



## **INTEGRATING SPATIAL MAPPING AND SOCIO-CULTURAL DYNAMICS FOR SUSTAINABLE ECOTOURISM MANAGEMENT AT GOA ERGENDANG: A GEO-ANTHROPOLOGICAL STUDY IN DELI SERDANG REGENCY**

### **AUTHORS INFO**

Mita Nalsalisa Br Barus  
Student at Geography Education  
State University of Medan  
[mitabarus88@gmail.com](mailto:mitabarus88@gmail.com)

Vadillah Raihto Hutasuhut  
Student at Geography Education  
State University of Medan  
[vadillahraihto@gmail.com](mailto:vadillahraihto@gmail.com)

Muhammad Najmul Fahmi  
Student at Geography Education  
State University of Medan  
[muhhammadnajmulfahmi@gmail.com](mailto:muhhammadnajmulfahmi@gmail.com)

Angelo Arevalo Simanullang  
Student at Geography Education  
State University of Medan  
[arevalosimanullang10@gmail.com](mailto:arevalosimanullang10@gmail.com)

Annisa Oktavita  
Student at Antropologic Education  
State University of Medan  
[annisaoktavira@gmail.com](mailto:annisaoktavira@gmail.com)

M Faoug Ghazali Matondang  
Lecturer at Geography Education Departement  
State University of Medan  
[farouqmatondang@unimed.ac.id](mailto:farouqmatondang@unimed.ac.id)

### **ARTICLE INFO**

ISSN: 2716-4837  
Vol. 7, No. 2, December 2025  
URL: <http://usnsj.id/index.php/geographica>

### ***Suggestion for the Citation and Bibliography***

#### *Citation in Text:*

*Barus, M. N. Br. et al (2025)*

*Bibliography:* Barus, M. N. Br., Hutasuhut, V. R., Fahmi, M. N., Simanullang, A. A., Oktavita, A., & Matondang, M. F. G. (2025). Integrating Spatial Mapping and Socio-cultural Dynamics for Sustainable Ecotourism Management at Goa Ergendang: a Geo-Anthropological Study in Deli Serdang Regency. *Geographica: Science & Education Journal*, 7 (2, December), 103-115.

### **Abstract**

*Goa Ergendang, a unique geo-cultural site in Deli Serdang, Indonesia, possesses significant ecotourism potential, including natural hot springs, stalactites, and rich local folklore (the Umang mythos). However, its development is severely hindered by informal community self-management, poor infrastructure, and a critical lack of spatial information for visitors. This research aims to (1) identify the fundamental challenges in its sustainable management and (2) formulate an integrated management model based on a geo-anthropological approach. This study employed a mixed-method design, integrating quantitative spatial analysis (GIS) with qualitative socio-cultural analysis. Methods included GIS mapping for accessibility, topography, and potential zoning, combined with in-depth interviews with local managers,*

*stakeholders, and visitors. The findings reveal four primary challenges: (1) weak institutional capacity due to informal management, leading to resource limitations and poor heritage protection (e.g., the destruction of the "sacred drum stone"); (2) severe infrastructural barriers, particularly damaged access roads; (3) a critical spatial information gap, evidenced by 16 hidden pools remaining unknown to visitors due to a lack of maps; and (4) high physical vulnerability from steep topography and corrosive acidic water. This research proposes a sustainable management model based on Community-Based Ecotourism (CBT) supported by GIS planning. In this model, GIS functions as the objective physical planning tool for conservation zoning and visitor navigation, while a formalized community institution (e.g., BUMDes/Village-Owned Enterprise) acts as the socio-cultural manager, responsible for revitalizing local culture (Ergendang and Umang myths) as a core attraction. This integrated geo-anthropological model provides a clear pathway to optimize the area's unique potential sustainably.*

**Keywords:** Geo-Anthropology, Spatial Planning, GIS, Community-Based Ecotourism, Sustainable Management, Goa Ergendang

## A. Introduction

North Sumatra, a province in Indonesia, is known for its extraordinary natural, cultural, and historical diversity. This province has potential for rapid development. Its strategic location on the island of Sumatra, coupled with its diverse geography, makes North Sumatra a unique tourist destination. From towering mountains and serene lakes to captivating beaches, even to caves filled with mystery and natural wonders, North Sumatra is also rich in ethnic cultures such as the Batak, Malay, and Nias, further enriching the tourist experience in this region (Siregar, 2020). One of the regencies in North Sumatra with significant tourism potential is Deli Serdang Regency. This regency is renowned for its rich natural resources and biodiversity.

Deli Serdang Regency boasts a varied topography, abundant natural resources, and natural attractions of high ecological and geological value. This area is renowned for its biodiversity, which includes tropical rainforests, wetlands, and a variety of rare flora and fauna. The geographic location of a place determines its accessibility to natural resources, trade, and interaction with other communities (Triyatno, W., & Sari, Y. I, 2024). According to data from the Central Statistics Agency of North Sumatra Province, in 2023, Deli Serdang Regency had an area of approximately 2,497 km<sup>2</sup> with a population of 1,931,441. This figure demonstrates the importance of managing tourist areas that consider not only ecological aspects but also the welfare of the local community. One unique tourist attraction in this area is Ergendang Cave, located in Penungkiren, Sinembah District, Tanjung Muda Hilir. This cave offers great potential for scientific research and geotourism. With various stalactite and stalagmite formations formed over thousands of years, Ergendang Cave provides in-depth insights into the geological processes in the area and the ecosystems that develop in and around the cave. According to preliminary surveys conducted by the local tourism office, Ergendang Cave is approximately 1.2 km long and boasts biodiversity that includes various species of bats, cavefish, and endemic flora.

Regulation of the Minister of Tourism and Creative Economy Number 9 of 2021 concerning Guidelines for Sustainable Tourism Destinations establishes comprehensive guidelines for managing sustainable tourism destinations (Kementerian Pariwisata dan Ekonomi Kreatif, 2021). The regulation encompasses three main aspects: ecological sustainability, social responsibility, and economic viability. These guidelines ensure that tourism destination management considers both community welfare and environmental preservation for long-term sustainability.

This study proposes the integration of spatial mapping and socio-cultural dynamics as an optimal approach to the sustainable management of the Ergendang Cave ecotourism area. This approach allows for a comprehensive understanding of the interactions between nature, society, and tourism management. Furthermore, this integration also has the potential to increase local community participation in tourism management, thereby creating positive social and economic impacts for the local community. Ergendang Cave is unique, with various stalactite and stalagmite formations formed naturally over thousands of years. The existence of this cave can provide in-depth insight into the geological processes that occur in the area as well as the potential ecosystems that develop in and around the cave.

## **B. Methodology**

### *1. Research Design*

This study employed a mixed-method design integrating quantitative and qualitative approaches within a geo-anthropological framework, structured as an intrinsic case study focused on the Goa Ergendang Ecotourism Area. The research followed a systematic, sequential procedure beginning with a preparation phase (comprehensive literature review, secondary data collection, and instrument development), followed by two parallel data collection phases of spatial mapping (quantitative) and socio-cultural study (qualitative), and concluding with integrated analysis and formulation of sustainable management recommendations. This design was specifically structured to address three research objectives: (1) to analyze the spatial characteristics and accessibility of Goa Ergendang through Geographic Information System (GIS) mapping, (2) to investigate socio-cultural dynamics and local community perspectives through qualitative ethnographic methods, and (3) to integrate spatial and socio-cultural findings to develop a sustainable ecotourism management strategy, thereby enabling a comprehensive understanding of how geographic factors, community values, and tourism practices intersect to shape sustainable development pathways.

### *2. Instruments*

Data was collected using three categories of instruments:

- a) **Spatial (Geographic) Instruments:** The primary instruments for spatial data collection were handheld GPS (Global Positioning System) receivers used for field surveys to capture precise coordinates of attractions and infrastructure. Geographic Information System (GIS) software (e.g., ArcGIS 10.8) served as the main instrument for processing, analyzing, and visualizing spatial data (e.g., topography, accessibility, and land suitability).
- b) **Socio-Cultural (Qualitative) Instruments:** The primary instruments for qualitative data were semi-structured interview guides (Interview Guide) used for in-depth interviews with key informants (managers, community leaders, stakeholders) and participant observation checklists (Observation Sheet) to record social activities and management practices.
- c) **Socio-Economic (Quantitative) Instruments:** A structured questionnaire (kuesioner) was developed and distributed to visitors and members of the local community to gather descriptive statistics on visitor perceptions, awareness (e.g., of the 16 hidden pools), and socio-economic characteristics.

### *3. Technique of Data Analysis*

The data analysis technique followed an integrated triangulation procedure:

- a) **Spatial Data Analysis:** Data from GPS surveys and secondary maps were processed using spatial analysis within the GIS software. This included topographical modeling, network analysis (for accessibility maps), and overlay analysis to determine land suitability and generate thematic maps (e.t., existing potential, proposed zoning).
- b) **Qualitative Data Analysis:** Data from in-depth interviews, Focus Group Discussions (FGDs), and observations were transcribed and analyzed using content analysis and thematic analysis. This technique was used to identify recurring themes, key challenges (management, cultural degradation), and local cultural values (Umang mythos).
- c) **Quantitative Data Analysis:** Data from the questionnaires was analyzed using descriptive statistics (frequencies, percentages) to quantify visitor perceptions and demographic profiles.
- d) **Integrated Analysis:** Finally, all data streams were integrated using data triangulation to validate the findings. A SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis was also conducted, synthesizing both the spatial and socio-cultural findings to identify key potentials and constraints, which directly informed the formulation of the sustainable management strategy.

## **C. Findings and Discussion**

### *1. Findings*

This section presents the primary findings obtained from the field, which combine spatial analysis (GIS) and socio-cultural data (observations and interviews) to provide a comprehensive overview of the existing conditions of the Ergendang Cave Ecotourism area.

*a). Condition of the Ergendang Cave Area*

Deli Serdang Regency is one of the regions in North Sumatra Province with diverse natural, cultural, and historical tourism potential. This region is located between Medan City and Karo Regency, resulting in a varied landscape ranging from lowlands to hills. This rich geographic location makes Deli Serdang home to many attractive tourist destinations, including nature tourism, water tourism, and cultural tourism, reflecting the rich ethnicity and traditions of its people. Part of the area consists of fertile lowlands, while other parts consist of cool, green hills. This condition makes Deli Serdang known as one of the regencies with significant natural tourism potential in North Sumatra.

In addition to its natural beauty, Deli Serdang is also known for its rich social and cultural diversity. Its people are made up of various ethnicities, including Karo, Malay, Batak, and Javanese, who live harmoniously side by side. This diversity has given rise to various traditions, languages, and arts that are an important part of the region's identity. This contributes to Deli Serdang's appeal as a tourist destination, offering not only natural beauty but also unique and authentic cultural experiences.

One of Deli Serdang's famous natural tourist destinations is Ergendang Cave, located in Penungkiren Village, Sinembah Tanjung Muda Hilir (STM Hilir) District. This location is approximately 40-41 kilometers from Medan City, taking approximately two hours by land. This cave is known for its natural hot springs, making it a favorite spot for tourists to soak in the natural atmosphere. The beauty of the stalactites and stalagmites within the cave adds to its charm. The pristine environment surrounding Ergendang Cave is also a major draw. Surrounded by green trees and cool air, this area provides a calming natural atmosphere. Furthermore, the cave's unique shape, with stalactites and stalagmites inside, adds to the beauty of the natural panorama. Many visitors come not only to enjoy the hot springs but also to admire the beautiful natural rock formations within the cave. Overall, Ergendang Cave is a natural tourism icon that enhances the appeal of Deli Serdang Regency. Its natural beauty, serene atmosphere, and inherent cultural values make it a special destination amidst the rapid development of tourism in North Sumatra. This area reflects a harmonious blend of nature and culture, demonstrating Deli Serdang's immense potential as a distinctive and valuable tourist destination.

*b). Integration of Spatial Mapping with Socio-Cultural Dynamics Supports Sustainable Management of the Ergendang Cave Ecotourism Area.*

The Ergendang Cave area was selected based on several geographical and social aspects. Based on direct field observations and interviews with the management and visitors to the area, it was found that:

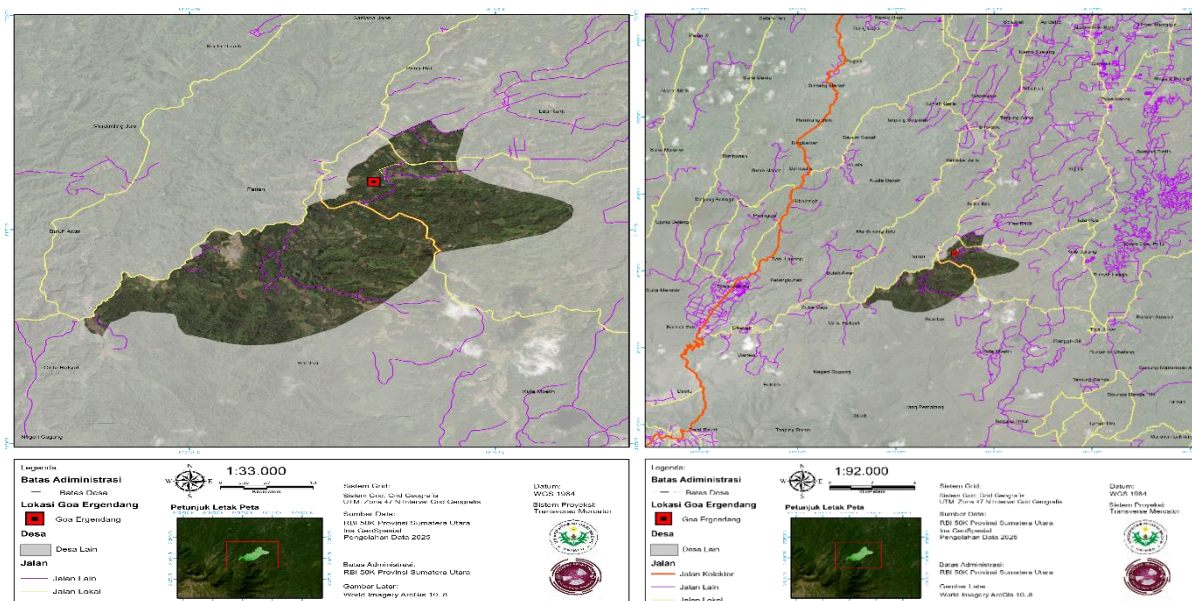
- a) Ergendang Cave is a natural cave with a hot spring pool, surrounded by rock walls with beautiful stalactites.
- b) In addition to its natural beauty, it also holds cultural values aimed at preserving the area. For example, the community believes in the existence of agricultural creatures in the form of invisible creatures called Umang (umang). Umang are believed to reside in the area and carry out their activities.
- c) The name Ergendang Cave arose from the frequent sound of ergendang, a traditional Karo dance and music tradition. This is evidenced by the presence of a drum-shaped rock that, when struck, produces a melodious sound. However, its preservation has faded and disappeared due to the stone being damaged or even broken due to frequent impact by visitors, thus eliminating evidence of its existence.
- d) Overall, Ergendang Cave is still managed independently by the local community, without any direct support or involvement from the government.
- e) The road access to Ergendang Cave is still in poor condition (if accessed from the Sibirubiru sub-district), thus posing a barrier to visitors and hindering the optimal development of the ecotourism area.
- f) Many visitors to the area are unaware of the numerous swimming pools, totaling 16, that they can enjoy. This is due to the lack of maps or other visual aids. The area is filled with caves that are naturally separated but interconnected, creating a network of hidden passages.
- g) Facilities in the area have also undergone changes. Initially, there was a children's playground, horses, and other facilities. These have now been removed.
- h) The water in Ergendang Cave is acidic and contains certain minerals, which can cause rust on metal objects around the cave. This is related to the mineral and chemical content of the natural hot water derived from the cave's geothermal source.

This occurs due to several interrelated factors. First, the management of Ergendang Cave, which is still carried out independently by the community without government support or involvement, has limited resources, including funding, technology, and management capacity, to optimally develop the area. Second, the poor condition of road access hampers the flow of tourists and the distribution of supporting facilities, making it difficult to fully develop tourism potential. Third, the lack of clear tourist information and directions is caused by minimal investment in promotional infrastructure and education for visitors, resulting in many attractive spots, such as hidden swimming pools, remaining unknown. Fourth, damage to the drum stones, a cultural symbol, occurs due to a lack of supervision and education for visitors about the importance of preserving cultural heritage, resulting in these objects often being treated without regard for long-term impacts. Finally, traditional cultural values and local beliefs have not been fully integrated into modern management systems, resulting in weak protection of socio-cultural aspects. All these factors contribute to the current situation, which demands an integrated approach between the government, communities, and other stakeholders to create sustainable and effective ecotourism management.

### c). Geographic Location and Accessibility

The Ergendang Cave Ecotourism Area is administratively located in Penungkiren Village, Sinembah Tanjung Muda Hilir District, Deli Serdang Regency, North Sumatra Province. Geographically, the research location is 40-41 kilometers from the center of Medan City, the provincial capital, equivalent to an estimated normal travel time of approximately two hours by road. This location is important because distance and travel time are crucial variables in tourist decision-making models and determine potential market segmentation.

The main determining factor in accessibility is the condition of the road network infrastructure. The results of spatial mapping of the area's connectivity are presented in the map below.



**Figure 1. Accessibility Map of the Ergendang Cave Area**  
(Source: Processed using ArcGIS 10.8 based on research)

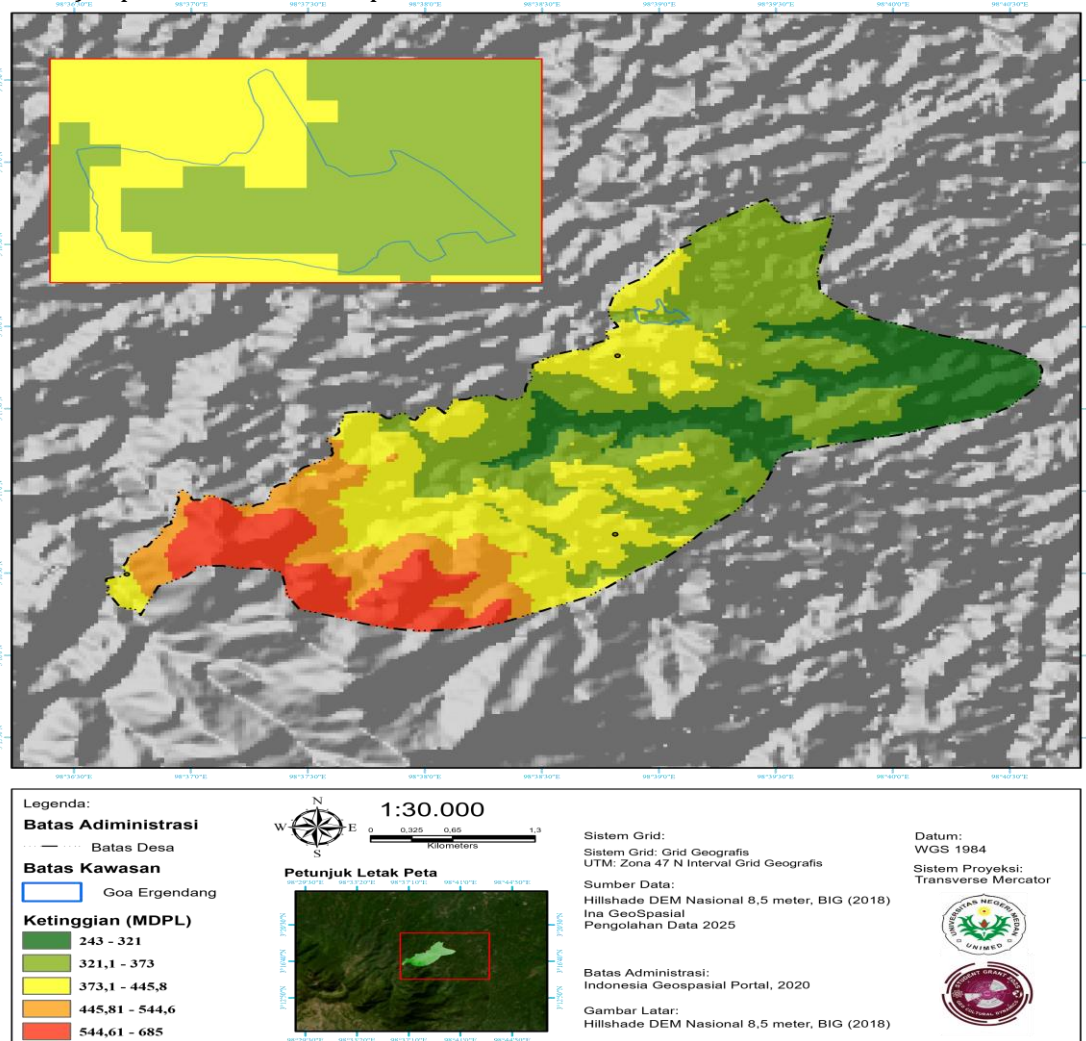
Based on the analysis of the image above, connectivity to Ergendang Cave is supported by a network of collector roads connected to local roads. This spatial finding is validated and reinforced by qualitative field findings, as identified in (finding point 'e'), which confirm that the road conditions (particularly from the Sibiru-biru District) are significantly damaged in several locations.

This inadequate infrastructure serves as a major bottleneck in the area's development. This not only directly hinders the flow of tourist visits but also complicates the logistics of facility development and indirectly impacts the low level of local government involvement, further reinforcing the area's current independent management.

### d). Topography, Geophysics, and Environmental Carrying Capacity

In addition to external factors (accessibility), the internal physical characteristics of an area are crucial data for determining environmental carrying capacity and land suitability for

ecotourism development. A topographic analysis of the area based on the National Hillshade DEM (BIG, 2018) is presented in the map.



**Figure 2.** Topographic Map of the Ergendang Cave Area  
 (Source: Processed using ArcGIS 10.8 based on research)

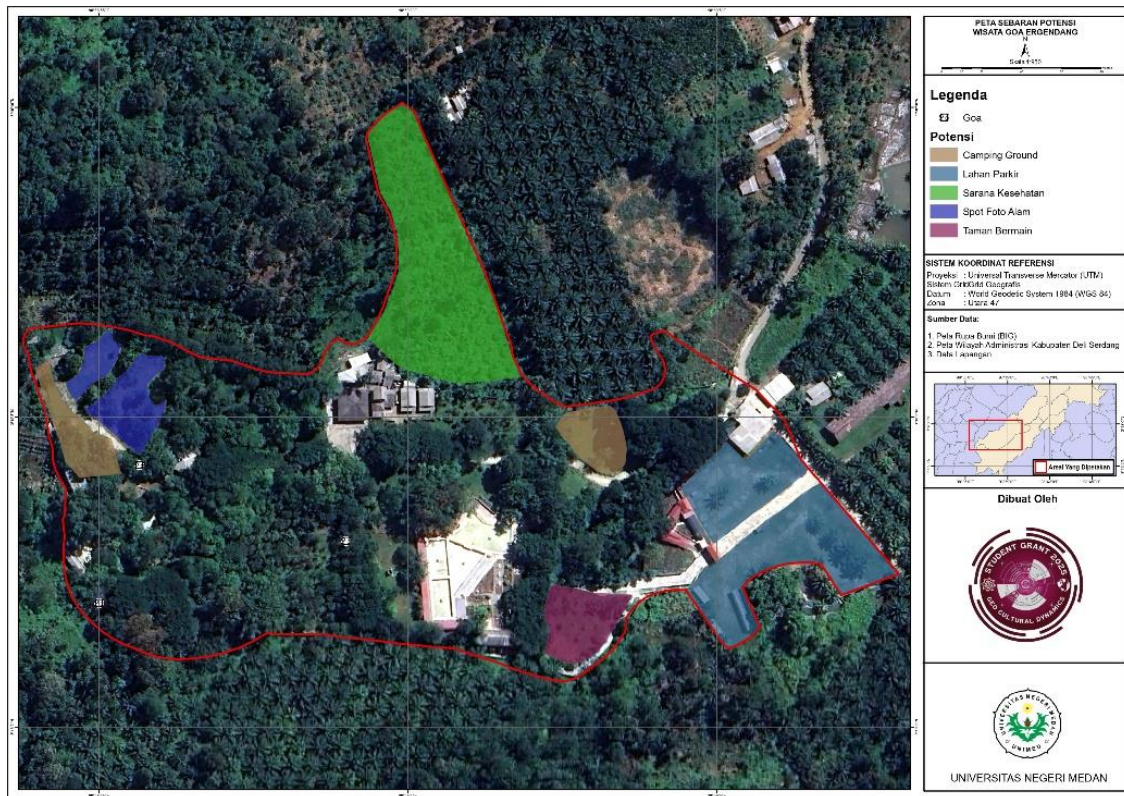
The analysis of the map above shows the varied and complex morphology of the area. This area has an elevation range of 243 meters above sea level in the valley area (the entrance zone and main bathing area) to 685 meters above sea level on the southwest ridge. The topographic gradient, dominated by orange and red colors on the map, indicates steep to very steep slopes. This steeply sloped area has a high biophysical vulnerability to hydrometeorological hazards, particularly surface erosion and potential landslides, if inappropriate land use interventions occur (for example, land clearing for facilities).

Geophysically, this area has a unique feature that is its main attraction, as identified in (finding point 'a'): a natural cave with an active hydrological system in the form of a hot spring pool and beautiful stalactite formations. This hydrological uniqueness also poses specific conservation challenges. Findings (point 'h') indicate that the water in Ergendang Cave is acidic and contains certain minerals. This is visibly evident in the corrosion (rust) phenomena on metal objects in the area, indicating the need to select special, corrosion-resistant materials for infrastructure development in wet zones.

The combination of these three physical findings steep topography (prone to erosion), corrosive water geochemistry (requiring special materials), and sensitive geological formations (stalactites) confirms that the Ergendang Cave area has specific and vulnerable bearing capacity. These physical findings serve as an imperative baseline for formulating conservation and development zoning, which will be presented in the next sub-chapter.

#### *e). Spatial Distribution of Potential and Condition of Existing Facilities*

Potential mapping was conducted to identify the distribution of existing and potential attractions and supporting facilities in the area. The mapping results are presented in.



**Figure 3.** Map of the Distribution of Ergendang Cave Tourism Potential  
(Source: Processed using ArcGIS 10.8 based on research)

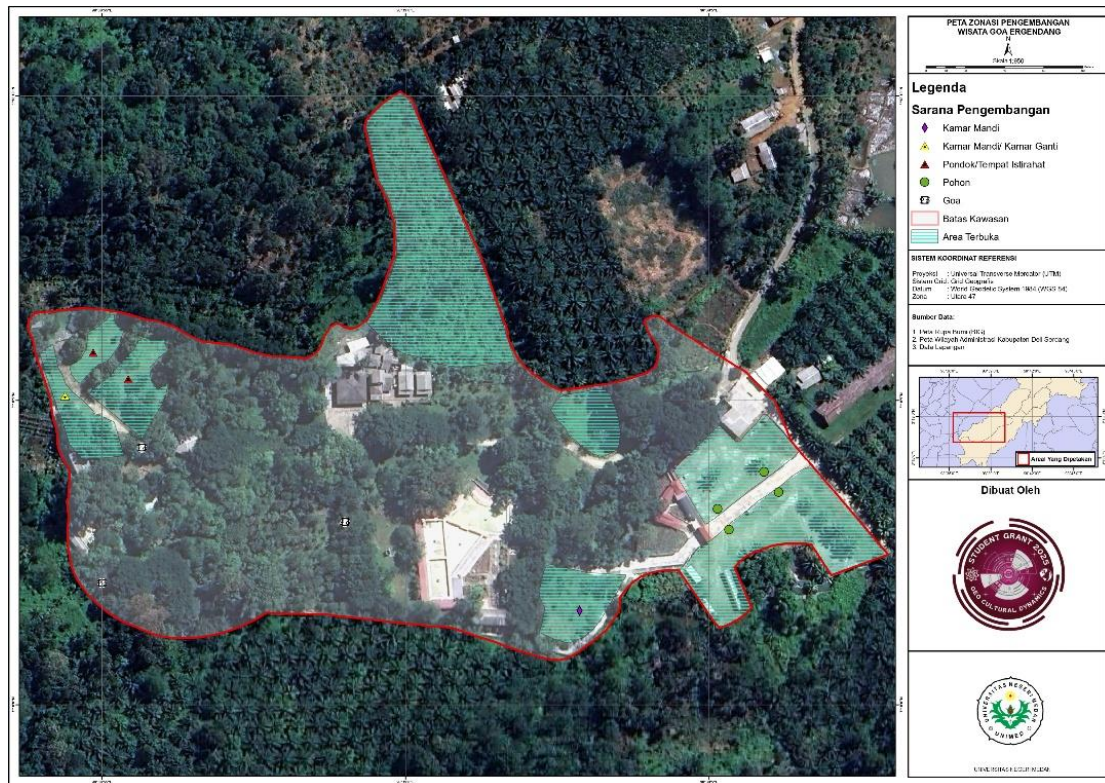
Based on the map above, several zones with specific functions have been identified. The mapped areas include basic facilities such as the Parking Lot (as the main reception area near the entrance) and Health Facilities (as a vital support area for risk mitigation), as well as attraction zones such as the Natural Photo Spot, Playground, and Camping Ground. This distribution of potential indicates that the Ergendang Cave area has the potential to be developed as a multifunctional ecotourism destination that relies not only on its primary geological attractions (caves and hot springs) but also supports other outdoor recreational attractions.

However, there is a discrepancy between the mapped potential and the actual conditions on the ground. The map above identifies a space allocated for a "Playground," but qualitative findings (point 'g') confirm that this facility (along with the horse attraction) has now been removed. This finding indicates a decline in attraction management, where areas with spatial potential have now become unmanaged land due to limited management resources.

Furthermore, qualitative findings (point 'f') identified a spatial potential far greater than that generally mapped, namely the existence of 16 separate swimming pool spots connected by a network of hidden passages. The map above (Potential Distribution) does not map these 16 spots in detail, but rather groups them generally. The fact that visitors are unaware of this potential due to the "lack of map guidance" indicates a critical gap between the spatial potential owned and the management of spatial information for visitors.

#### *f). Analysis of Area Development Zoning*

Based on an overlay analysis between the Topographic Map, which shows safe (sloping) areas, and the Potential Map, which shows the distribution of attractions, a Development Zoning Map was compiled. This map, a synthesis of research results, serves as a spatial planning guide for future facility development, as presented in.



**Figure 4.** Ergendang Cave Tourism Development Zoning Map  
(Source: Processed using ArcGIS 10.8 based on research)

The map above identifies the "Open Area" (shaded green) as the primary development zone. This zone is allocated to areas with relatively gentle topography (based on the topographic map) and good internal accessibility to key attractions. This zone is projected as the location for the development of key supporting facilities (such as information centers, food courts, and plazas) and mapped supporting facilities (bathrooms/changing rooms, rest huts).

This zoning designation is the initial step in implementing sustainable spatial management principles, clearly separating the intensive development zone (Open Area) from the conservation zone (steep and geologically sensitive areas) where development is prohibited. These spatial findings (potential, zoning, and information gaps) will form the basis for discussing the management model.

## 2. Discussion

The current situation at Ergendang Cave, encompassing its unique natural environment, strong cultural values, independent community management, inadequate access, limited visitor information, and changing facilities, are factors influencing the complexity of integrating spatial mapping with socio-cultural dynamics. These factors present both challenges and opportunities in supporting sustainable ecotourism management, including ecotourism development that integrates environmental conservation, community empowerment, and local capacity building (Guerrero-Moreno & Oliveira-Junior, 2024).

Cave tourism management faces significant challenges related to ecosystem preservation and infrastructure development. Research demonstrates that sustainable cave management requires comprehensive approaches that balance visitor experience with environmental protection (Mammola et al., 2024). The integration of Geographic Information Systems (GIS) in tourism planning has proven essential for spatial analysis and sustainable destination management, particularly in ecologically sensitive areas (Çınar et al., 2025). Furthermore, community-based ecotourism has emerged as an effective approach for integrating environmental conservation with local economic development (Torsney et al., 2025).

The application of GIS technology in ecotourism development provides concrete examples of how spatial mapping can be used effectively in natural resource management and sustainable tourism planning. GIS-based spatial analysis enables managers to identify area zoning, conservation zones, and tourism development potential that minimizes ecosystem damage (Ramaano, 2025). This technological approach allows managers to make more informed decisions based on accurate data while facilitating regular monitoring and evaluation of environmental conditions. In the context of cave ecotourism, spatial mapping integration

becomes a primary focus to support sustainable management by addressing challenges such as limited visitor information, conservation zone management, and monitoring of vulnerable natural features.

Community-based tourism initiatives have demonstrated transformative potential in fostering inclusive economic growth and empowering marginalized communities. Research by Mateen (2025) highlights that community-based tourism places local communities at the center of tourism development, aligning with sustainable development goals. This approach emphasizes active participation of local communities in natural resource management, application of conservation principles, and development of environmentally friendly facilities and infrastructure. The success of such initiatives depends heavily on effective community engagement, appropriate policy frameworks, and multi-stakeholder collaboration (Utama et al., 2024).

The development of Ergendang Cave ecotourism must be carried out in an integrated manner, taking into account natural, cultural, social, and technological aspects. The management approach should strengthen ecological resilience through natural resource conservation and environmental impact control, while simultaneously increasing community social capacity through active participation and local economic development. The integration of spatial mapping technology can support more effective monitoring and management of natural resources, in line with principles of ecological resilience. Thus, an approach that combines ecological and social aspects holistically can serve as a model for the development of sustainable ecotourism in cave environments, ensuring both environmental preservation and community welfare.

### 1) SWOT Analysis of Ergendang Cave Ecotourism Area Management

To identify the strategic position of the area and formulate appropriate management directions, a SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) was conducted integrating spatial and sociocultural findings. This analysis functions as a bridge between empirical findings and strategic recommendations for sustainable management.

#### a) Strengths:

Based on spatial mapping results and field studies, several main strengths of the area were identified. The Ergendang Cave area possesses high geological and ecological uniqueness, with stalactite and stalagmite formations naturally formed over thousands of years and an active hydrological system in the form of natural hot spring pools. Mapping results identified 16 swimming pool points connected through a network of hidden corridors, demonstrating diverse spatial potential to be developed as a multifunctional destination. Strong local cultural values are reflected in the existence of the Umang myth and Ergendang tradition, which can serve as capital for storytelling-based tourist attractions and cultural tourism. Active participation of local communities in independent management demonstrates high sense of ownership, which constitutes important social capital for community-based tourism development. Additionally, proximity to Medan City (40-41 km or approximately 2 hours travel) positions the area within the accessibility radius of a large urban tourism market.

#### b) Weaknesses

Field findings also identified critical weaknesses hindering management optimization. The absence of formal management institutions causes limitations in accessing external funding, ability to develop standard operating procedures, and legitimacy to partner with government or investors. Poor accessibility infrastructure, particularly the severely damaged road condition from Sibiru-Biru District, becomes a major obstacle hampering visitor flow and facility development logistics. Minimal spatial information systems for visitors, such as unavailability of tourism maps or directional signs, results in the potential of 16 hidden pools being unknown to tourists, reflecting the gap between physical potential and tourist experience management. Degradation of tangible cultural assets, such as damage to drum-shaped stones, indicates weak cultural heritage conservation efforts. Decline in supporting facilities, with elimination of playgrounds and horse attractions without alternative replacements, demonstrates limited management capacity in maintaining area attractiveness. Furthermore, physical vulnerability of the area due to steep topography and acidic and corrosive nature of hot water to metal demands special material investment that is more expensive for infrastructure development.

#### c) Opportunities

External context analysis identified several strategic opportunities that can be utilized. The growth trend of the national ecotourism market, especially increasing awareness among urban communities regarding the importance of nature-based tourism and post-pandemic conservation, opens large market opportunities. Government policy support through Ministry of

Tourism and Creative Economy Regulation Number 9 of 2021 concerning Guidelines for Sustainable Tourism Destinations provides a regulatory framework supporting community-based ecotourism development. Potential multi-stakeholder cooperation with Tourism Office, academics, and environmental non-governmental organizations can be utilized for manager capacity building. Affordable digitalization and geographic information system technology enables creation of interactive digital maps accessible to visitors via smartphones. Additionally, geographical location adjacent to other tourist destinations in Deli Serdang opens opportunities for developing integrated tourism products in the form of group tour packages.

#### d) Threats

On the other hand, external threats need to be anticipated. Competition with similar nature tourism destinations with better infrastructure can divert tourist preferences. Environmental degradation risk due to excessive visits can occur if development is uncontrolled without establishing area carrying capacity, potentially damaging stalactite formations and polluting hot water. Climate change and hydrometeorological disasters pose serious threats considering steep topography makes the area vulnerable to landslides and erosion due to changes in extreme rainfall patterns. Cultural value erosion due to modernization and penetration of external culture through tourist flows can erode local cultural practices if active revitalization is not carried out. Additionally, uncertainty in local government support due to changes in local political priorities can result in inconsistency in infrastructure development and institutional assistance.

## 2) Strategic Management Formulation

Based on the SWOT analysis, four main development strategies were formulated. The SO (Strengths-Opportunities) or aggressive strategy leverages internal strengths to capture external opportunities, including developing tourism products based on geological uniqueness and local culture packaged in storytelling-based premium ecotourism packages, formalizing managers into ecotourism village-owned enterprises to access government funding programs, and creating interactive digital maps based on geographic information systems displaying 16 hidden pool points. The WO (Weaknesses-Opportunities) or diversification strategy aims to minimize weaknesses by leveraging opportunities, such as advocating for road infrastructure improvements by using accessibility mapping results as proposal materials in regional spatial planning, conducting manager capacity building through university cooperation, and implementing zoning systems based on geographic information system mapping results to prevent facility development in landslide-prone areas.

The ST (Strengths-Threats) or competitive strategy uses strengths to face threats, by positioning the area as an exclusive ecotourism destination through establishing daily visit limits based on carrying capacity, strengthening brand imaging based on local cultural uniqueness for competitive differentiation, and conducting cultural revitalization programs to maintain cultural identity. The WT (Weaknesses-Threats) or defensive strategy aims to minimize weaknesses and avoid threats, by prioritizing internal institutional consolidation before external expansion, creating local wisdom-based conservation regulations integrated into modern management standard operating procedures, and conducting routine monitoring of area physical conditions in cooperation with academic institutions for early detection of environmental degradation.

The SWOT analysis demonstrates that the Ergendang Cave Ecotourism Area is positioned in the growth quadrant, where internal strengths comprising geological uniqueness, cultural values, and community participation, along with external opportunities comprising ecotourism trends and policy support, are more dominant than weaknesses and threats. However, optimization of sustainable management can only be achieved if structural weaknesses, particularly informal institutions, poor infrastructure, and minimal spatial information, are immediately addressed through diversification strategies, especially formalization of management institutions and advocacy for accessibility improvements. The findings of this SWOT analysis become the empirical basis for formulating a community-based ecotourism management model supported by geographic information system spatial planning, which integrates spatial mapping as an objective physical planning tool for conservation zoning and visitor navigation, while formalized community institutions serve as sociocultural managers responsible for revitalizing local culture as core attractions, thereby providing a clear path to optimize the area's unique potential sustainably.

## D. Conclusion

Based on the research results and discussion on "Integration of Spatial Mapping and Socio-Cultural Dynamics in Optimizing Sustainable Management of the Ergendang Cave Ecotourism Area," two main conclusions can be drawn:

### 1. Spatial Characteristics and Accessibility Analysis

GIS-based mapping successfully identified critical spatial characteristics of Ergendang Cave. The area possesses significant geological uniqueness with stalactite and stalagmite formations and natural hot spring pools. Topographic analysis revealed complex morphology with elevation ranging from 243 to 685 meters above sea level, dominated by steep slopes creating high vulnerability to erosion and landslides. Accessibility mapping identified severely damaged road conditions, particularly from Sibiru-Biru District, as a major bottleneck. The potential mapping revealed 16 swimming pool points connected through hidden corridors that remain unknown to visitors due to absent spatial information systems. Zonation analysis successfully delineated "Open Areas" with gentle topography as primary development zones, separated from conservation zones in steep and sensitive areas, establishing a scientific foundation for sustainable spatial planning.

### 2. Socio-Cultural Dynamics and Community Perspectives

The investigation revealed strong cultural values rooted in local traditions, including the Umang myth and Ergendang tradition, which constitute significant intangible cultural heritage for tourism development. However, critical challenges exist in cultural preservation, exemplified by the destruction of the drum-shaped stone due to inadequate visitor education. Community management remains informal without government support, resulting in limited resources, funding, and management capacity. Despite these limitations, active local participation demonstrates high sense of ownership representing important social capital for community-based tourism. Traditional cultural values have not been fully integrated into modern management systems, creating weak protection of socio-cultural aspects and tension between cultural preservation and tourism development pressures.

### 3. Integrated Sustainable Management Strategy

Integration of spatial and socio-cultural findings formulated a comprehensive management model based on Community-Based Tourism (CBT) supported by GIS planning. SWOT analysis positioned Ergendang Cave in the growth quadrant, where strengths (geological uniqueness, cultural values, community participation) and opportunities (ecotourism trends, policy support, GIS technology) dominate weaknesses and threats. The model assigns spatial mapping as the physical planning instrument for conservation zoning, development zoning, and visitor navigation through digital maps displaying all 16 pools. Formalized community institutions serve as socio-cultural managers responsible for implementing local wisdom-based conservation, revitalizing cultural attractions, and ensuring community participation. Four priority strategies were identified: (1) SO strategy—developing premium ecotourism packages and creating GIS-based digital maps; (2) WO strategy—advocating infrastructure improvements and capacity building; (3) ST strategy—establishing carrying capacity-based visit limits and cultural branding; (4) WT strategy—prioritizing institutional consolidation and environmental monitoring. Implementation requires immediate action on structural weaknesses, particularly institutional formalization, road infrastructure improvement, and comprehensive spatial information system development.

Based on the conclusions above, several operational recommendations can be formulated for stakeholders to follow up.

- 1) For area managers (local communities), the primary recommendation is to immediately formalize their independent management status as a legal entity, such as a Village-Owned Enterprise (BUMDes) Ecotourism or Tourism Awareness Group (Pokdarwis). This legalization step is crucial for establishing official partnerships with the government. Furthermore, managers are encouraged to directly adopt the spatial mapping results from this study. The development zoning map and topographic analysis should serve as a reference for spatial planning, while the potential distribution map can be processed into a functional Informative Tourism Map to address information gaps regarding the 16 swimming pools. Finally, the identified "Open Areas" should be utilized to revitalize cultural attractions (such as Ergendang performances and storytelling of the Umang myth) to enrich the visitor experience.
- 2) For the Deli Serdang Regency Government and related agencies, the most urgent recommendation is to prioritize road infrastructure improvements (based on the accessibility map analysis), as without adequate access, the area's optimal development will

not be achieved. Government support is also expected in the form of assistance with the legalization of local institutions (BUMDes/Pokdarwis) and the provision of ecotourism management training. Strategically, the spatial mapping (zoning) results from this study are recommended for adoption as input into the Regional Spatial Plan (RTRW) or the Regional Tourism Master Plan (RIPPARDA).

- 3) For future researchers, this study opens two crucial avenues for further research. It is recommended to conduct quantitative research on the Tourism Carrying Capacity of the Area to determine visitation limits, and to conduct more in-depth geochemical studies on the impact of acidic water on stalactite conservation and the selection of corrosion-resistant infrastructure materials.

### Acknowledgments (Optional)

The successful completion of this research would not have been possible without the support and contributions of various parties. The authors express their deepest gratitude to the Research and Community Service Institute (LPPM) of Universitas Negeri Medan (UNIMED) for providing financial support through the Student Grant Program, which enabled the authors to conduct this research more comprehensively and systematically. Special thanks are extended to Mr. Muhammad Farouq Ghazali Matondang, S.Pd., M.Sc., as the research supervisor, for his invaluable guidance, constructive feedback, and continuous support throughout the research process. His commitment and dedication have been instrumental in refining this scholarly work.

The authors would also like to acknowledge the local community of Penungkiren Village, Sinembah District, and the managers of Goa Ergendang for their cooperation and hospitality during fieldwork. Their willingness to share knowledge and provide access to the site was essential to the success of this study. Finally, the authors hope that the findings of this research can contribute meaningfully to the sustainable management of Goa Ergendang ecotourism area and serve as a reference for similar geo-anthropological studies in the future.

### E. References

- Achmad, A., Firdus, F., Mellisa, S., Ramli, I., & Hasan, Z. (2024). Perencanaan penataan kawasan mangrove di Gampong Lamnga berbasis pemetaan spasial guna menjadi kawasan ekowisata. *Suluah Benda: Jurnal Ilmiah Pengabdian Kepada Masyarakat*, 24(3), 178–188.
- Ahdasabila, N. (2025). Strategi pengembangan ekowisata berkelanjutan di Hutan Adat Guguk Kecamatan Renah Pembarap Kabupaten Merangin [Disertasi doktoral, Universitas Jambi].
- Akbar, B. A., Cahyani, N. S. N., Ratasari, A., Rahayu, G. S., Anisa, M. S., Gunawan, W. A., Komalasari, D., Khaerunnisa, H., Sukanto, K. Y., Al Fuqhi, A., & Fajar, A. N. (2023). Strategi pengelolaan ekowisata berkelanjutan di Desa Pasanggrahan. *Jurnal Pengabdian kepada Masyarakat Nusantara (JPKMN)*, 4(4), 1104–1108.
- Antropedia Kawan Undip. (2022, Juli 17). Marvin Harris: Sapi suci dan materialisme budaya. <https://antropediakawanundip.wordpress.com/2022/07/17/marvin-harris-sapi-suci-dan-materialisme-budaya/> [Diakses 6 Januari 2025]
- Badan Pusat Statistik. (2023). Kabupaten Deli Serdang dalam angka 2023. BPS Kabupaten Deli Serdang.
- Çınar, K., Kavacık, S. Z., & Erul, E. (2025). Bibliometric analysis of GIS-based tourism research: Trends, topics, and future directions in terms of sustainable tourism management. *SAGE Open*, 15(1).
- Dinas Pariwisata Kabupaten Deli Serdang. (2023). Survei awal potensi ekowisata Goa Air Gondang. Dinas Pariwisata Kabupaten Deli Serdang.
- Guerrero-Moreno, M. A., & Oliveira-Junior, J. M. B. (2024). Approaches, trends, and gaps in community-based ecotourism research: A bibliometric analysis of publications between 2002 and 2022. *Sustainability*, 16(7), 2639.
- Harris, M. (2001). *Cultural materialism: The struggle for a science of culture*. Rowman Altamira.
- Iqbal, A., Ramachandran, S., Siow, M. L., Subramaniam, T., & Latiff, K. (2023). Insights into the role of community participation as a tool for local support: A normative model for competitive and sustainable destination development. *International Journal of Academic Research in Business and Social Sciences*, 13(1), 807–816.
- Kementerian Pariwisata dan Ekonomi Kreatif Republik Indonesia. (2021). Peraturan Menteri Pariwisata dan Ekonomi Kreatif Nomor 9 Tahun 2021 tentang pedoman destinasi pariwisata berkelanjutan. Kementerian Pariwisata dan Ekonomi Kreatif RI.
- Lasaiba, M. A. (2022). Integrasi kearifan lokal dalam pengelolaan ekowisata berkelanjutan dari perspektif masyarakat adat. *Jendela Pengetahuan*, 15(2), 84–91.

- Mammola, S., Cardoso, P., Angyal, D., Balázs, G., Blick, T., Brustel, H., ... Zigmajster, M. (2024). Advancing tourism sustainability in show caves. *Cell Reports Sustainability*, 1(3), 100069.
- Martayadi, U., Suteja, I. W., Bhakti, W. A., & Dewi, B. F. C. (2025). Pengelolaan ekowisata berbasis ketahanan ekologi dan sosial untuk mendukung pariwisata berkelanjutan di Gili Trawangan, Lombok Utara. *Altasia Jurnal Pariwisata Indonesia*, 7(1), 134–147.
- Mateen, A. (2025). Community-based tourism: A catalyst for achieving the United Nations sustainable development goals one and eight. *Tourism and Hospitality*, 6(1), 29.
- Maulidina, A. Z. N., Fadjarajani, S., & Darmawan, C. (2024). Analisis pariwisata berkelanjutan di kawasan Candi Prambanan dalam aspek lingkungan. *JUPARITA: Jurnal Pariwisata Tawangmangu*, 2(3), 147–156.
- Pasulu, E. P., Budiandriami, Suriyanti, & Mahmudnurnajamuddin. (2024). Pengembangan pariwisata berkelanjutan di Kabupaten Toraja Utara berbasis green tourism. *Edunomika*, 8(4).
- Putri, R. D. (2023). Identifikasi potensi pengembangan ekowisata berwawasan kearifan lokal di Taman Wisata Alam Puntih Kayu Palembang. *Jurnal KaLIBRASI: Karya Lintas Ilmu Bidang Rekayasa Arsitektur, Sipil, Industri*, 6(1), 50–58.
- Ramadhan, A. A., Huda, M. M., & Suhindarno, H. (2025). Tata kelola pariwisata berbasis ecotourism (Studi kasus di Taman Wisata Goa Ngerong Kecamatan Rengel). *Jurnal Ilmiah Dinamika Sosial*, 9(1), 1–16.
- Ramaano, A. I. (2025). Toward tourism-oriented community-based natural resource management for sustainability and climate change mitigation leadership in rural municipalities. *Journal of Humanities and Applied Social Sciences*, 7(2), 107–131.
- Rasid, A. U., Novriansyah, M. A., Taniu, S., Karundeng, D. R., Yusuf, B. R., Gani, R., ... Ishak, O. (2025). Pengembangan ekowisata berkelanjutan sebagai sumber pendapatan alternatif bagi masyarakat pesisir Gorontalo. *Jurnal Pengabdian kepada Masyarakat Nusantara*, 6(2), 2049–2056.
- Setijawan, A. (2018). Pembangunan pariwisata berkelanjutan dalam perspektif sosial ekonomi. *Jurnal Planoearth PWK FT UMMat*, 3(1).
- Siregar, M. (2020). Politics of cultural tourism in the North Sumatera Samosir Island. *International Journal of Applied Science*, 3(1), 18–28.
- Torsney, B. M., Lynn, N. A., & Courtney, P. (2025). Defining ecotourism for mainstream application and to support sustainable tourism governance. *Ecological Solutions and Evidence*, 6(2), e70050.
- Triyatno, W., & Sari, Y. I. (2024). Perspektif geografi kajian geografi manusia: Dinamika kebudayaan dan identitas sosial dalam konteks globalisasi. *Jurnal Penelitian dan Pendidikan IPS*, 69–76.
- Utama, I. G. B. R., Junaedi, I. W. R., & Krismawintari, N. P. D. (2024). Concept of participation model in community-based ecotourism programs adjacent to conservation forests. *International Journal of Sustainable Development and Planning*, 19(12), 5149–5160.