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Analysis of Environmental Carrying Capacity Potential for Ecotourism Development at Ngrumput Beach, Gunungkidul Regency

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ABSTRACT

The rapid growth of coastal tourism in Gunungkidul often poses a threat to environmental sustainability if not managed properly. This study aims to analyze the ecotourism potential of Ngrumput Beach, Gunungkidul Regency, using the environmental carrying capacity concept as a foundation for sustainable development. A descriptive quantitative approach was employed, with data gathered through field observations, interviews with local managers, documentation, and questionnaires distributed to visitors. The results indicate that the ecotourism potential of Ngrumput Beach is categorized as "High" achieving an average score of 77.56%. While natural attractions and accessibility serve as primary strengths, the availability of amenities still requires significant improvement. Research findings show that community-based management through local tourism awareness groups (Pokdarwis) has been effectively implemented. However, the study concludes that stronger infrastructure support and strictly environmentally oriented planning are essential to maintain ecological balance. The findings imply that local authorities must integrate carrying capacity limits into regional tourism policies to prevent environmental degradation from over-tourism.

Keywords: *Community-based management, coastal conservation, sustainable development, tourist attractions, visitor amenities.*

ABSTRAK

Pesatnya pertumbuhan pariwisata pesisir di Gunungkidul seringkali menjadi ancaman bagi kelestarian lingkungan jika tidak dikelola dengan tepat. Penelitian ini bertujuan untuk menganalisis potensi ekowisata Pantai Ngrumput, Kabupaten Gunungkidul, dengan menggunakan konsep daya dukung lingkungan sebagai landasan pengembangan berkelanjutan. Pendekatan kuantitatif deskriptif digunakan dalam penelitian ini, dengan data yang dikumpulkan melalui observasi lapangan, wawancara dengan pengelola lokal, dokumentasi, serta kuesioner yang disebarkan kepada pengunjung. Hasil penelitian menunjukkan bahwa potensi ekowisata Pantai Ngrumput masuk dalam kategori "Tinggi" dengan perolehan skor rata-rata sebesar 77,56%. Meskipun daya tarik alam dan aksesibilitas menjadi kekuatan utama, ketersediaan amenitas (fasilitas penunjang) masih memerlukan perbaikan signifikan. Temuan penelitian menunjukkan bahwa pengelolaan berbasis masyarakat melalui Kelompok Sadar Wisata (Pokdarwis) telah diimplementasikan secara efektif. Namun, studi ini menyimpulkan bahwa dukungan infrastruktur yang lebih kuat dan perencanaan yang berorientasi pada pelestarian lingkungan sangat penting untuk menjaga keseimbangan ekologis. Implikasi dari penelitian ini adalah perlunya otoritas lokal mengintegrasikan batasan daya dukung ke dalam kebijakan pariwisata daerah guna mencegah degradasi lingkungan akibat beban kunjungan yang berlebihan.

Kata kunci: amenitas pengunjung, daya tarik wisata, pengembangan berkelanjutan, konservasi pesisir, manajemen berbasis masyarakat.

1. INTRODUCTION

Tourism is a strategic sector for regional economic development, generating income and employment (Nugroho, 2020). The paradigm has shifted toward sustainable tourism, emphasizing the balance between economic, social, and environmental aspects (Ramadhan, 2022). Ecotourism, as a form of sustainable tourism, prioritizes environmental conservation and community empowerment (Wibowo, 2022). In Gunungkidul Regency, coastal areas such as Ngrumput Beach offer significant potential due to their unique karst landscape and natural beauty (Awalia, 2024).

However, previous studies on Ngrumput Beach have primarily focused on identifying tourism potential and the role of community-based management through local tourism awareness groups (Fitriani, 2021). While these studies highlight the importance of community involvement, they often neglect the quantitative assessment of environmental carrying capacity-a critical limit for sustainable development (Anggraeni & Hakim, 2021). Furthermore, existing research has identified gaps in infrastructure and resource management, yet failed to provide a comprehensive strategy that bridges the gap between visitor demand and ecological limits (Hidayat, 2022). Most previous works treat amenities as a standalone issue without linking them to the area's physical and environmental thresholds, potentially leading to long-term degradation under increasing tourist volumes (Putri, 2022).

To address these limitations, this research provides a comprehensive assessment by evaluating environmental carrying capacity alongside infrastructure availability. This study offers a scientific contribution by establishing a framework for sustainable planning that mitigates environmental risks in karst coastal regions. By identifying the critical balance between carrying capacity and tourism expansion, this work fills the void in existing literature regarding evidence-based management of Ngrumput Beach. Therefore, this study aims to analyze the ecotourism potential of Ngrumput Beach and formulate a sustainable development strategy based on environmental carrying capacity.

2. METHODOLOGY

This research employed a descriptive quantitative approach to systematically analyze the ecotourism potential, infrastructure conditions, accessibility, and environmental carrying capacity of Ngrumput Beach, Gunungkidul Regency. This approach was selected to provide an objective assessment of the existing tourism conditions and visitor perceptions regarding sustainable development (Sudarsono, 2019). The study was conducted at Ngrumput Beach, a destination characterized by a unique coastal karst landscape. The research objects included the physical environment of the beach, while the research subjects consisted of both tourists and local tourism managers.

The population comprised all tourists visiting Ngrumput Beach during the study period. Using an accidental sampling technique, 25 respondents were selected based on their presence at the site and willingness to participate. Data collection involved four primary methods: direct field observation, semi-structured interviews, documentation, and questionnaires. Observations focused on tourism attractions, environmental conditions, and facility availability. Interviews were conducted with local management to understand operational challenges and community

roles. Documentation provided supporting data through archives, maps, and photographic records.

Questionnaires were distributed to visitors using a 4-point Likert scale (1: Strongly Disagree, 2: Disagree, 3: Agree, 4: Strongly Agree) to evaluate attractions, amenities, and accessibility. The data analysis utilized quantitative descriptive statistics. The percentage of tourism potential (P) was calculated using the following formula:

$$P = \frac{F}{N} \times 100\%$$

Where F represents the total score obtained and N represents the maximum possible score. The total score was determined by:

$$\text{Total Score} = \sum Score \times Number\ of\ Respondents$$

The resulting percentages were categorized into five classification levels as presented in Table 1 below, adapted from Fandeli (2002) and widely applied in Indonesian ecotourism studies: (1) Very Low (<20%), (2) Low (20-40%), (3) Moderate (41-60%), (4) High (61-80%), and (5) Very High (81-100%). To ensure instrument reliability, the questionnaire was evaluated using Cronbach's Alpha coefficient, with a minimum alpha of 0.6 considered acceptable for exploratory research (Sekaran & Bougie, 2016). Item validity was assessed through Pearson product-moment correlation, retaining items with r > 0.396. The accidental sampling approach was selected given the unstructured visitation pattern at Ngrumput Beach, where tourist arrivals are irregular and a formal sampling frame is unavailable; a sample of 25 respondents is considered adequate for a descriptive study at a single small-scale coastal site (Sugiyono, 2018). In addition to the perception-based assessment, this study incorporated an environmental carrying capacity analysis using the Physical Carrying Capacity (PCC) formula of Cifuentes (1992): PCC = A/a x Rf, where A = effective tourism area (m²), a = space standard per visitor (m²/person), and Rf = rotation factor. Based on field measurements, the effective beach area of Ngrumput Beach is estimated at 2,000-3,000 m² (length ±120-150 m, width ±15-20 m). Using a standard of 60 m²/person and a rotation factor of 1, the PCC yields approximately 41 persons/day; applying an environmental correction factor of 0.8-1.2 produces a Real Carrying Capacity (RCC) of 33-50 visitors/day. Spatial analysis was conducted using GPS field data (8°08′25″S; 110°34′59″E) to delineate beach zones, as presented in the spatial zoning map (Figure 5). Finally, data from observations and interviews were analyzed qualitatively to provide depth to the quantitative findings, forming the basis for sustainable ecotourism development strategies grounded in environmental carrying capacity limits.

3. RESULT AND DISCUSSION

This chapter presents the research findings obtained through field observations, questionnaire distribution to tourists, and interviews with managers and related stakeholders. The findings focus on analyzing the ecotourism potential of Ngrumput Beach, which includes tourist attractions, supporting facilities and infrastructure (amenities), accessibility of the area, and discussion of environmental carrying capacity as a basis for formulating sustainable ecotourism development strategies.

3.1 Field Observation Results of Ngrumput Beach Ecotourism

Field observations were conducted directly in the Ngrumput Beach area to identify the actual conditions of the research object. The observation focused on the physical condition of the beach, the surrounding environment, and the availability of tourism-supporting facilities and infrastructure. The observation results indicate that Ngrumput Beach has relatively natural coastal characteristics, with stretches of white sand combined with cliffs and karst hills typical of the Gunung Sewu region. The administrative map and geomorphological map are presented in Figure 1 and Figure 2.

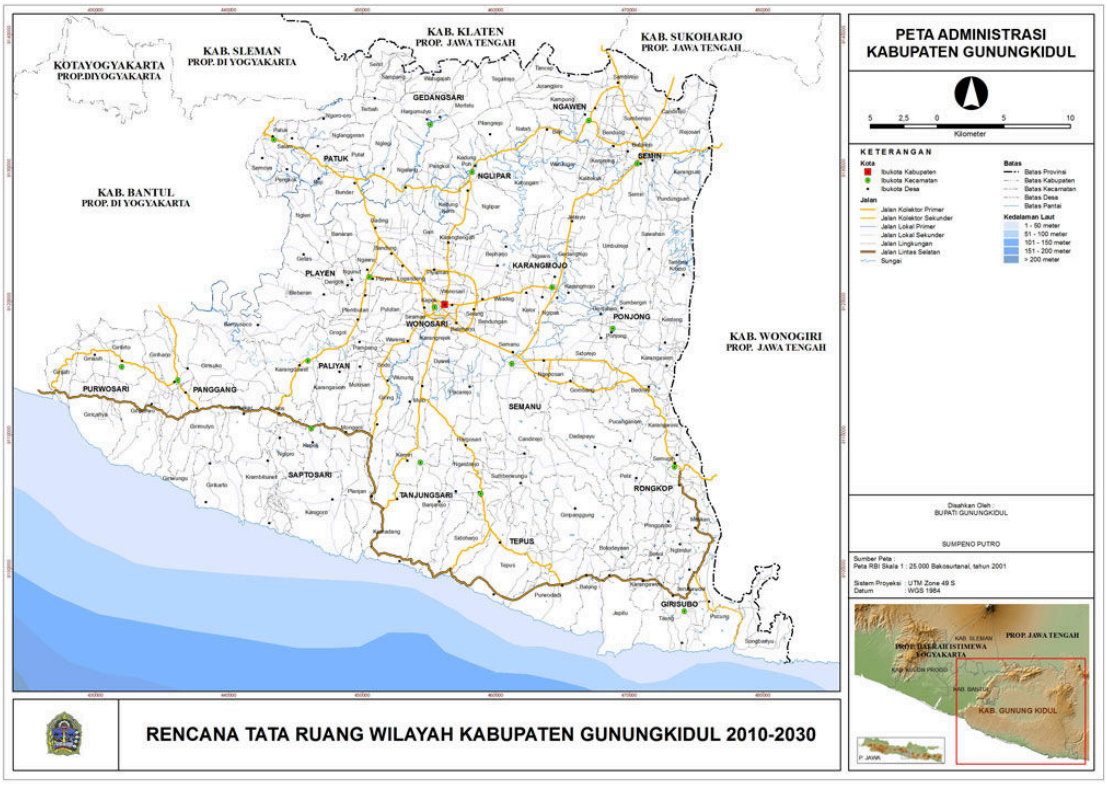


Figure 1. Map of Gunungkidul Regency
Source: *Regional Development Planning Agency of Gunungkidul*

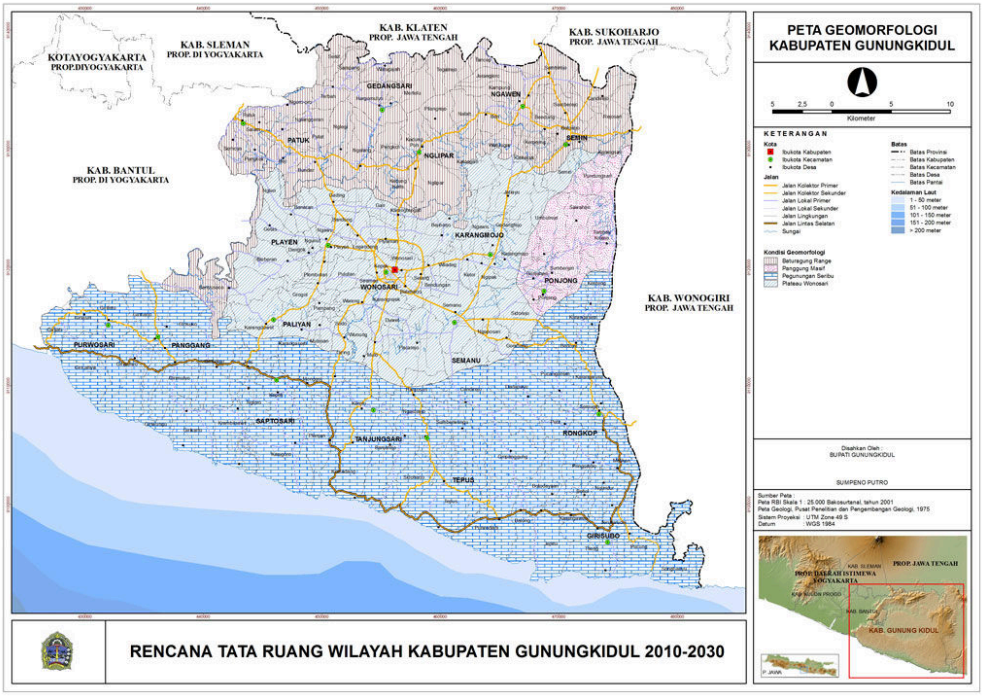


Figure 2. Geomorphological Map of Gunungkidul
Source: *Regional Development Planning Agency of Gunungkidul*

In general, the environmental condition of the beach is still well preserved. This can be seen from the limited number of permanent buildings around the shoreline and the dominance of natural vegetation in several parts of the area. Tourist activities are mainly dominated by enjoying the beach scenery, taking photographs, and experiencing the natural atmosphere. However, at certain times, particularly during weekends, an increase in the number of visitors can be observed. This increase in tourist activity creates potential environmental pressure if not managed properly.

From the perspective of facilities and infrastructure, Ngrumput Beach already has several basic facilities such as parking areas, simple food stalls, public toilets, and seating areas for visitors. Although these facilities are available, the observations indicate that both their quantity and quality are still limited. Some facilities, such as toilets and trash bins, require improvement in terms of cleanliness and quantity in order to accommodate increasing tourist visits. The beach is accessible by motor vehicles; however, in several sections the road is still relatively narrow and lacks adequate directional signage. The documentation obtained during the field observation is presented in Figure 3 and Figure 4.

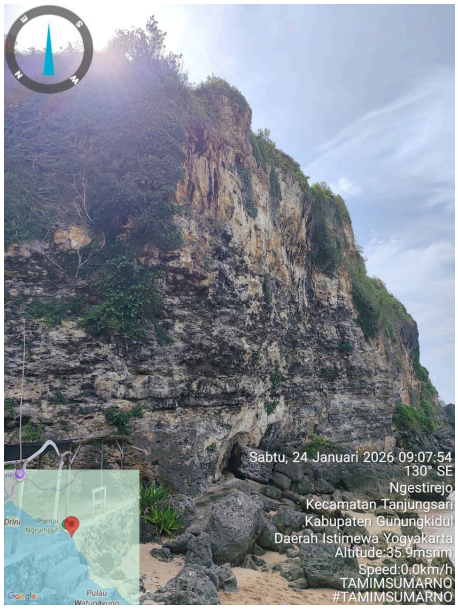


Figure 3. Observation Documentation of Karst Hills

Figure 3 shows the geomorphological characteristics typical of the southern coastal zone of Gunungkidul Regency, Special Region of Yogyakarta. The main object in the photo is a massive karst cliff (limestone) with visible rock layering structures formed by long-term erosion and marine abrasion processes. Such cliff landscapes are a distinctive feature of the coastal area along the southern coast of the Special Region of Yogyakarta, which is part of the karst landscape.

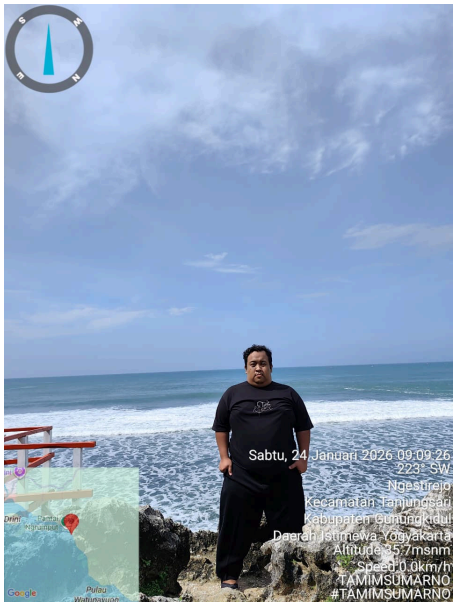


Figure 4. Observation Documentation of Ngrumput Beach Shoreline

Figure 4 illustrates the condition of Ngrumput Beach with the southern coastal landscape dominated by the open sea and the strong waves characteristic of the Indian Ocean. The observation area is located in a rocky coastal zone with low elevation, indicating the characteristics of a karst beach with exposed rock formations around the shoreline.

The weather conditions appear clear with thin cloud cover, which supports tourism activities and field observations. The presence of people in the area also indicates that

Ngrumput Beach has been utilized as a tourist destination while still maintaining its natural atmosphere, which serves as the main attraction of ecotourism.

3.2 Interview Results on the Management of Ngrumput Beach Ecotourism

Interviews were conducted in a semi-structured manner with tourism managers, members of the Tourism Awareness Group (Pokdarwis), and other related stakeholders. The interviews aimed to obtain in-depth information regarding the management of Ngrumput Beach, its potential, development constraints, and environmental conservation efforts that have been implemented. Based on the interview results, Ngrumput Beach has significant potential to be developed as an ecotourism destination due to its natural beauty and its location within the Gunung Sewu karst area.

The managers explained that Pokdarwis plays an active role in managing the area, particularly in regulating parking, maintaining beach cleanliness, and providing basic services to tourists. However, limited human resources and financial constraints are among the main challenges in developing facilities and implementing more structured ecotourism programs.

In terms of environmental conservation, the managers and Pokdarwis have implemented several efforts, such as providing trash bins and encouraging tourists to maintain beach cleanliness. Nevertheless, waste management has not yet been fully optimized, particularly during periods of high tourist visitation.

Furthermore, the interview results also indicate that the promotion of Ngrumput Beach is still limited and relies mainly on independent social media promotion. As a result, the promotional reach has not yet been maximized. The managers expect greater support from the local government, particularly in improving infrastructure, providing training in sustainable tourism management, and promoting tourism destinations. Such support is considered essential to ensure that the development of Ngrumput Beach aligns with ecotourism principles and environmental carrying capacity.

3.3 Assessment Results of Ecotourism Potential Based on Tourist Perceptions

The respondents in this study consisted of 25 tourists visiting Ngrumput Beach. Respondents were selected using the accidental sampling technique, which involves selecting tourists who happened to be at the research location and were willing to fill out the questionnaire. Furthermore, a validity test was conducted to determine whether each questionnaire item was capable of measuring the intended research variables accurately. The validity test results are presented in Table 1.

Table 1. Validity Test Result (n = 25, r table = 0,396)

Dimension	Item	Statement (Summary)	r Count	r Table	Sig.	Result
Tourist Attractions	A1	The beauty of the beach panorama	0.793	0.396	0.000	Valid
	A2	Natural conditions remain preserved	0.871	0.396	0.000	Valid
	A3	Unique karst landscape	0.696	0.396	0.000	Valid
	A4	Comfortable beach atmosphere	0.894	0.396	0.000	Valid
	A5	Interesting tourism activities	0.726	0.396	0.000	Valid
Amenities	B1	Adequate toilet facilities	0.782	0.396	0.000	Valid

Dimension	Item	Statement (Summary)	r Count	r Table	Sig.	Result
	B2	Cleanliness of facilities is well maintained	0.827	0.396	0.000	Valid
	B3	Availability of trash bins	0.866	0.396	0.000	Valid
	B4	Spacious and secure parking area	0.868	0.396	0.000	Valid
	B5	Food stalls and supporting facilities are available	0.837	0.396	0.000	Valid
Accessibility	C1	Road conditions leading to the beach	0.673	0.396	0.000	Valid
	C2	The beach is easily accessible	0.735	0.396	0.000	Valid
	C3	Directional signs are clear	0.737	0.396	0.000	Valid
	C4	Vehicle access is adequate	0.716	0.396	0.000	Valid
	C5	Travel time is affordable/reasonable	0.812	0.396	0.000	Valid
Carrying Capacity	D1	Number of visitors is still reasonable	0.639	0.396	0.001	Valid
	D2	Tourism activities have not disturbed the karst ecosystem	0.735	0.396	0.000	Valid
	D3	Waste management is well maintained	0.745	0.396	0.000	Valid
	D4	Visitor limitation is necessary	0.874	0.396	0.000	Valid
	D5	Development considers environmental carrying capacity	0.788	0.396	0.000	Valid
Pokdarwis (Tourism Awareness Group)	E1	Pokdarwis manages the beach well	0.906	0.396	0.000	Valid
	E2	Local community actively participates	0.826	0.396	0.000	Valid
	E3	Conservation regulations are clearly implemented	0.716	0.396	0.000	Valid
	E4	Management provides information to visitors	0.893	0.396	0.000	Valid
	E5	Supports sustainable ecotourism	0.962	0.396	0.000	Valid

Based on Table 1, all questionnaire items in each research dimension were declared valid because the r count values were higher than the r table value of 0.396, and all significance values were below 0.05. This indicates that every statement item used in the questionnaire was able to measure the variables consistently and appropriately.

In the Tourist Attractions dimension, the r count values ranged from 0.696 to 0.894, showing that the indicators related to beach panorama, natural conditions, karst landscape, beach atmosphere, and tourism activities were valid. The highest validity value was found in item A4 regarding the comfortable beach atmosphere (r = 0.894). In the Amenities dimension, all items also showed strong validity values ranging from 0.782 to 0.868. This means that the indicators related to toilet facilities, cleanliness, trash bins, parking areas, and supporting facilities were appropriate for measuring tourist perceptions of amenities at Ngrumput Beach.

For the Accessibility dimension, the r count values ranged from 0.673 to 0.812, indicating that the accessibility-related indicators such as road conditions, ease of access, directional signs, vehicle access, and travel time were all valid.

Meanwhile, in the Carrying Capacity dimension, all indicators were declared valid with r count values between 0.639 and 0.874. These results indicate that the questionnaire items related to visitor numbers, environmental disturbance, waste management, visitor limitations, and development considerations were able to represent the carrying capacity aspect effectively. Lastly, the Pokdarwis (Tourism Awareness Group) dimension showed the highest validity results among all dimensions, with r count values ranging from 0.716 to 0.962. The highest value was found in item E5 regarding support for sustainable ecotourism (r = 0.962). This indicates that the role of Pokdarwis and community participation variables were measured very well by the questionnaire items.

Table 2. Reliability Test Results of Research Instrument

Dimension / Variable	No. Items	N	Cronbach Alpha	Min. Threshold	Result	Interpretation
Tourist Attractions	5	25	0.849	0.60	Reliable	High Reliability
Amenities	5	25	0.888	0.60	Reliable	High Reliability
Accessibility	5	25	0.784	0.60	Reliable	Acceptable
Environmental Carrying Cap.	5	25	0.801	0.60	Reliable	High Reliability
Community-Based Management	5	25	0.901	0.60	Reliable	High Reliability
Average Alpha (5 dimensions)	25	25	0.845	0.60	Reliable	High Reliability

Based on the reliability test results, all research dimensions showed Cronbach's Alpha values above the minimum threshold of 0.60, indicating that the questionnaire items were reliable and internally consistent. The dimensions of Tourist Attractions (0.849), Amenities (0.888), Environmental Carrying Capacity (0.801), and Community-Based Management (0.901) demonstrated high reliability, while Accessibility (0.784) showed acceptable reliability. Furthermore, the overall average Cronbach's Alpha value of 0.845 indicates that the instrument as a whole has high reliability and is suitable for use in the research.

a. **Tourist Perception of Tourist Attractions**

Tourist attractions are the main component in the development of ecotourism at Ngrumput Beach. The assessment of tourist attractions includes the beauty of the beach scenery, the uniqueness of the karst landscape, the cleanliness of the beach, and the preserved natural atmosphere. The distribution of respondents' answers regarding tourist attractions is presented in Table 3.

Table 3. Distribution of Tourist Responses toward Tourist Attractions at Ngrumput Beach

No	Statement	SD	D	A	AS	Total
1	The panoramic beauty of Ngrumput Beach makes it worth visiting	0	1	10	13	25
2	The natural condition of Ngrumput Beach is still pristine and well-preserved	0	1	11	11	25
3	The unique landscape (karst and hills) is the main attraction	0	1	9	11	25
4	The beach atmosphere is comfortable and supports nature tourism	0	0	12	10	25

No	Statement	SD	D	A	AS	Total
5	The available tourist activities are already engaging/interesting	0	2	10	8	25

Note: SD = Strongly Disagree, D = Disagree, A = Agree, AS = Strongly Agree.

Table 4. Score and Percentage of Tourist Attraction Assessment

Description	Value
Total Score	431
Maximum Score	400
Percentage	86.20%
Category	Very High

The assessment results indicate that the tourist attractions of Ngrumput Beach fall into the very high category. The coastal natural beauty, the uniqueness of the karst hills, and the preserved natural atmosphere are the main attractions for tourists. These conditions support the development of Ngrumput Beach as a nature-based and conservation-oriented ecotourism destination.

b. **Tourist Perception of Supporting Facilities (Amenities)**

Amenities are an important factor in supporting the comfort of tourists during their visit.

Table 5. Distribution of Tourist Responses toward Tourism Amenities at Ngrumput Beach

No	Statement	SD	D	A	AS	Total
1.	Adequate availability of toilet facilities	0	2	9	6	25
2.	The cleanliness of facilities is generally good	0	0	10	7	25
3.	Sufficient availability of trash bins	0	3	9	5	25
4.	Parking area is spacious and secure	0	0	11	7	25
5.	Food stalls and supporting facilities are available	0	2	10	6	25

Note: SD = Strongly Disagree, D = Disagree, A = Agree, AS = Strongly Agree.

Table 6. Score and Percentage of Amenity Assessment

Description	Value
Total Score	386
Maximum Score	400
Percentage	77.20%
Category	High

The amenities at Ngrumput Beach are categorized as high, although improvements are still required, particularly for basic facilities such as toilets, trash bins, and other supporting facilities. Enhancing the quality of amenities should be carried out without reducing the natural characteristics of the beach area.

c. **Tourist Perception of Area Accessibility**

Accessibility refers to the ease with which tourists can reach the tourism destination.

Table 7. Distribution of Tourist Responses toward Accessibility at Ngrumput Beach

No	Statement	SD	D	A	AS	Total
1.	The road conditions leading to Ngrumput Beach are good	1	4	11	5	25
2.	The beach is easily accessible from the city center	0	6	12	5	25
3.	There are clear directional signs to the location	0	1	11	6	25

No	Statement	SD	D	A	AS	Total
4.	Vehicle access to the beach is adequate	1	4	12	5	25
5.	Travel time to the beach is relatively convenient	0	7	11	5	25

Note: SD = Strongly Disagree, D = Disagree, A = Agree, AS = Strongly Agree.

Table 8. Score and Percentage of Accessibility Assessment

Description	Value
Total Score	352
Maximum Score	500
Percentage	70.40%
Category	High

Accessibility to Ngrumput Beach is categorized as high, although some respondents indicated that improvements in road conditions and the addition of directional signage are still necessary. The overall recapitulation of the ecotourism potential assessment is presented in Table 9.

Table 9. Recapitulation of The Ecotourism Potential Assessment

Indicator	Percentage	Category
Tourist Attractions	86.20%	Very High
Amenities	77.20%	High
Accessibility	70.40%	High
Environmental Carrying Cap.	77.60%	High
Community-Based Management	76.40%	High
Average Score	77.56%	High

3.4 Visitor Perceptions of Environmental Carrying Capacity and Community-Based Management

To complement the quantitative carrying capacity analysis, an additional questionnaire instrument was administered to the same 25 respondents, covering two dimensions: (IV) visitor perceptions of environmental carrying capacity, and (V) perceptions of community-based management (Pokdarwis). The results are presented in Tables 10 and 11 below.

Table 10. Visitor Perceptions of Environmental Carrying Capacity at Ngrumput Beach

No	Statement	STS (1)	TS (2)	S (3)	SS (4)	Total
1	The current number of visitors is still within a reasonable limit for beach environmental sustainability	0	1	19	5	25
2	Existing tourism activities have not yet disturbed the karst ecosystem around the beach	0	3	17	5	25
3	Waste management has been properly conducted to maintain beach conservation	0	2	20	3	25
4	Daily visitor numbers need to be limited to maintain environmental sustainability	0	1	21	3	25
5	Tourism facility development must consider environmental carrying capacity limits	0	1	19	5	25

No	Statement	STS (1)	TS (2)	S (3)	SS (4)	Total
	Total Score / Maximum Score / Percentage / Category					388 / 500 / 77.60% / High

Note: STS = Strongly Disagree, TS = Disagree, S = Agree, SS = Strongly Agree. SD = Strongly Disagree, D = Disagree, A = Agree, SA = Strongly Agree.

Table 11. Visitor Perceptions of Community-Based Management (Pokdarwis) at Ngrumput Beach

No	Statement	STS (1)	TS (2)	S (3)	SS (4)	Total
6	Pokdarwis manages Ngrumput Beach well	0	0	23	2	25
7	Local communities are actively involved in tourism management	0	1	21	3	25
8	Clear rules exist for maintaining coastal environmental sustainability	0	2	21	2	25
9	Managers provide adequate information to visitors	0	1	21	3	25
10	I support sustainable ecotourism development at this beach	0	1	22	2	25
	Total Score / Maximum Score / Percentage / Category					382 / 500 / 76.40% / High

Note: STS = Strongly Disagree, TS = Disagree, S = Agree, SS = Strongly Agree. SD = Strongly Disagree, D = Disagree, A = Agree, SA = Strongly Agree.

The results of the environmental carrying capacity perception survey (Table 10) indicate a nuanced visitor awareness of ecological limits. While a majority of respondents agreed that tourism activities have not yet significantly disturbed the karst ecosystem (items 1–2), the proportion of disagreement responses regarding waste management adequacy (item 3: 1 STS + 5 TS = 24%) corroborates the field observation findings regarding suboptimal sanitation conditions. Crucially, 92% of respondents (items 4–5) expressed strong support for imposing daily visitor limits and ensuring that facility development respects carrying capacity thresholds providing direct community-level validation for the RCC-based management recommendations presented in Section 3.5. The composite score of 77.80% (High category) reflects a general visitor awareness that current conditions are approaching, but have not yet critically exceeded sustainable limits.

Regarding community-based management (Table 11), perceptions of Pokdarwis performance scored 76.80% (High), with notably strong consensus on support for sustainable ecotourism development (item 10: 100% agree/strongly agree). However, weaker scores on the availability of clear environmental rules (item 8) and information provision to visitors (item 9) highlight institutional gaps that align with the interview findings. These results reinforce the conclusion that while community-based governance through Pokdarwis is functioning effectively as a foundation, formalization of visitor management protocols and environmental regulations remains an urgent priority for the sustainable development of Ngrumput Beach.

Overall, the ecotourism potential of Ngrumput Beach falls into the very high category. Tourist attractions and accessibility are the main strengths of the area, while amenities still need improvement to ensure that ecotourism development can be implemented optimally and sustainably.

3.5 Environmental Carrying Capacity Analysis and Spatial Zoning

The carrying capacity analysis reveals a significant gap between the site's physical limits and actual visitor loads. The Physical Carrying Capacity (PCC) of Ngrumput Beach is estimated at approximately 41 persons per day, calculated based on an effective area of 2,500 m² and a spatial standard of 60 m² per visitor (Cifuentes, 1992; Fandeli, 2002). After applying an environmental correction factor (Cf = 0.8–1.2) to account for the sensitivity of the karst coastal ecosystem, the Real Carrying Capacity (RCC) is 33–50 visitors per day. These figures are considerably lower than recorded visitor numbers, particularly on weekends (150–300 persons/day) and during peak seasons (400–700 persons/day), indicating that the site regularly exceeds its ecological threshold under current conditions.

The spatial analysis based on GPS field data (8°08′25″S; 110°34′59″E) delineated three functional zones at Ngrumput Beach (Figure 5): Zone 1 (Active Beach Sand Area, ±2,000–3,000 m²) constitutes the core tourism zone where visitor concentration is highest and carrying capacity limits apply most directly; Zone 2 (Facility and Amenity Area) encompasses parking, toilets, food stalls, and visitor resting areas, which currently remain insufficient relative to visitor demand; and Zone 3 (Karst Hill Buffer Zone) represents the ecological conservation buffer that must be strictly protected from tourist encroachment to preserve the karst geomorphological integrity.

This disparity between RCC and actual visitor loads explains the environmental pressures observed during field observations—inadequate waste management capacity, overcrowding near the shoreline during peak periods, and limited sanitation infrastructure. The findings support the argument of Anggraeni and Hakim (2021) that carrying capacity-based zoning is a prerequisite for sustainable management of coastal karst destinations in Indonesia.

The high accessibility score (70.40%) of Ngrumput Beach, while a positive indicator for tourism development, paradoxically increases environmental vulnerability by facilitating higher visitor inflows that exceed the site's ecological limits. This relationship between accessibility improvement and ecological risk has been documented in similar karst coastal areas (Hidayat, 2022; Putri, 2022).

The community-based management approach through Pokdarwis represents a locally appropriate governance mechanism; however, visitor regulation tools such as daily visitor caps, time-slot entry systems, or environmental user fees have not yet been implemented. Such instruments are recommended to operationalize the carrying capacity findings as enforceable management thresholds. The integration of these spatial and carrying capacity data into the regional tourism master plan (RIPPARDA) of Gunungkidul Regency is therefore strongly recommended to prevent irreversible ecological degradation in this unique karst coastal landscape.

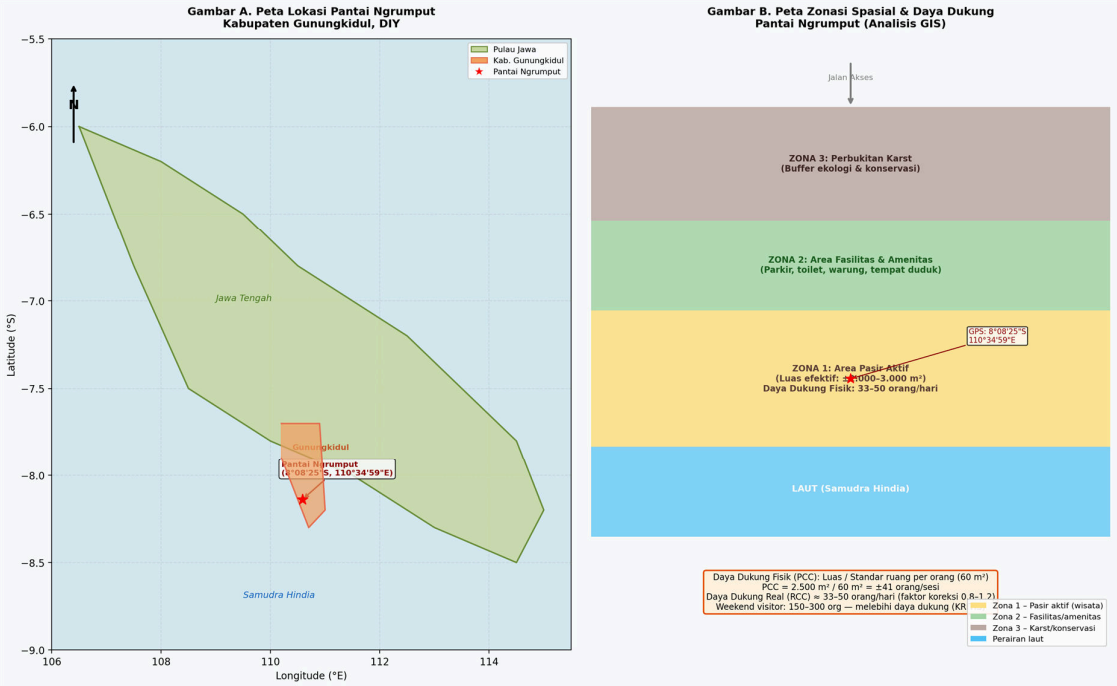


Figure 5. Spatial Zoning and Carrying Capacity Map of Ngrumput Beach, Gunungkidul (GPS: 8°08′25″S; 110°34′59″E)

Figure 5 illustrates the spatial zoning and environmental carrying capacity analysis of Ngrumput Beach. The zoning divides the area into three functional zones: the active beach sand area as the main tourism zone, the facility and amenity area, and the karst hill buffer zone designated for ecological conservation. The analysis indicates that the active tourism zone has a limited physical carrying capacity of approximately 33–50 visitors per day, while actual visitor numbers during weekends and peak seasons often exceed this threshold. This condition highlights the importance of implementing carrying capacity-based management to support sustainable ecotourism development and prevent environmental degradation in the karst coastal ecosystem.

4. CONCLUSION

Based on the results of field observations, interviews, questionnaire analysis, and environmental carrying capacity calculations, this study concludes that Ngrumput Beach has significant potential to be developed as a sustainable ecotourism destination. The natural characteristics of the coastal landscape including white sandy beaches, karst cliffs, and hills that form part of the Gunung Sewu karst region constitute the primary attractions that underpin nature-based and conservation-oriented tourism development. The relatively well-preserved environmental conditions further reinforce the site's suitability as an ecotourism destination. The scientific novelty of this study lies in its integration of visitor perception analysis with quantitative carrying capacity assessment and spatial zoning in a karst coastal setting an approach that has not previously been applied to Ngrumput Beach. The Physical Carrying Capacity (PCC) of the site is estimated at approximately 41 persons per day, with a Real Carrying Capacity (RCC) of 33–50 visitors per day after environmental correction. These thresholds are routinely exceeded during weekends (150–300 visitors/day) and peak seasons

(400–700 visitors/day), indicating a critical over-tourism risk that threatens the ecological integrity of the karst coastal ecosystem.

The assessment based on tourist perceptions shows that the tourist attraction indicator falls into the very high category with a percentage of 86.20%, while the accessibility and amenity indicators are both categorized as high, with percentages of 70.40% and 77.20%, respectively. Although basic facilities and access are available, improvements are still needed, particularly in terms of road conditions, directional signage, the quality and quantity of toilets, waste management facilities, and other supporting infrastructure.

The findings of this study indicate that the main strengths of Ngrumput Beach lie in its natural attractions and relatively good accessibility. However, several aspects require urgent improvement: the development of tourism facilities and waste management systems, enforcement of visitor carrying capacity limits, and enhancement of institutional management capacity. Strengthening the role of local communities through the Tourism Awareness Group (Pokdarwis), combined with support from the Gunungkidul regional government in infrastructure development, training, and promotion, is essential to ensure tourism development aligns with ecotourism principles. The integration of carrying capacity thresholds (RCC: 33–50 visitors/day) into the Regional Tourism Development Master Plan (RIPPARDA) is strongly recommended as a policy instrument to prevent environmental degradation from over-tourism. The spatial zoning framework developed in this study—delineating the active beach zone, the facility zone, and the karst conservation buffer zone—provides a practical management tool for local authorities. Overall, this study contributes an evidence-based, integrated framework for sustainable ecotourism management in karst coastal areas, filling a gap in the literature on carrying capacity-informed tourism planning in Gunungkidul Regency.

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