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Assessment of Geotourism Potential in Maruni and Surrounding Areas Using the Modified Geosite Assessment Model (M-GAM) Method in Manokwari Regency, West Papua

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A B S T R A C T

This research was conducted in the Maruni area and its surroundings, located in South Manokwari District, Manokwari Regency, West Papua Province. The area exhibits diverse geological landscapes such as coastal zones, karst hills, and river systems that hold significant potential for geotourism development based on conservation principles. The objectives of this study are to assess the geotourism potential of the Maruni area through the identification and evaluation of its scientific, aesthetic, accessibility, and additional values that support sustainable geotourism development. The research also aims to provide benefits in terms of geological resource management, local economic enhancement, and the preservation of geological heritage in West Papua. The research method employed is the Modified Geosite Assessment Model (M-GAM), a quantitative approach that evaluates geosites based on two major value groups: Main Values (MV) and Additional Values (AV). Data were collected through field observation, documentation, interviews with local communities and related stakeholders, and literature review. Each parameter was scored on a scale of 0–5, and the total MV and AV scores were calculated to determine the potential level of each geosite. The results show that the Maruni area possesses a high potential for geotourism development. The Maruni Beach geosite achieved an MV score of 5,00 and an AV score of 4,20, while the score Maruni Karst Hill MV score 4,21 and an AV 4,00, Maruni River, and Coastal Panorama geosites also demonstrated significant potential. Based on their positions within the M-GAM matrix, all geosites fall into the high-potential geosite category, indicating strong prospects for development as educational, conservation-based, and competitive geotourism destinations. These findings emphasize that geotourism development in the Maruni area can contribute substantially to regional geopark promotion and local community empowerment

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INTRODUCTION

The West Papua region, especially Manokwari Regency, has unique and interesting landscapes to study, namely mountain structures, denuded hills, morphology, rock formations, coastal areas, and rivers that reflect important tropical geomorphological processes and other natural resources that can be managed and utilized. Geology-based tourism or geotourism has grown rapidly in the last two decades as a form of sustainable tourism that not only pursues economic value but also conservation and educational value.

One area with high geotourism potential is Maruni and its surroundings in South Manokwari District, Manokwari Regency. This area has a variety of landforms such as Maruni Beach, Maruni Karst Hill, Maruni River, Coastal Panorama, and others, each of which has its own scientific, educational, and aesthetic value. Despite its unique geology and attractive landscape, this area has not received serious attention in scientific geotourism studies or regional development policies. The lack of quantitative data on geosite potential is a major obstacle to planning and promoting geology-based tourism in West Papua.

To fill in this information, this study uses the Modified Geosite Assessment Model (M-GAM) as the main analytical approach (Tomić, 2014). This method was developed to systematically assess geosite potential through a combination of main values such as scientific, educational, aesthetic, and accessibility, as well as additional values including infrastructure, promotion, and socioeconomic support. It enables measurable analysis by integrating expert assessments and visitor perceptions, resulting in findings that are more representative of actual geotourism potential.

LITERATURE REVIEW

Research Location and Time

This research was conducted in the Maruni area and its surroundings with geographical coordinates of approximately 0°52′–0°57′ LS and 133°45′–133°50′ BT. The administrative boundaries include the South Manokwari District with an area of 169.13 km2, Manokwari Regency, West Papua Province.

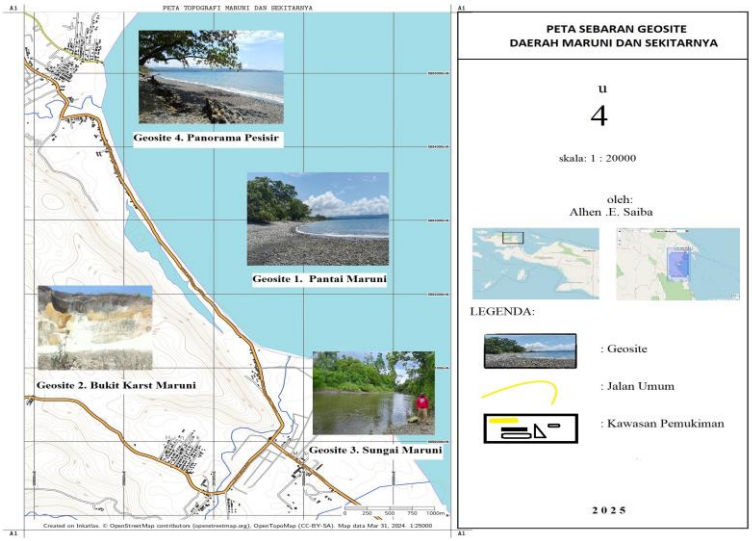

Figure 1. Research Location Map

Types and Sources of Data

The types and sources of data are field observations, interviews, and documentation, which are primary data, and geological maps, literature, BPS data, Tourism Office data, BAPPEDA data, ESDM data, and satellite imagery, which are secondary data. Data collection techniques include conducting field surveys to identify and document geosites, interviewing geologists, tourism managers, and local communities, and distributing data through questionnaires to tourists and communities. The data is then processed and analyzed to assess geosites using the M-GAM method to determine geotourism potential. Teknik Pengumpulan Data

Data was collected through literature studies, field observations, expert questionnaires, and visitor surveys. Each piece of data obtained was used to assess 27 M-GAM model indicators divided into two main value groups, namely Main Values (scientific and educational values) and Additional Values (additional tourism values).

METHODOLOGY

M-GAM Analysis Method

In the process of analyzing the Maruni Geosite and its surroundings, the Modified Geosite Assessment Model (M-GAM) method will be used. This method is a development of the Geosite Assessment Model (GAM). The Geosite Assessment Model (GAM) is based on several existing evaluation methods, and most of the criteria proposed for numerical assessment are taken from field data.

Assessment Based on Two Groups of Variables (Main Values & Additional Values)

Table 1. M-GAM Structure

Kelompok	Kode	Indikator / Parameter	Deskripsi Penilaian
MAIN VALUES (MV)	MV1	Scientific Knowledge	Tingkat pengetahuan ilmiah yang tersedia tentang geosite (publikasi, riset, referensi).
	MV2	Representativeness	Seberapa baik geosite mewakili fenomena geologi tertentu.
	MV3	Key Geologic Element	Keunikan elemen geologi (struktur, mineral, fosil, batuan).
	MV4	Integrity (Condition of Site)	Keutuhan fitur geologi, minim kerusakan atau modifikasi.
	MV5	Level of Scientific Interest	Pentingnya lokasi dalam konteks ilmu geologi regional/nasional.

Kelompok	Kode	Indikator / Parameter	Deskripsi Penilaian
	MV6	Educational Level (Complexity)	Kemudahan fenomena dijelaskan untuk berbagai tingkat pendidikan.
	MV7	Interpretative Potential	Potensi lokasi untuk dibuat media interpretatif (panel, tur edukatif).
	MV8	Scenery and Landscape	Keindahan panorama dan komposisi visual geologi.
	MV9	Contrast / Color Diversity	Variasi warna, bentuk, dan tekstur elemen alam.
	MV10	Viewpoints and Visibility	Ketersediaan titik pandang dan visibilitas elemen utama.
	MV11	Environmental Protection Level	Status perlindungan atau konservasi alam yang berlaku.
	MV12	Vulnerability (Threat Level)	Tingkat ancaman terhadap kelestarian geosite (erosi, vandalism, dll).
	MV13	Scientific Rarity	Tingkat kelangkaan atau keunikan ilmiah dibanding situs lain.
ADDITIONAL VALUES (AV)	AV1	Accessibility	Kemudahan akses (jalan, transportasi, jarak dari kota).
	AV2	Proximity to Other Sites	Kedekatan dengan objek wisata lain (geosite/non-geosite).
	AV3	Tourist Infrastructure	Ketersediaan fasilitas fisik (toilet, tempat parkir, papan informasi).
	AV4	Tourist Services	Akomodasi, restoran, pemandu wisata, pusat informasi.
	AV5	Tourist Safety	Tingkat keamanan lokasi bagi wisatawan.
	AV6	Promotion (Marketing)	Aktivitas promosi dan eksposur di media, internet, dan brosur wisata.
	AV7	Interpretation Facilities	Ketersediaan papan informasi, jalur edukatif, media interaktif.
	AV8	Level of Interpretation	Kualitas dan kedalaman interpretasi geologi di lapangan.

Kelompok	Kode	Indikator / Parameter	Deskripsi Penilaian
	AV9	Local Community Involvement	Partisipasi masyarakat lokal dalam pengelolaan geosite.
	AV10	Economic Value	Dampak ekonomi geosite terhadap masyarakat sekitar.
	AV11	Ecological Value	Nilai ekologis: keberadaan flora/fauna khas atau fungsi ekosistem.
	AV12	Cultural / Historical Value	Nilai budaya, sejarah, atau spiritual yang melekat pada lokasi.
	AV13	Potential for Further Development	Potensi pengembangan geowisata ke depan (infrastruktur, edukasi, promosi).
	AV14	Management & Maintenance	Tingkat pengelolaan, perawatan, dan tata kelola site.

Weighting of M-GAM Assessment

Table 2. M-GAM Assessment Weight

Kelompok	Parameter Utama	Bobot (%)	Keterangan
MAIN VALUES (Total 60%)	Scientific Knowledge	8%	Dasar ilmiah paling penting, menunjukkan nilai geowarisan.
	Representativeness	5%	Mewakili fenomena geologi utama wilayah.
	Key Geologic Element	5%	Keunikan unsur geologi.
	Integrity / Condition	4%	Keutuhan bentuk alami.
	Scientific Interest	4%	Penting bagi riset dan pendidikan.
	Educational Value	6%	Potensi untuk pembelajaran dan interpretasi.
	Interpretative Potential	5%	Daya tarik untuk edukasi publik.
	Scenery / Landscape	5%	Daya tarik visual geosite.
	Color / Contrast	3%	Variasi visual dan estetika.

Kelompok	Parameter Utama	Bobot (%)	Keterangan
	Viewpoint & Visibility	3%	Kemudahan observasi di lapangan.
	Protection / Vulnerability	4%	Tingkat perlindungan dan ancaman.
	Scientific Rarity	4%	Kelangkaan fenomena geologi.
	Environmental Value	4%	Hubungan dengan ekosistem dan konservasi.
Subtotal Main Values		60%	
ADDITIONAL VALUES (Total 40%)	Accessibility	6%	Kemudahan dicapai dan kualitas akses.
	Proximity to Other Sites	4%	Keterhubungan dengan destinasi lain.
	Tourist Infrastructure	5%	Fasilitas wisata di lokasi.
	Tourist Services	4%	Akomodasi, pemandu, dan layanan pengunjung.
	Safety	3%	Keamanan pengunjung.
	Promotion	3%	Aktivitas promosi dan eksposur media.
	Interpretation Facilities	3%	Papan informasi, jalur edukatif, dll.
	Local Community Involvement	3%	Partisipasi masyarakat lokal.
	Economic Impact	3%	Kontribusi ekonomi ke masyarakat.
	Cultural / Historical Value	3%	Nilai budaya atau sejarah tambahan.
	Ecological Value	2%	Nilai ekologis, flora-fauna unik.
	Potential for Further Development	2%	Potensi pengembangan jangka panjang.
	Management & Maintenance	2%	Kualitas pengelolaan dan perawatan lokasi.
Subtotal Additional Values		40%	

In M-GAM, the weight of each indicator is calculated based on the level of importance according to visitors (Im). The weight formula is obtained by normalizing the visitor importance value (Im) against the total of all visitor assessments (Im), then multiplying it by the expert value (V).

$$W_i = \frac{X_i}{\sum_{i=1}^{n} X_i}$$

Formula:
Where:

- Wi = Weight of variable i
- Xi = Raw score from experts for variable i
- n = Number of variables

Score for Each Parameter From 0 To 5

Tebel 3. Bbot Penilaian M-GAM

Nilai	Kriteria Kualitatif	Makna
0.0 – 1.0	Sangat Rendah	Hampir tidak ada nilai atau potensi
1.1 – 2.0	Rendah	Nilai terbatas, kurang menarik
2.1 – 3.0	Sedang	Cukup potensial, perlu pengembangan
3.1 – 4.0	Tinggi	Daya tarik jelas, pengelolaan sudah baik
4.1 – 5.0	Sangat Tinggi	Potensi unggul, layak dikembangkan sebagai geosite prioritas

The score in M-GAM is a quantitative assessment value (0–5) given to 27 geosite indicators. This value reflects the actual condition of the geosite based on field observations and expert assessments.
Rumus:

$$M - GAM = \sum (Wi \times Ii)$$

Description:
Variable Weight (Wi)

- Provided by experts
- Experts assign weights to each assessment variable (scientific value, aesthetics, and accessibility)
- The weight scale is usually between 10 and 100, and the total of all weights = 100 or 100%.

Indicator Score (Ii)

- Provided by visitors (tourists).
- Visitors rate each variable on a scale of 1–5.
- Final Value Calculation using the general formula: M−GAM = ∑ (Wi × Ii)

This means that the weight from the experts is multiplied by the score from the visitors for each variable, then added together. The result shows the total value of the geosite's potential.
Rumus:

$$TPG = \sum_{i=1}^{n} (W_i \times I_i)$$

Explanation:

- Wi = weight of variable i (determined by experts)
- Ii = score of indicator i (from visitors)
- n = number of variables/indicators assessed

Total Score or Geosite Rating

Table 4. Geosite Ranking / M-GAM Total Assessment Score

Klasifikasi	Main Values (MV)	Additional Values (AV)	Kategori Potensi Geowisata
Tinggi	≥ 3.5	≥ 3.5	Geosite potensial tinggi dan siap dikembangkan
Sedang	2.0 – 3.4	2.0 – 3.4	Geosite potensial sedang, butuh penguatan fasilitas
Rendah	< 2.0	< 2.0	Geosite potensial rendah atau belum layak dikembangkan

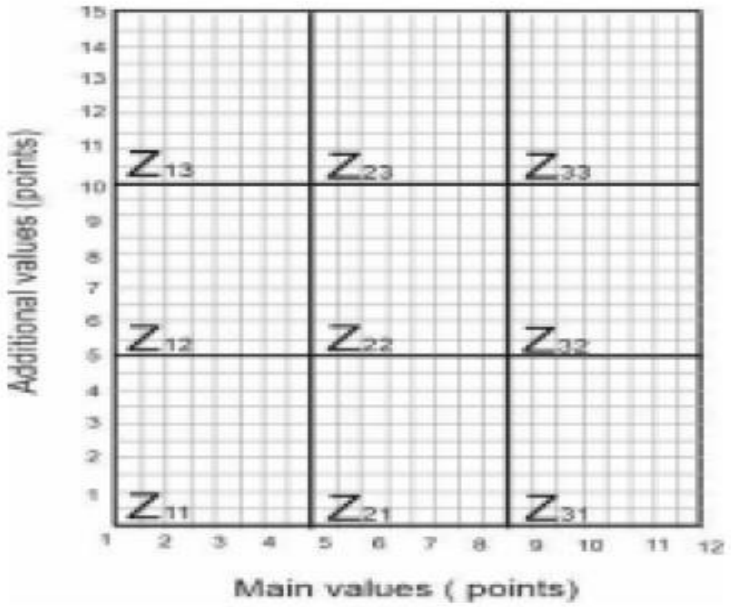

Figure 2. Modified M-GAM Z-Matrix

RESULTS AND DISCUSSION

Geological Aspects

Maruni Beach Geosite

The Maruni Beach Geosite is located in the southern coastal zone of Manokwari City and geologically belongs to the Kais Formation unit dating from the Late Miocene to Pliocene-Pleistocene. The main rock units at this location are reef limestone and bioclastic limestone interspersed with carbonate sandstone lenses. These rocks were formed in a shallow neritic to sublittoral marine environment, where reef-building organisms such as corals, algae, and mollusks were dominant. In addition to lithological factors, the morphology of Maruni

Beach is also controlled by geological structures and active coastal dynamics. There are indications of northwest-southeast trending fractures and small faults that are part of a regional deformation system and local faults. These structures also control the orientation of limestone cliffs and wave abrasion zones. Tectonic activity and coastal denudation processes interacting with the energy of the Pacific Ocean waves have resulted in coastal karst morphology (coastal karst cliffs) and raised reefs. The combination of tectonic processes, carbonate dissolution, and wave erosion makes the Maruni Beach Geosite a representative location for studying the evolution of active tropical coastal geology with high scientific and educational value in the context of geotourism and geoheritage.

Karst Hill Geosite

Composed of predominantly carbonate rocks in the form of limestone (packstone, wackestone, mudstone, and crystalline) ranging in color from grayish white to brownish, massive to layered in nature, stratigraphically belonging to the Kais Limestone Formation dating from the early to middle Miocene (Yorana Tabuni, 2021). These rocks were formed in a high-energy tropical shallow marine environment, characterized by the presence of bioclastic fossils and calcite ($CaCO_3$) crystalline texture, muddy micrite, and local napalan, indicating biogenic deposition processes. Structurally, this carbonate rock unit underwent mild to moderate deformation due to tectonic activity, which produced minor fractures and faults that accelerated the infiltration of meteoric water into the rock. These conditions are the main controlling factors of the karstification process in the Maruni region. The dissolution of limestone by meteoric water containing CO_2 produces typical tropical karst landforms, such as dolines, caves, ponors, and underground water systems. The undulating surface morphology with round to conical karst hills (tower karst) and inter-hill valleys (cockpits) indicates advanced dissolution and active karst evolution. Secondary deposits in the form of caves in this area indicate ongoing underground hydrological dynamics.

Maruni River Geosite

Located in the transition zone between karst hills and alluvial plains, lithologically, this area consists of a combination of crystalline limestone and carbonate sandstone, which in the downstream section is covered by Quaternary alluvial deposits in the form of gravel, sand, and silt resulting from erosion in the upstream area. The geological structure around the river shows the presence of northwest-southeast-trending fractures and small faults, which help control the direction of the Maruni River and reveal the influence of the local fault system. The combination of carbonate lithology and fault structures makes this area an interesting example of the influence of geological control on drainage patterns and river morphology in the region. In terms of geological processes, the Maruni River displays fluvial-karstic dynamics, where surface water mostly originates from runoff in the karst area upstream, which then interacts with the carbonate rock substrate. In addition, some river cliffs expose weathered and lightly karstified limestone, revealing continuous dissolution processes that form microkarst features along the river channel.

Coastal Panorama Geosite

The Maruni Coastal Panorama Geosite is highly valuable because it shows the continuity of karst-coastal geological evolution in an integrated geomorphological system. The constituent materials that form the coastal region are an ideal natural laboratory for the study of paleogeography and sea level change. The presence of features such as abrasion, tidal action, and karst cavities enriches the scientific value of the geosite and simultaneously demonstrates the sensitivity of the landscape to climate change and ocean dynamics.

CONCLUSIONS AND RECOMMENDATIONS

1. The Maruni Beach geosite has the highest geotourism potential (Z33) with a total score of 5.00. Its strengths lie in its aesthetic value, accessibility, and educational potential regarding coastal geomorphological processes. This beach is easily accessible from the center of Manokwari and is suitable as a prime location for coastal geotourism development. Improvements in basic facilities and cleanliness management are needed to maintain its appeal.
2. The Maruni Karst Hill Geosite has moderate to high potential (Z33) with a score of 4.23. Its scientific and educational value is highlighted by the exposure of a distinctive tropical karst landscape. The main constraints are access and interpretive facilities. With the development of trails and educational facilities, this location has the potential to become a leading geosite for geology and geomorphology learning in the Maruni area.
3. The Maruni River Geosite has moderate potential (Z21) with a score of 2.65. Its scientific and ecological value are dominant aspects, particularly for hydrology studies and conservation ecotourism. Limited access and lack of facilities are the main obstacles. Development based on conservation and environmental education will increase its added value as a research geosite and educational freshwater tourism destination.
4. The Panorama Pesisir geosite has moderate to high potential (Z22) with a score of 3.73. Its main attractions are its visual aesthetic value and potential for coastal landscape interpretation. This location is suitable for observation, photography, and light tourism activities. The provision of viewpoints, pedestrian paths, and interpretation boards will strengthen its function as a visual icon of the Maruni geotourism area.
5. Overall, the four geosites in the Maruni area and its surroundings have high, moderate to low geotourism potential, with complementary characteristics:
    1. Maruni Beach excels in aesthetic value and accessibility and is suitable as a center for tourist activities.
    2. Maruni Karst Hill is strong in scientific and educational aspects.
    3. The Maruni River is important as a conservative element and for environmental research.
    4. The Maruni Coastal Panorama reinforces the visual image and landscape appeal of the area.
6. With integrated management based on conservation, education, and local community participation, the Maruni area has the potential to become a coastal and educational geotourism cluster in Manokwari City, West Papua.

FURTHER STUDY

- Integrated geotourism development is needed to integrate all geosites into a single tourist trail (geotrail) so that tourists can enjoy the diversity of potential attractions in one area.
- The provision of basic facilities (toilets, rest areas, information centers, and interpretation boards) is very important to improve comfort and tourist appeal.
- Conservation-based and sustainable management must be prioritized, especially at Maruni Beach (threats of abrasion and waste), Karst Hill (vulnerability to erosion and deforestation), and Maruni River (sedimentation and seasonal flooding).
- Local communities in the surrounding area need to be actively involved as tour guides, facility managers, and providers of creative economic services so that the benefits of geotourism can be directly felt by local communities.
- Strengthening education and promotion of geosites in the Maruni area and its surroundings can be used as a natural laboratory for formal education (university students, schools) and non-formal education (educational tourism). Digital-based geotourism promotion is also important to increase tourist appeal.

Figure 3. Information on the Distribution of Geosites in Maruni and Surrounding Areas

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