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The canyon of Haidamatskyi Iar in the village of Busha: Geotourism assessment

Yulian Braychevskyy [a,*], Volodymyr Korinnyi [b], Olga Kovtoniuk [c], Nataliia Pohorilchuk [c]

[a] Reginoal Geography and Tourism Department, Faculty of Geography, Taras Shevchenko National University of Kyiv, Ukraine
[b] Faculty of Natural Sciences, Zhytomyr Ivan Franko State University, Ukraine
[c] Earth Science and Geomorphology Department, Faculty of Geography, Taras Shevchenko National University of Kyiv, Ukraine

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ABSTRACT

The purpose of this work was to quantitatively assess the Haidamatskyi Iar canyon as a geotourism site, draw attention to geotourism development outside of the Carpathian Mountains region in Ukraine, and further contribute to the assessment methods choice and application debate. We based our analysis on field observations and combined three evaluation algorithms, namely the Kubalikova's method, the geosite assessment model, and the Brilha method. For each algorithm, we presented results as a percentage of the maximum for easier comparison. Our assessment concluded that the Haidamatskyi Iar canyon received rather high scores with all three approaches (86.11% with the Kubalikova's method, 76.88% with Brilha's method, and 62.96% with the geosite assessment model), revealing its strong potential as a geological and geomorphological research and education site. Poor tourist infrastructure (due to the area's peripheral location) and lack of specialized promotional products highlighting geoeducational attractions of the area explained lower scores by the geosite assessment model. Overall, we concluded that the Haidamatskyi Iar canyon was a unique geomorphosite of regional and even national significance. It displayed a wide range of geological features, especially those related to weathering, fluvial, and Aeolian erosion. Its location next to a historical and cultural destination (the village of Busha) made it valuable for geotourism promotion. In the wider context of similar geoattractions in Central and Eastern Europe, our analysis demonstrated the benefits of choosing methods, which were previously applied to comparable geosites. Variation in assessment scores confirmed better reliability of simultaneous application of several assessment methods.

1. Introduction

Since UNESCO declared its support for geosites in 1995, geoheritage promotion and research has become a rapidly growing trend gaining in popularity all over the world (Herrera-Franco, Carrión-Mero, Montalván-Burbano, Caicedo-Potosí, & Berrezueta, 2022; Quesada-Valverde & Quesada-Román, 2023). Over time, several research trajectories became visible. Theoretical conceptualizations of geoheritage and geotourism (e.g., Newsome & Dowling, 2006; Pralong, 2006) were followed by debates on methodology of geosite evaluation and assessment (Pralong & Reynard, 2005; Reynard et al., 2016; Brilha, 2016; Kuleta, 2018; Mucivuna,

* Corresponding author.
E-mail address: yulian_b@ukr.net (Y. Braychevskyy).

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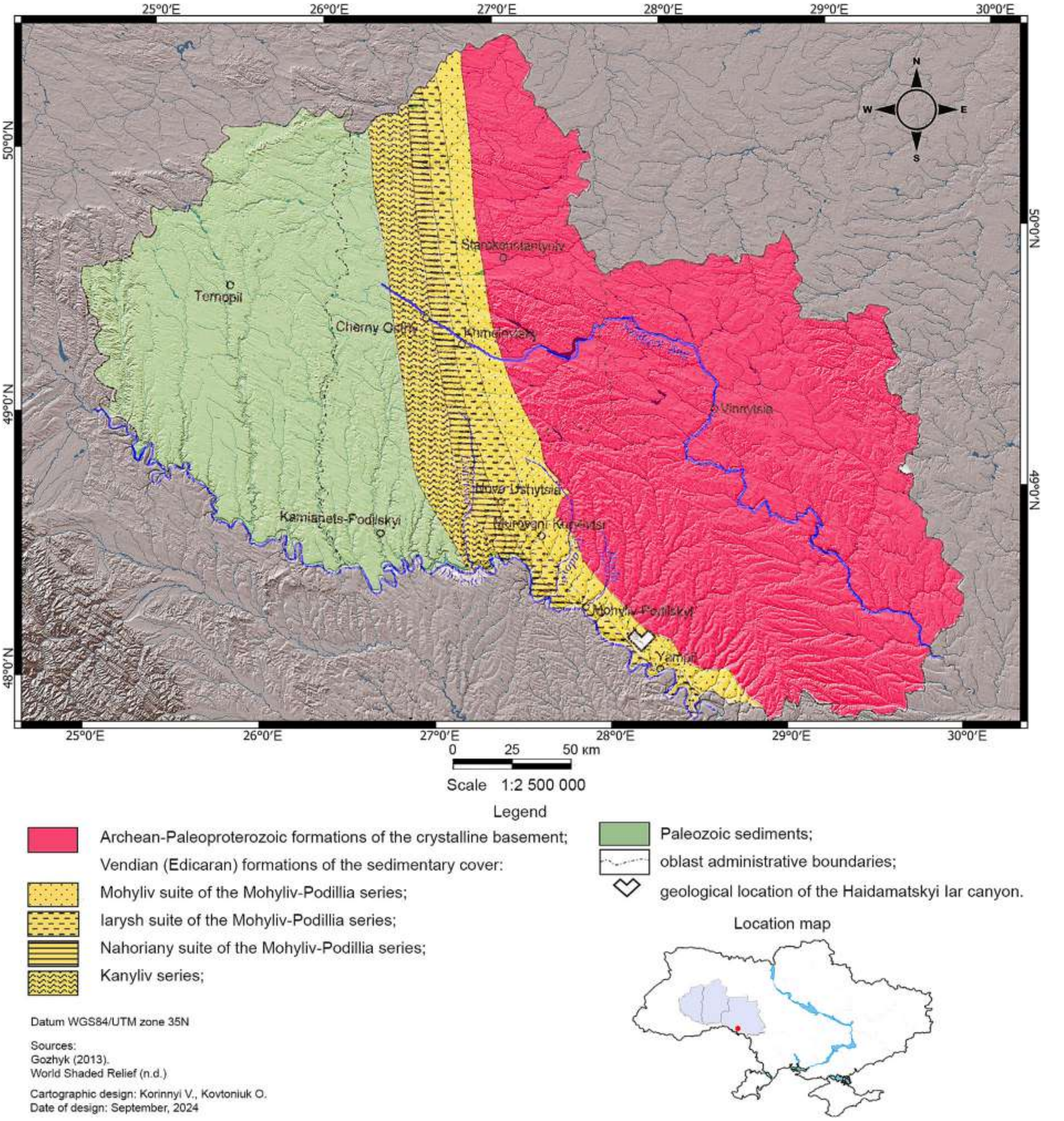

Fig. 1. Pre-Mesozoic sediments of the Podillia region.
Base map source: World Shaded Relief (n.d.). ArcGIS REST Services Directory. https://services.arcgisonline.com/arcgis/rest/services/World_Shaded_Relief/MapServer/0.

Reynard, & Garcia, 2019; Zafeiropoulos & Drinia, 2023—to name a few). In recent years, another interesting direction emerged, exploring resources and methods of geosite promotion including GIS, 3D and other forms of digital and physical modelling (for example, Amzil & Oukassou, 2023; Martínez-Graña, González-Delgado, Nieto, Villalba, & Cabero, 2023; Pasquaré Mariotto & Bonali, 2021; Ziarek, 2024). Yet, developing national geosite inventories and assessment case studies remain, by far, the most voluminous stream of work equally popular all over the world (e.g., Ansori, Warmada, Setiawan, & Yogaswara, 2021; Berrezueta, Sánchez-Cortez, & Aguilar-Aguilar, 2021; Ghosh, Mukhopadhyay, & Chatterjee, 2021; Güngör, 2024; Kubalíková & Kirchner, 2016; Kudla, Javorská, Vašková, Čech, & Tometzová, 2024; Lewis, 2020; Manyoe, Pongoliu, & Napu, 2022; Matshusa & Leonard, 2024; Migoń, 2016; Miller, Bremner, & Wilson, 2013; Pereira, Pereira, & Caetano, 2007; Pérez-Umaña, Quesada-Román, & Zangmo Tefogoum, 2020; Quesada-Román, Zangmo, & Pérez-Umaña, 2020).

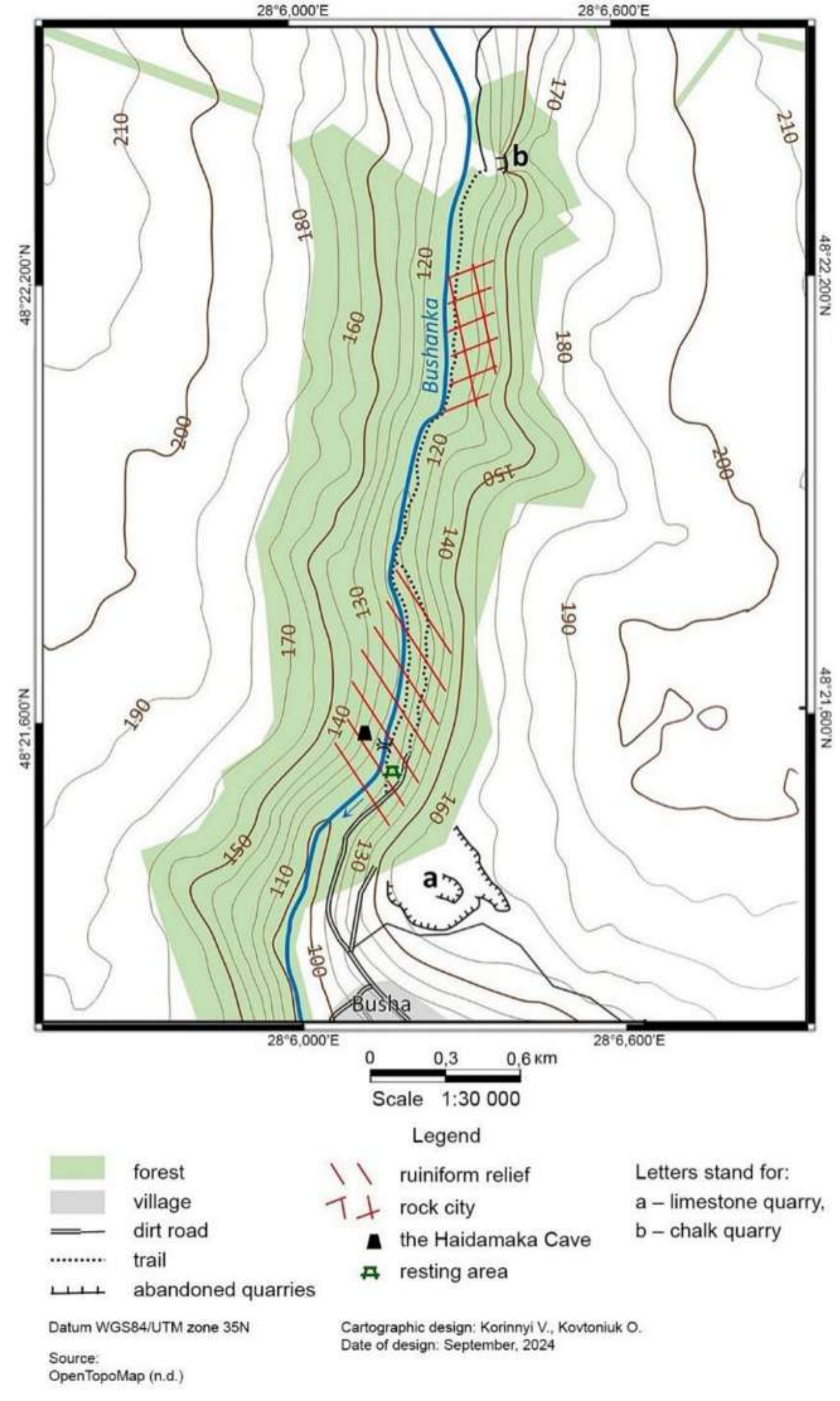

Fig. 2. Haidamatskyi Iar canyon terrain.
Base map source: https://opentopomap.org/#map=13/48.37045/28.07384

Ukraine's efforts on geoheritage promotion followed international trends (Manyuk, Bondar, & Yaholnyk, 2020). With the first inventories of geological monuments dating back to the Soviet period (Bondarchuk, 1961; Zaritskyi, 1985), it was not until 1996 (when Ukraine joined the ProGeo international working group under the UNESCO auspices) that geotourism research gained popularity and a classification framework for geosite inventory in Ukraine was produced (Wimbledon, Gerasimenko, Ischenko, Lisichenko, & Lisichenko, 1999). Two major strains of research emerged. The first one, following the European experience, focused on developing proposals for the nation-wide network of geoparks (Zinko, 2008; Kravchuk, Zinko, Khomyn, & Shevchuk, 2012;

Yaholnyk & Manyuk, 2017; Fundova, 2016). The second (and ever more popular) direction comprised a bunch of works on geotourism and geoeducation promotion (for example, Bortnyk, Gerasimenko, & Wimbledon, 2018; Malska, Zinko, & Shevchuk, 2014; Muntyan, Prikhodchenko, & Polyashov, 2018; Pobigun, 2015; Vertel, 2020; Zinko, Kravchuk, & Shevchuk, 2009; Zinko, Shevchuk, Khomyn, & Ivanyk, 2017). A number of researchers have extensively written on individual geosites as potential tourist destinations and offered proposals of additional geotourism routes (Bayrak et al., 2019; Bayrak & Teodorovych, 2020; Brusak & Palianytsia, 2014; Halaiko, Zinko, Ivanyk, Maydansky, & Shevchuk, 2018; Manko et al., 2021; Zinko, 2008; Zinko, 2022; Zinko et al., 2009).

Yet, in spite of the growing academic and public interest, there are two major lacunes in the existing geotourism literature in Ukraine. Firstly, the vast majority of the assessed geosites are located within the Carpathian mountainous region of Ukraine (e.g., Bayrak, 2020; Bortnyk et al., 2019; Bortnyk et al., 2021; Bubniak et al., 2018; Bubniak & Solecki, 2013; Giletskyi, 2014; Kondratiuk, 2022; Kravchuk & Khomyn, 2016; Popyk, 2024), which makes only as much as 5% of the country's territory. Secondly, there are only a few attempts (Luschyk, 2016; Zinko & Ivanyk, 2016; Halahan et al., 2019; Halahan, Kovtoniuk, Korohoda, & Pohorilchuk, 2021; Yulian, Nataliia, Olga, Nataliia, & Oleksandra, 2023) that provide a systematic quantitative evaluation of geoheritage, geoeducation, and geotourism potential needed for broader initiatives on conservation and promotion.

In this work, we have quantitatively evaluated the geotourism potential of the Haidamatskyi Iar canyon near the village of Busha in the Podillia region. We suggest that it has sufficient value to be promoted as a geotourism destination of both regional and national significance. Such promotion may draw greater public attention to the geological heritage of the region and facilitate sustainable tourism development by the local community. Our broader goal is to attract wider attention to geotourism potential outside of the Carpathian Mountains region and make a further contribution to systematic quantitative geoheritage assessment in Ukraine. By applying internationally acknowledged and widely practiced assessment methods, we attempt to connect Ukraine's national geosite inventory to a wider geographical network of comparable geoheritage destinations, especially in the context of Eastern and Central Europe, and add to the debate on assessment methods choice and application.

There is an ample body of research dedicated to the methods of geosite assessment (e.g., Fassoulas, Mouriki, Dimitriou-Nikolakis, & Iliopoulos, 2012; Kubalíková, 2013; Pereira et al., 2007; Pralong & Reynard, 2005; Reynard, Fontana, Kozlik, & Scapozza, 2007; Reynard et al., 2016; Tomić & Božić, 2014; Vereb, 2020). Several accounts (e.g., Herrera-Franco, Carrión-Mero, Mora-Frank, & Caicedo-Potosí, 2020; Herrera-Franco, Erazo, Mora-Frank, Carrión-Mero, & Berrezueta, 2021; Turner-Carrión et al., 2021; Navarrete et al., 2022; Zafeiropoulos & Drinia, 2022; Yulian et al., 2023) argued in favor of simultaneous application of several assessment algorithms for verification purposes. While sharing similar ideas, most assessment methods have their specifics, highlight different geosite features, and, therefore, produce somewhat different quantitative results. In this work, we chose to rely on a combination of the three assessment methods, namely those offered by Kubalíková's (2013) method (KM), Vujičić et al.'s (2011) geosite assessment model (GAM), and Brilha's (2016) method (BM).

2. Material and methods

2.1. Study area

The study area is located in the Podillia region. It stretches within the two tectonic units—the Ukrainian Shield and the Volyn'-Podillia monocline. It features Vendian (V) sedimentary stratum (Fig. 1), whose age corresponds to the Ediacaran sediments in South Australia. These rocks, outcropping in the Dnister river basin, produce a number of geosites of national significance (Strashevska, 2012; Denysyk et al., 2014; Strashevska & Korinnyi, 2015).

The site we focus upon in this research is located next to the village of Busha, not far from the village of Homulivka in the Vinnytsia oblast. The Haidamatskyi Iar canyon itself constitutes a part of the Bushanka river valley, tributary to the Dnister river (48°22′N–48°21′N; 28°07′E–28°06′E) with a total area of 96 ha. The canyon is roughly 2 km long, 100–200 m wide, and up to 80 m deep, overgrown with oak and hornbeam forests (see Fig. 2 for the canyon's terrain).

Since 1975, the canyon has an official status of a national level geological monument (Denysyk et al., 2014; Hudzevych, 2009; Kalinin & Gurskiy, 2006; Zaritskyi, 1985). According to Kalinin and Gurskiy (2006), Haidamatskyi Iar canyon can be referred to as a geomorphological site. It is cut by the Bushanka river stream in the Vendian arkosic sandstones. Among hundreds of stream valleys and gullies in the Podillia region, Haidamatskyi Iar canyon is unique, featuring numerous butte-like landforms with surfaces vividly decorated by Aeolian microforms, which have evolved due to the combined processes of weathering, corrasion, and deflation during the Quaternary ice-age.

2.2. Methods

The three assessment algorithms employed in this study are GAM (Vujičić et al., 2011), BM (Brilha, 2016), and KM (Kubalíková, 2013). Of all the variety of available approaches to geotourism potential evaluation, GAM and BM stand out from the bunch for several reasons meticulously pinpointed by Vereb (2020). Firstly, they are quantitative and not tailored towards any particular national geoconservation framework, hence their results are easily comparable. Secondly, they are—in a way—syntheses of the previous quantitative assessment approaches and comprehensively summarize major ideas researchers came up with over recent decades. Thirdly, both approaches feature a reasonable number of indicators with parameters allowing for easy and repeatable assessments not dependent on scale or geographical and geological context. The latter makes these two methods universally applicable.

A more recent, modified version of GAM (M-GAM) by Tomić and Božić (2014) also gets a lot of attention on the premises that one has to base evaluation on actual tourists' opinion in order to assess the tourist potential of a site. However, as what the followers of this method confirm (Pál & Albert, 2021), there are significant difficulties with gathering enough statistically meaningful data, which makes this method less practically applicable. Besides, for the most part, regular visitors judge geosites by their visual attractiveness rather than geological or geomorphological significance. Zafeiropoulos and Drinia (2022) pointed out that without formal training, the majority of tourists lacked necessary cognitive geological background, and, therefore, underestimated the sites with objectively high geological value.

Kubalíková (2013) offered a comprehensive geomorphosite evaluation scheme, which parallelled the abovementioned methods in many ways. We found Kubalíková's (2013) approach specifically useful in our case since it was already applied (Kubalíková & Kirchner, 2016) to the sites with geological and geomorphological features resembling those found in the Haidamatskyi Iar canyon, which allowed to place it in a geographically wider comparative context. For this reason, we applied KM first as a reference evaluation.

KM is the most straightforward of the three approaches. Focused on geotourism potential of a geosite, it considers five criteria including scientific and intrinsic values (Vtsci), educational values (Vted), economical values (Vtecon), conservation values (Vtcon), and added values(Vtadd). Together, they comprise 18 specific indicators, which can be scored from 0.00 to 1.00 in 0.50 intervals (see Appendix for detailed indicator list). The sum of all scores makes the final result of the assessment.

GAM offers another comprehensive quantitative assessment of geosites for geotourism purposes based on two groups of indicators, i.e., main values (MV) and additional values (AV). MV include scientific and educational values (VSE), scenic and aesthetic values (VSA), and protection values (VPr), all representing intrinsic qualities of a geosite. AV consist of functional values (VFn) and touristic values (VTr), focusing more on a geosite's concomitant features and surroundings. MV break down to 12 subindicators and AV to 13 (see Appendix). Each subindicator can be scored from 0.00 to 1.00 in 0.25 increments, resulting in maximum of 12 points for MV and 13 points for AV. Results are then charted on a graph with MV on the horizontal axis and AV on the vertical one, visually representing a geosite's significance on both MV and AV. The area on the graph is divided into nine sections, setting ranges for low, medium, and high values on both axes (see Vujičić et al., 2011 for details).

Similarly to KM and GAM, BM offers an extensive geosite assessment algorithm, but unlike the former two, it does not focus exclusively on geotourism. On the contrary, it considers four geosite assessment criteria (i.e., scientific value [SV], potential for educational use [PEU], potential for touristic use [PTU], and degradation risk [DR]) separately on the premises that there are three types of values (scientific, educational, and touristic), each of which requires a different evaluation perspective and management strategy. Geosites with primarily scientific value should preserve their geo(morpho)logical features regardless of their short-term utility, while locations with strong educational and/or touristic value should be considered and preserved in accordance with their practical use potential (Brilha, 2016). Degradation risk, on the other hand, may prioritize conservation over any type of practical use. There are 7 specific indicators for evaluation of SV, 12 for PEU, 13 for PTU and 5 for DR (see Appendix). Each indicator can be scored from 0 to 4 and then multiplied by special weight coefficients (see Brilha, 2016 for details). Some indicators repeat for different criteria (for instance, PEU and PTU share 10 same indicators), but they may have varying weights, depending on which criterion is being evaluated. Ultimately, all four criteria use the same assessment scale (0.00–400.00). Therefore, unlike KM and GAM, scores for each criterion are not summed up; SV, PEU, and PTU can be compared as alternative values rather than complimentary ones. In our analysis, we focus upon geotourism potential (with geoeducation as its integral part). In order to quantitatively cross-verify assessment results with those obtained with the KM and GAM methods, we used the average of the PEU and PTU scores.

A number of followers have practiced transforming final assessment scores into percentage for easier interpretation and comparison (e.g., Ansori et al., 2021; Berrezueta et al., 2021; Ghosh et al., 2021; Zafeiropoulos & Drinia, 2022). There are varying conversion approaches for GAM based results. Berrezueta et al. (2021) summed MV and AV, dividing the result by 25 (maximum added scores). Zafeiropoulos and Drinia (2022), on the other hand, calculated the distance between the point on the graph (representing a geosite's score) and the beginning of the MV and AV axes (full diagonal on the graph being 100%). In our case, we followed the former approach by adding MV and AV as it would better correspond with the KM algorithm. We calculated score percentages as follows (Equations 1, 2, 3):

$$PS_{KM} = \frac{(SIV + EdV + EcV + CV + AV)}{18} \times 100\% \quad (1)$$

where PS_{KM} is KM score percentage; SIV is scientific and intrinsic values; EdV iseducational values; EcV is economical values; CV is conservation values; AV is added values.

$$PS_{GAM} = \frac{(MV + AV)}{25} \times 100\% \quad (2)$$

where PS_{GAM} is GAM score percentage; MV is main values; AV is additional values.

$$PS_{BM} = \frac{(PEU + PTU)/2}{400} \times 100\% \quad (3)$$

Table 1
The KM analysis scores.

Criteria	Indicators	Scores
Scientific and intrinsic values	1. Integrity	1.00
	2. Rarity	1.00
	3. Diversity	1.00
	4. Scientific knowledge	0.50
	Total	**3.50**
Educational values	1. Representativeness and visibility/clarity of the features/processes	1.00
	2. Exemplarity, pedagogical use	1.00
	3. Existing educational products	0.00
	4. Actual use of a site for educational purposes (excursions, guided tours)	1.00
	Total	**3**.00
Ecomonical values	1. Accessibility	0.50
	2. Presence of tourist infrastructure	1.00
	3. Local products	0.00
	Total	**1.50**
Conservation values	1. Actual threats and risks	1.00
	2. Potential threats and risks	1.00
	3. Current status of a site	1.00
	4.Legislative protection	1.00
	Total	**4**.00
Added values	1. Cultural values: presence of historical/archaeological/religious aspects related to the site	1.00
	2. Ecological values	1.00
	3. Aesthetic values: number of colours; structure of the space, viewpoints	1.50
	Total	**3.50**
Sum		**15.50**

where PS_{BM} is BM percentage score; PEU is potential educational uses; PTU is potential touristic uses.

The analysis and scoring of the geological and geomorphological features, accessibility, tourist infrastructure, and degradation risk were primarily based upon our own field observations.

Table 2
GAM analysis scores.

	Indicators	Sub-indicators	Scores
Main values (MV)	Scientific/Educational value (VSE)	1. Rarity	0.50
		2. Representativeness	1.00
		3. Knowledge on geoscientific issues	0.75
		4. Level of interpretation	1.00
	Scenic/Aesthetic (VSA)	5. Viewpoints	1.00
		6. Surface	0.50
		7. Surrounding landscape and nature	1.00
		8. Environmental fitting of sites	1.00
	Protection (VPr)	9. Current condition	1.00
		10. Protection level	0.75
		11. Vulnerability	0.75
		12. Suitable number of visitors	0.75
	Total MV		**10.00**
Additional values (AV)	Functional values (VFn)	1. Accessibility	1.00
		2. Additional natural values	0.50
		3. Additional anthropogenic values	0.75
		4. Vicinity of emissive centers	0.50
		5. Vicinity of important road network	0.25
		6. Additional functional values	0.25
	Touristic values (VTr)	7. Promotion	0.75
		8. Organized visits	0.50
		9. Vicinity of visitors centers	0.00
		10. Interpretative panels	0.00
		11. Number of visitors	0.25
		12. Tourism infrastructure	0.25
		13. Tour guide service	0.25
		14. Hostelry service	1.00
		15. Restaurant service	0.75
	Total AV		**7.00**

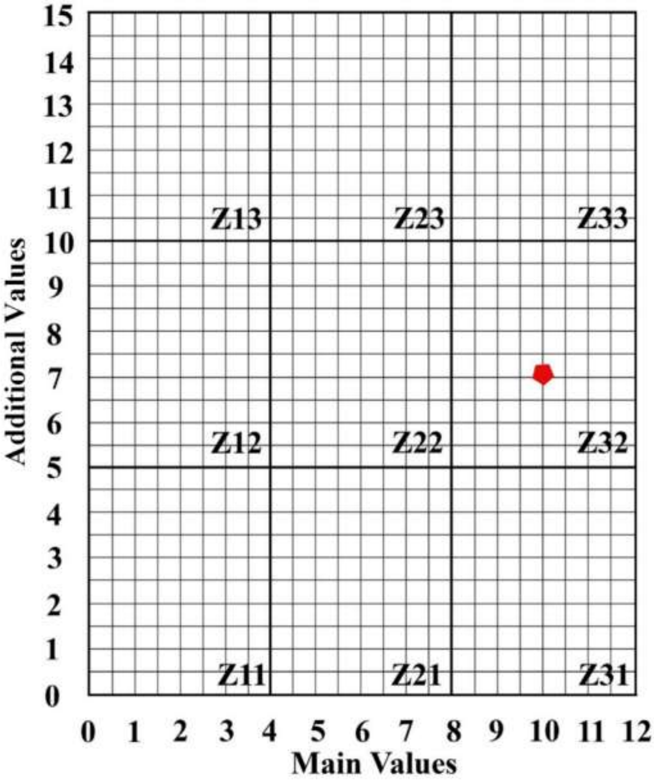

Fig. 3. GAM analysis results plot.

3. Results and discussion

3.1. Results

3.1.1. The KM analysis

The KM analysis results are shown in the Table 1.

Haidamatskyi Iar canyon scores maximum points for preservation as it is currently in quite a good state, does not face major risks of degradation, and has a legal protection status as a geological monument at the national level. It also scores 3.50 points (next to the maximum) for the added values. It is extremely pleasing aesthetically. Suitable neither for agriculture nor for construction, the Haidamatskyi Iar canyon provides habitat for several species of protected plants (oak, hornbeam, ferns, mosses) and birds (kite, great spotted woodpecker, common rock thrush, etc.) (Hudzevych, 2009). Haidamatskyi Iar canyon benefits from close proximity to the well-promoted cultural and historical site of the village of Busha with its archeological, historical, and architectural landmarks. Moreover, cultural artefacts in Busha can be linked to the geological features of Haidamatskyi Iar canyon, since it is the same Vendian sandstones, in which the ancient rock shrine was cut (Bornyak & Protsyuk, 2020) and which were and still are used by local artists for stone carving (Alekseeva, 2018; Kapelista, 2013).

At the same time, Haidamatskyi Iar canyon's economic scores are lower (1.50 out of 3.00) due to the site's peripheral location with poor quality of roads, long distances to larger cities or towns, and very limited availability of the promotion products, especially those presenting geological and geomorphological features of the site. Altogether, the Haidamatskyi Iar canyon has scored 15.50 points under the KM, which makes 86.11% of the maximum possible score.

3.1.2. GAM analysis

Evaluation of the Haidamatskyi Iar canyon based on the GAM approach follows in Table 2:

Based upon GAM algorithm, the Haidamatskyi Iar canyon scores 3.25 out of 4.00 points for its scientific and educational value, 3.50 out of 4.00 for aesthetic qualities, and 3.25 out of 4.00 for the level of protection. As these indicators for the most part overlap with those in the KM, the rationale behind the detailed scoring is similar. All the above-mentioned indicators group into the MV and together make 10.00 points out of 12.00. In the AV, functional values sum up to 3.25 out of 6.00 points (an average score) and touristic ones make 3.75 out of 9.00 (being on the low side). The peripheral location explains average and low scores for the three out of six functional values sub-indicators, namely the vicinity of emissive centers (0.50), vicinity of important road network (0.25), and additional functional values (0.25). Sub-indicators, responsible for the low scores on touristic values, include dedicated visitor's center (0.00), interpretative panels with geological and geomorphological information (0.00), very limited availability of

Table 3
The BM analysis scores.

Criteria	Indicators	Scores
Scientific value (SV)	1. Representativeness	120.00
	2. Key locality	20.00
	3. Scientific knowledge	10.00
	4. Integrity	60.00
	5. Geological diversity	20.00
	6. Rarity	60.00
	7. Use limitations	40.00
	Total SV	**330**.00
Potential educational uses (PEU)	1. Vulnerability	30.00
	2. Accessibility	20.00
	3. Use limitations	20.00
	4. Safety	20.00
	5. Logistics	5.00
	6. Density of population	5.00
	7. Association with other values	20.00
	8. Scenery	20.00
	9. Uniqueness	15.00
	10. Observation conditions	40.00
	11. Didactic potential	80.00
	12. Geological diversity	40.00
	Total PEU	**315**.00
Potential touristic uses (PTU)	1. Vulnerability	30.00
	2. Accessibility	20.00
	3. Use limitations	20.00
	4. Safety	20.00
	5. Logistics	5.00
	6. Density of population	5.00
	7. Association with other values	20.00
	8. Scenery	60.00
	9. Uniqueness	30.00
	10. Observation conditions	20.00
	11. Interpretative potential	40.00
	12. Economic level	10.00
	13. Proximity of recreational areas	20.00
	Total PTU	**300**.00
Degradation risk (DR)	1. Deterioration of geological elements	35.00
	2. Proximity to areas/activities with potential to cause degradation	20.00
	3. Legal protection	40.00
	4. Accessibility	30.00
	5. Density of population	10.00
	Total DR	**135**.00

tourist guide services (0.25), low actual number of visitors (0.25) and overall poor tourist infrastructure (0.25). Total score for the AV is 7.00.

According to the GAM, the Haidamatskyi Iar canyon's scores are high on the MV and medium on the AV (Fig. 3).

Together, it makes 17 points on both main and additional values or 62.96%. A more detailed analysis of the score differences with the KM follows in the discussion.

3.1.3. The BM analysis

The results yielded by the BM are presented in Table 3.

The Haidamatskyi Iar canyon receives high scores on both scientific and educational values (330.00 and 315.00 out of 400.00, respectively). The BM renders similar results to the KM and GAM methods. It reveals the rather high significance of geological heritage for both science and education and indicates problems related to the peripheral location, logistics issues, and underdeveloped promotion. The overall potential of the touristic use scores 300.00 points out of 400.00. This is quite high, which means that the attractiveness of the site compensates for a lot of logistical and infrastructural shortcomings. There is a low score on the degradation risk (135.00 out of 400.00), indicating that the site is in a relatively good condition and has low vulnerability, thus requiring fewer additional conservation measures. As proposed earlier, we have averaged the PEU and PTU scores for comparison purposes, which makes 307.50 points out of 400 or 76.88% of the maximum.

To sum up, the Haidamatskyi Iar canyon receives quite high scores based on all three evaluation schemes, i.e., 86.11% with KM, 62.96% with GAM, and 76.88% with BM. It appears to be a valuable site for scientific research, specialized geological and geomorphological education, and geotourism. It received scores close to the maximum for geological diversity and representativeness as the only location in Ukraine with exposures of Vendian (Ediacaran) sandstones. Together with additional, less prominent features, including granite exposures in the river bed and limestone quarries, the Haidamatskyi Iar canyon presents a wide range of geological features, displaying sediments, traces of paleofauna, signs of past and present processes of weathering, fluvial, and Aeolian erosion. Structure and surfaces of the outcrops provide rich evidence of Quaternary period geology and paleoenvironments. Outcrop morphology makes them regionally unique among the flat terrain of the surrounding area.

Scores related to tourism attractiveness and potential are relatively high as well since Haidamtskyi Iar is located at the outskirts of the village of Busha, where basic visitor needs can be met and additional historical and cultural attractions are available. It has decent road access, and with some inconveniences, it can be reached by public transport. However, peripheral location and generally underdeveloped tourism and hospitality industry in the region somewhat reduce the scores, especially using GAM method. It also lacks general and specialized promotional products, which makes the Haidamatskyi Iar canyon less known to the general public.

3.2. Discussion

Although the Haidamatskyi Iar canyon has scored relatively high points with all three assessment methods, variation in results is rather significant. The largest difference is between KM and GAM results and there are several explanations for this gap. First of all, there is a methodological variation in the assessment of similarly formulated indicators, mainly in the level of details in evaluation of tourist and functional values. For example, GAM differentiates tourism infrastructure from hostelry and restaurant services, while KM mainly focuses upon combined lodging and dining availability as a measure of tourism infrastructure. The latter is sufficiently present in the village of Busha, while other elements of tourist infrastructure are underdeveloped. Therefore, there is a maximum score for tourism infrastructure with the KM and just 25.00% with the GAM. Site accessibility with the GAM focuses mostly on road access to the site, while the KM prioritizes public transport (hence, twice as high score for accessibility with the GAM than with the KM). Secondly, there is a technical scale-related factor. KM employs a three-level scale, where each indicator can be marked as 0.00, 0.50 or 1.00. The GAM offers five levels for each indicator in 0.25 increments, thus allowing a wider range of middle-course assessments.

Overall score of BM is in-between compared to the other two. This, again, reflects a more detailed attention paid to specific tourist infrastructure aspects of a site. While the Haidamatskyi Iar canyon is easily accessible by car, it takes some time and efforts to reach actual outcrops. Although there is no immediate danger for visitors, the absence of a dedicated medical facility for tourists on the spot is the reason for the lower safety score. Similar to GAM, BM is more scrupulous to tourist logistics and the availability of potential visitors in the vicinity of a site, including population density and economic welfare level. Another factor affecting the overall score is leaving scientific value largely out of assessment when focusing on tourism and education (unlike in the other two methods). For these purposes, Brilha (2016) reduced scientific value to geological diversity and didactic potential in PEU and to interpretative potential in PTU evaluations.

In a wider geographical context, sandstone outcrops of the Haidamatskyi Iar canyon can be compared to a number of other geomorphosites with similar appearances of massive heavily jointed sandstone rocks containing vivid signs of weathering and Aeolian processes, which have been assessed as potential geotourism destinations in Ukraine (Bayrak & Teodorovych, 2018, 2020; Waśkowska et al., 2019; Yulian et al., 2023), Poland (Wasiluk et al., 2017; Welc & Miśkiewicz, 2020; Alexandrowicz, 2008), and Czech Republic (Kubalíková & Kirchner, 2016; Migoń, 2016; Migoń, 2024). Most of these represent mountainous areas of the Carpathian Flysch Belt, Bohemian Massif, and Sudetes. The Haidamatskyi Iar canyon, on the other hand, is located in the generally flat terrain of the Volyn'-Podillia Upland. For this reason, it is much more unique at both local and regional level than many similar outcrops. Migoń (2024) emphasized the importance of the added cultural values to sandstone geomorphosites, and this aspect makes the Haidamatskyi Iar canyon stand out among similar geosites in Ukraine as right next to it, in the village of Busha, there are multiple attractions involving sandstone carving and masonry with significant historical, archeological, and cultural value. It is this added value that primarily draws visitors to the area.

However, most of the above-mentioned accounts, while delivering extensive geological and geomorphological descriptions, lack systematic quantitative evaluations that would allow listing those sites in larger (inter)national inventories. The problem of comparability was the very reason why attempts at unification of geosite assessment methods started to emerge over the past two decades. In this context, we would like to emphasize the work by Kubalíková and Kirchner (2016), where four geomorphosites (Čertovy skály, Láz, Horní skály, and Dolní skály in the Klášťovský ridge area of the Western Carpathians) of similar geological origin and comparable morphological appearance were evaluated using the KM. Numerical scores, both total and by individual criteria, allow for easy and direct comparisons. Viewed in a wider land management perspective, such direct comparisons may help in exchanging best practices, as well as learning strengths and weaknesses of tourism promotion and/or conservation measures. This, we suggest, should be an important consideration when choosing assessment methods. As the body of applied research expands, combining multiple assessment methods—particularly by including at least one previously applied to comparable, geographically proximate geosites—will help identify the most effective and universally applicable approaches. Following best practice principles, this strategy will ultimately yield optimal methods tailored to specific geoheritage types and evaluation perspectives (e.g., conservation, tourism, education, or scientific research).

4. Conclusions

Quantitative assessment reveals that the Haidamatskyi Iar canyon has significant potential as a geotourism destination with multiple features making it valuable for research, specialized education, and geoheritage popularization alike. Although similar geomorphosites are not uncommon in mountainous areas of Eastern and Central Europe, the predominantly flat topography of the surrounding area of the Podillia Upland makes the sandstone outcrops of the Haidamatskyi Iar canyon regionally unique and they definitely stand out among other geoheritage sites in Ukraine outside of the Carpathian region. Additional geological features, including limestone and chalk quarries and granite outcrops in the river basin, make it even more valuable for geological research and education, while direct proximity to the well-known historical and archeological destination in the village of Busha attracts a wider circle of visitors. Its overall geotourism potential scores based on three assessment methods are 62.96% (GAM), 76.88%(BM), and 86.11% (KM). The variation reflects methodological differences in the selected assessment algorithms and confirms the need to use several assessment approaches simultaneously for more balanced and comprehensive results. Comparative analysis of assessment results across broader geographical contexts demonstrates a preference for employing universally applicable and internationally recognized evaluation methods. Best practice involves selecting at least one method previously applied to geo(morpho)logically similar sites.

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Yulian Braychevskyy: Methodology, Visualization, Writing – review & editing, Formal analysis, Conceptualization, Resources, Data curation. **Volodymyr Korinnyi:** Writing – review & editing, Visualization, Formal analysis, Data curation, Writing – original draft, Resources. **Olga Kovtoniuk:** Formal analysis, Project administration, Conceptualization, Writing – review & editing, Supervision, Methodology, Writing – original draft. **Nataliia Pohorilchuk:** Methodology, Data curation, Writing – original draft, Formal analysis.

Ethical statement

Herewith, we declare that, to our knowledge, we do not conflict with any of the ethical standards of research work, including academic integrity, copyright, etc. In this work, we did not use any animals or human subjects, which could require special ethical approval.

Declaration of competing interest

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Appendix A. Supplementary data

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