Original Article

e-ISSN: 2581-0545 - https://journal.itera.ac.id/index.php/jsat/

Received 19th March 2025
Accepted 28th April 2026
Published 30th June 2026

Open Access

DOI: 10.35472/jsat.v10i1.2179

Exploring the Geosites of Ngalau Basurek, Ngalau Talago, and Batang Taye Waterfall: A Comprehensive Assessment of Silokek's Geotourism Potential in Sijunjung, West Sumatra

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Abstract: The Silokek Geopark in West Sumatra, known for its rich geodiversity, includes key geosites such as Ngalau Basurek, Ngalau Talago, and Batang Taye Waterfall. A comprehensive reassessment of these geosites was conducted using the Kubalíková geosite assessment method, which evaluates scientific value, educational significance, economic potential, conservation priorities, and added cultural and aesthetic values. Ngalau Basurek received a high feasibility score of 70.8%, while Ngalau Talago and Batang Taye Waterfall scored 68.8% and 66.3%, respectively, indicating strong geotourism potential despite limitations in access. All three geosites suffer from limited public transportation, requiring private vehicles or motorcycles, which restricts accessibility. Nevertheless, they demonstrate high educational use, moderate economic prospects, and are supported by legislative conservation measures. These findings offer a solid basis for sustainable geosite management and can guide the Silokek Geopark Management Authority in enhancing accessibility, infrastructure, education, and conservation practices to improve visitor experience and long-term preservation.

Keywords: *Silokek Geopark, geosites, Kubalíková method, Ngalau Basurek, Ngalau Talago, Batang Taye Waterfall*

Introduction

A geopark is a sustainable management approach that combines the conservation of geological aspects, biodiversity, and cultural diversity with the principles of regional spatial planning [1]. It is a geographic region that features exceptional geological heritage sites, incorporated into a comprehensive framework for conservation, educational sectors, and sustainable development [2][3].

Assessing geological diversity (geodiversity) is a crucial step in evaluating a region's potential as a geopark candidate. Geodiversity encompasses the presence of varied Earth materials, landforms, and geological processes that shape the planet, either at a broad scale or within a specific area of interest [4]. According to Presidential Regulation No. 9 of 2019 of the Republic of Indonesia, geodiversity is defined as the unique representation of many components in geology such as rocks, minerals, geological structures, fossils and landforms, which constitute the intrinsic wealth of a region. These elements collectively illustrate the geological evolution of an area, forming an essential part of its geoheritage[5].

The Silokek region in West Sumatra is recognized for its exceptional geodiversity, characterized by ancient rock formations and unique geological features [6], [7]. Conducting a comprehensive reassessment of the Silokek Geopark and its geosites is imperative to ensure its development aligns with internationally recognized

standards. Such an approach would not only facilitate the geopark's sustainable growth but also enhance its global competitiveness while maximizing the region's geotourism and conservation potential.

Conducting this study offers significant benefits by providing a scientific basis for informed decision-making in geopark management and planning. By thoroughly reassessing the Silokek Geopark's geosites, stakeholders can identify key areas of geological, ecological, and cultural importance that require prioritization for conservation and sustainable use. This not only strengthens the region's nomination or revalidation for global geopark status but also enhances community engagement through educational outreach and local empowerment. Ultimately, the study contributes to increasing public awareness of geoheritage, promoting sustainable geotourism, and supporting the socio-economic development of local communities in harmony with environmental preservation.

Study Area

Silokek Geopark, one of Indonesia's officially recognized geoparks, derives its name from the Nagari (village) of Silokek. Situated on the fringes of a forest, this geopark possesses significant tourism potential due to its rich natural and cultural heritage [6], [7]. On November 30, 2018, Silokek Geopark was officially designated as a National Geopark [7].

Located in Sijunjung Regency, West Sumatra, this geopark not only holds historical significance but also features a remarkable diversity of geological attributes. Among its most notable geosites are Ngalau Basurek, Ngalau Talago, and Batang Taye Waterfall, which have been the subject of geological research (**Figure 1**).

Ngalau Basurek and Ngalau Talago, two prominent caves in Silokek, Sijunjung, West Sumatra, are named after their distinct geological features, with *Basurek* referring to historical inscriptions and *Talago* indicating the presence of a pond[6]. Their entrances measure approximately 9 × 7 meters and 10 × 8 meters, respectively. Meanwhile, the waterfalls of Silokek Geopark, including Sangkiamo, Kajai, Batang Taye, and Palukahan, enhance the quantity and quality of region's geodiversity. Formed through erosion and faulting, these waterfalls create striking vertical drops in the mountainous landscape, surrounded by dense tropical forests that support rich biodiversity [6].

Figure 1. Geosite locations of the study area: a) Ngalau Basurek; b) Ngalau Talago; c) Batang Taye Waterfall. (Google Satellite)

Based on the regional geological map of the Solok Sheet [8], the study area comprises four formations: three Pre-Tertiary formations and one Tertiary formation. Arranged from oldest to youngest, these include the Limestone Member of the Kuantan Formation, the Shale and also Phyllite Member of the Kuantan Formation, Granite, and the Lower Member of the Ombilin Formation (Tertiary) (**Figure 2**).

Geologically, Silokek is significant as it records three geological eras. The oldest rocks, dating to the Paleozoic Era (Permian and Carboniferous periods), are depicted by the Kuantan Formation, some parts from the formations have gone through metamorphism. The presented limestone suggests a shallow tropical marine environment in the past. In the Mesozoic Era, granitic intrusions formed large batholiths that penetrated the Kuantan Formation during the Triassic and Jurassic periods, leading to contact metamorphism and potential mineralization along fractures and dissolution cavities. The youngest rocks, from the Cenozoic Era, belong to the Ombilin Formation, consisting of Tertiary sedimentary deposits rich in coal [7][9](**Figure 3**).

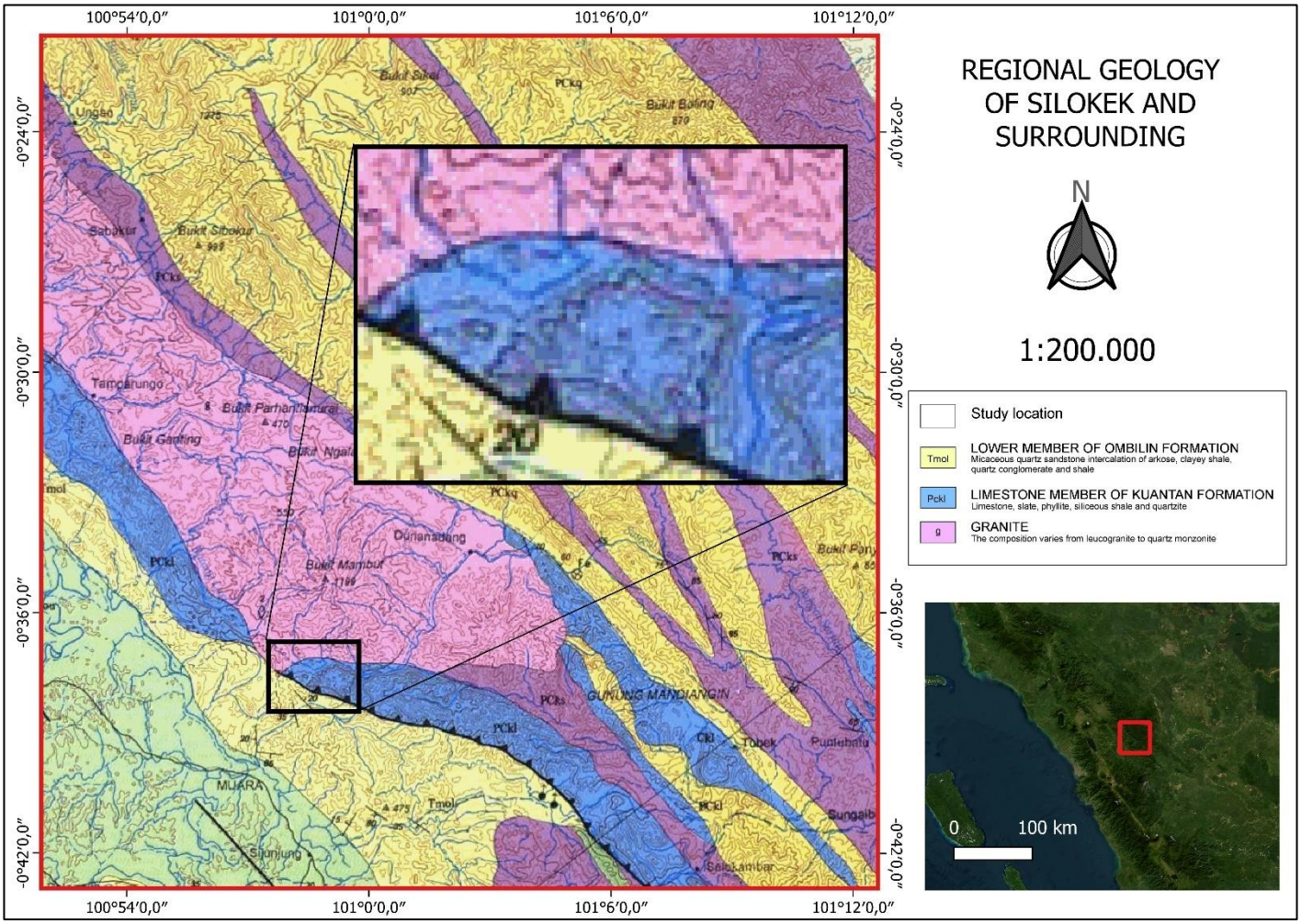

Figure 2. Geology Regional Map of Silokek [8]

Method

Data Analysis

This research adopts the geosite assessment method proposed by Kubalíková [10] due to its comprehensive nature, which evaluates various aspects, including educational significance, risk factors, economic potential, and cultural value. This method is particularly suitable for assessing the feasibility of geosites, as it provides a detailed framework for determining their role in education and scientific advancement. Key evaluation criteria include representativeness, exemplarity, pedagogical utility, educational resources, diversity, and scientific relevance (**Table 1**).

The assessment process integrates two primary approaches: a literature review and field surveys. The literature review aims to analyze regional geology and the characteristics of formations within the study area. Additionally, it aids in identifying the detailed geological attributes of the geosites, contributing to scientific understanding, particularly in reconstructing geological history. This phase is crucial for evaluating diversity, scientific significance, representativeness, and exemplarity.

Meanwhile, field surveys are conducted to assess various parameters, including site integrity, rarity of the similar sites, educational materials that still exist, accessibility, tourism

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infrastructure, local products, current and potential risks, as well as cultural, ecological, and aesthetic values. However, certain aspects, such as exemplarity, representativeness, and aesthetic appeal, involve subjective judgment. To enhance objectivity, the study provides a detailed rationale for each assessment decision, ensuring transparency in the evaluation process.

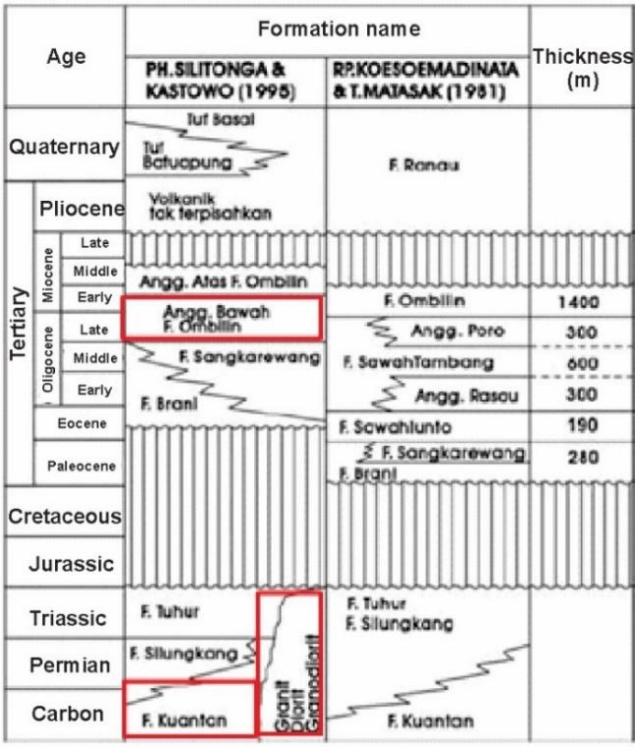

Figure 3. Regional stratigraphy of studied area

Table 1. Kubalikova's [10] assessment aspect, criteria and score

Scientific and intrinsic values	
Integrity	0 - totally destroyed site, 0.5 - disturbed site, but with visible abiotic features, 1 - site without any destruction
Rarity (number of similar sites)	0 - more than 5 sites, 0.5 - 2-5 similar sites, 1 - the only site within the area of interest
Diversity (number of different partial features and processes within the geosite or geomorphosite)	0 - only one visible feature/processes, 0.5 - 2-4 visible features/processes, 1 - more than 5 visible features/processes
Scientific knowledge	0 - unknown site, 0.5 - scientific papers on national level, 1 - high knowledge of the site, monographic studies about the site
Educational values	
Representativeness and visibility/clarity of the features/ processes	0 - low representativeness/clarity of the form and process, 0.5 - medium representativeness, especially for scientists, 1 - high representativeness of the form and process, also for the laic public
Exemplarity, pedagogical use	0 - very low exemplarity and pedagogical use of the form and process, 0.5 - existing exemplarity, but with limited pedagogical use, 1 - high exemplarity and high potential for pedagogical use, geodidactics and geotourism
Existing educational products	0 - no products, 0.5 - leaflets, maps, web pages, 1 - info panel, information at the site
Actual use of a site for educational purposes (excursions, guided tours)	0 - no educative use of the site, 0.5 - site as a part of specialized excursions (students), 1 - guided tours for public
Economical values	
Accessibility	0 - more than 1000 m from the parking place, 0.5 - less than 1000 m from the parking place, 1 - more than 1000 m from the stop of public transport
Presence of tourist infrastructure	0 - more than 10 km from the site existing tourist facilities, 0.5 - 5 – 10 km tourist facilities, 1 - less than 5 km tourist facilities
Local products	0 - no local products related to a site, 0.5 - some products, 1 - emblematic site for some local products
Conservation values	
Actual threats and risks	0 - high both natural and anthrophic risks, 0.5 - existing risks that can disturb the site, 1 - low risks and almost no threats
Potential threats and risks	0 - high both natural and anthrophic risks, 0.5 - existing risks that can disturb the site, 1 - low risks and almost no threats
Current status of a site	0 - continuing destruction of the site,

	0.5 - the site destroyed, but now with management measures for avoid the destruction, 1 - no destruction
Legislative protection	0 - no legislative protection, 0.5 - existing proposal for legislative protection, 1 - existing legislative protection (Natural monument, Natural reservation…)
	Added values
Cultural values: presence of Historical/archaeological/ religious aspects related to the site	0 - no cultural features, 0.5 - existing cultural features but without strong relation to abiotic features, 1 - existing cultural features with the strong relations to abiotic features
Ecological values	0 - not important, 0.5 - existing influence but not so important, 1 - important influence of the geomorphologic feature on the ecologic feature
Aesthetic values: number of colours; structure of the space, viewpoints	0 - one color, 0.25 - 2-3 colors, 0.5 - more than 3 colors; 0 - only one pattern, 0.25 - two or three patterns clearly distinguishable, 0.5 - more than 3 patterns; 0 - none, 0.25 - 1-2, 0.5 - 3 and more

Results And Discussion

Geosite Assessment

The feasibility as a geosite was evaluated using the geosite assessment framework proposed by Kubalíková [10]. This assessment is structured into five key categories: scientific and intrinsic values, educational significance, economic potential, conservation priorities, and additional values. Each category provides a comprehensive evaluation of the site's geological importance, educational utility, economic viability, preservation needs, and its broader contributions to tourism and cultural heritage.

Scientific and Intrinsic Values

Table 2 outlines four critical assessment aspects: object integrity, rarity, diversity of geosites, and scientific knowledge. Integrity evaluates the completeness and preservation of the geosite, ensuring its structural and geological wholeness. Rarity measures the site's exclusivity, determining its uniqueness within a broader geological framework. Geological diversity assesses the site's contribution to geodiversity, considering the variety of rock types, formations, and geological processes present. Lastly, scientific knowledge examines the extent to which the geosite enhances geological understanding, serving as a valuable resource for research and education.

Table 2. Scientific and intrinsic assessment result.

Scientific and Intrinsic values	Ngalau Basurek	Ngalau Talago	Batang Taye Waterfall
	Score		
Integrity	0.5	0.5	0.5
Rarity (number of similar sites)	0	0	0.5
Diversity (number of different partial features and processes within the geosite or geomorphosite)	1	1	0.5
Scientific knowledge	0.5	0.5	0.5

The scientific and intrinsic value assessment of Ngalau Basurek, Ngalau Talago, and Batang Taye Waterfall resulted in a total score of 2 out of 4. Integrity scored 0.5/1 due to vandalism, such as graffiti on cave walls and littering, which threaten site preservation. Rarity scored 0/1 for the caves and 0.5/1 for the waterfall, as while karst landscapes are common, distinct geological features and attractions like rafting and rock climbing enhance tourism appeal that we can see in **Figure 4**.

Geological diversity is highlighted by karst ornaments in the caves, including stalactites, stalagmites, flowstones, and veins, with lithology dominated by crystalline limestone and metamorphosed marble (**Figure 4**). The waterfall features granitic lithology, with normal faulting contributing to its formation, aligning with fault analysis [11]. Publication scores remain low, it scored 0.5 /1, as

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research on these sites is limited to a few national-level scientific papers.

Figure 4. a) Vandalism on the cave walls; b) Rafting, one of the offered attractions; c) Cave formations, including stalactites, stalagmites, and flowstone.

Educational Significance

Table 3 presents four key educational assessment aspects: representativeness and visibility, pedagogical use, educational products, and actual use for education. Representativeness evaluates the site's accessibility and appeal to the general public. Pedagogical use and exemplarity assess its suitability as an educational resource, particularly for geological studies. The educational product aspect examines the availability of learning materials that provide geological insights. Lastly, actual use for education determines whether the site is actively utilized as a learning tool, measuring its effectiveness in supporting educational activities.

Table 3. Educational assessment result.

Educational values	Ngalau Basurek	Ngalau Talago	Batang Taye Waterfall
	Score		
Representativeness and visibility	0.5	0.5	0.5
Exemplarity, pedagogical use	1	1	0.5
Educational Product	0.5	0.5	0.5
Actual use of a site for educational purposes	1	1	1

The educational assessment of Ngalau Basurek, Ngalau Talago, and Batang Taye Waterfall considers four key parameters: geological feature clarity, pedagogical value, informational signage, and site utilization (**Figure 5**). The clarity of geological features scored 0.5/1, as publications on these sites exist at the national level but lack comprehensive geological explanations for the general public. Pedagogically, Ngalau Basurek and Ngalau Talago received full scores (1/1) due to established educational activities, while Batang Taye Waterfall scored 0.5/1 due to limited educational materials. Informational signage was rated 0.5/1 across all sites, with interpretive boards and directional signs available, supplemented by Google Maps listings. Site utilization scored 1/1, as these locations attract visitors across various educational levels. In total, Ngalau Basurek and Ngalau Talago achieved a score of 3/4, while Batang Taye Waterfall scored 2.5/4, highlighting its potential for further educational development.

Figure 5. a) Information board for Silokek Geopark; b) Educational activities at Ngalau Basurek.

Economic Potential

Table 4 outlines three key aspects: accessibility, tourist infrastructure, and educational products. Accessibility is a crucial factor in determining the ease of reaching the site, directly influencing visitor interest and engagement. Tourist infrastructure is equally significant, as the site's designation as a geosite necessitates adequate facilities to accommodate increasing visitor numbers. Additionally, the educational product and its actual use are assessed to evaluate the site's potential for scientific learning and public education. Furthermore, the local product aspect is examined to identify opportunities for economic benefits, ensuring sustainable development through geotourism.

Table 4. Economic value assessment result.

Economic value	Ngalau Basurek	Ngalau Talago	Batang Taye Waterfall
	Score		
Accessibility	0.5	0.5	0.5
Tourist Infrastructure	1	1	1
Local Product	0.5	0.5	0.5

The economic value assessment of Ngalau Basurek, Ngalau Talago, and Batang Taye Waterfall resulted in a total score of 2 out of 3. Accessibility received 0.5/1, as the geosites are located 15 km from public transportation, making access difficult for visitors without private vehicles. Tourist infrastructure scored 1/1, with well-established facilities such as prayer rooms, toilets, gazebos, trash bins, and photo spots (**Figure 6**) The local product aspect scored 0.5/1, as economic opportunities exist but remain underdeveloped. Locally produced items, including Gaharu tea, traditional headbands, and coconut shell crafts, offer potential for boosting community income through geotourism.

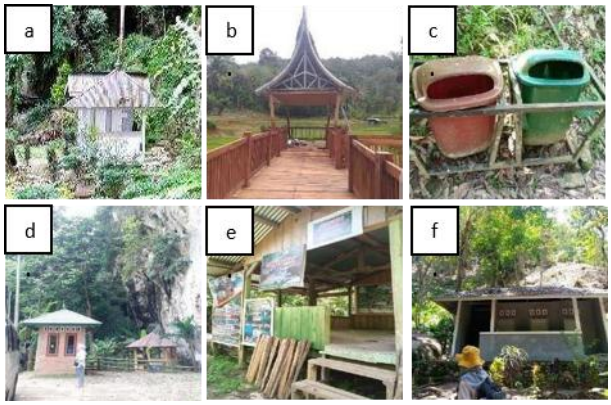

Figure 6. Several infrastructures available include: a) mosque; b) photo spot; c) trash bin; d) security post; e) gazebo; (f) toilet.

Conservation Priorities

Table 5 presents four critical aspects: actual risks and threats, potential risks and threats, current site status, and legislative protection. Assessing actual and potential risks is essential to evaluate the site's vulnerability and guide appropriate conservation measures. The current status of the site provides insight into its existing condition and ongoing preservation efforts. Additionally, the legislative protection aspect examines the extent of government regulations and policies in safeguarding the site, ensuring its long-term sustainability and protection.

Table 5. Conservation value assessment result.

Conservation Values	Ngalau Basurek	Ngalau Talago	Batang Taye Waterfall
	Score		
Actual risk and threat	0.5	0.5	0.5
Potential risk and threat	0.5	0.5	0.5
Current Status of the site	0.5	0.5	0.5
Legislative Protection	1	1	1

The assessment of conservation values for Ngalau Basurek, Ngalau Talago, and Batang Taye Waterfall reveals significant risks and protective measures. Actual risks include slippery cave floors due to underground rivers in Ngalau Basurek, steep 70° slopes at Ngalau Talago, and fallen trees obstructing paths to Batang Taye Waterfall (**Figure 7**). Potential risks involve flash floods in Ngalau Basurek and Batang Taye Waterfall during heavy rainfall, as well as landslides at Ngalau Talago due to steep terrain. These hazards necessitate strict safety protocols and continuous monitoring by site managers.

Figure 7. a) Actual risk of fallen trees at Batang Taye Waterfall; b) Potential risk of landslides due to the steep cliffs.

The site status receives a score of 0.5 out of 1, indicating ongoing conservation efforts but highlighting issues such as illegal mining, vandalism, and waste accumulation. However, management initiatives are in place to mitigate these threats. In terms of legislative protection, the geosites benefit from comprehensive legal frameworks, including Presidential Regulation No. 9/2019, Regional Regulation No. 10/2019, and Sijunjung Regency Regulation No. 5/2012, ensuring their preservation. Consequently, all three sites achieve a conservation score of 2.5 out of 4, reflecting a structured yet improvable protection strategy.

In the case of the Silokek Geopark, the overall coordination is handled by the Geopark Silokek Management Authority, under the supervision of the Sijunjung Regency Government, in collaboration with the Kelompok Sadar Wisata (Pokdarwis) of Silokek Village. The geosites are located within government-managed land, with certain areas adjacent to

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community lands, requiring coordinated stewardship. Site-specific management, including safety monitoring, maintenance, and education programs, is overseen by local Pokdarwis teams. These community-based groups play a vital role in operational tasks but often face limitations in capacity and funding.

Additional Values

The evaluation encompasses three key aspects: cultural values, ecological values, and aesthetic value, which includes elements such as color, spatial structure, and viewpoint as what we see on **Table 6**.

Table 6. Added values assessment result.

Added values	Ngalau Basurek	Ngalau Talago	Batang Taye Waterfall
	Score		
Cultural values	1	0,5	0,5
Ecology values	1	1	1
Aesthetic values: Color	1	1	1
Space Structure	1	1	1
Viewpoint	1	1	1

The cultural value of Silokek is reflected in traditional arts such as Tari Mandulang Ameh, Randai, and historical inscriptions in Ngalau Basurek (**Figure 8**). Based on these aspects, Ngalau Basurek scores 4, while Ngalau Talago and Batang Taye Waterfall score 2 out of 4. In terms of ecology, all three geosites achieve the highest score (4) due to their geomorphic influence on the surrounding environment, with diverse flora such as single-leaved plants and fauna like spiders, millipedes, chameleons, and sipungguak (**Figure 8**). Batang Taye Waterfall is also characterized by distinctive vegetation, including ferns, jengkol, and teak trees.

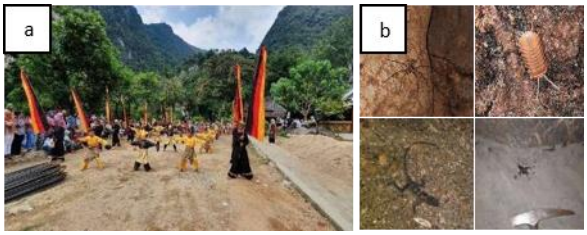

Figure 8. a) Tari Mandulang Ameh; b) Various fauna found around Ngalau Basurek and Ngalau Talago.

For aesthetic value, the geosites showcase a natural color palette dominated by green from vegetation, brown from soil, and gray-black from rocks, complemented by yellow and orange hues from built infrastructure. Each site also earns the highest score (4) in spatial structure and viewpoint due to their well-defined landscapes. Ngalau Basurek features karst cliffs, underground rivers, and resting areas, while Batang Taye Waterfall presents waterfalls and forested surroundings. Ngalau Talago is distinguished by karst formations and caves with intricate ornaments.

Combining scientific, educational, economic, and conservation values with cultural, ecological, and aesthetic considerations, the overall feasibility scores indicate Ngalau Basurek as the most viable site (70.8%), followed by Ngalau Talago (68.8%) and Batang Taye Waterfall (66.3%) (**Table 7**).

Table 7. Accumulated assessment based on Kubalikova [10].

Number	Geosite	Percentage (%)					Feasibility (%)
		1	2	3	4	5	
1	Ngalau Basurek	10	15	13,3	12,5	20	70,8%
2	Ngalau Talago	10	15	13,3	12,5	18	68,8%
3	Batang Taye Waterfall	10	12,5	13,3	12,5	18	66,3 %

Development Suggestion

Based on the assessment conducted, several recommendations have been formulated to optimize the potential of the geosites. In terms of scientific and intrinsic value, the geosites that particularly those exhibiting Paleozoic to Cenozoic stratigraphy, active fault structures, and karst morphology holds great potential for geological research, including studies on regional tectonics, paleoenvironments, and hydrogeological systems. To support this, collaborative research should be encouraged with national and international universities, promoting the publication of findings in indexed journals. Scientific infrastructure, such as on-site sample points or QR-coded panels linking to open-access databases, can boost academic interest and accessibility [12], [13].

From an educational perspective, the development of field-based teaching modules, digital resources, and interpretive signage aligned with geodidactic best practices is necessary to increase the pedagogical value of each geosite. Case studies from established geoparks like Langkawi UNESCO Global Geopark (Malaysia) and the English Riviera Geopark (UK) show that integrating

storytelling, guided experiences, and digital platforms (e.g., AR/VR apps) significantly enhances learning outcomes and visitor engagement [14].

To support economic potential and ensure sustainable development, future efforts should prioritize improving accessibility and basic infrastructure across all geosites. The upgrades are required to meet national service standards (SNI) [15]. While tourist facilities like gazebos, toilets, and security posts are available, the road conditions and signage leading to more remote locations, especially Batang Taye Waterfall, require upgrades to accommodate a wider range of visitors. Enhanced security measures, including monitoring systems and first-aid stations, would increase visitor confidence and safety. In addition, promoting local handicrafts and traditional products through designated marketplaces near the geosites could foster economic engagement with local communities, increasing their stake in conservation efforts. These developments should be implemented with strict adherence to environmental and conservation guidelines to preserve the natural and geological integrity of the sites.

Conclusions

Based on the assessment using the Kubalikova method, Ngalau Basurek achieved an assesment score of 70.8%. This geosite attracts more visitors due to its easy accessibility, strategic location near the main road, comprehensive security facilities, and fulfillment of various other criteria. In contrast, Ngalau Talago received an assesment score of 68.8%. This lower score reflects the challenging access to the site, which is located far from the main road, and the inadequate facilities available at the location. Batang Taye Waterfall, with an assessment score of 66.3%, also boasts significant appeal. However, its accessibility is limited as the site can only be reached by motorcycle.

In conclusion, optimizing the potential of the Silokek geosites requires a multifaceted approach that integrates scientific research, educational enrichment, economic development, and conservation management. Strengthening collaborations with academic institutions and promoting the publication of geological findings at national and international levels will enhance the scientific value of these sites. Simultaneously, developing digital platforms, educational materials, and interpretive media can improve public engagement and awareness. Infrastructure improvements particularly road access, signage, and safety measures are essential for increasing visitor accessibility, especially to remote areas like Batang Taye Waterfall. Supporting local economic activities through the promotion of traditional products and crafts near geosites will foster community involvement and sustainable geotourism. These efforts must be implemented alongside strict conservation practices to ensure the long-term preservation of the region's geological and ecological heritage.

Conflicts of interest

There are no conflicts to declare.

Acknowledgements

We would like to extend our heartfelt thanks to the management team of Geopark Silokek, the Kelompok Sadar Wisata Desa Silokek, the village authorities, and the local community for their invaluable support during this research. Their help and collaboration have been crucial to the success of this study, and we are truly grateful for their contributions.

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