

TOURISM SUITABILITY INDEX OF PERJIWA WATERFALL IN KUTAI KARTANEGARA REGENCY

Indeks Kesesuaian Wisata Air Terjun Perjiwa di Kabupaten Kutai Kartanegara

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ABSTRACT

This study aims to analyze the level of tourism suitability and area carrying capacity as an ecological basis for managing the Perjiwa Waterfall tourism area in Kutai Kartanegara Regency. The research was conducted using a quantitative descriptive approach through field observations, spatial mapping, measurement of physical environmental parameters, and distribution of structured questionnaires to 33 visitors. Data analysis included the calculation of the Tourism Suitability Index (TSI) for three recreational activities and the Area Carrying Capacity (ACC) based on spatial-temporal limits. The results revealed that before the rain, the tourism suitability index for sitting/relaxing and viewing scenery was classified as highly suitable (S1), while water activities were classified as suitable (S2). However, after rainfall, the suitability for water activities significantly dropped to unsuitable (S3) due to a drastic increase in turbidity and water current velocity. The ecological carrying capacity calculation showed that the maximum threshold of visitors that the ecosystem can accommodate is 858 people per day across all activities. Management recommendations focus on implementing a strict daily visitor quota and early warning systems during adverse weather to maintain ecological sustainability and visitor safety.

Keywords: Carrying Capacity, Tourism Suitability Index, Perjiwa Waterfall, Water Quality, Ecotourism Management.

ABSTRAK

Penelitian ini bertujuan untuk menganalisis tingkat kesesuaian wisata dan daya dukung kawasan sebagai dasar ekologis dalam pengelolaan kawasan wisata Air Terjun Perjiwa di Kabupaten Kutai Kartanegara. Penelitian dilakukan dengan pendekatan deskriptif kuantitatif melalui observasi lapangan, pemetaan spasial, pengukuran parameter fisik lingkungan, serta penyebaran kuesioner terstruktur kepada 33 responden pengunjung. Analisis data meliputi perhitungan Indeks Kesesuaian Wisata (IKW) untuk tiga aktivitas rekreasi utama dan Daya Dukung Kawasan (DDK) berdasarkan batasan ruang dan waktu. Hasil penelitian menunjukkan bahwa sebelum hujan, indeks kesesuaian wisata untuk aktivitas duduk santai dan melihat

pemandangan tergolong sangat sesuai (S1), sedangkan aktivitas bermain air tergolong sesuai (S2). Namun, setelah turun hujan, tingkat kesesuaian untuk aktivitas bermain air menurun drastis menjadi tidak sesuai (S3) yang dipicu oleh lonjakan kekeruhan dan kecepatan arus secara signifikan. Perhitungan kapasitas daya dukung ekologis menunjukkan bahwa ambang batas maksimum pengunjung yang dapat ditampung kawasan adalah 858 orang per hari untuk seluruh akumulasi aktivitas. Rekomendasi pengelolaan difokuskan pada penerapan kuota pengunjung harian yang ketat serta sistem peringatan dini cuaca buruk demi menjaga keberlanjutan ekosistem dan keselamatan pengunjung.

Kata Kunci: Daya Dukung Kawasan, Indeks Kesesuaian Wisata, Air Terjun Perjiwa, Kualitas Air, Manajemen Ekowisata.

INTRODUCTION

Ecotourism is a form of natural resource utilization that integrates environmental conservation, education, and the economic well-being of local communities. Along with the shift in global tourism trends from mass tourism to alternative tourism, inland water landscape-based attractions—such as rivers and waterfalls—are becoming increasingly popular. Kutai Kartanegara Regency, located in East Kalimantan Province, is blessed with immense hydrological and topographical potential, featuring dozens of waterfall landscapes scattered across various sub-districts. Most of these tourist destinations are categorized as "hidden gems" due to their lush vegetation and exotic physical forms; however, they have not been scientifically explored to determine the safe limits of their utilization.

Although previous studies have extensively examined the carrying capacity of coastal and marine ecosystems, research integrating physical suitability values and ecological thresholds in waterfall ecosystems within East Kalimantan remains highly limited. Currently, most local management of waterfall tourism is oriented solely toward economic targets and visitor numbers, disregarding fluctuations in biophysical water parameters, such as the impact of rainfall on flow velocity and river turbidity. The lack of standardized zoning for recreational space utilization leaves the area vulnerable to environmental pollution and poses high safety risks for tourists. Therefore, a comprehensive study that specifically integrates spatial-ecological analysis with the formulation of applicable management strategies is urgently needed.

Perjiwa Waterfall, located in Perjiwa Village, Tenggarong Seberang Sub-district, is one of the potential lotic water destinations experiencing a rising trend in visitor numbers. Its river structure flows over rock formations beneath a dense secondary forest canopy, making it an ideal location for various recreational activities such as wading, swimming, taking selfies, and camping. However, the characteristics of lotic waters are highly sensitive to global environmental changes, sedimentation, and surface runoff. Increased human activity in the water without capacity control is feared to trigger physical damage to the waterfall pool, riverbank erosion, the decline of aquatic biota, and the accumulation of solid domestic waste.

To prevent over-tourism and environmental degradation, scientific instruments such as the Tourism Suitability Index (TSI) and Regional Carrying Capacity (RCC) analysis are absolutely essential. TSI measures the extent to which the physical characteristics of the water support the comfort and safety of specific activities, while RCC determines the maximum threshold of individuals that the geographical space of the attraction can accommodate simultaneously without causing ecological stress. Through this comprehensive research, it is expected that accurate quantitative biophysical data will be obtained as a foundation for developing operational policies for managers to maintain the sustainable existence of the Perjiwa Waterfall ecosystem.

Although several previous studies have extensively examined the carrying capacity of areas in coastal and beach ecosystems, research on the integration of physical suitability values and ecological threshold limits in waterfall ecosystems in East Kalimantan remains very limited. Most local waterfall tourism management currently focuses solely on economic targets and visitor quantity, without considering fluctuations in aquatic biophysical parameters, such as the influence of rainfall on current velocity and river turbidity levels. The absence of standardized zoning for recreational space utilization renders these areas vulnerable to environmental pollution and poses high safety risks to tourists. Therefore, a comprehensive study is needed that specifically integrates spatial-ecological analysis with the formulation of applicable management strategies.

Air Terjun Perjiwa is one of the potential inland-water ecotourism sites that has experienced a continuous increase in visitor numbers. This surge in tourist activities in the lotic (flowing) water area poses a risk of environmental degradation if not accompanied by rigid capacity management restrictions. In the absence of science-based data management, tourist activities such as playing in the water, taking photos, and sitting leisurely in sensitive ecosystems can trigger local ecological damage. Therefore, research on the Tourism Suitability Index (IKW) and the Carrying Capacity of the Area (DDK) becomes highly crucial as a foundational instrument for policy-making to minimize the impacts of over-tourism while preserving natural sustainability. This study is designed to identify the IKW value and calculate the daily visitor threshold through the DDK approach.

METHODS

A. Research Time and Location

This field research was conducted at the Perjiwa Waterfall natural tourism area, which is administratively located in Perjiwa Village, Tenggara Seberang Sub-district, Kutai Kartanegara Regency, East Kalimantan Province. The determination of sampling and observation points was based on a purposive sampling method, where the ecotourism area was divided into two main zones (Spots) representing the centers of tourist concentration and possessing distinct physical aquatic characteristics.

1. **Spot 1:** The downstream area or lower main pool, characterized by a gentle slope and dense canopy cover, which serves as the primary concentration zone for water-based recreational activities.
2. **Spot 2:** The upstream area or upper reach, featuring a higher waterfall cliff, steep rock formations, and a more open landscape viewpoint.

B. Data Collection Method

The data collected in this study includes primary data and secondary data:

1. **Primary Data:** Obtained through direct field measurements (in-situ) of environmental biophysical parameters, including pool water depth (cm), surface current velocity (m/s) using a flowmeter or float method, and water clarity level (%). The availability of dry land area was measured using a measuring tape and spatial mapping to estimate the actual area available for recreation. Visitor perception and sociodemographic data were collected through structured questionnaires randomly distributed to 33 respondents encountered at the research location.
2. **Secondary Data:** Includes secondary climatological data in the form of regional rainfall data from the Meteorology, Climatology, and Geophysics Agency (BMKG), general village governance profiles, as well as literature studies from relevant national and international scientific journals.

Data Analysis

1. Tourism Suitability Index (TSI) Analysis

The suitability analysis aims to assess the feasibility of the site based on a matrix of physical parameters for three recreational sub-activities: relaxing/sitting, water-based activities (wading), and sightseeing. The assessment refers to the index formula developed by Yulianda (2019):

$$\sum_{i=1}^n (B_i \times S_i)$$

Where:

TSI = Tourism Suitability Index

B_i = Weight of the i -th parameter

S_i = Score of the i -th parameter

Each biophysical parameter is evaluated using a score range of 1 to 3 (Highly Suitable = 3, Suitable = 2, Not Suitable = 1). The total obtained index value is then matched with the following suitability level classifications:

- a) Highly Suitable (S1): $TSI \geq 2.5$
- b) Suitable (S2): $2.0 \leq TSI < 2.5$
- c) Not Suitable (S3): $1.0 \leq TSI < 2.0$.

2. Calculation of Area Carrying Capacity (DDK)

The Area Carrying Capacity is calculated to limit the number of daily visits so that it remains below the tolerance threshold of the physical environment. The ecological mathematical formula applied is as follows:

$$DDK = K \frac{Lp}{Lt} \times \frac{Wt}{Wp}$$

Where:

K = ecological carrying capacity coefficient (typically set at 0.5 for waterfall ecosystems to account for recovery periods)

Lp = total available physical area for recreational activities (m^2)

L_t = area required per visitor for specific activities (e.g., sitting leisurely: $2 m^2/person$; playing in the water: $5 m^2/person$; sightseeing: $1 m^2/person$)

W_t = total daily operating hours (hours)

W_p = average time spent per visitor per activity (hours)

The resulting DDK value represents the maximum number of visitors allowed per day to maintain ecological sustainability without causing significant environmental degradation. Standardization for the spatial requirement unit value (L_t) and time allocation (W_p) refers to standard literature on freshwater ecotourism management (Yulianda, 2019), adjusted for real-life tourist behavior observations at Perjiwa Waterfall.

RESULT

A. Hydro-Biophysical Characteristics of Perjiwa Waterfall

Based on geomorphological observations, Perjiwa Waterfall exhibits a continuous lotic flow type, with water volume fluctuations that are highly dependent on rainfall intensity within the upstream catchment area. The area is surrounded by secondary forest vegetation dominated by tree stands from the Dipterocarpaceae family, which provide a dominant natural shading effect. The riverbed formation consists of a mixture of solid sedimentary rocks, gravel, and partial mud substrates in the calm-current peripheral areas.

Physical parameter measurements reveal contrasting profile differences between Spot 1 and Spot 2. Spot 1 has a pool depth ranging from 30 cm to 60 cm, with an average surface

current velocity of 0.15 m/s under normal, pre-rainfall conditions. This condition makes Spot 1 a favorite area for children and families to bathe and wade. Conversely, Spot 2 is characterized by a steeper morphological configuration, with a pool depth directly beneath the waterfall plunge basin reaching 120 cm and a stronger current ranging around 0.35 m/s. Under normal conditions, water clarity at both spots ranges from 85% to 90%, where the bottom of the pool remains clearly visible, providing high aesthetic comfort for tourists.

B. In-Depth Analysis of Tourism Suitability Index (TSI)

The physical suitability level of the area was evaluated under two contrasting atmospheric conditions: clear weather (pre-rainfall) and post-rainfall conditions. This evaluation is crucial because the hydrological nature of waterfalls in East Kalimantan is highly vulnerable to sudden changes caused by surface runoff phenomena (flash floods).

1. Relaxing and Sightseeing Activities

Passive recreational activities, such as relaxing by the pool and sightseeing, showed highly stable and satisfactory index values. Prior to rainfall, the TSI value for relaxing was 2.65 at Spot 1 and 2.12 at Spot 2. This assessment is supported by the adequate availability of dry land, the absence of foul odor pollution around the waters, and a tree canopy cover percentage reaching over 80%. Shady trees along the riverbanks reduce direct solar radiation exposure, thereby creating a cool microclimate with air temperatures ranging between 26°C and 28°C.

For sightseeing activities, both spots achieved the "Highly Suitable" (S1) classification, with index values exceeding 2.50. The pristine landscape of the secondary tropical forest combined with the roaring sound of cascading water offers a psychological relaxation effect for visitors. Land-area cleanliness regarding plastic waste was observed to be well-maintained, thanks to the provision of waste bins along the trekking paths by the local management group.

2. Water-Based Activities and the Influence of Weather Dynamics

Water-based activities (wading/swimming) represent the sub-activity most vulnerable to changes in environmental parameters driven by meteorological factors. Prior to rainfall, the suitability analysis classified Spot 1 as "Suitable" (S2) with an index score of 2.25, and Spot 2 as "Highly Suitable" (S1) with an index score of 2.55, owing to adequate water depth and pool area for swimming activities.

However, post-rainfall observations revealed a drastic decline in the physical feasibility of the environment for water-based activities at both observation points:

DISCUSSION

A. Tourism Suitability Index (IKW) Analysis

The physical assessment results show significant fluctuations in the index, primarily influenced by external parameters such as rainfall. The following is a summary of the calculated biophysical parameter values for the Tourism Suitability Index (IKW) across various condition categories:

Table 1. Tourism Suitability Index (IKW)

Tourism Activity Category	Titik Pengamatan	Kondisi Lingkungan	Nilai IKW	Klasifikasi Kelayakan
Relaxing	Spot 1	Pre-Rainfall	2,65	Highly Suitable (S1)
	Spot 2	Pre-Rainfall	2,125	Suitable (S2)
Water-Based Activities	Spot 1	Pre-Rainfall	2,25	Suitable (S2)
	Spot 2	Pre-Rainfall	2,55	Highly Suitable (S1)
	Spot 1	Post-Rainfall	1,65	Not Suitable (S3)
	Spot 2	Post-Rainfall	1,95	Not Suitable (S3)
	Spot 1 & 2	Pre-Rainfall	≥ 2,5	Highly Suitable (S1)

Spot 1 & 2	Post-Rainfall	< 2,0	Not Suitable (S3)
Post-Rainfall Dynamics Analysis: When moderate to high-intensity rainfall falls over the catchment area for more than an hour, surface runoff occurs, carrying total suspended solids (laterite soil and leaf litter) from the surrounding hills into the river. Consequently, water clarity drops sharply from 90% to below 30%, causing the water to turn a turbid, muddy brown color. Furthermore, the river current velocity surges drastically, reaching 0.65 m/s at Spot 2, accompanied by a sudden rise in the pool's water level by 30–40 cm. Based on the Yulianda matrix calculation, the TSI value for water-based activities plummets to 1.65 at Spot 1 and 1.95 at Spot 2, which automatically categorizes the area under the "Not Suitable" (S3) classification. The high current velocity, combined with slippery aquatic substrates, increases safety risks for tourists, such as slipping, being swept away, or drowning. This fluctuating phenomenon in the index values underscores that the primary limiting factor in the ecotourism sustainability of Perjiwa Waterfall is the post-high rainfall hydrological condition.			

B. Regional Carrying Capacity (RCC) Analysis Study

The determination of regional carrying capacity aims to provide concrete numerical limits for the daily operations of ecotourism managers. In calculating the RCC value, the geographical space that is genuinely safe for recreation was measured in detail using tape-measure mapping. The total areas for landscape sightseeing, water pools, dry riverbanks, and designated camping zones were calculated separately.

The operational time provided by the management (\$W_t\$) is set at 9 hours per day (from 08:00 WITA to 17:00 WITA). Based on the questionnaire tabulation results regarding visitor behavior, the average time spent by a tourist for recreation at the site (\$W_p\$) is 3 hours, thereby yielding a daily rotation value (turnover rate) of 3 times a day.

The results of the spatial-temporal calculation integration for each tourism activity allocation are presented in the table below:

Table 2. The Spatial-Temporal Calculation Integration For Each Tourism Activity Allocation

Existing Tourism Activity	Available Area (L_p) (m^2)	Space Standard/ Person (L_t) ($m^2/person$)	Daily Turnover (W_t/W_p)	Maximum Capacity (Visitors/Day)
Sitting/Relaxing	1.600	15	3	320
Viewing Scenery	3.580	50	3	215
Water Activities	1.540	25	3	185
Camping	2.200	75	3	88
Boating	1.250	75	3	50
Total Accumulation (DDK)	10.170	—	—	858 person /day

Based on the spatial table analysis results above, the total cumulative regional carrying capacity of Perjiwa Waterfall is 858 people per day. This figure represents the maximum ecological saturation limit. Relaxing activities account for the largest capacity share at 320 people/day, as the spatial requirement per individual is relatively small (15 m^2) and the available dry riverbank area is quite extensive. Meanwhile, water-based activities are restricted to only 185 people per day to maintain the stability of the aquatic pool sediment, preventing excessive agitation of the bottom mud layer that could compromise the aesthetic clarity of the water.

If in practice, the number of daily visitors exceeds 858 people (overcrowding occurs), the forest and river ecosystems at Perjiwa Waterfall will endure environmental stress loads

beyond their natural recovery capacity (carrying capacity exceedance). The tangible impacts of this overcapacity include:

- a) **Soil Compaction:** The compaction of topsoil layers along the riverbanks caused by the trampling of thousands of tourists, which inhibits root aeration of pioneer plants and accelerates the rate of riverbank erosion.
- b) **Solid Waste Accumulation:** The volume of domestic plastic waste will surge sharply, surpassing the daily collection and removal capacity of the management, posing a risk of waste entering the river body and polluting the lotic ecosystem.
- c) **Decline in Tourist Comfort Index:** Overcrowding reduces the tranquility and psychological-aesthetic comfort sought by visitors, which in the long run decreases the re-visit rate.

Therefore, limiting the number of daily visits through a ticket-quota application system is the only preventive ecological policy that must be consistently enforced by the management and relevant government agencies.

C. Implications for Sustainable Management

By moving away from conventional business analysis approaches and focusing entirely on a conservation-based management approach, the results of this TSI and RCC study provide an adaptive governance blueprint. There are two primary interventions that must be structurally implemented:

1. **Implementation of a Visitor Restriction System (Carrying Capacity Pricing & Quota):** The management of Perjiwa Waterfall must abandon the unrestricted ticket sales system. The maximum quota of 858 people per day should be divided into designated visiting time slots (for instance, a maximum of 286 people allowed within the area during morning, midday, and afternoon blocks). Once the daily quota is reached, the entrance gate must be closed for environmental sustainability reasons.
2. **Weather-Based Water Activity Closure Management (Weather-Based Early Warning System):** Given that the TSI value for water-based activities drops to the "Not Suitable" (S3) category immediately after rainfall due to strong currents and turbidity, the management is required to station specialized lifeguards at Spot 1 and Spot 2. When visual indicators show a decline in water clarity and an increase in river discharge driven by upstream rainfall, the evacuation of tourists from the water must be executed promptly, and water-based activities must be temporarily suspended until hydrological parameters return to normal.

CONCLUSION

Based on the field research and ecological quantitative analysis conducted at the Perjiwa Waterfall tourism object in Kutai Kartanegara Regency, several fundamental conclusions can be drawn as follows:

1. The Tourism Suitability Index (TSI) in the Perjiwa Waterfall area is highly influenced by fluctuations in weather parameters and hydrological conditions. Under normal, pre-rainfall conditions, relaxing and sightseeing activities fall into the "Highly Suitable" (S1) category, while water-based activities range from "Suitable" (S2) to "Highly Suitable" (S1). However, post-rainfall, the suitability level for water-based activities drops drastically to "Not Suitable" (S3) due to limiting factors such as a surge in river current velocity ≥ 0.65 m/s and high water turbidity.
2. The maximum cumulative spatial-temporal threshold for the Regional Carrying Capacity (RCC) of Perjiwa Waterfall is 858 people per day across all types of recreational activities (relaxing, sightseeing, water-based activities, camping, and boating). Enforcing this quota limit is highly crucial to prevent environmental degradation in the form of soil compaction, water pollution, and the accumulation of domestic solid waste.

3. Future ecotourism management recommendations must center on restricting daily ticket quotas based on carrying capacity, as well as establishing a severe weather early warning safety system to ensure tourist safety while sustainably preserving the pristine nature of the lotic ecosystem.

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