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Environmental Carrying Capacity of Tourist Attractions in Mangunan Forest Resort, Bantul Regency

Daya Dukung Lingkungan Objek Wisata pada Resort Pemangkuan Hutan Mangunan, Kabupaten Bantul

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RESEARCH ARTICLE

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ABSTRACT

The growth of nature tourism at Mangunan Forest Resort in Bantul Regency has created challenges in balancing environmental sustainability with tourism activities. This study assessed tourism carrying capacity at three main destinations — Puncak Becici, Hutan Pinus Sari, and Seribu Batu Songgo Langit — using Physical Carrying Capacity (PCC), Real Carrying Capacity (RCC), and Effective Carrying Capacity (ECC). Ecological correction factors included herpetofauna diversity, slope, and soil erodibility, while tourist satisfaction was measured via Customer Satisfaction Index (CSI) from 100 respondents per site. All three attractions operated below their ECC limits, indicating sustainable current visitation. Hutan Pinus Sari had the highest ECC at 1,478 people/day (CSI 77.85%) due to a larger area, shorter stays, and higher herpetofauna diversity. Puncak Becici followed with 1,150 people/day (CSI 76.32%), supported by high turnover. Seribu Batu Songgo Langit had the lowest ECC at 597 people/day despite the highest CSI (80.52%), reflecting spatial and ecological constraints. The results highlighted a strong link between carrying capacity and tourist satisfaction. Integrating ecological parameters with CSI yields a more comprehensive assessment for sustainable, conservation-based tourism management in Mangunan Forest Resort.

KATA KUNCI
objek wisata alam,
daya dukung lingkungan,
kepuasan pengunjung,
Resort Pemangkuan Hutan Mangunan

INTISARI

Perkembangan pariwisata alam di kawasan Hutan Mangunan di Kabupaten Bantul menimbulkan tantangan dalam upaya menyeimbangkan antara pelestarian lingkungan dan aktivitas wisata. Penelitian ini menilai daya dukung lingkungan pada tiga destinasi utama - Puncak Becici, Hutan Pinus Sari, dan Seribu Batu Songgo Langit - melalui pengukuran Physical Carrying Capacity *(PCC),* Real Carrying Capacity *(RCC), dan* Effective Carrying Capacity *(ECC). Faktor koreksi ekologi, seperti keanekaragaman herpetofauna, kemiringan lereng, dan risiko erosi tanah. Kepuasan wisatawan diukur menggunakan* Customer Satisfaction Index *(CSI) dari 100 responden per destinasi. Hasil analisis menunjukkan bahwa ketiga destinasi wisata beroperasi di bawah batas ECC masing-masing, yang menandakan bahwa keberlanjutan tingkat kunjungan pada saat ini. Hutan Pinus Sari memiliki ECC tertinggi sebesar 1.478 orang/hari (CSI 77,85%) karena luas area yang lebih besar, lama kunjungan yang lebih singkat, dan keanekaragaman herpetofauna yang lebih tinggi. Puncak Becici menyusul dengan 1.150 orang/hari (CSI 76,32%), didukung oleh tingkat pergantian pengunjung yang tinggi. Seribu Batu Songgo Langit memiliki ECC terendah sebesar 597 orang/hari meskipun memiliki CSI tertinggi (80,52%), yang mencerminkan keterbatasan spasial dan ekologis. Hasil penelitian menyoroti hubungan kuat antara daya dukung dan kepuasan wisatawan. Integrasi parameter ekologis dengan CSI menghasilkan penilaian komprehensif untuk mendukung pengelolaan pariwisata berkelanjutan berbasis konservasi di Mangunan Forest Resort.*

Introduction

The increasing interest in nature tourism is having consequences for the sustainability of the environment, specifically in production forest areas that have been allocated to tourist destinations (Maldonado & Montagnini 2005). A reliable evaluation of ecotourism carrying capacity should consider the intensity of tourist activities, the socio-economic context of surrounding communities, and environmental limits of the destination—both in terms of space and time (Du et al. 2024). The Mangunan Forest Resort (RPH Mangunan) in Bantul Regency is an example that has experienced a spike in visits since the middle of the last decade, fueled by trends in nature tourism and social media. This growth, although economically beneficial, can put ecological pressure when not managed in line with sustainability principles. In the context described, the concept of environmental carrying capacity is an important tool for assessing the number of visits an area can tolerate without causing ecological degradation or a decrease in the quality of the tourism experience (Muntasib et al. 2023).

According to Cifuentes (1992), tourism carrying capacity is assessed at three distinct levels: Physical Carrying Capacity (PCC), Real Carrying Capacity (RCC), and Effective Carrying Capacity (ECC). The stated descriptions emphasize the need for a multidimensional analysis—including ecological, sociocultural, and economic aspects—to maintain harmony between environmental capacity and tourist satisfaction (Laksana et al. 2023). This approach becomes increasingly relevant with the inclusion of Customer Satisfaction Index (CSI) in the calculation of ECC, which combines ecological aspects and tourist perceptions (Rocha et al. 2021).

Tourists visiting the RPH Mangunan tourist area often show a lack of environmental awareness, as evidenced by litter scattered around and cigarette butts found in spots where smoking is strictly prohibited. The regulation exists to mitigate the risk of forest fires and applies to tourists and management staff (Utami et al. 2020). Research has shown that exceeding carrying capacity can negatively impact the environment and tourist satisfaction. Carrying capacity calculations serve as a planning tool and as the basis for managing the area to achieve adaptive, sustainable tourism. Accordingly, this research sought to assess the tourism carrying capacity of three destinations within the RPH Mangunan area: Puncak Becici, Hutan Pinus Sari, and Seribu Batu Songgo Langit, taking into account ecological aspects such as herpetofauna diversity, land slope, and soil characteristics, as well as visitor satisfaction levels. The results could feed the management of conservation-based nature tourism that takes into consideration the quality of service and tourist comfort.

Methods

Research Location

This research took place between August and September 2024 across several tourist destinations: Puncak Becici, Hutan Pinus Sari, and Seribu Batu Songgo Langit—located within the RPH Mangunan area of the Yogyakarta Forest Management Unit (KPH Yogyakarta) in Dlingo District, Bantul Regency. The destinations were selected for their 2023 visitation rates, which were the highest, and because they are located in state forests with protection functions. Continuous development has been observed since the allocation to tourist attractions, as evidenced by the annual increase in visits, thereby requiring the calculation of carrying capacity for tourism planning. The spatial position of the study site, including observation points and surrounding areas, is illustrated in Figure 1.

Data Collection

To address the research objectives, several variables and their corresponding data sources were identified and analyzed. A detailed description of the variables and data sources is presented in Table 1.

This research adopted a quantitative approach, in which data were derived from calculations of PCC, RCC, and ECC. The approach points out that the Cifuentes (1992) method offers a structured framework that integrates ecological variables and spatial constraints, thereby establishing suitability as a basis for managing tourist areas to support tourism activities without exceeding their environmental carrying capacity, which is essential for sustainable tourism management (Rasidi et al. 2023).

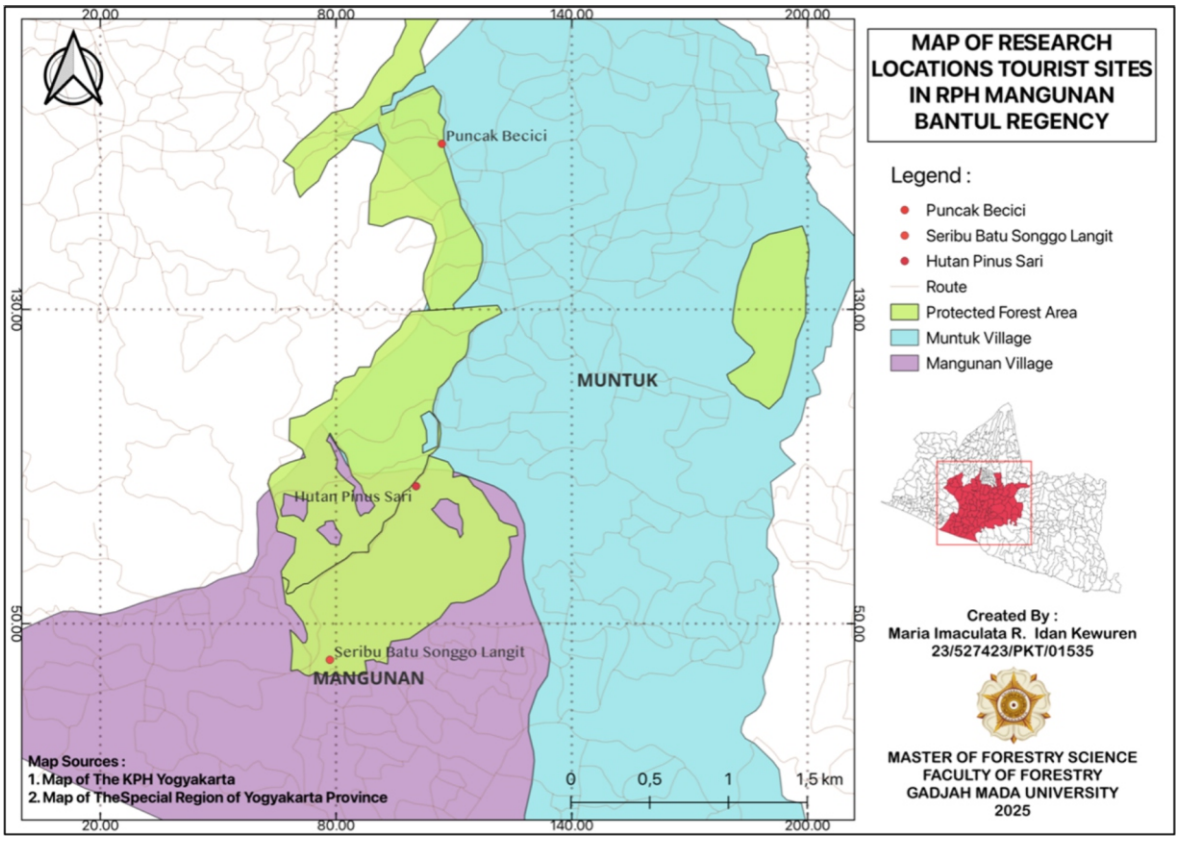

Figure 1. Research location map

Table 1. Variables and data sources based on research objectives

Research purposes	Variables	Data Source	Data Collection Technique
Identifying environmental carrying capacity: (Physical Carrying Capacity, Real Carrying Capacity, and Effective Carrying Capacity)	**Physical Carrying Capacity (PCC)**		
	Area of each tourist attraction (A)	Map of the KPH Yogyakarta	Spatial analysis (Quantum GIS 3.42)
	Tourist space requirement for recreation (B)	Field observation	questionnaire
	Rotation factor (Rf)	Field observation	questionnaire
	Real Carrying Capacity (RCC)		
	Correction factors: Herpetofauna Diversity	VES Method *(line transect)*	Shannon-Wiener diversity
	Slope	DEM SRTM by the Indonesian Geospatial Information Agency	Spatial analysis (Quantum GIS 3.42)
	Soil erodibility	Soil map by the National Land Agency (BPN) of Bantul Regency, 2021	Literature review
	Effective Carrying Capacity (ECC)		
	Tourist satisfaction	Field observation	Questionnaire and CSI (Customer Satisfaction Index) Analysis using MS Excel

Data collection on herpetofauna was conducted from morning to late afternoon (07:00–16:00 WIB) using the Visual Encounter Survey (VES) method with a modified line transect, following the planned transect placement (Leyte-Manrique et al. 2019). The survey was carried out along trekking paths in a tourist area, covering a distance of 500 m, with 200 m between each transect (Priambodo et al. 2019). Data collection using a structured questionnaire designed to assess tourist perceptions of the importance and performance of various tourism attributes. These attributes included environmental quality, facility availability, accessibility, cleanliness, safety, comfort, and overall visitor experience. In this study, 100 tourists visiting

the study area were selected as respondents using an accidental sampling approach, in which visitors encountered at the site during the research period were invited to participate voluntarily. The selection of respondents was also based on specific considerations, such as age, level of education, and their familiarity with the tourism site. The questionnaire was administered directly to tourists at the study site after they had completed their visit to ensure that their responses reflected their experience. Respondents were asked to rate each attribute using a Likert scale, typically ranging from 1 (very dissatisfied/not important) to 5 (very satisfied/very important).

Data Analysis

Physical Carrying Capacity (PCC)

PCC denotes the maximum number of tourists a given area can physically accommodate within a defined time frame, based on its spatial dimensions and available infrastructure. To calculate PCC, the formula was used as follows and shown in Equation (1).

PCC = A x 1 /B x Rf ..... *Equation 1*

Remarks: A = Area of each tourist attraction; B = Tourist space requirement for recreation; Rf = Rotation factor (which indicates the frequency of visitor turnover in a given area per day. It is determined by dividing the total duration the site is open to visitors by the average length of stay of each visitor)

Real Carrying Capacity (RCC)

RCC represents the maximum number of tourists a tourism destination can sustain without causing substantial environmental harm or diminishing the quality of the tourist experience. Previous research recommended that environmental thresholds should be realistically considered when managing tourism to ensure ecological systems continue to support human activity without degradation (Aswirna et al. 2023). The RCC formula is shown in Equation (2). RCC value was obtained by applying correction factors (Cf) derived from site-specific characteristics to the PCC calculation.

$RCC = PCC \times Cf_1 \times Cf_2 \times Cf_3 \times \ldots \times Cf_n$ ..... *Equation 2*

After collecting data on biotic and abiotic variables. The calculation of correction factors was carried out based on the equation 3.

Cf = 1 – (Mn / Mt) ..... *Equation 3*

Remarks: Mn = Number of limiting units; Mt = Total number of measured units

Effective Carrying Capacity (ECC)

ECC refers to the maximum number of tourists that can visit a tourism area without causing environmental degradation, socio-cultural disruption, or a decline in quality that can reduce tourist satisfaction. The carrying capacity of a destination encompasses physical aspects and is influenced by the quality of the tourist experience. This perspective aligns with previous research (Rocha et al. 2021), which argues that carrying capacity assessments should not rely solely on physical and technical aspects but also incorporate qualitative variables, such as tourist satisfaction, as indicators of impact and a basis for more comprehensive management strategies. The following formula, adapted from Cifuentes (1992), as modified by Rocha et al. (2021), was used to measure ECC. The formula used to calculate ECC is given in Equation (4).

ECC = RCC x Cm ..... *Equation 4*

Remarks: ECC = Effective Carrying Capacity; RCC = Real Carrying Capacity; Cm = Management correction factor based on tourist satisfaction (expressed as the average satisfaction percentage calculated from CSI).

The CSI method is an index that measures tourist satisfaction across specific attributes (Manurung et al. 2024). Managing carrying capacity effectively is essential to ensure visitor satisfaction and environmental sustainability. The collected data were then analyzed using the CSI method, which involves four stages, and the calculations were performed using Microsoft Excel.

1. Determination of Mean Importance Score (MIS) and Mean Satisfaction Score (MSS). These scores were obtained by averaging the levels of expectation and performance.

$$MIS = \frac{[\sum_{i=1}^{n} Yi]}{a},\ MSS = \frac{[\sum_{i=1}^{n} Xi]}{a}\ i = 1 \quad \text{..... Equation 5}$$

Remarks: a = Number of respondents; N = Number of customers; Yi = Importance value of the i-th attribute Y; Xi = Importance value of the i-th attribute X; i = Performance of the i-th attribute

2. Creation of Weight Factors (WF). Weight Factors were the percentage of each MIS value relative to the total MIS of all attributes.

$$WFi = \frac{MISi}{\sum_{i=1}^{p} MISi} \text{ x } 100 \quad \text{..... Equation 6}$$

Remarks: p = p-th attribute of interest; i = i-th attribute performance

3. Creation of Weight Score (WS). This weight was the product of WF and the average satisfaction level or MSS.

$$WSi = Wfi \text{ x } MSSi \quad \text{..... Equation 7}$$

4. Determination of CSI. The calculation of CSI was carried out by dividing the total satisfaction score by the maximum satisfaction score on a 5-point scale. Furthermore, the maximum score of 5 is multiplied by 100%.

$$CSI = \frac{\sum_{i=1}^{p} WSi}{HS} \text{ x } 100\% \quad \text{..... Equation 8}$$

The results of the satisfaction measurement using the CSI method were classified with a scale representing the level of tourist satisfaction in a range of 0-100%. The classification of visitor satisfaction levels based on CSI values is shown in Table 2. The criteria for tourist satisfaction levels were used according to the recommendation by (Sari & Lestari 2021).

Table 2. Table of visitor satisfaction level criteria (Source: (Sari & Lestari 2021))

No.	CSI Value (%)	CSI Category
1.	81%–100%	Very Satisfied
2.	66%–80.99%	Satisfied
3.	51%–65.99%	Moderately Satisfied
4.	35%–50.99%	Less Satisfied
5.	0–34.99%	Dissatisfied

Result and Discussion

Components of Correction Factors

Herpetofauna Diversity

Tourism-related activities, including the construction of hiking paths, the establishment of camping areas, and rising numbers of tourists, could negatively affect ecosystems by causing habitat fragmentation, altering microclimatic conditions, and increasing noise and light pollution. The fragmentation alters microhabitat temperature and humidity, which can lead to physiological stress and interfere with the reproductive processes of herpetofauna (Kwatrina et al. 2019).

Puncak Becici

The results of the herpetofauna diversity index calculation at Puncak Becici are presented in Table 3. Six species of herpetofauna were recorded based on the survey conducted along areas intensively traversed by tourists. These consisted of two amphibian species and four reptile species.

The calculation results showed that the H' value was 1.614. This value was assigned as Mn, while Mt was set at 3, representing the upper threshold in the Shannon-Wiener diversity index classification. The correction factor (Cf_i) was 0.46.

Table 3. Herpetofauna diversity index calculation at Puncak Becici

Class	Scientific Name	Local Name	Family	Count	Pi (ni/N)	ln Pi	Pi lnPi
Amphibian	*Duttaphrynus melanostictus*	Kodok Buduk	Bufonidae	25	0.362	-1.015	-0.367
	Ingerophrynus biporcatus	Kodok Puru Hutan	Bufonidae	10	0.144	-1.931	-0.279
Reptile	*Gekko gecko*	Tokek Rumah	Gekkonidae	5	0.072	-2.624	-0.190
	Hemidactylus frenatus	Cicak Kayu	Gekkonidae	4	0.057	-2.847	-0.165
	Eutropis rugifera	Kadal Matahari	Scincidae	10	0.144	-1.931	-0.279
	Eutropis multifasciata	Kadal Kebun	Scincidae	15	0.217	-1.526	-0.331
		Total			69 Individuals		H' = 1.614

Source: Processed primary data by the authors, 2025

Hutan Pinus Sari

The results of the herpetofauna diversity index calculation at Hutan Pinus Sari are presented in Table 4. Four species of reptiles were recorded from the survey conducted along areas intensively traversed by tourists. Based on the calculation results, the H' value was 1.335, and the correction factor (Cf_1) was 0.55.

Seribu Batu Songgo Langit

The results of the herpetofauna diversity index calculation at Puncak Becici are presented in Table 5. Five species of herpetofauna, consisting of two amphibians and three reptiles, were recorded from the intensively traversed areas of Seribu Batu. The calculation results showed an H' value of 1.560, and the correction factor (Cf_1) was 0.48.

Slope

Slope is considered both a supporting and limiting factor for a tourism area. The degree of slope in a given area tends to influence the number of tourists and directly or indirectly affects the carrying capacity. The average slope was calculated at 15.75% based on the analysis of the three tourist destinations. The value fell into the moderately steep category, with a slope gradient ranging from 15% to 25%.

Soil Erodibility

Soil present across the three tourist destinations was classified as latosol according to data provided by the National Land Agency (BPN) of Bantul Regency in 2021. This soil type is officially recognized and categorized under national soil classification standards in reference to the Minister of Agriculture Decrees No. 837/Kpts/Um/11/1980 and No. 683/Kpts/Um/8/1981. Latosol soil was classified as moderately susceptible to erosion, with a score of 30. The obtained value of Mn was 30, and Mt was 75, resulting in the correction factor (Cf_3) of 0.6.

The overall value shown in Table 6 was obtained from the evaluation conducted through data collection of correction factors across the entire areas effectively used for tourism activities.

Tourist Satisfaction

Puncak Becici

The CSI score was calculated at 76.32% using satisfaction data from 100 respondents who visited the

Table 4. Herpetofauna diversity index calculation at Hutan Pinus Sari

Class	Scientific Name	Local Name	Family	Count	Pi (ni/N)	ln Pi	Pi lnPi
Reptile	*Hemidactylus frenatus*	Cicak Kayu	Gekkonidae	5	0.47	-1.917	-0.282
	Eutropis rudis	Kadal Serasah Coklat	Scincidae	10	0.294	-1.224	-0.360
	Eutropis rugifera	Kadal Matahari	Scincidae	7	0.206	-1.580	-0.325
	Eutropis multifasciata	Kadal Kebun	Scincidae	12	0.353	-1.041	-0.368
		Total			34 Individuals		H' = 1.335

Source: Processed primary data by the authors, 2025

Table 5. Herpetofauna diversity index calculation at Seribu Batu Songgo Langit

Class	Scientific Name	Local Name	Family	Count	Pi (ni/N)	ln Pi	Pi lnPi
Amphibian	*Duttaphrynus melanostictus*	Kodok Buduk	Bufonidae	9	0.180	-1.715	-0.309
	Ingerophrynus biporcatus	Kodok Puru Hutan	Bufonidae	8	0.160	-1.833	-0.293
Reptile	*Eutropis rugifera*	Kadal Matahari	Scincidae	6	0.120	-2.120	-0.254
	Eutropis multifasciata	Kadal Kebun	Scincidae	12	0.240	-1.427	-0.343
	Eutropis rudis	Kadal Serasah Coklat	Scincidae	15	0.300	-1.204	-0.361
		Total			50 Individuals		H' = 1.560

Source: Processed primary data by the authors, 2025

Table 6. Factor correction value

Factor correction variable	Parameters	Factor correction value
Biotic	Herpetofauna Diversity at Puncak Becici *(Cf_1)*	0.46
	Herpetofauna Diversity at Hutan Pinus Sari *(Cf_1)*	0.55
	Herpetofauna Diversity at Seribu Batu *(Cf_1)*	0.48
Abiotic	Slope at Becici *(Cf_2)*	0.4
	Slope at Hutan Pinus Sari *(Cf_2)*	0.4
	Slope at Seribu Batu Songgo Langit *(Cf_2)*	0.4
	Soil erodibility *(Cf_3)*	0.6

Puncak Becici tourist attraction. The score was in the 66%-80.99% range, placing it in the satisfied category. Therefore, Puncak Becici tourist attraction management needs to continuously strive to improve performance until the tourist satisfaction index nears or even reaches 100%. Tourists had the highest satisfaction rating at 20.82% for the appropriateness of ticket prices to the facilities at tourist attractions. The lowest satisfaction rating at 16.35% was for the availability of insurance and health facilities (health posts/ambulances).

Tourists to Puncak Becici expressed satisfaction with the appropriateness of ticket prices and the facilities provided. The relatively low-ticket price was considered comparable to, or even higher than, tourists' expectations because of the inclusion of facilities such as natural scenery, photo spots, seating, restrooms, places of worship, and food stalls. This high perceived value provided a pleasant experience without requiring much spending, thereby increasing tourist satisfaction with the economic and comfortable aspects of the visit.

The lowest satisfaction was associated with the availability of insurance and health facilities, such as health posts or ambulances, due to a lack of information, limited visibility, and the actual presence of medical facilities in the tourist attraction area. Tourists felt medically unsafe due to a lack of knowledge of emergency response procedures and the absence of signage or safety education. These results showed that although the functional aspects of tourism were quite good, the security and safety aspects required greater attention to improve overall satisfaction.

Hutan Pinus Sari

The CSI score was estimated at 77.85% using satisfaction data from 100 respondents who visited the Sari Pine Forest tourist attraction and was classified as satisfactory. Therefore, the management needs to continuously strive to improve performance until the tourist satisfaction index nears or even reaches 100%. Tourists had the highest satisfaction rating for toilet cleanliness and comfort, at 21.41%. Meanwhile, the lowest satisfaction rating was for the availability of insurance and health facilities (health posts/ambulances), at 16.80%.

Toilet cleanliness and comfort received the highest rating because toilets are considered basic and essential facilities that directly impact comfort during tourism. Clean, comfortable, and easily accessible toilet facilities made a positive impression, as their needs were met. The presence of adequate toilets was considered a significant added value in the context of natural tourism, such as Hutan Pinus Sari, which is located far from residential areas or public facilities.

The lowest scores for insurance and health facilities (health posts/ambulances) can be explained by the facilities' passive nature and their indirect visibility. Many tourists were unaware of the availability of health facilities during their stay due to the lack of information boards, the absence of visual signs such as ambulances, or the limited interaction with the facilities, except in emergencies. Health aspects were not prioritized unless experiencing medical problems, leading to low perceptions. The unavailability or invisibility of these facilities gave the impression that management was not prepared to handle emergencies, which lowered the score for the safety aspect. Tourists' perceptions of the health facilities tended to be lower, despite the potential functional necessity in certain circumstances.

Seribu Batu Songgo Langit

Satisfaction data from 100 respondents who visited the Seribu Batu Songgo Langit tourist attraction showed that the CSI score was 80.52%. This score was in the 66%-80.99% range, placing it in the satisfactory category. Therefore, the management needs to continuously strive to improve performance until CSI (75) nears or even reaches 100%. The highest satisfaction score (22.71%) was given to the attribute "Suitability of Promotions to Services at Tourist Attraction". The lowest satisfaction score at 16.46% was given to the attribute "Availability of Supporting Facilities", such as Souvenir Shops. The correspondence between promotion and service had the highest score because the advertised facilities were actually available and met tourists' expectations. For example, glamorous camping (glamping) with complete hotel-like facilities was available, providing a unique and comfortable tourism experience, as promised in the promotional materials. Tourists' confidence increased because there was no gap between expectations and

reality. The suboptimal provision of on-site souvenir shops led to the lowest score for the availability of these facilities. Tourists often requested souvenirs as part of their tourism experience, and the lack of adequate choices gave the impression that supporting aspects were not yet fully developed.

Carrying Capacity

Puncak Becici

The PCC of a tourist attraction can be determined by identifying the area of the tourist destination (A), the area required per tourist for a comfortable and satisfying experience (B), and the rotation factor (Rf). The area of Puncak Becici intensively used for tourism activities (A) was 0.51 ha. The operational period of the tourist attraction was 06:00 to 17:00 (11 hours). Based on questionnaire data, the average space required per tourist was 2.52 m^2, the average duration of stay was 1.6 hours, and the rotation factor (Rf) was 6.8.

The calculation results for environmental carrying capacity showed a consistent pattern: PCC values exceeded RCC and were greater than ECC. Given the total available area, the attraction could accommodate up to 13,719 people daily. However, when correction factors related to spatial limitations and tourist activities were applied, the figure dropped to 1,514 people/day. Incorporating an additional correction factor based on tourist satisfaction reduced the capacity to 1,150 people/day, equivalent to roughly 34,500/month and 419,750/year. The results suggested that the actual number of tourists visiting Puncak Becici between 2021 and 2023 remained within sustainable limits. This was evidenced by the peak annual tourism in 2023, which reached 198,224 tourists—an average of 16,519 monthly or 543 daily—still significantly below the attraction's ecological carrying capacity.

Hutan Pinus Sari

According to the spatial analysis, the area of tourist attraction along the trekking path covered 0.97 ha. The operational period of Hutan Pinus Sari spanned from 06:00 to 17:00, totaling 11 hours. The questionnaire results showed that each tourist required an average of 2.6 m^2 of space and typically stayed for about 2.8 hours, resulting in a calculated rotation factor (Rf) of 3.92.

An environmental carrying capacity analysis at the Hutan Pinus Sari tourist attraction showed a consistent trend: PCC exceeded RCC, and RCC exceeded ECC. Given the total available area, the attraction could accommodate up to 14,550 people /day. After applying correction factors for spatial constraints and tourist activities, the number decreased to 1,920 people/day. Further adjustment using the tourist satisfaction factor yielded an ECC of 1,478 people/day, corresponding to an estimate of 44,340 tourists/month and approximately 539,470/year. The results suggested that the actual number of daily tourists visiting Hutan Pinus Sari between 2021 and 2023 remained within environmental limits. This was supported by the peak tourism in 2023, which totaled 277,712 tourists, translating to an average of 23,143 /month or 760/day.

Seribu Batu Songgo Langit

The area of Seribu Batu Songgo Langit, intensively used for tourism activities (A), was 0.63 ha, as confirmed by spatial area analysis. The attraction operated from 06:00 to 19:00, for a total of 13 hours. Based on the questionnaire analysis, the average space required per tourist was 2.9 m^2, with an average visit duration of 4.32 hours, and the rotation factor (Rf) was calculated to be 3.

An environmental carrying capacity analysis at the Seribu Batu Songgo Langit tourist attraction showed a consistent hierarchy: PCC was greater than RCC, and RCC exceeded ECC. The area could physically accommodate up to 6,489 people/day based on the total space. This figure dropped to 747 people/day when adjustments were made for spatial constraints and the nature of tourist activities. Incorporating the satisfaction factor further reduced ECC to 597 people/day, equivalent to roughly 17,910 tourists /month, or 217,905 annually. The results showed that the number of daily tourists visiting Seribu Batu Songgo Langit from 2021 to 2023 remained within the attraction's ecological limits. This was confirmed by the highest annual tourism in 2023, which totaled 89,601 tourists, averaging 7,466/month or 245/day.

Comparative Analysis of Carrying Capacity

Table 7 presents a comparison of carrying capacity values across tourist attractions. Conducting a

comparative analysis of carrying capacity values is essential for determining the maximum number of tourists that each attraction can handle without compromising environmental integrity or diminishing the overall experience (Eagles & McCool 2002). Ecotourism carrying capacity assessment requires a systematic approach that integrates ecological, social, and economic indicators, along with the minimum limiting factor method to produce realistic and actionable outcomes (Aldalbahi 2025).

Table 7. Comparison of carrying capacity values across tourist attractions

Location	PCC (people/day)	RCC (people/day)	ECC (people/day)
Puncak Becici	13,719	1,514	1,150
Hutan Pinus Sari	14,550	1,920	1,478
Seribu Batu Songgo Langit	6,489	747	597

Physical Carrying Capacity (PCC)

The comparison of PCC values showed that Hutan Pinus Sari had the highest capacity of receiving tourists, with 14,550 people/day, followed by Puncak Becici with 13,719 people/day, and the lowest was Seribu Batu Songgo Langit with 6,489 people/day. These values were determined by three main factors, including the total attraction area, the space required per tourist, and the rotation factor (i.e., the number of possible visits per day based on the average duration of stay). Hutan Pinus Sari performed optimally due to its relatively large area of 9,700 m^2 and shorter average visit duration, resulting in a high tourist rotation rate. Puncak Becici, despite having the smallest area (5,100 m^2), maintained a high PCC value due to the extremely short average visit duration (approximately 1.6 hours), which directly increased the potential for higher daily turnover. Seribu Batu Songgo Langit, although spatially larger than Puncak Becici (6,300 m^2), recorded the lowest PCC value.

Real Carrying Capacity (RCC)

RCC comparison showed that the ranking of values matched that of PCC, namely Hutan Pinus Sari (1,920 people/day), Puncak Becici (1,514 people/day), and Seribu Batu Songgo Langit (747 people/day). However, the rate of decrease varied across attractions due to differences in the ecological correction factors applied to each. This research used three correction parameters, including herpetofauna diversity (Cf_1), slope (Cf_2), and soil type (Cf_3). The herpetofauna correction factor (Cf_1) varied across the attractions and was considered the primary determinant of RCC variation (Cruz-Garcia et al. 2017). Hutan Pinus Sari had the highest Cf_1 value (0.55), representing a relatively more stable and diverse ecosystem. Puncak Becici had the lowest Cf_1 (0.46), and Seribu Batu Songgo Langit remained in between with a value of 0.48. Meanwhile, the slope (Cf_2) and soil type (Cf_3) correction factors were the same across all three attractions (0.4 and 0.6, respectively), as all were located in moderately steep areas with latosol soil slightly susceptible to erosion.

Effective Carrying Capacity (ECC)

ECC was calculated by multiplying RCC, adjusted for ecological correction factors, by CSI. Evaluating the physical, real, and effective carrying capacities of attraction areas is essential to prevent tourism pressure from exceeding environmental limits (Siahaan et al. 2023). This method enabled a more comprehensive evaluation by accounting for environmental capacity to accommodate tourists and integrating experience quality. The results showed that Hutan Pinus Sari had the highest ECC (1,478 people/day) due to the high RCC and CSI of 77.85%, making it the most suitable attraction for further development. Puncak Becici had an ECC of 1,150 people/day (CSI 76.32%), with potential for improvement through enhanced services. Seribu Batu Songgo Langit, despite having the highest CSI (80.52%), recorded the lowest ECC (597 people/day) due to ecological constraints, suggesting the need for stricter visitation limits.

CSI scores provide only a general overview of satisfaction levels, without explaining which attributes have the greatest influence. At each attraction area, tourists had different levels of satisfaction with each attribute. For example, at Puncak Becici, tourists were satisfied with the ticket prices relative to the facilities available. This satisfaction occurred because the ticket price was considered reasonable or low, leading tourists to feel the costs incurred were proportional to the benefits obtained. Facilities such as gazebos, photo spots, toilets, rest areas, and parking lots were found to be quite complete, well-maintained, and clean, even though the ticket price

was not high. In addition, the expectations of tourists were met because they aligned with the available reality. The scenery, natural atmosphere, and comfort experienced enhanced the tourism experience, which was considered "worth it." The main factor influencing satisfaction was the match between the value (ticket price) and the benefits received from the facilities and the tourism experience.

Nursyam et al. (2023) found that exceeding ECC thresholds led to a decline in the quality of the tourist experience. The case of La Tigra National Park in Honduras further reinforced the importance of keeping tourism in ECC limits to ensure sustainable development, a principle highly relevant to the RPH Mangunan area. Hutan Pinus Sari had the highest carrying capacity, while Seribu Batu Songgo Langit had the lowest. Therefore, Hutan Pinus Sari holds the greatest potential for further development, provided that conservation priorities are maintained. The other two attractions require more rigorous tourist management strategies further.

Correlation Between Environmental Carrying Capacity and Tourist Satisfaction

Tourism development that exceeds ecological capacity can degrade environmental quality and reduce tourist satisfaction. This is consistent with the ECC model, which integrates RCC and CSI to reflect both the ecological and psychological aspects of tourism carrying capacity (Istacahyani et al. 2024). The results showed a strong relationship between environmental carrying capacity (PCC, RCC, ECC) and tourist satisfaction in the RPH Mangunan tourism area. Attractions with higher carrying capacities, such as Hutan Pinus Sari, could offer greater comfort and satisfaction than those with more limited capacity, such as Seribu Batu Songgo Langit. Seribu Batu, with the highest CSI score (80.52%), had the lowest ECC value due to spatial and ecological limitations. Meanwhile, Hutan Pinus Sari demonstrated a balanced relationship between environmental carrying capacity and tourist satisfaction, underscoring the importance of integrating both in tourism planning.

This research was supported by a previous investigation (Nursyam et al. 2023) that found that exceeding the ECC threshold led to decreased satisfaction, while managing tourist numbers within ECC limits helped maintain a high-quality tourism experience. Sustainable tourism should not focus solely on increasing visits, but must be accompanied by regulation of tourist numbers to prevent long-term environmental strain (Darwis et al. 2024). Well-managed ECC enhances tourist satisfaction while preserving environmental sustainability. Therefore, carrying capacity-based management is essential for achieving sustainable and high-quality tourism development (Kaharuddin 2020).

Conclusion

This research shows that all three tourist attractions operate significantly below the respective ECC thresholds, confirming that current tourist numbers remain in ecologically and managerially sustainable limits. Puncak Becici can accommodate up to 1,150 people/day (CSI 76.32%), and Hutan Pinus Sari can accommodate up to 1,478 people/day (CSI 77.85%). Seribu Batu Songgo Langit, despite achieving the highest tourist satisfaction (CSI 80.52%), has the lowest ECC at 597 people/day. These results contribute empirical evidence that maintaining tourism in ECC limits is closely associated with high satisfaction levels, signifying the strategic value of carrying capacity–based management for preserving environmental integrity while improving service quality and destination competitiveness.

Ecological correction factors, such as herpetofauna diversity, slope conditions, and soil type, help refine RCC. By adjusting PCC to reflect on-site ecological realities, the stated factors tend to yield more accurate, context-sensitive ECC values. This methodological contribution strengthens the accuracy of carrying capacity assessments in forest tourism areas. Overall, integrating ecological parameters with tourist perception metrics (CSI) offers a more comprehensive approach to carrying capacity analysis. The implications extend to tourism managers and policymakers by showing that sustainable development requires balancing biophysical constraints with experiential quality. This integrated framework supports evidence-based decision-making correlated with ecotourism principles and long-term destination sustainability.

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