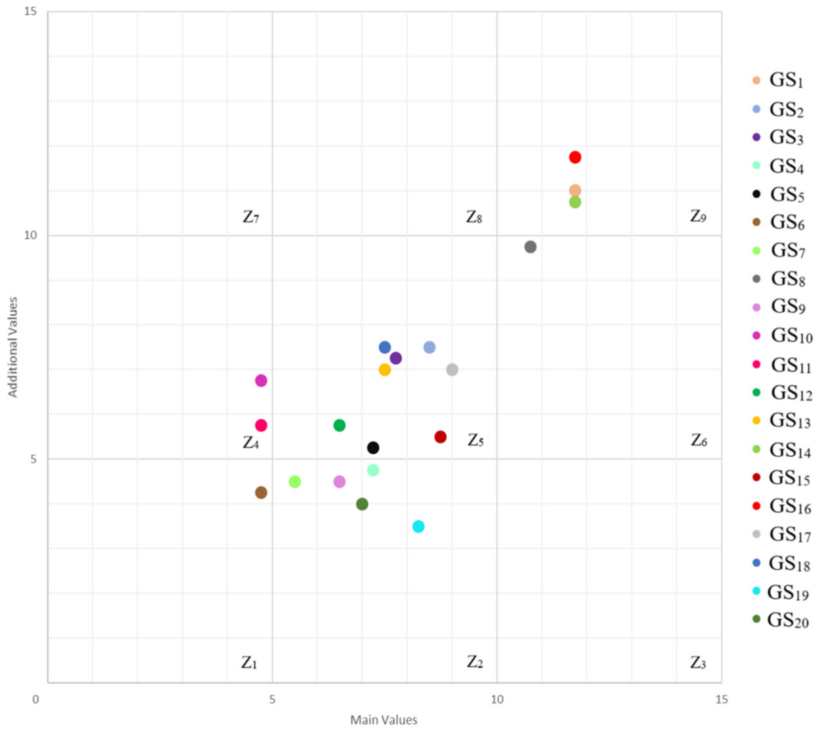

Figure 13. The matrix of the geosites and their values.

4. Results

From an analysis of the assessment results according to the GAM (Table 6), it follows that the highest point values are achieved by the accessible caves of the territory registered in the UNESCO World Natural and Cultural Heritage List, which proves our previous assumption. According to the matrix (Figure 13), three geosites (Jasovská Cave (GS_1), Baradla Cave (GS_{16}), and Domica Cave (GS_{14})) belong to field Z_9 (high main and high additional values).

Table 6. Point values of individual geosites and their inclusion in the different fields.

Geosite Label	Geosite Name	Main Values (VSE + VSA+ VPr)	Sum of Main Values	Additional Values (VFn + VTr)	Sum of Additional Values	Overall	Field
GS_1	Jasovská Cave	3.75 + 3.75 + 4.25	11.75	4 + 7	11	22.75	Z_9
GS_2	Jasovská Rock	2 + 3.25 + 3.25	8.5	3.5 + 4	7.5	16	Z_5
GS_3	Premonstratensian Monastery, Jasov	2.75 + 2.5 + 2.5	7.75	3.5 + 3.75	7.25	15	Z_5
GS_4	NNR Jasovské Oaks	2.5 + 1.75 + 3	7.25	3 + 1.75	4.75	12	Z_2
GS_5	Jasovský Lake	2.25 + 2.25 + 2.75	7.25	2.75 + 2.5	5.25	12.5	Z_5
GS_6	Hatinská Cave	1 + 1.5 + 2.25	4.75	2.25 + 2	4.25	9	Z_1
GS_7	Devil's Rock	1.75 + 1.5 + 2.25	5.5	2.5 + 2	4.5	10	Z_2
GS_8	Gombasecká Cave	3.5 + 3.75 + 3.5	10.75	3.5 + 6.25	9.75	20.5	Z_6
GS_9	Gombasek Quarry	2.25 + 3.25 + 1	6.5	2.5 + 2	4.5	11	Z_2
GS_{10}	Ruins of the Pauline Monastery, Gombasek	1.75 + 1.5 + 1.5	4.75	3 + 3.75	6.75	11.5	Z_4
GS_{11}	Pauline Quarry	2 + 1.5 + 1.25	4.75	3.25 + 2.5	5.75	10.5	Z_4
GS_{12}	Black Resurgence	2 + 1.25 + 3.25	6.5	2.75 + 3	5.75	12.25	Z_5
GS_{13}	White Resurgence	3 + 1.75 + 2.75	7.5	3 + 4	7	14.5	Z_5
GS_{14}	Domica Cave	4 + 3.75 + 4	11.75	3.75 + 7	10.75	22.5	Z_9
GS_{15}	Domické Karrens	2.75 + 3 + 3	8.75	2.25 + 3.25	5.5	14.25	Z_5
GS_{16}	Baradla Cave, Aggtelek	3.75 + 4 + 4	11.75	4 + 7.75	11.75	23.5	Z_9
GS_{17}	Aggtelecká Rock	3.25 + 2.75 + 3	9	3.25 + 3.75	7	16	Z_5
GS_{18}	Aggtelecké Lake	2.5 + 1.75 + 3.25	7.5	3.5 + 4	7.5	15	Z_5
GS_{19}	Kečovské Karrens	2.5 + 2.5 + 3.25	8.25	1.75 + 1.75	3.5	11.75	Z_2
GS_{20}	Kečovská Resurgence	2.5 + 1.75 + 2.75	7	2.25 + 1.75	4	11	Z_2

A high point value is particularly shown in the Scientific/Educational and Scenic/Aesthetic values. Caves are rare and represent a good level of interpretation of natural processes; scientific research and education projects are often carried out "in situ" within them. Due to the high degree of protection of these sites (domestic and international), however, in the case of the aforementioned scientific research and education, special permits are required from the relevant authorities, and the sites are locked and secured by security elements. The three studied caves are spatially extensive, with rugged relief and diverse sinter decoration, and have high Scenic/Aesthetic value. They are in the highest level of protection according to national legislation (national natural monument—fifth level of protection), which reflects their high natural value. From the point of view of the current state, we classify these three sites as slightly damaged due to accessibility works or other interactions with humans. We also register a high level of additional values here—both Functional and Touristic. The caves' scores in both of these subcategories mainly represent good transport accessibility due to the vicinity of roads of regional and national importance and developed tourist infrastructure (parking lots, shops selling souvenirs and educational materials, local restaurants and accommodation services, etc.). These caves represent the most visited geosites in the Slovak and Aggtelek Karst territory for individual visitors and organized domestic and foreign bus tours. The annual number of visitors to these monitored caves reaches tens of thousands. They are well advertised in the media and by various tourist guides, and commentary is carried out by their guide services and supplemented by educational panels.

Gombasecká Cave (GS_8) achieves a high level of main values and an intermediate level of additional values, thus reaching the Z_6 field. In the group of main values, it achieves parameters similar to those of GS_1, GS_{16}, and GS_{14}. A relatively short tour route conditions its intermediate level of additional values compared to the three aforementioned geosites, as well as a lower level of accommodation development and catering services and slightly worse transport accessibility.

Within the matrix, most geosites are located in field Z_5 (intermediate level of main values and intermediate level of additional values). These include the following eight geosites: the Jasovská Rock, GS_2; the Premonstratensian Monastery, Jasov, GS_3; Jasovský Lake, GS_5; the Black Resurgence (Čierna vyvieračka), GS_{12}; the White Resurgence (Biela vyvieračka), GS_{13}; the Domické Karrens, GS_{15}; the Aggtelek Rock, GS_{17}; and Aggtelek Lake, GS_{18}. Their common feature is their proximity to the four highest-rated geosites (accessible caves). The Jasovská Rock and Jasovský Lake geosites are located close to Jasovská Cave. Both of these locations' Scientific/Educational value is identical and reaches an intermediate level. The Jasovská Rock has a higher Scenic/Aesthetic value due to its panoramic possibilities. Jasovský Lake has a slightly higher conservation value due to the presence of protected biota. Both locations are sparsely visited, and no significant markings exist for them. At the Jasovská Rock, overcoming an elevation gain is also necessary.

Near Gombasecká Cave are two geosites: the Black Resurgence (Čierna vyvieračka) and the White Resurgence (Biela vyvieračka). Both represent point geosites with dimensions of several m^2; at the same time, they are equipped with educational panels, and their perspectives in geotourism are limited by their small dimensions and low point values. Three other geosites are located near Domica Cave: the Domické Karrens and, further east (already in Hungary's territory), the Aggtelek Rock and Aggtelek Lake. The geosite Domické Karrens is made accessible by an educational trail. However, its attendance is low due to the small promotion of the location, the necessity to overcome a slight elevation, the worse condition of the marked trail, and the overall lower attractiveness for tourists.

The location of the Domické Karrens achieves higher conservation values, as it is a protected area in terms of national legislation (i.e., a national nature reserve) with the occurrence of protected biota. The Aggtelek Rock geosite (with the Aggtelek entrance to Baradla Cave (GS_{16}) at its foot) achieves higher Scenic/Aesthetic values, mainly due to the view parameters. It is accessible via a marked path with a stone staircase, which tempts the visitors of Baradla Cave to climb to the top. The geosite Aggtelek Lake is a peculiarity in this karst area; its bottom is clogged with clay, so rainwater is retained there. There is no marked path leading to it. Moreover, it dries up during the dry summer. It has a higher conservation value due to the presence of protected biota.

A unique site is the Premonstratensian Monastery in Jasov, which represents an anthropogenic (geohistorical) geosite related to the historical use and formation of the surrounding monitored natural geosites. The monastery building is accessible to visitors after prior reservation of entry, while its attendance is significantly lower than the accessible caves of the studied territory. The monastery is still currently used by the Premonstratensian monastic order, which limits its tourist potential.

Two monitored geosites reached the Z_4 field: the Ruins of the Pauline Monastery, GS_{10}, and the Pauline Quarry, GS_{11}. A common characteristic of both of these anthropogenic sites in this field is a low level of main values and an intermediate level of additional values.

From the point of view of the main values, the current state of geosites is an unfavorable indicator. We see favorable indicators of additional values—especially near the Gombasecká Cave visitor center. At the same time, they lag in other indicators, especially regarding the number of visitors. The reason for this is their small capacity and insufficient promotion.

Within the matrix, there are five geosites in field Z_2: the NNR Jasovské Oaks, GS_4; Devil's Rock, GS_7; Gombasek Quarry, GS_9; the Kečovské Karrens, GS_{19}; and the Kečovská Resurgence (karst spring), GS_{20}. The geosites in this field have a medium level of primary values and a low level of additional values. The geosite of the NNR Jasovské Oaks has favorable Protection values, but its Functional values are less favorable, especially regarding its accessibility and the vicinity of important road networks. Among the additional values, the promotion or implementation of organized visits at this site lags significantly behind. It becomes the destination of a few tourists ascending to the Jasovská Rock, who descend towards Jasovský Lake. The geosite Devil's Rock attracts a minimum number of visitors from Jasovská Cave, conditioned not only by insufficient promotion but mainly by insufficient transport infrastructure and the absence of a nearby visitor center or information panels. The geosite Gombasek Quarry, with an intermediate level of main values, is mainly conditioned by geological values. At the same time, this site is at high risk and is characterized by insufficient accessibility and the absence of a visitor center with tourism infrastructure. The neighboring geosites of the Kečovské Karrens and Kečovská Resurgence (karst spring) are characterized by unfavorable accessibility from Domica Cave and unfavorable distance from a road network, as well as insufficient tourist infrastructure. In contrast, only a fraction of visitors to Domica Cave visit both geosites.

In field Z_1, characterized by low levels of main and additional values, only the geosite Hatinská Cave, GS_6, was placed. It is not characterized by attractiveness, conditioned by Educational and Scenic values. There is no hiking trail leading to this small cave that is freely accessible to the public, and there is no tourism infrastructure. Due to the absence of information panels, this geosite is challenging, and visitors are negligible.

5. Discussion

The research findings presented here indicate that within each of the three case studies, a dominant geosite is identified, represented by three caves listed as UNESCO World Natural Heritage Sites. Domica Cave and Jasovská Cave receive the highest ratings for both main and additional values. In contrast, Gombasecká Cave ranks lower in additional values, which we classify as intermediate. These caves serve as the primary attractions and focal points for visitors. They are well promoted in media, tourist guides, and directional signage. While visitor awareness is strong, there is a need for improvements in transportation and tourist infrastructure.

In the immediate vicinity of these three caves (within a 1 to 50 min walk), several additional geosites remain relatively unknown to the general public, apart from the Baradla Cave in Aggtelek, Hungary. Enhanced promotion of these sites could encourage visitors to extend their stay in the region and help reduce the concentration of tourists in the more accessible caves. Ideally, these geosites could be interconnected by an educational trail, forming a thematic route with a broader appeal. A unified ticket could be introduced, both granting access to the caves and offering visitors the opportunity to explore additional geolocations. Revenue from ticket sales could fund the maintenance and development of the educational trail. These geosites can be considered "satellite geosites", with their attractiveness and potential visitor numbers being dependent on the extent of connectivity through educational trails, local awareness, and effective promotion. We view these initiatives as crucial for developing a sustainable geopark and fostering geotourism in this area. The lower ratings of these "satellite geosites"—most of which fall into the medium category for both main and additional values—can be offset by the more prominent caves, which have the potential to serve as a catalyst for geotourism in the surrounding areas.

Our research results confirm that the chosen methodology is well suited for analyzing the potential of the observed geosites, particularly in evaluating their main and additional values as key elements of the proposed geopark. This is also confirmed by the results of the works of other authors [34,129]. The geosites studied here are not limited to natural or karst sites; many are cultural and historical landmarks that reflect the use of the surrounding landscape and the anthropogenic changes it has undergone. This analysis provides an in-depth insight into the interaction between the region's natural environment and human activity throughout history. Our approach envisions connecting these geosites through educational trails or organized tourist excursions, designed thematically to highlight the continuity and interconnectedness of the sites. This networking will enhance the public's understanding of their value and create opportunities to develop services beyond the accessible caves.

Based on the applied methodology, our research team independently conducted individual evaluations and quantified the main and additional values of each studied geosite. To enhance future research, it would be advantageous to broaden the sample of respondents to include the general public, possibly through questionnaires. Visitors to the studied accessible caves would be an ideal target group for evaluating these geosites, which would help minimize the subjectivity inherent in our research team's assessments. One limitation of this research is its narrow geographical focus, restricted to the areas surrounding Jasovská Cave, Gombasecká Cave, and Domica Cave. Future studies would benefit from expanding the scope to cover the entire Slovak Karst National Park, allowing for a more comprehensive analysis of the potential geosites across the entire region rather than just select sites. Establishing a network of geosites throughout this national park holds significant potential for boosting tourism, a particularly urgent goal given the recent notable decline in visitor numbers, including those to the accessible caves.

A forward–looking analysis of geosite potential, aimed at optimizing their use for tourism, would also require a well–organized record and systematic documentation of relevant knowledge. Therefore, we propose creating a comprehensive database of geosites in Slovakia. This database would systematically catalog and organize the collected data in a readily accessible and searchable format using inventory sheets. It could be modeled on existing resources such as the State List of Specially Protected Parts of Nature and Landscape of the Slovak Republic or the Cave Database of the Slovak Republic. For the Slovak Karst National Park, the database could be managed by the national park administration or, as in the examples above, by the Slovak Museum of Nature Protection and Speleology.

To effectively implement conservation measures and assess the prospects for geotourism and the networking of sites within potential geoparks, we propose categorizing geosites into at least three levels of importance: international, national, and local. This categorization would not only guide conservation efforts but also provide a framework for evaluating and enhancing the geotouristic potential of these sites.

6. Conclusions

This study makes a significant contribution to the literature by identifying and showcasing geosites with potential interest in a region currently underdeveloped for tourism. By increasing public interest in these sites, it will be possible to retain tourists in the region and redistribute them from major attractions, like the caves, to surrounding geosites. This strategy offers the public a more comprehensive understanding of natural geological values within the context of their interaction with human activity and the landscape. Shifting visitors from the caves to nearby locations could also lead to better integration and enhancement of services, acting as a catalyst for the broader development of geotourism and overall tourism in the Slovak Karst region.

Exploring these geosites is crucial in raising awareness of the region's natural, cultural, and historical significance. These sites have the potential to serve as field study locations not only for students of geography, geology, and related sciences but also as valuable excursion destinations for elementary– and secondary–school students. This approach fosters regional awareness, emphasizing the appreciation and protection of the national park's natural assets.

Establishing a Slovak Karst Geopark would significantly boost and further develop tourism in the area. This paper serves as an initial study, focusing on the analysis and evaluation of geosites through three case studies. Expanding this analysis to include the entire Slovak Karst area is essential for further discussions about establishing a geopark. If realized, the accessible caves will continue to be the main attractions, while visitors will also have the opportunity to explore thematic routes connecting various geosites near these caves. These geosites offer diverse potential in attractiveness and other factors, providing a viable alternative to the caves and adding significant value to educational and research initiatives.

However, a challenge in developing geotourism within the potential Slovak Karst Geopark is balancing the demands of nature conservation with the current technical and tourism infrastructure limitations. Addressing these challenges will be critical to ensuring the effective and sustainable management of the area.

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Conflicts of Interest: The authors declare no conflicts of interest.

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