

Integrated assessment of geoheritage resources for geoconservation and sustainable geotourism in Malësi e Madhe, Albania

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ABSTRACT: Mountainous rural areas often contain geological and geomorphological features with important scientific, educational, and tourism value, but their use for geotourism requires careful consideration of accessibility, visitor safety, site sensitivity, and conservation needs. This study assesses the geoheritage resources of Malësi e Madhe Municipality, northern Albania, with the aim of examining how selected geosites can support geoconservation, geoeducation, and sustainable geotourism. An initial review of 32 officially recognised natural monuments identified 22 geomonuments, from which 12 representative geosites were selected for detailed assessment. The study combined documentary research, thematic mapping, field observations, photographic documentation, and an exploratory local stakeholder questionnaire. Each geosite was assessed separately for scientific value, educational potential, tourism potential, and degradation risk using a semi-quantitative 0–4 scale. The results indicate that accessible and clearly observable surface geosites generally provide stronger opportunities for educational and tourism use, whereas caves and karst shafts, although scientifically significant, are more constrained by difficult access, visitor-safety concerns, and higher sensitivity to degradation. On this basis, three management profiles are proposed: public educational use, guided or seasonally controlled use, and restricted or specialist use. The study contributes a practical municipality-scale approach that links geoheritage assessment with differentiated site management, interpretation, access planning, and conservation. Its findings also underline the need to avoid treating tourism potential as equivalent to actual tourism demand and to adapt geotourism development to the specific physical and management conditions of each site. The results are limited to the 12 assessed geosites and should be regarded as an initial evidence base for further geological, ecological, safety, visitor-use, and carrying-capacity studies.

KEYWORDS: geoheritage assessment, geoconservation, visitor safety, degradation risk, karst landscapes, management planning, Albanian Alps

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1. INTRODUCTION

Mountain landscapes are often read first through their scenery, yet much of their value lies in the geological history recorded in rocks, landforms, springs, caves, and river valleys. These features reveal how a landscape has evolved and provide tangible settings in which geological processes can be observed, interpreted, and communicated. In rural mountain regions, geoheritage may therefore serve several purposes at once: it can support scientific research, enrich environmental education, strengthen local

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identity, and create opportunities for small-scale nature-based tourism and local guiding. When conservation and interpretation are carefully combined, geological heritage can also contribute to broader forms of sustainable territorial development (Dowling, 2011; Gray, 2019).

Scientific importance alone does not make a geosite suitable for public visitation. Accessibility, visibility, interpretive clarity, visitor safety, and site sensitivity strongly influence whether geological features can support education or tourism use, particularly in mountain and karst environments where difficult terrain, seasonal conditions, and restricted rescue access may impose important constraints (Brilha, 2016; Štrba et al., 2023; Zafeiropoulos & Drinia, 2023).

The key management question is therefore not simply whether a geosite should be promoted, but how it should be used and under what conditions. Depending on local circumstances, appropriate use may range from open public access to guided, seasonal, specialist, or restricted visitation. Carrying-capacity considerations are important in relating visitor use to site sensitivity, safety, and management needs (Santos & Brilha, 2023).

In this context, tourism potential should be distinguished from actual tourism demand. Tourism potential refers here to the suitability of a geosite for visitation based on characteristics such as accessibility, visibility, safety, interpretive value, and surrounding services, whereas actual tourism demand depends on observed visitor flows, travel behaviour, and market conditions. The present study assesses the former and uses locally informed perceptions only as contextual evidence; it does not measure actual visitor demand.

Malësi e Madhe Municipality, in northern Albania, offers a particularly suitable setting in which to examine these issues. Tourism activity in Malësi e Madhe is closely associated with its mountain landscapes, natural attractions, and cross-border setting, but detailed and site-specific visitor statistics are not consistently available for the assessed geosites. Instead, tourism-related conditions are interpreted through field observations and exploratory local stakeholder evidence, while tourism potential is assessed separately on the basis of site characteristics, accessibility, safety, and management conditions.

Although individual geological and natural attractions in northern Albania have been described in previous research, the geoheritage of Malësi e Madhe has not yet been examined through a common framework that compares scientific value, educational potential, tourism potential, and degradation risk. Existing studies provide useful descriptions of geological and geomorphological features, but offer limited comparative evidence for site-specific decisions concerning access, interpretation, visitor management, monitoring, and conservation. This study addresses that gap through an integrated municipality-scale assessment that links geoheritage significance with public-use conditions and differentiated management needs.

The primary objective of this study is to assess the geoheritage resources of Malësi e Madhe Municipality and determine how differences in scientific significance, educational potential, tourism suitability, accessibility, visitor safety, and degradation risk can inform site-specific geoconservation and sustainable geotourism management.

Given the exploratory and comparative character of the study, the analysis was guided by the following research questions:

1. What principal geological and geomorphological processes are represented by the 12 assessed geosites?
2. How do scientific value, educational potential, tourism potential, and degradation risk vary among the selected geosites?
3. How can these differences inform decisions concerning public access, guided visitation, seasonal control, and specialist use?

Rather than producing a single overall ranking, the assessment supports preliminary decisions on interpretation, local guiding, access planning, monitoring, and site-specific conservation. The results should be regarded as an initial evidence base rather than a final regulatory framework. The remainder of the paper is organised as follows: Section 2 reviews the relevant literature, Section 3 describes the study area and methodological approach, Section 4 presents the results, Section 5 discusses their implications, and Section 6 summarises the main conclusions, limitations, and directions for future research.

2. LITERATURE REVIEW

Geoheritage assessment has evolved from the compilation of descriptive inventories towards a broader evaluation of the scientific, educational, tourism, and conservation significance of geological sites. This shift reflects a growing understanding that geoheritage is not limited to the preservation of geological evidence, but also includes the ways in which such evidence can support learning, public interpretation, local identity, and sustainable territorial development (Brilha, 2016; Gray, 2019). Recent research has extended this perspective by placing greater emphasis on sustainability, management, community development, and regional planning. Although inventories and quantitative assessments remain fundamental, there is increasing interest in approaches that connect geoheritage conservation with geotourism and broader sustainable development objectives (Gupta et al., 2024). In mountain tourism research, these issues are also increasingly associated with community participation, environmental conservation, climate-related challenges, and sustainable development (Dobhal & Kala, 2026). This reflects a broader shift from documenting geoheritage resources towards considering how assessment can support their long-term use and management.

Multidimensional geoheritage assessment increasingly recognises that scientific significance, educational potential, tourism suitability, and conservation concern represent related but distinct dimensions of site value. Sites with high rarity or representativeness may still be difficult to access, poorly exposed, physically fragile, or unsuitable for non-specialist visitors. For this reason, contemporary approaches generally retain scientific value, educational potential, tourism potential, and degradation risk as separate analytical dimensions rather than combining them into a single overall score (Brilha, 2016; Pál & Albert, 2021; Štrba et al., 2023). Recent applications provide further support for this multidimensional approach. Assessment of geosites in Safi Province, Morocco, for example, combined scientific and additional values with potential use, educational and tourism values, and degradation risk, illustrating how quantitative evaluation can support geoconservation, geoeducation, geotourism, and local sustainable development (El Hamidy & Errami, 2025).

In mountainous and karst environments, the interpretation of assessment results is particularly sensitive to terrain, seasonal variability, site exposure, and other physical constraints that may not be fully represented by numerical scores alone (Štrba et al., 2023; Santos & Brilha, 2023).

Accessibility has consequently become a more prominent component of contemporary geosite evaluation. Rather than being treated as a simple measure of distance or road access, it is increasingly understood as a combination of terrain difficulty, travel effort, visibility, infrastructure, and the practical conditions under which visitors reach and experience a site. Recent studies have therefore called for more systematic and visitor-centred approaches to accessibility assessment, particularly where assessment results are intended to guide geoeducation or geotourism planning (Bilgiç et al., 2024; Pál & Albert, 2025; Štrba et al., 2023).

Educational potential also depends on more than the scientific quality of a geological feature. A site becomes educationally useful when geological processes can be observed directly, explained clearly, and connected to the broader evolution of the landscape. Visibility, interpretive clarity, thematic diversity, spatial scale, and suitability for different audiences all influence whether a geosite can support formal teaching, guided excursions, or informal public learning (Zafeiropoulos & Drinia, 2023).

Vulnerability and conservation have also become increasingly important components of geoheritage assessment. Geological sites may be affected by both natural processes and human pressures, although the type and intensity of these pressures vary considerably among sites. Conservation-oriented assessment therefore seeks not only to establish the significance of geoheritage resources, but also to identify the conditions that may threaten their integrity over time. Recent research has further linked geoheritage vulnerability with preventive conservation and management intervention, emphasising the importance of management measures that respond to identified sources of vulnerability (Ferdowsi, 2025).

Assessment methods must also be interpreted in relation to territorial context. Criteria developed for one landscape cannot always be transferred directly to another because mountain, island, volcanic, rural, and protected-area settings differ in their geology, infrastructure, visitor services, rescue capacity, settlement patterns, and exposure to natural hazards. Comparative studies from the northern Apennines, Malta, Brazil, Uganda, and New Zealand demonstrate that the practical meaning of accessibility,

vulnerability, educational use, and tourism potential varies according to local environmental and institutional conditions (Guerra & Lazzari, 2022; Kayima & Karasiewicz, 2025; Possenelli et al., 2024; Santos & Brilha, 2024; Zakharovskiy et al., 2024).

A broader international comparison further shows that geoheritage management is strongly conditioned by institutional capacity, visitor infrastructure, hazard exposure, and the maturity of destination-management systems. In European contexts, geosite assessment is increasingly linked with accessibility, interpretation, conservation status, and visitor-management needs, reinforcing the view that numerical evaluation should support rather than replace site-specific management decisions (Štrba et al., 2023; Bilgiç et al., 2024).

Asian experience likewise demonstrates the importance of integrating scientific value with accessibility, visitor safety, conservation, and sustainable use; for example, geosite evaluation in Japan has incorporated management-oriented criteria to support sustainable geotourism planning (Suzuki & Takagi, 2018). Research on geoparks in Hebei Province, China, further illustrates how geoheritage protection, geotourism promotion, infrastructure, and regional sustainable development can be considered within the same planning context (Wang et al., 2023). Evidence from established geotourism destinations also shows that infrastructure and interpretation alone do not guarantee sustainable use, since congestion, inappropriate visitor behaviour, and management pressure may still occur (Newsome et al., 2012). Regional coordination, geotrails, stakeholder involvement, and interpretation therefore remain important components of long-term geotourism development (Lewis, 2023). Recent empirical research published in CEJGSD similarly highlights the importance of accessibility, infrastructure, stakeholder involvement, and context-sensitive planning when natural and cultural resources are translated into sustainable regional tourism products (Luvsandavaajav et al., 2025).

Despite the growing sophistication of geoheritage assessment, methodological differences remain in criterion selection, weighting, scoring thresholds, and the balance between expert judgement and visitor-oriented indicators (Brilha, 2016; Pál & Albert, 2021; Štrba et al., 2023). These differences limit direct comparison among studies and reinforce the need to interpret quantitative scores as context-dependent decision-support indicators. Standardised scoring systems are therefore most informative when combined with site-specific interpretation that considers the criteria applied, the available evidence, and the environmental and management context of each site.

Geoheritage research in Albania has provided a valuable basis for understanding the scientific and tourism potential of the country's geological landscapes. Previous studies have examined geotourism opportunities in Theth National Park, Mali i Tomorrit, and Zall Gjoçaj, highlighting the scientific, scenic, educational, and recreational significance of these areas (Bollobani & Uruçi, 2019; Dollma, 2019; Pazari & Dollma, 2019). More recently, geodiversity assessment at the municipal scale in Shkodra has demonstrated the value of systematic spatial assessment for interpreting Albania's diverse geological landscapes (Kraja & Albert, 2026).

Geological and hydrogeological studies have also contributed to the interpretation of carbonate formations, karst development, groundwater circulation, and glacial landforms in northern Albania and the Albanian Alps (Eftimi et al., 2022; Milivojević et al., 2008; Qiriazzi, 2022; Serjani et al., 2001). Evidence of Pleistocene glaciation, including cirques, moraines, and glacially modified valleys, further confirms the importance of glacial processes alongside karst, fluvial, and tectonic influences in the development of the regional landscape (Milivojević et al., 2008).

Despite these contributions, much of the Albanian literature has focused on individual attractions, the geological or geomorphological description of particular landscapes, or the general potential for geotourism development (Bollobani & Uruçi, 2019; Dollma, 2019; Pazari & Dollma, 2019; Kraja & Albert, 2026). Comparative multidimensional assessment at the municipal scale appears to remain limited, particularly where surface and underground geosites with contrasting physical characteristics occur within the same territory. This gap provides a basis for applying a common assessment framework while retaining the analytical distinction among scientific value, educational potential, tourism potential, and degradation risk.

3. RESEARCH METHODS

The methodological procedure followed a sequence of documentary and cartographic review, identification and screening of natural monuments, selection of geomonuments for detailed assessment, field verification, collection of locally informed questionnaire evidence, and semi-quantitative evaluation. Scientific value, educational potential, tourism potential, and degradation risk were assessed separately.

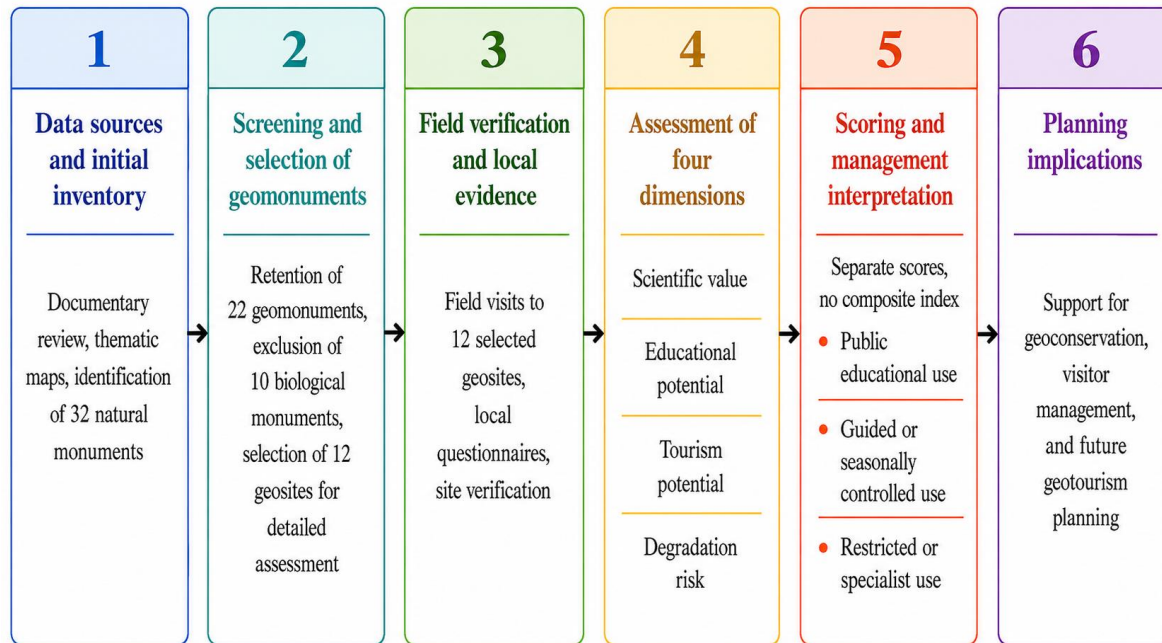


Figure 1. Methodological sequence of natural-monument screening, geosite selection, assessment, and management classification.

Source: Authors' own elaboration.

The resulting scores were subsequently interpreted together with field-recorded conditions to define differentiated management profiles. The overall methodological sequence is presented in Figure 1.

The principal research instruments used across these stages comprised documentary and cartographic source review, thematic maps, a structured field-observation framework, mobile-phone GPS and photographic documentation, an exploratory stakeholder questionnaire, and criterion-based geosite assessment sheets using the defined 0–4 scoring scale.

3.1. Study area and spatial data sources

Malësi e Madhe Municipality is located in northern Albania, between Lake Shkodra, the Albanian Alps, and the border with Montenegro (Figure 2). The municipality includes strong contrasts in relief, hydrography, accessibility, and settlement patterns that are relevant to the spatial distribution and management of geoheritage resources. Geologically, the study area is dominated by carbonate formations affected by karst, fluvial, and former glacial processes (Qiriazhi, 2022; Serjani et al., 2001; Milivojević et al., 2008).

From a tourism perspective, Malësi e Madhe forms part of the wider northern Albanian mountain destination system and is promoted for its mountain landscapes, hiking opportunities, nature-based recreation, and traditional rural character (National Tourism Agency, n.d.-a). Municipal performance data indicate that the number of tourists accommodated in hotels increased from 19,277 in 2023 to 26,190 in 2024 and 37,000 in 2025 (Municipality of Malësi e Madhe, 2025). These figures describe accommodation activity at the municipal level and should not be interpreted as visitor counts for the individual geosites assessed in this study.

Accessibility within the municipality varies considerably. Official tourism information places Razëm approximately 41 km from Shkodër and Vermosh approximately 95 km from Shkodër (National Tourism Agency, n.d.-b). Razëm is also promoted as a year-round destination, including for winter recreation

(National Tourism Agency, n.d.-b), while Vermosh is promoted for hiking and other nature-based mountain activities (National Tourism Agency, n.d.-c). In terms of national accessibility, Malësi e Madhe is reached from Tirana through the main northward road corridor via Shkodër and Koplik, with Shkodër functioning as the principal regional gateway to Razëm, Vermosh, and other mountain areas of the municipality.

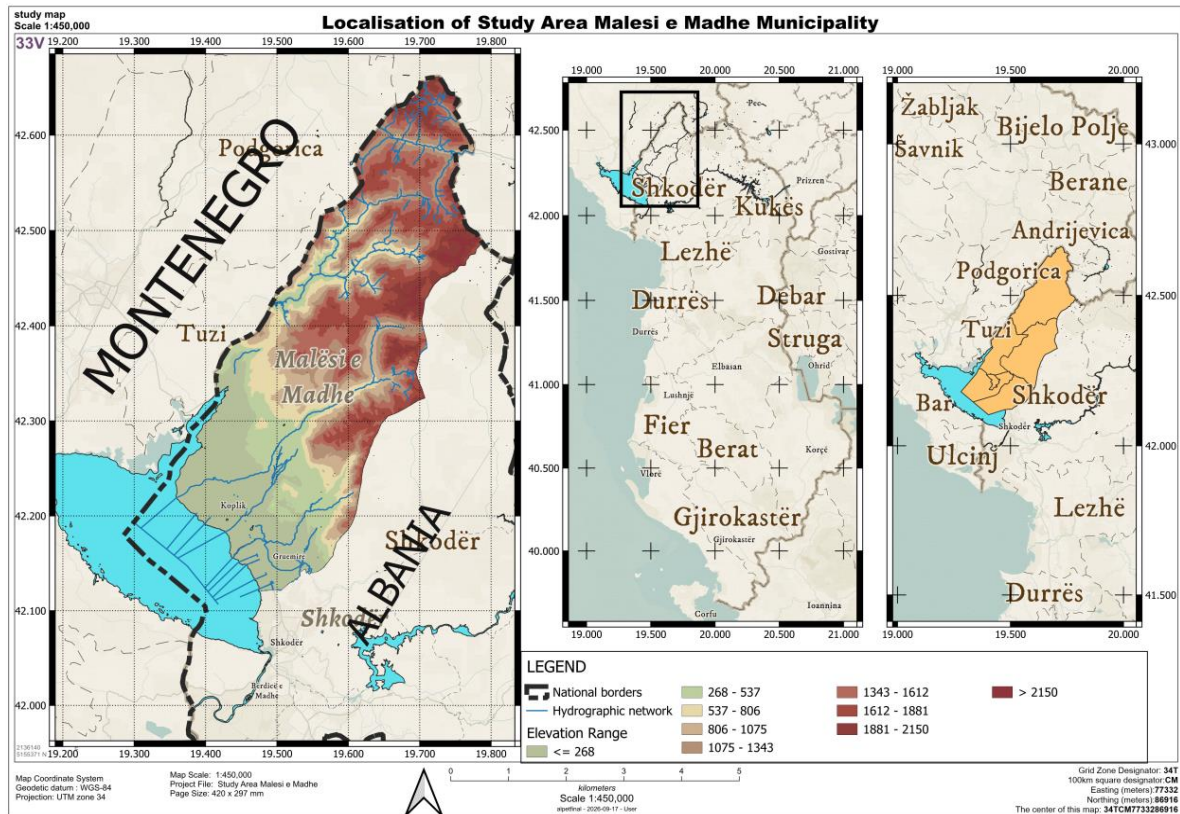


Figure 2. Geographical location and principal physical and administrative features of Malësi e Madhe Municipality, northern Albania.

Source: Cartographic preparation by the authors, 2026.

Seasonal conditions nevertheless influence the practical accessibility of mountain geosites. Based on the climatic and field-access conditions relevant to the present assessment, May–September represents the generally most suitable period for visiting the assessed open geosites, when conditions are typically more favourable for hiking, mountain travel, and access to higher-elevation locations. Outside this period, lower temperatures, precipitation, snow, and more variable road and trail conditions may restrict access to some sites. This seasonal interpretation should be treated cautiously because consistent monthly visitor statistics for the assessed geosites are not available.

Consequently, the suitability of individual geosites for visitation depends not only on regional road connectivity but also on local roads, trails, terrain, altitude, weather, and seasonal conditions.

Three thematic maps were prepared to support the spatial interpretation of the selected geosites: geographical location, geology and relief, and hydrography. The location map presents the national and cross-border position of Malësi e Madhe and its principal physical and administrative features. The geological and relief map supports interpretation of lithological, structural, and topographic relationships, while the hydrographic map illustrates the association of selected water-related geosites with drainage networks and groundwater-emergence points.

Spatial layers were processed in ArcGIS Pro and harmonised within a common coordinate reference system. Relief representation was derived from a digital elevation model, while the locations of the selected geosites were recorded during the field campaigns using mobile-phone GPS. Geological and

hydrogeological interpretation was supported by published research and the broader national cartographic framework of Albania (Eftimi et al., 2022; Qiriaz, 2022; Serjani et al., 2001).

The maps were used for territorial contextualisation and comparative interpretation rather than for predictive modelling, route optimisation, or quantitative accessibility analysis. The recorded coordinates were considered suitable for locating the geosites at the municipal scale, but they were not treated as high-precision geodetic measurements.

3.2. Identification and selection of geosites

A preliminary inventory of 32 natural monuments was compiled through the combined review of geological, geomorphological, hydrographic, cartographic, documentary, and locally informed evidence. Of these, 22 were classified as geomonuments because their principal significance was geological, geomorphological, or hydrogeological (Table 1). The remaining ten were biological monuments, including individual trees, forest stands, and botanical sites, and were excluded from the geosite assessment.

Table 1. Inventory of geomonuments and selection for detailed assessment.

No.	Geomonument	Main geoheritage category	Detailed assessment
1	Shegani Karst Spring	Karst spring	Yes
2	Fortesa e Kelmendit	Karst and erosional limestone landform	No
3	Koprishti Springs	Karst springs	Yes
4	Syri i Gjonit	Karst spring	No
5	Krevenica Cave	Karst cave	No
6	Razma Moraines	Glacial deposits	Yes
7	Livadhi i Bogës Glacial Cirque	Glacial landform	Yes
8	Vukli Springs	Karst springs	Yes
9	Gërça Rock Terrace	Structural and erosional landform	No
10	Gjolaj Cave	Glacio-karst cave	No
11	Bashkimi Canyon, Vermosh	Fluvial canyon	Yes
12	Mullaret e Radit, Rapsh	Karst and erosional limestone landforms	Yes
13	Puci Cave	Karst cave	Yes
14	Pusi i Xhek Markut	Karst shaft	Yes
15	Shpella e Njerëzve të Lagur	Karst cave	Yes
16	Poica Canyon (Përroi i Thatë Canyon)	Fluvial and karst canyon	Yes
17	Mullarët e Gurtë të Bajzës	Karst and erosional limestone landforms	No
18	Pusi i Cilikokajve	Glacio-karst shaft	No
19	Kalaja e Shtegut të Dhenëve	Karst and erosional limestone landform	Yes
20	Runica Glacial Trough	Glacial and karst landform	No
21	Boga Fluvioglacial Deposits	Fluvioglacial deposits	No
22	Seferça Glacial Trough	Glacial landform	No

Source: Authors' compilation based on documentary, cartographic, field, and locally informed evidence.

Only features with a clearly identifiable geological, geomorphological, or hydrogeological basis were retained as geomonuments. Scenic attractiveness, cultural importance, and local recognition were treated as supporting characteristics rather than sufficient criteria for geosite classification. This approach is consistent with established geoheritage-assessment principles, which place scientific representativeness at the centre of geosite identification while treating educational, tourism, accessibility, and conservation characteristics as complementary dimensions (Brilha, 2016; Štrba et al., 2023; Possenelli et al., 2024).

From the inventory of 22 geomonuments, 12 geosites were selected for detailed field assessment (Table 1). The selection followed a purposive, expert-informed approach rather than a random sampling procedure. The intention was not to produce a statistically representative sample of all geomonuments, but to identify a coherent set of sites that captured the main geoheritage processes present in the municipality while also reflecting contrasting conditions of accessibility, visibility, educational potential, tourism relevance, field feasibility, and conservation sensitivity. The selected group included representative examples of the principal glacial, karst, hydrogeological, and fluvial processes identified

within Malësi e Madhe. Selection was guided by geological representativeness, typological diversity, integrity, visibility, accessibility, educational potential, field-verification feasibility, and the availability of sufficient documentary information.

Locally reported visitor interest was also considered as supporting evidence. Residents, local guides, tourism operators, and institutional representatives referred to these sites as locations that were visited, requested, or frequently discussed by visitors. Because official visitor statistics were unavailable at the individual-site level, this information was treated as locally informed contextual evidence rather than as a direct measurement of tourism flows or demand.

Together, the 12 selected geosites form a diverse and comparable sample of the principal geoheritage processes represented in the study area, including former glacial activity, carbonate dissolution, groundwater emergence, underground karst development, erosional modelling of limestone, and fluvial incision. These processes have also been documented more widely in northern Albania and the Albanian Alps (Eftimi et al., 2022; Milivojević et al., 2008; Qiriaz, 2022; Serjani et al., 2001).

The ten geomonuments not included in the detailed assessment remain part of the wider preliminary inventory. Their exclusion should not be interpreted as evidence that they lack geoheritage significance. They were not subjected to criterion-level scoring or management-profile classification and may provide a basis for future field assessment and inventory expansion.

3.3. Field investigation and questionnaire survey

Two field campaigns were conducted in May and June 2026. All 12 selected geosites were visited and examined using the same field-observation framework. Attention was given to the visibility and physical condition of geological features, road and trail access, terrain difficulty, visitor safety, seasonal hazards, and visible signs of natural or human-induced pressure. Field photographs and mobile-phone GPS records were used to confirm site locations and support their general cartographic representation.

Locally informed evidence was collected through an exploratory questionnaire administered to 20 purposively selected participants. The group included 14 local residents, four local guides or tourism operators, and two municipal or institutional representatives. Participants were selected because they lived or worked in Malësi e Madhe Municipality and were familiar with its natural sites. The questionnaire was designed to provide contextual evidence on locally perceived visitor interest and site-use conditions rather than to measure actual tourism demand or to generate statistically representative estimates of either the municipal population or the wider visitor market. The sample size was therefore considered appropriate for the exploratory and contextual role assigned to the questionnaire, rather than as a basis for statistical generalisation. Participant selection prioritised direct familiarity with the municipality and its natural sites, allowing locally informed observations to complement, but not replace, field-based and documentary evidence.

The questionnaire addressed familiarity with the selected geosites, perceived visitor interest, landscape attractiveness, accessibility, visitor safety, educational value, conservation concerns, nearby services, guiding needs, and seasonal conditions (Appendix I). Developed specifically for the exploratory objectives of this study, it was informed by the assessment dimensions and management issues identified in the geoheritage literature. It was not adapted from a previously validated survey instrument, because its purpose was to obtain contextual, site-specific stakeholder evidence rather than to generate statistically generalisable measures of tourism demand or visitor behaviour. Before field administration, the questionnaire was reviewed by the authors for clarity, consistency with the assessment dimensions, and suitability for the local exploratory context, and minor wording adjustments were made where necessary. Participation was voluntary, and all responses were recorded anonymously. Before taking part, participants were informed about the purpose of the study, the voluntary nature of their participation, the anonymous use of their responses, and their right to decline or stop at any time. Informed consent was obtained from all participants. No names, contact details, sensitive personal information, or other directly identifying data were collected.

Each questionnaire took approximately 20 minutes to complete. Participants were asked to answer the site-specific visitor-interest question only for geosites with which they were familiar. “Yes” responses

were treated as positive and “No” responses as negative, while “Unsure” responses, missing responses, and responses concerning unfamiliar geosites were excluded from the analysis. In the final dataset, all 20 participants provided a valid “Yes” or “No” response for each of the 12 selected geosites. The valid-response count was therefore 20 for every site, as reported in Table 8.

For each geosite, the percentage of positive responses was calculated by dividing the number of valid “Yes” responses by the total number of valid “Yes” and “No” responses and multiplying the result by 100. The resulting percentages were converted into criterion TV6, locally reported visitor interest, using the thresholds presented in Table 3: 0 for 0–19%, 1 for 20–39%, 2 for 40–59%, 3 for 60–79%, and 4 for 80–100% positive responses.

These percentages were interpreted as locally informed perceptions rather than as official visitor statistics, direct measurements of visitor flows, or statistically representative estimates of tourism demand. Questionnaire results contributed directly to the numerical assessment only through criterion TV6. Responses concerning accessibility, visitor safety, nearby services, guiding needs, and seasonal conditions were used as contextual evidence to support the interpretation of field observations and practical management needs. They were not treated as an independent validation dataset for the broader tourism-potential assessment.

3.4. Geosite assessment framework

The 12 selected geosites were assessed using a semi-quantitative ordinal scale from 0 to 4 across four separate dimensions: scientific value, educational potential, tourism potential, and degradation risk. As shown in Table 2, each dimension was represented by a defined set of criteria and corresponding codes, allowing the selected geosites to be evaluated consistently and compared on the same basis.

Scientific value was assessed through criteria SV1–SV5, educational potential through EV1–EV5, tourism potential through TV1–TV6, and degradation risk through DR1–DR6. Together, these criteria captured the scientific significance of each site, its educational and tourism-related potential, and the main factors affecting its vulnerability and management needs.

For scientific value, educational potential, and tourism potential, scores ranged from 0 for absent or highly unfavourable conditions to 4 for very high or highly favourable conditions. For degradation risk, 0 indicated negligible risk and 4 indicated very high risk.

Visitor-safety constraints were treated separately from degradation risk. Safety criteria referred to conditions affecting visitors, whereas degradation risk referred to the vulnerability of the geosite itself. The four dimensions were therefore reported separately, and no overall composite score was calculated.

Table 2. Assessment dimensions and criteria.

Dimension	Code	Criterion
Scientific value	SV1	Representativeness
	SV2	Rarity
	SV3	Integrity
	SV4	Geological diversity
	SV5	Availability of scientific knowledge
Educational potential	EV1	Interpretive clarity
	EV2	Visibility
	EV3	Thematic diversity
	EV4	Suitability for educational groups
	EV5	Educational safety
Tourism potential	TV1	Scenic quality
	TV2	Accessibility
	TV3	Visitor safety
	TV4	Proximity to services
	TV5	Connection with other attractions
	TV6	Locally reported visitor interest

Degradation risk	DR1	Natural fragility
	DR2	Active natural processes
	DR3	Visitor pressure
	DR4	Infrastructure-related pressure
	DR5	Proximity to potential threats
	DR6	Protection and management deficit

Source: Authors' own elaboration based on established geoheritage-assessment frameworks.

3.5. Operational scoring thresholds

All criteria were assessed on a 0–4 ordinal scale, following the general logic commonly applied in semi-quantitative geoheritage-assessment frameworks (Brilha, 2016; Pál & Albert, 2021; Štrba et al., 2023; Possenelli et al., 2024). Higher scores indicated more favourable conditions for scientific value, educational potential, and tourism potential, whereas higher degradation-risk scores indicated greater vulnerability, pressure, and management concern.

As shown in Table 3, the same numerical scale was interpreted differently according to the assessment dimension. For scientific value, educational potential, and tourism potential, scores ranged from absent or highly unfavourable conditions to very high or highly favourable conditions. For degradation risk, scores ranged from negligible to very high risk. Scores of 0, 2, and 4 served as the principal operational anchors, while scores of 1 and 3 represented intermediate conditions between adjacent levels.

Table 3. General interpretation of the 0–4 scoring scale.

Score	Scientific, educational, and tourism dimensions	Degradation risk
0	Absent or highly unfavourable conditions	Negligible
1	Low value or unfavourable conditions	Low
2	Moderate value or moderately favourable conditions	Moderate
3	High value or favourable conditions	High
4	Very high value or highly favourable conditions	Very high

Source: Authors' own elaboration.

For criterion TV6, locally reported visitor interest was converted into scores using the thresholds 0 for 0–19%, 1 for 20–39%, 2 for 40–59%, 3 for 60–79%, and 4 for 80–100% positive responses among valid questionnaire responses. The complete criterion-level scores and dimension means are reported in Supplementary Table S1.

Both assessors initially evaluated each geosite independently using field observations, photographs, thematic maps, documentary and scientific sources, and questionnaire evidence where applicable. Differences were reviewed against the available evidence, and final scores were agreed through discussion and consensus. This procedure was used to reduce individual subjectivity and strengthen the internal consistency of the assessment (Brilha, 2016; Štrba et al., 2023; Possenelli et al., 2024).

3.6. Weighting, calculation, and classification

All criteria were assigned equal weight within their respective assessment dimensions. This approach ensured a transparent and consistent calculation procedure and avoided introducing differences in criterion importance without a formally validated weighting system. Equal weighting is commonly applied in semi-quantitative geoheritage assessment when there is no sufficiently robust basis for assigning different levels of importance to individual criteria (Brilha, 2016; Štrba et al., 2023; Possenelli et al., 2024). For each geosite, the score of each assessment dimension was calculated as the arithmetic mean of the corresponding criterion-level scores:

$$I_d = \frac{\sum_{i=1}^n x_i}{n}$$

where I_d is the dimension index, x_i is the score assigned to each criterion i , and n is the number of criteria included in that dimension.

Because the criteria were measured on a 0–4 ordinal scale, the arithmetic means were used as comparative summary indicators rather than as precise interval-scale measurements. Their use was intended to provide a transparent summary of the relative assessment profile of each geosite across the criteria included within a given dimension. Accordingly, the resulting mean values were interpreted descriptively and comparatively, without assuming that the numerical distance between adjacent ordinal categories represents an equivalent quantitative interval. Their purpose was to compare the relative assessment profiles of the selected geosites, following established practice in semi-quantitative geoheritage assessment (Brilha, 2016; Pál & Albert, 2021; Possenelli et al., 2024).

The resulting dimension scores were classified using the non-overlapping intervals presented in Table 4. For scientific value, educational potential, and tourism potential, the classes were interpreted as very low, low, moderate, high, and very high. For degradation risk, the same intervals represented very low, low, moderate, high, and very high levels of risk.

The four dimensions were retained and reported separately, and no overall composite index was calculated. This made it possible to preserve the individual assessment profile of each geosite and to avoid masking differences between scientific importance, use potential, and conservation concern. The complete criterion-level scores and dimension means are provided in Supplementary Table S1 (Appendix II).

Table 4. Classification of dimension mean scores.

Mean score	Classification
0.00–0.79	Very low
0.80–1.59	Low
1.60–2.39	Moderate
2.40–3.19	High
3.20–4.00	Very high

Source: Authors' own elaboration.

3.7. Management-profile classification

Management profiles were assigned after the four assessment dimensions had been calculated and classified. The classification was based on the combined interpretation of dimension scores and field-recorded conditions, including accessibility, visibility, terrain difficulty, seasonal constraints, visitor safety, rescue feasibility, and site sensitivity. Numerical results were therefore not used in isolation, which is consistent with approaches that link geosite assessment to site-specific management conditions (Brilha, 2016; Štrba et al., 2023; Possenelli et al., 2024; Santos & Brilha, 2024).

Sites with high or very high educational and tourism potential, clearly observable features, and no major access or safety constraints were assigned to the public educational-use profile. Sites with otherwise favourable assessment results but with terrain, seasonal, accessibility, or safety limitations were assigned to the guided or seasonally controlled-use profile. Underground, vertical, hazardous, or sensitive sites where existing access, rescue, safety, or conservation conditions did not support general visitation were assigned to the restricted or specialist-use profile. These profiles were used as comparative management recommendations rather than as formal access regulations.

4. RESULTS

4.1. Composition and spatial distribution of the assessed geosites

Field investigation resulted in the detailed assessment of 12 geosites selected from the broader preliminary inventory of 22 geomonuments in Malësi e Madhe Municipality. The assessed sample included karst springs, underground karst features, fluvial canyons, surface limestone landforms, and landforms associated with former glacial activity (Table 5).

Table 5. Composition of the assessed geosite sample.

Geoheritage category	Selected geosites	No.	Share
Karst springs	Shegani Karst Spring; Koprishiti Springs; Vukli Springs	3	25.0%

Caves and karst shafts	Puci Cave; Pusi i Xhek Markut; Shpella e Njerëzve të Lagur	3	25.0%
Fluvial canyons	Bashkimi Canyon; Poica Canyon	2	16.7%
Karst and erosional limestone landforms	Mullaret e Radit; Kalaja e Shtegut të Dhenëve	2	16.7%
Glacial landforms and deposits	Razma Moraines; Livadhi i Bogës Glacial Cirque	2	16.7%
Total		12	100.0%

Source: Authors' own elaboration.

Note: Percentages refer exclusively to the 12 geosites selected for detailed assessment. Because values are rounded to one decimal place, the category percentages sum to 100.1%, while the total is reported as 100.0%.

The spatial distribution of the selected geosites shows two main geographical concentrations (Figure 3). The western mountain sector includes the Razma Moraines, Mullaret e Radit, the Livadhi i Bogës Glacial Cirque, and Puci Cave. Poica Canyon is located outside the densest part of this concentration but is situated near the Razëm–Bogë–Shkrel mountain area.

The northern Kelmend sector includes Bashkimi Canyon, Koprishiti Springs, Vukli Springs, Kalaja e Shtegut të Dhenëve, Pusi i Xhek Markut, and Shpella e Njerëzve të Lagur. Shegani Karst Spring is located outside the two main spatial concentrations.

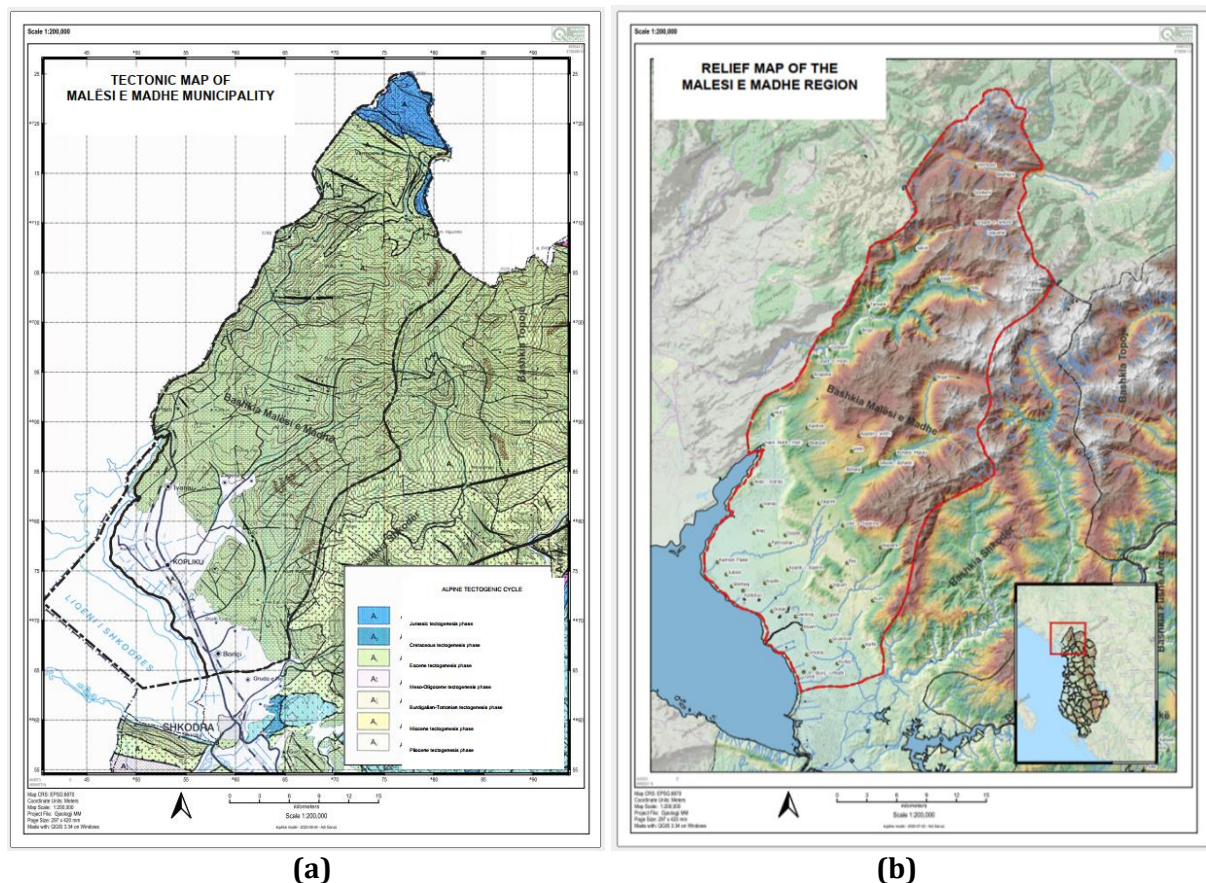


Figure 3. Geological (a) and relief (b) framework of Malësi e Madhe Municipality and the spatial distribution of the selected geosites.

Source: Cartographic preparation by the authors, 2026.

4.2. Field-observed geological, geomorphological, and hydrogeological characteristics

Most of the selected geosites are located within carbonate formations and dissected mountain terrain (Figure 4). Field observations identified glacial, karst, hydrogeological, erosional, and fluvial characteristics across the assessed sample.

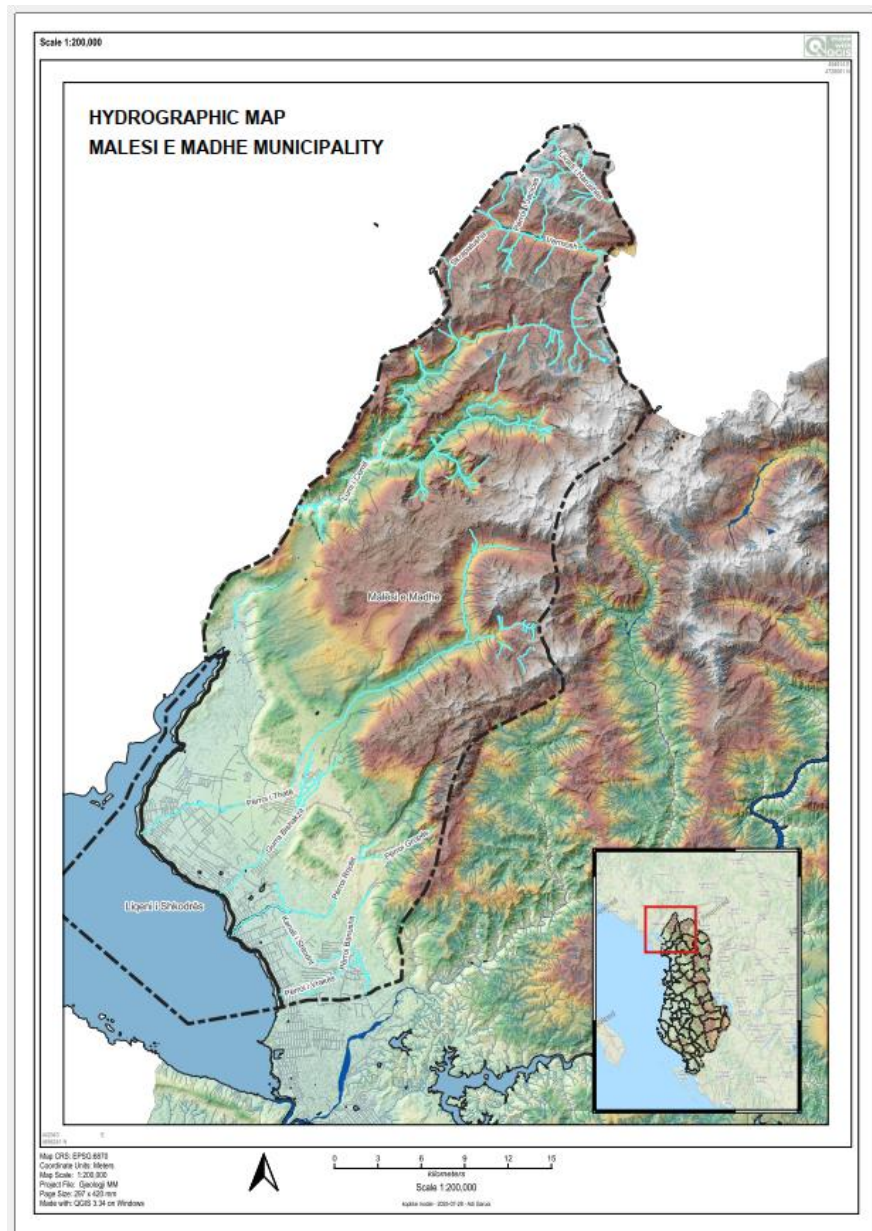


Figure 4. Hydrographic network of Malësi e Madhe Municipality and the spatial distribution of the selected water-related geosites.

Source: Cartographic preparation by the authors, 2026.

The Razma Moraines consist of deposits with morphological characteristics associated with glacial transport and deposition (Figure 5a). The Livadhi i Bogës site contains a cirque-shaped depression and surrounding relief characteristics associated with former glacial erosion and ice accumulation. No sedimentological or geochronological analyses were undertaken at these two sites.

Mullaret e Radit and Kalaja e Shtegut të Dhenëve consist of exposed carbonate relief. Field observations recorded visible limestone surfaces, erosional forms, weathered rock features, fractures, and dissolution-related morphology.

The Shegani, Koprishiti, and Vukli springs represent groundwater emergence points associated with fractured and karstified carbonate formations (Figure 5b). No discharge measurements, tracer tests, hydrochemical analyses, or recharge-area delineation were undertaken during the study.

Puci Cave, Pusi i Xhek Markut, and Shpella e Njerëzve të Lagur represent underground karst features. Recorded field conditions included darkness, wet or uneven surfaces, restricted visibility, difficult access, and underground or vertical exposure. Vertical exposure was particularly evident at Pusi i Xhek Markut.

Bashkimi Canyon and Poica Canyon contain narrow valley sections, exposed rock surfaces, steep terrain, and active or seasonal water channels (Figure 5c and 5d). Field observations also recorded restricted movement, erosion, unstable surfaces, and water-related access limitations.

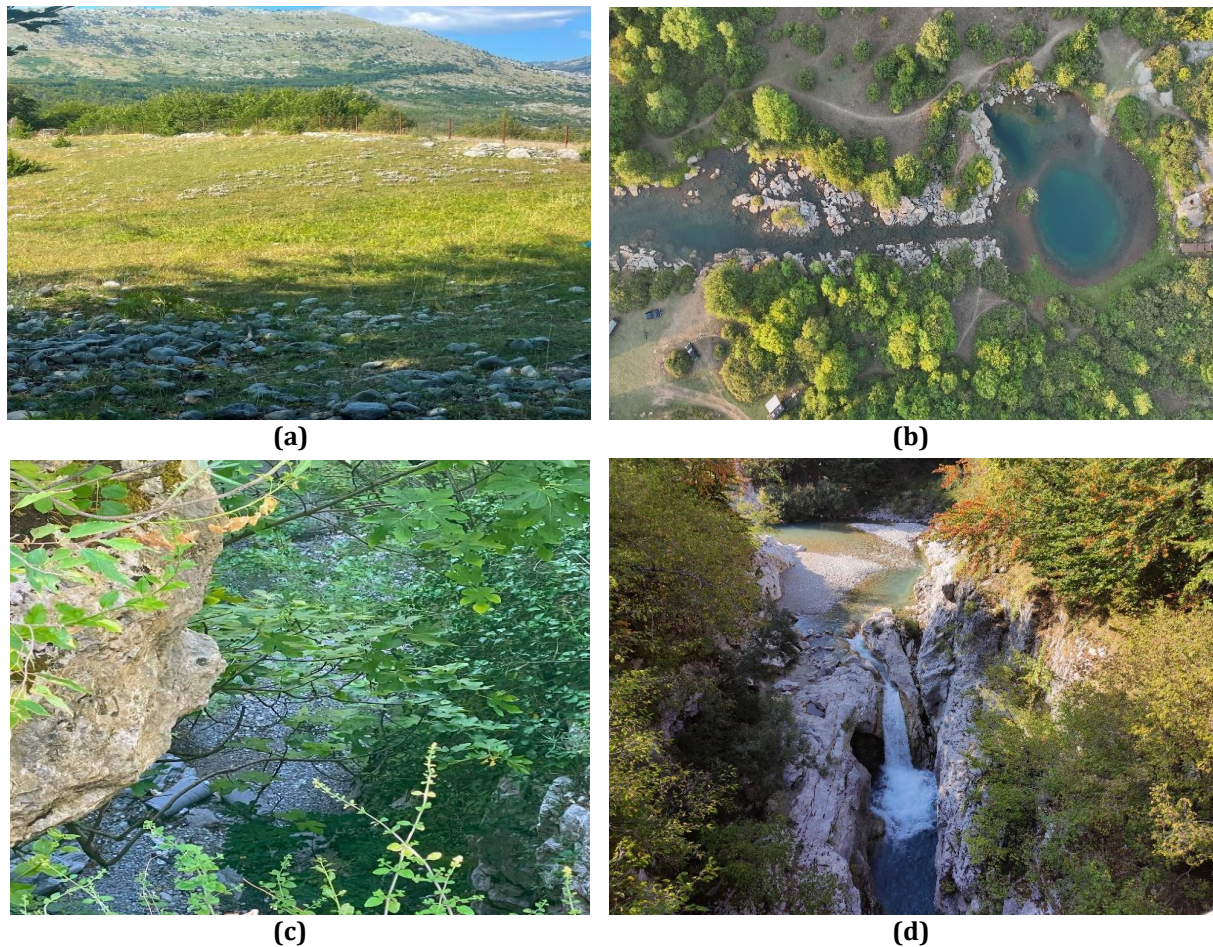


Figure 5. Representative field views of selected geosites in Malësi e Madhe Municipality: (a) Razma Moraines; (b) Shegani Karst Spring; (c) Poica Canyon (Përroi i Thatë Canyon), and (d) Bashkimi Canyon, Vermosh.

Source: Photographs by Rustja D., 2026.

The spatial distribution of springs, canyons, and underground karst features in relation to the municipal hydrographic network is presented in Figure 4.

4.3. Multidimensional assessment results

The 12 selected geosites were assessed according to scientific value, educational potential, tourism potential, and degradation risk. The decimal values reported in Table 6 represent dimension-level arithmetic means calculated from the corresponding 0–4 ordinal criterion scores, as described in Section 3.6 and detailed in Supplementary Table S1 (Appendix II).

The mean scientific-value score across the 12 assessed geosites was 3.22. Educational potential recorded the highest overall mean score, at 3.37. The mean tourism-potential score was 3.11, while the mean degradation-risk score was 2.68.

Table 6. Multidimensional assessment of the selected geosites.

Geosite	Scientific value	Educational potential	Tourism potential	Degradation risk
Razma Moraines	3.2	3.4	3.5	2.2
Mullaret e Radit	2.8	3.2	3.2	2.2
Livadhi i Bogës Glacial Cirque	3.4	3.6	3.3	2.3

Kalaja e Shtegut të Dhenëve	3.0	3.2	3.0	2.5
Bashkimi Canyon	3.4	3.8	3.7	3.2
Poica Canyon	3.2	3.8	3.5	3.0
Shegani Karst Spring	3.6	3.8	3.7	2.3
Koprishti Springs	3.4	3.6	3.3	2.2
Vukli Springs	3.2	3.6	3.3	2.2
Puci Cave	3.2	3.0	2.5	3.3
Pusi i Xhek Markut	3.0	2.6	2.0	3.5
Shpella e Njerëzve të Lagur	3.2	2.8	2.3	3.3
Mean	3.22	3.37	3.11	2.68

Source: Authors' own elaboration.

Scientific-value scores ranged from 2.8 to 3.6, while educational and tourism potential showed wider contrasts among the assessed geosites. Shegani Karst Spring and Bashkimi Canyon recorded some of the strongest educational and tourism profiles. The clearest contrast concerned the three underground geosites, which recorded tourism-potential scores of 2.0–2.5 and degradation-risk scores of 3.3–3.5, indicating more restrictive conditions for public use.

The assessment scores for all 12 geosites are presented visually in Figure 6.

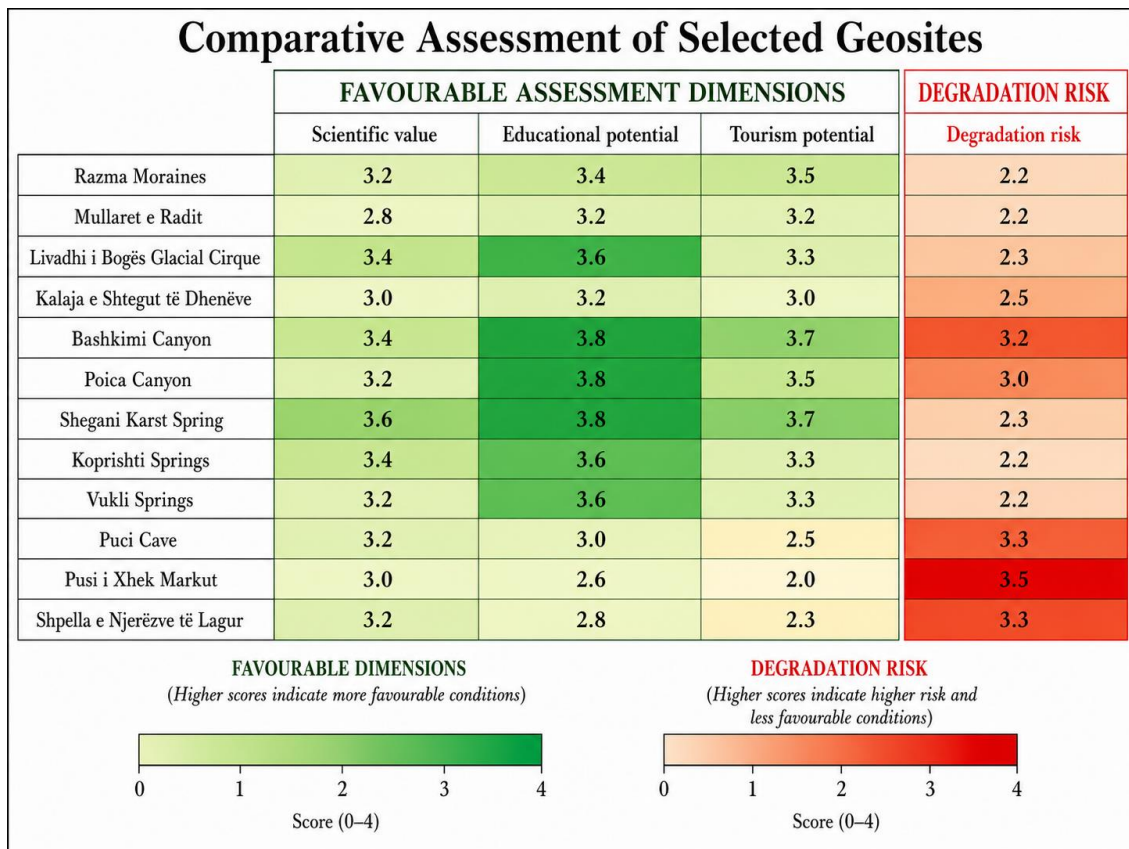


Figure 6. Heatmap of scientific value, educational potential, tourism potential, and degradation risk across the 12 selected geosites.

Source: Authors' own elaboration.

4.4. Comparison of open and underground geosites

The selected geosites were divided into nine open geosites and three underground geosites. Mean scores were calculated separately for the two groups.

Open geosites recorded a mean scientific-value score of 3.24, compared with 3.13 for underground geosites (Table 7). The difference between the two group means was 0.11.

The mean educational-potential score was 3.56 for open geosites and 2.80 for underground geosites. Mean tourism potential was 3.39 for open geosites and 2.27 for underground geosites.

Underground geosites recorded a mean degradation-risk score of 3.37, compared with 2.46 for open geosites (Table 7).

Table 7. Mean assessment scores for open and underground geosites.

Setting	Scientific value	Educational potential	Tourism potential	Degradation risk
Open geosites, n = 9	3.24	3.56	3.39	2.46
Underground geosites, n = 3	3.13	2.80	2.27	3.37

Source: Authors' own elaboration.

The comparison was descriptive because the underground group contained only three geosites. No inferential test of differences between the two groups was conducted.

4.5. Relationships among assessment dimensions

Relationships among the four assessment dimensions were examined on an exploratory basis using Spearman's rank correlation coefficient (Spearman, 1904). This non-parametric measure was selected because the assessment was based on ordinal scores and a small sample of 12 selected geosites. Six pairwise correlations were tested, and the corresponding *p*-values were adjusted using the Holm procedure to account for multiple comparisons. The analysis was intended to describe patterns within the assessed sample rather than to support population-level inference.

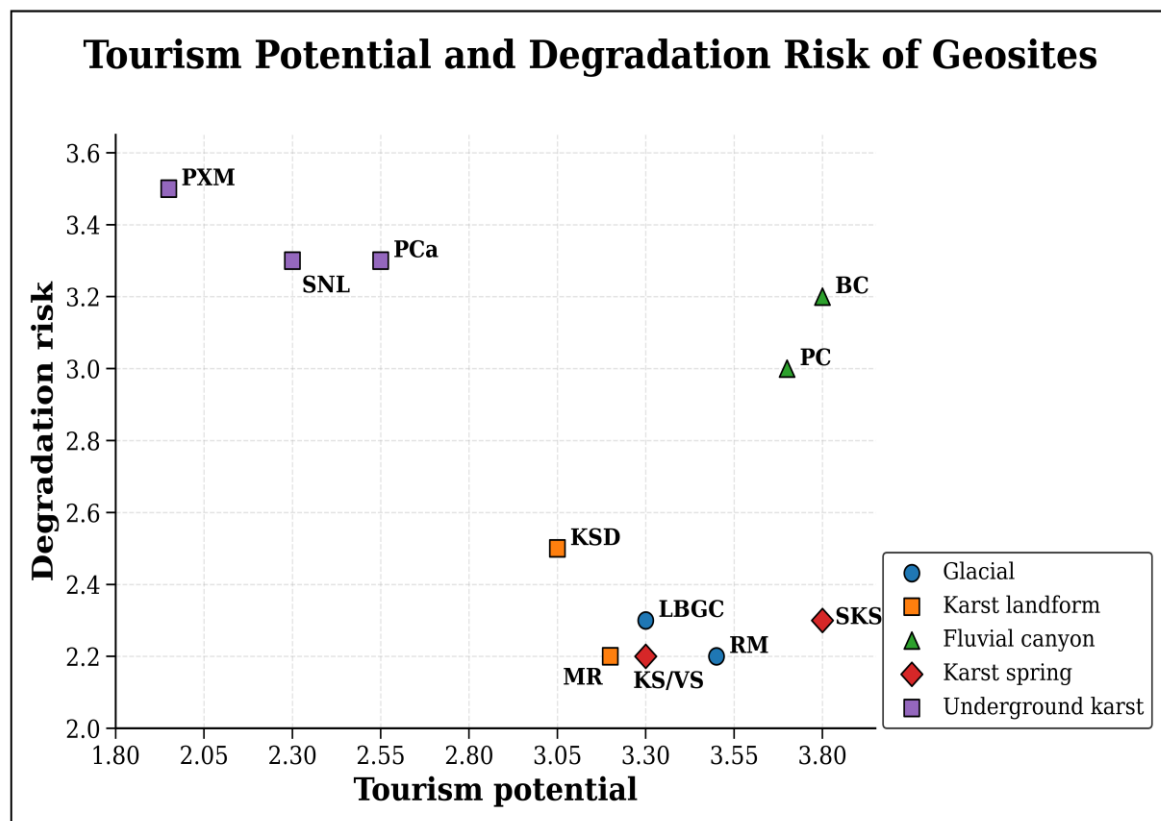


Figure 7. Relationship between tourism potential and degradation risk for the selected geosites. Markers represent individual geosites, while symbol types distinguish surface and underground geosites.

Source: Authors' own elaboration.

Note: RM = Razma Moraines; MR = Mullaret e Radit; LBGC = Livadhi i Bogës Glacial Cirque; KSD = Kalaja e Shtegut të Dhenëve; BC = Bashkimi Canyon; PC = Poica Canyon; SKS = Shemani Karst Spring; KS = Koprishiti Springs; VS = Vukli Springs; PCa = Puci Cave; PXM = Pusi i Xhek Markut; SNL = Shpella e Njerëzve të Lagur.

Educational potential and tourism potential showed the strongest positive relationship ($\rho = 0.934$, unadjusted $p < 0.001$, Holm-adjusted $p < 0.001$). Within the 12 selected geosites, higher educational-potential scores tended to occur together with higher tourism-potential scores. This association should be

interpreted cautiously because the two dimensions include conceptually related attributes, particularly accessibility, safety, visibility, and suitability for organised visitation.

Scientific value showed positive relationships with educational potential ($\rho = 0.694$, unadjusted $p = 0.012$, Holm-adjusted $p = 0.060$) and tourism potential ($\rho = 0.662$, unadjusted $p = 0.019$, Holm-adjusted $p = 0.076$). Neither relationship remained statistically significant at the 0.05 level after correction for multiple testing. The positive coefficients should therefore be interpreted as exploratory patterns within the selected geosites rather than as evidence of general relationships among geosites in Malësi e Madhe or elsewhere.

Degradation risk showed negative relationships with scientific value ($\rho = -0.127$, unadjusted $p = 0.694$, Holm-adjusted $p = 0.694$), educational potential ($\rho = -0.387$, unadjusted $p = 0.214$, Holm-adjusted $p = 0.432$), and tourism potential ($\rho = -0.448$, unadjusted $p = 0.144$, Holm-adjusted $p = 0.432$). None of these relationships was statistically significant. Although the coefficients for educational and tourism potential were negative, the small and selective sample does not support conclusions about a general association between degradation risk and public-use potential.

The relationship between tourism potential and degradation risk is illustrated in Figure 7. Surface geosites are generally positioned towards higher tourism-potential scores and lower or moderate degradation-risk scores, whereas the three underground geosites occupy positions characterised by lower tourism potential and higher degradation risk. This pattern is descriptive and applies only to the selected geosites.

4.6. Locally perceived visitor interest

Locally perceived visitor interest was assessed using responses from 20 purposively selected participants. The results reflect the perceptions of the respondents and should not be interpreted as estimates of actual or total tourism demand.

Shegani Karst Spring recorded the highest level of locally perceived visitor interest, with 80.0% positive responses, followed by Bashkimi Canyon with 70.0%. The lowest values were recorded for Mullaret e Radit, Pusi i Xhek Markut, and Shpella e Njerëzve të Lagur, each with 40.0% positive responses. The remaining geosites recorded intermediate values ranging from 50.0% to 65.0%, as presented in Table 8.

Table 8. Locally perceived visitor interest in the selected geosites.

Geosite	Positive responses, n	Valid responses, n	Positive responses, %	TV6 score
Razma Moraines	12	20	60.0	3
Mullaret e Radit	8	20	40.0	2
Livadhi i Bogës Glacial Cirque	12	20	60.0	3
Kalaja e Shtegut të Dhenëve	13	20	65.0	3
Bashkimi Canyon	14	20	70.0	3
Poica Canyon	12	20	60.0	3
Shegani Karst Spring	16	20	80.0	4
Koprishti Springs	12	20	60.0	3
Vukli Springs	13	20	65.0	3
Puci Cave	10	20	50.0	2
Pusi i Xhek Markut	8	20	40.0	2
Shpella e Njerëzve të Lagur	8	20	40.0	2

Source: Authors' own elaboration.

Participants also identified several recurring barriers to visitation, including poor or incomplete access paths, limited signage and interpretive information, visitor-safety concerns, insufficient nearby services, and the absence of organised guiding.

The questionnaire responses were incorporated into criterion TV6 of the tourism-potential assessment. Accordingly, they were used as locally informed evidence for one component of the assessment and were not treated as an independent validation dataset.

4.7. Management profile classification

Application of the management-profile classification rules resulted in three geosites being assigned to the public educational-use profile, six to the guided or seasonally controlled-use profile, and three to the restricted or specialist-use profile.

The public educational-use profile included the Razma Moraines, Livadhi i Bogës Glacial Cirque, and Shegani Karst Spring. These geosites combined very high educational and tourism-potential scores with clearly observable geological features, comparatively favourable access and safety conditions, and moderate degradation-risk scores ranging from 2.2 to 2.3. These characteristics supported their classification as suitable for organised educational visits and low-impact public use, subject to appropriate interpretation, visitor information, and routine monitoring.

The guided or seasonally controlled-use profile included Bashkimi Canyon, Poica Canyon, Mullaret e Radit, Kalaja e Shtegut të Dhenëve, Koprishti Springs, and Vukli Springs. These geosites generally recorded high or very high scientific, educational, or tourism-potential scores but were also affected by one or more field-observed constraints related to terrain, seasonal water conditions, accessibility, visitor safety, or visitor-management requirements. Their assessment profiles therefore supported visitation under local guidance, seasonal restrictions, or other forms of controlled use rather than unrestricted access.

The restricted or specialist-use profile included Puci Cave, Pusi i Xhek Markut, and Shpella e Njerëzve të Lagur. All three are underground karst features characterised by difficult access, restricted visibility, wet or uneven surfaces, underground or vertical exposure, and very high degradation-risk scores ranging from 3.3 to 3.5. These field conditions and assessment results supported a more restrictive management approach, despite the scientific significance of the sites.

The public educational-use profile accounted for 25.0% of the assessed sample, the guided or seasonally controlled-use profile for 50.0%, and the restricted or specialist-use profile for 25.0%. The classification results are summarised in Table 9.

Table 9. Management profiles of the selected geosites.

Management profile	Geosites	Assessment and field-based classification basis
Public educational use	Razma Moraines; Livadhi i Bogës Glacial Cirque; Shegani Karst Spring	Very high educational and tourism potential, clearly observable geological features, comparatively favourable access and safety conditions, and moderate degradation risk
Guided or seasonally controlled use	Bashkimi Canyon; Poica Canyon; Mullaret e Radit; Kalaja e Shtegut të Dhenëve; Koprishti Springs; Vukli Springs	High or very high assessment scores combined with field-observed constraints related to terrain, seasonal water conditions, accessibility, visitor safety, or visitor management
Restricted or specialist use	Puci Cave; Pusi i Xhek Markut; Shpella e Njerëzve të Lagur	Underground conditions, difficult access, restricted visibility, wet or uneven surfaces, underground or vertical exposure, and very high degradation risk

Source: Authors' own elaboration.

4.8. Preliminary geographical concentrations

Descriptive spatial interpretation identified two main geographical concentrations and one geosite located outside both. These concentrations were defined on the basis of geographical proximity and the observed distribution of the selected geosites rather than through formal cluster analysis.

The western Razëm–Bogë–Shkrel concentration comprised the Razma Moraines, Mullaret e Radit, the Livadhi i Bogës Glacial Cirque, Puci Cave, and Poica Canyon. Together, these five geosites represent glacial, surface-karst, underground-karst, and fluvial features within the western mountain sector of the municipality.

The northern Kelmend concentration comprised Bashkimi Canyon, Koprishti Springs, Vukli Springs, Kalaja e Shtegut të Dhenëve, Pusi i Xhek Markut, and Shpella e Njerëzve të Lagur. These six geosites include karst springs, underground karst features, a fluvial canyon, and an exposed limestone landform.

Shegani Karst Spring was located outside the two main geographical concentrations.

Within the western concentration, two geosites were classified under the public educational-use profile, two under the guided or seasonally controlled-use profile, and one under the restricted or specialist-use profile. Within the northern concentration, four geosites were classified under the guided or seasonally controlled-use profile and two under the restricted or specialist-use profile. Shegani Karst Spring was classified under the public educational-use profile.

5. DISCUSSION

The geoheritage of Malësi e Madhe cannot be understood simply in terms of the number or variety of its geological features. Its significance lies in the coexistence of different geological processes within a relatively compact territory, producing sites with contrasting possibilities for interpretation, visitation, and conservation. Carbonate lithology and groundwater circulation account for the widespread occurrence of springs and underground karst, while fluvial erosion and former glacial activity explain the presence of canyons, moraines, and glacially modified landforms. These characteristics are consistent with the geological and geomorphological development documented in northern Albania and the Albanian Alps (Serjani et al., 2001; Milivojević et al., 2008; Eftimi et al., 2022; Qiriazi, 2022).

The comparison between open and underground geosites reveals an important distinction between geological significance and suitability for public use. Mean scientific-value scores were similar for the two groups (3.24 for open geosites and 3.13 for underground geosites), whereas the differences in educational potential, tourism potential, and degradation risk were much more pronounced. Open geosites recorded higher mean educational (3.56) and tourism potential (3.39) scores than underground geosites (2.80 and 2.27), while degradation risk showed the opposite pattern, with a mean score of 2.46 for open geosites compared with 3.37 for underground geosites. Difficult access, restricted visibility, uneven surfaces, and limited rescue possibilities therefore constrain the visitor potential of caves and karst shafts despite their scientific significance. Open landforms are generally easier to observe and interpret, although greater accessibility does not remove the need for conservation. These contrasts underline the importance of considering scientific significance alongside educational potential, tourism suitability, accessibility, visitor safety, and degradation risk when planning geoheritage use at the municipal scale (Brilha, 2016; Štrba et al., 2023; Santos & Brilha, 2023).

A multidimensional perspective is particularly useful for understanding these differences. Scientific, educational, tourism, and conservation-related dimensions represent distinct qualities of a geosite and should therefore remain analytically separate. Scientific value may reflect rarity, representativeness, or the quality of geological evidence, whereas educational and tourism use depends more directly on whether that evidence can be seen, understood, reached safely, and experienced without unacceptable pressure on the site. In Malësi e Madhe, the value of this approach lies not simply in comparing scores, but in using the differences among dimensions to inform management choices. This is especially relevant in mountain and karst environments, where high scientific significance can coexist with limited visitor suitability or greater conservation concern (Brilha, 2016; Pál & Albert, 2021; Štrba et al., 2023; Santos & Brilha, 2023).

The strong positive relationship between educational and tourism potential ($p = 0.934$; Holm-adjusted $p < 0.001$) reflects the practical conditions shared by these two dimensions. Geological features are more likely to support both learning and visitation when they are visible, understandable, accessible, and suitable for organised groups. Educational and tourism value should not, however, be treated as interchangeable. A site may remain valuable for specialist teaching or carefully guided interpretation even where broader tourism development would be inappropriate. The strength of the relationship should also be interpreted cautiously because the two dimensions include conceptually related criteria, particularly accessibility, safety, visibility, and suitability for organised visitation.

Scientific value showed positive associations with both educational and tourism potential, but neither relationship remained statistically significant after Holm correction. These patterns should therefore be regarded as exploratory within the assessed sample rather than evidence of a general relationship. Scientific evidence can remain highly important even when it is difficult for non-specialists to recognise or

understand. For such sites, the management question is not how to maximise visitation, but how to communicate geological significance without compromising safety or conservation. Digital interpretation, specialist excursions, off-site educational materials, and controlled field visits may offer more appropriate forms of engagement than unrestricted access.

Degradation risk requires separate consideration from visitor safety. A site may present substantial hazards to visitors without being especially vulnerable to physical damage, while an easily accessible landform may experience trampling, littering, collecting, or pressure from new infrastructure. The distinction matters because measures designed to protect visitors are not necessarily the same as those needed to protect the geological feature. Safety may require supervision, barriers, route control, or technical equipment, whereas conservation may depend more on monitoring, visitor limits, restrictions on collecting, or avoiding inappropriate infrastructure development.

Local stakeholder evidence adds an important practical perspective to these patterns. Participants identified incomplete paths, limited signage, insufficient interpretation, safety concerns, weak visitor services, and the absence of organised guiding as recurring constraints. Similar limitations have been reported in earlier studies of geotourism development in Albania, where geological potential is often stronger than the infrastructure and management systems available to support sustainable visitation (Bollobani & Uruçi, 2019; Dollma, 2019; Pazari & Dollma, 2019).

For Malësi e Madhe, the immediate challenge is therefore not to identify more attractions, but to prepare existing sites for forms of use that are realistic and appropriate. Promotion without interpretation risks reducing geoheritage to scenery, while promotion without adequate safety and conservation measures may generate new pressures. Initial priorities should include clear site information, trained local guides, appropriate route marking, seasonal warnings, basic monitoring, and restrictions where sites are particularly sensitive or hazardous.

The three management profiles provide a practical way to translate these differences into site-specific use. Public educational use is most appropriate where the defining geological feature is clearly visible and access can be managed with limited intervention. Guided or seasonally controlled use is better suited to sites where terrain, water conditions, or visitor safety require supervision or temporal restrictions. Restricted or specialist use is more appropriate where physical conditions, rescue limitations, or conservation concerns make general visitation unsuitable.

These profiles should be treated as adaptive rather than permanent classifications. Improvements in access, interpretation, monitoring, or rescue capacity may change the suitability of a site over time. Conversely, increasing visitor pressure or evidence of degradation may justify stricter controls. Periodic review is therefore important if management classifications are to remain responsive to actual field conditions rather than becoming fixed labels.

The two preliminary geographical concentrations identified in the Razëm–Bogë–Shkrel and Kelmend sectors also have potential implications for future route planning. Geographical proximity alone, however, is not enough to establish a viable geotourism route. Route development would also depend on compatible access conditions, realistic travel times, seasonal reliability, local services, guiding capacity, and coordination among landowners and relevant institutions. Spatial concentration should therefore be regarded as a starting point for planning rather than evidence that a route is already feasible.

The municipal scale is particularly useful because it brings together geologically related sites that differ substantially in their practical conditions of use. In Malësi e Madhe, significant geoheritage resources coexist with uneven accessibility, limited visitor infrastructure, seasonal constraints, and varying local management capacity. These differences favour a differentiated approach to planning rather than uniform tourism promotion. In the Albanian context, such an approach may help connect geoheritage with environmental education, local guiding, and rural tourism development while keeping visitor safety and conservation needs central to management decisions.

Responsibilities also differ among stakeholder groups. Destination managers can focus on interpretation, visitor information, route organisation, and guiding services in accordance with the management profile of each geosite. Geosite and protected-area authorities have a stronger role in monitoring, visitor safety, access control, and conservation at sensitive or hazardous locations. Local

communities and guides can contribute local knowledge, interpretation, visitor guidance, and small-scale tourism services compatible with conservation objectives. At municipal and national levels, priorities include basic access infrastructure, signage, guide training, inter-institutional coordination, and periodic monitoring rather than uniform tourism promotion. This distribution of responsibilities is consistent with recent approaches that emphasise visitor experience, accessibility, conservation, and stakeholder coordination in sustainable geoheritage management (Crofts, 2024; Santos & Brilha, 2024; Lewis, 2023).

The interpretation of the results is constrained by the scope of the assessment. Only 12 of the 22 identified geomonuments were examined in detail, so the observed patterns should not be generalised to the complete municipal inventory. The questionnaire provided locally grounded observations, but the small purposive sample cannot be considered representative of wider public opinion or actual visitor demand. Field observations were also conducted only in May and June and may not reflect winter access, high-water conditions, prolonged rainfall, or seasonal changes in vegetation and trail quality.

Further limitations concern the spatial and geological evidence. Mobile-phone GPS was appropriate for locating sites and supporting municipal-scale mapping, but not for high-precision spatial analysis. The scoring process retained an element of expert judgement, and agreement between assessors was reached through discussion rather than evaluated statistically. Geological and hydrogeological interpretations were based on field evidence and existing literature rather than laboratory analysis, hydrological monitoring, tracer testing, hydrochemical investigation, or geochronological dating.

Future research should extend the field assessment to the remaining geomonuments and reassess the selected sites under contrasting seasonal conditions. More detailed investigation of hazards, accessibility, carrying capacity, ownership, visitor behaviour, and conservation status would provide a stronger basis for future management decisions. Further scientific study of the glacial, karst, and hydrogeological features would also strengthen interpretation and help clarify which sites are most appropriate for public education and which should remain primarily scientific or specialist locations.

6. CONCLUSIONS

The assessment of 12 selected geosites in Malësi e Madhe shows that geoheritage resources with comparable scientific importance may differ substantially in their educational potential, tourism suitability, accessibility, visitor-safety conditions, and degradation risk. These differences are important for management because they affect the forms of use that individual sites can realistically support. The results therefore reinforce the value of assessing scientific, educational, tourism, and conservation-related dimensions separately rather than relying on geological significance alone.

At the municipal scale, the study provides a practical basis for linking geoheritage assessment with differentiated management decisions. The proposed management profiles translate the assessment results and field-observed conditions into broad forms of public, guided or seasonally controlled, and specialist use. Their purpose is not to establish formal access regulations, but to support preliminary decisions concerning interpretation, visitation, safety, monitoring, and conservation. In this respect, the Malësi e Madhe case illustrates how municipality-scale geoheritage assessment can contribute to geoconservation and carefully planned geotourism without assuming that all geosites should be managed or promoted in the same way.

The conclusions are limited to the geosites and evidence examined in this study. Only 12 of the 22 identified geomonuments were assessed in detail, the questionnaire provided exploratory local evidence rather than a representative measure of tourism demand, and field observations covered only part of the seasonal cycle. Further assessment of the remaining geomonuments, together with more detailed investigation of seasonal conditions, hazards, carrying capacity, visitor use, and conservation status, would strengthen the evidence available for future management of geoheritage in Malësi e Madhe.

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Use of AI tools declaration

The authors declare that artificial intelligence (AI) tools were used solely for language editing and improving the clarity of the manuscript. All scientific interpretations, analyses, and conclusions were developed and verified by the authors, who take full responsibility for the final content of the article.

Author contributions

Both authors contributed to the conceptualisation and design of the study, field investigation, geosite assessment, interpretation of the findings, and preparation of the manuscript. Both authors read and approved the final manuscript.

Conflicts of interest

The authors declare no conflict of interest.

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Appendix I. Short questionnaire on geosite perceptions

Participation is voluntary and anonymous. Please answer the site-specific questions only for geosites with which you are familiar. For the visitor-interest question, “Yes” responses were treated as positive and “No” responses as negative, while “Unsure” responses and responses concerning unfamiliar sites were excluded from the valid-response count.

A. Participant profile

Participant category:

☐ Local resident, ☐ Tourism operator, ☐ Local guide, ☐ Public-sector representative, ☐ Other

Place of residence or principal activity: _____

B. Geosite awareness and visitor interest

Geosite	Familiar with the site?	Visitor interest observed or reported?
Razma Moraines	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unsure
Mullaret e Radit	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unsure
Livadhi i Bogës Glacial Cirque	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unsure
Kalaja e Shtegut të Dhenëve	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unsure
Bashkimi Canyon	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unsure
Poica Canyon	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unsure
Shegani Karst Spring	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unsure
Koprishti Springs	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unsure
Vukli Springs	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unsure
Puci Cave	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unsure
Pusi i Xhek Markut	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unsure
Shpella e Njerëzve të Lagur	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unsure

C. Educational and visitor-management conditions

1. Which geosites are most suitable for educational visits?

2. Which geosites require guided or controlled access?

3. What are the main constraints affecting visitation?

- ☐ Difficult access ☐ Safety risks ☐ Lack of signage ☐ Limited interpretive information
☐ Lack of nearby services ☐ Seasonal conditions ☐ Other:

4. Which management measures should be prioritised?

- ☐ Interpretive information ☐ Visitor-safety measures ☐ Guided visits ☐ Site monitoring
☐ Waste management ☐ Local-community involvement ☐ Access improvements ☐ Other:

Appendix II. Supplementary material

Supplementary Table S1. Criterion-level scores and dimension means for the selected geosites.

Geosite	SV1-SV5	SV mean	EV1-EV5	EV mean	TV1-TV6	TV mean	DR1-DR6	DR mean
Razma Moraines	3-3-4-3-3	3.2	4-4-3-3-3	3.4	4-4-4-3-3-3	3.5	2-2-2-2-2-3	2.2
Mullaret e Radit	3-3-3-3-2	2.8	3-4-3-3-3	3.2	4-3-3-3-4-2	3.2	2-2-2-2-2-3	2.2
Livadhi i Bogës Glacial Cirque	4-3-4-3-3	3.4	4-4-4-3-3	3.6	4-3-3-3-4-3	3.3	2-3-2-2-2-3	2.3
Kalaja e Shtegut të Dhenëve	3-3-4-3-2	3.0	4-4-3-3-2	3.2	4-3-3-2-3-3	3.0	3-3-2-2-2-3	2.5
Bashkimi Canyon	4-3-4-4-2	3.4	4-4-4-4-3	3.8	4-4-4-3-4-3	3.7	4-4-3-3-2-3	3.2
Poica Canyon	4-3-3-4-2	3.2	4-4-4-4-3	3.8	4-4-3-3-4-3	3.5	4-4-3-2-2-3	3.0
Shegani Karst Spring	4-3-4-4-3	3.6	4-4-4-4-3	3.8	4-4-4-3-3-4	3.7	2-3-2-2-2-3	2.3
Koprishti Springs	4-3-4-4-2	3.4	4-4-4-3-3	3.6	4-3-3-3-4-3	3.3	2-2-2-2-2-3	2.2
Vukli Springs	4-3-4-3-2	3.2	4-4-4-3-3	3.6	4-3-3-3-4-3	3.3	2-2-2-2-2-3	2.2
Puci Cave	4-3-4-3-2	3.2	3-3-4-2-3	3.0	4-2-2-2-3-2	2.5	4-3-3-3-3-4	3.3
Pusi i Xhek Markut	4-3-3-3-2	3.0	3-2-3-2-3	2.6	3-1-1-2-3-2	2.0	4-4-3-3-3-4	3.5
Shpella e Njerëzve të Lagur	4-3-4-3-2	3.2	3-3-3-2-3	2.8	3-2-2-2-3-2	2.3	4-3-3-3-3-4	3.3
Overall mean		3.22		3.37		3.11		2.68

Note. SV = scientific value; EV = educational potential; TV = tourism potential; and DR = degradation risk. Criterion codes and names are presented in Table 2, while the general interpretation of the 0–4 scoring scale is provided in Table 3. Criterion-level scores were initially assigned independently by both assessors using field observations, photographs,

thematic maps, documentary and scientific sources, and questionnaire data where applicable. Differences were reviewed against the available evidence and resolved through consensus. TV6 scores were derived directly from the valid questionnaire-response percentages reported in Table 8. Dimension means were calculated from the original criterion-level scores and rounded to one decimal place. Overall means were calculated from the unrounded dimension scores and are reported to two decimal places.



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