

Evaluating Ecological Suitability and Carrying Capacity for Budo's Mangrove Ecosystem: Unveiling Ecotourism Potential and Limits

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Abstract:

Budo Village in North Sulawesi stands out as one of the top 50 recipients of the prestigious 2022 Indonesian Tourism Village Award. Notably, Budo is a popular tourist destination with a thriving mangrove area on Minahasa's northern peninsula. The Budo mangrove area has been designated as a tourist attraction since 1994 and garnered increased recognition in 2017, thanks to active promotional efforts aimed at coastal tourist destinations. Surprisingly, despite its transformation into a tourist destination, research has yet to be undertaken to assess the ecological suitability of mangroves in this context or determine the carrying capacity of the mangrove area. This study seeks to delve into the ecological suitability of Budo's mangrove ecological resources and investigate the carrying capacity of the area as a tourist destination. The results of this analysis categorize the Budo mangrove tourist destination as 'unsuitable,' as indicated by an IKW score of 1.5. Consequently, a comprehensive restoration approach is required to render this mangrove area suitable and viable for tourism. Mangrove restoration initiatives, coupled with more stringent adherence to ecotourism principles in the Budo mangrove area, along with considerations for its carrying capacity, could serve as vital steps towards achieving this objective.

Keywords: mangrove ecological suitability, carrying capacity analysis, Budo mangrove, mangrove restoration

1. Introduction

Mangrove ecosystems hold a pivotal role as one of the essential ecological systems in coastal regions. Alongside coral reef ecosystems and seagrass beds, mangroves actively contribute to the intricate web of life in coastal areas. In the global context, mangroves have garnered recognition for their remarkable capacity to mitigate global warming (1). They excel in carbon storage within biomass and sediments, surpassing terrestrial forests by four to fivefold (2–4). Furthermore, mangroves provide critical environmental services (5).

Indonesia is a significant custodian of mangrove ecosystems, accounting for approximately 20.7% of the world's total mangrove area (6). According to data from the Ministry of Environment and Forestry, Indonesia's mangrove area in 2021 extended to 3,364,076 hectares, marking an increase compared to the 2013-2019 period, when it was 3,311,207 hectares (7). Mangrove ecosystems in Indonesia play a crucial role in preserving coastal regions and their associated biodiversity (3,8). Various marine species depend on mangroves for different stages of their life cycles, including spawning, nurseries, and as sources of food and nutrients (2,9,10). The biodiversity of mangrove ecosystems is evident with the presence of 62 fish species, 91 mollusk species, and 28 crustacean species, as well as providing habitats for 167 bird species, diverse arthropods, and reptiles (11,12).

Indonesia's mangrove areas host a rich diversity of flora as well. Wardani et al. (13) have cataloged 202 plant species within Indonesia's mangroves, consisting of 89 tree species, 5 palms, 19 climbers, 44 ground herbaceous species, 44 epiphytes and 1 fern species. Of the 202 species, 43 species (including 33 tree species and several shrubs) were found to be true mangroves, while other species were found around mangroves, known as associated mangrove species (11,12).

The robust root systems and dense tree stand structure of mangroves reduce the impact of waves, mitigate erosion, and protect against intrusion and tsunami threats (11,14,15). These features, along with the unique

community structure of mangroves, make these areas safe and attractive for tourism and particular interest in recreational activities (16).

Given the vital ecological functions and rich biodiversity of mangrove ecosystems, it is not surprising that they have increasingly been developed as tourism destinations. Their uniqueness and inherent values make them attractive destinations for visitors, particularly considering the vast expanse of mangrove areas in Indonesia that span all its provinces (5,17). The Indonesian Ministry of Tourism, in collaboration with regional authorities, has actively promoted marine tourism destinations, including mangrove ecotourism.

The North Sulawesi Province, with its numerous mangrove areas across 13 regencies and cities, is rich in potential tourist destinations. More than 60 locations related to mangrove tourism have been identified, with some established in the last five years and others operational for a more extended period. Among these, the Budo Village mangrove tourism destination in North Minahasa Regency, North Sulawesi Province, has been a pioneer since 1994. It experienced further development 2017, establishing itself as a prominent mangrove tourism attraction. The promotion of Budo's mangrove tourism continues to gain momentum, increasing recognition at local, national, and even international levels, attracting both Indonesian and foreign tourists.

Since Budo Village's mangrove tourism is highly dependent on the area's mangrove resources, it is crucial to examine the sustainability of these coastal ecosystems. Sustainable management involves the utilization of mangroves for economic interests while upholding ecological and social considerations, as affirmed by a recent study on Budo's mangrove community conducted by Ruru et al. in 2023 (18). Within this framework, it is critical to research the carrying capacity of mangrove areas for tourism activities and the suitability of mangrove ecological resources to support the sustainable management of mangrove ecotourism destinations in Budo Village.

This study aims to analyze the suitability of mangrove ecotourism resources in the Budo Village mangrove tourism area and assess the carrying capacity of the Budo Village mangrove tourism area. By evaluating the suitability and carrying capacity, this research endeavors to determine the impact of development and the pressure on the mangrove area, assessing whether these resources remain suitable for their designation as an ecotourism destination. The study also aims to quantify the carrying capacity of the mangrove area, providing valuable insights into its potential for tourism activities.

2. Materials and Methods

2.1 Research Location

The research was conducted in the mangrove tourism destination area located in Budo Village, Wori District, North Minahasa Regency, North Sulawesi Province, Indonesia. The research was carried out over six months, spanning from February to July 2023.

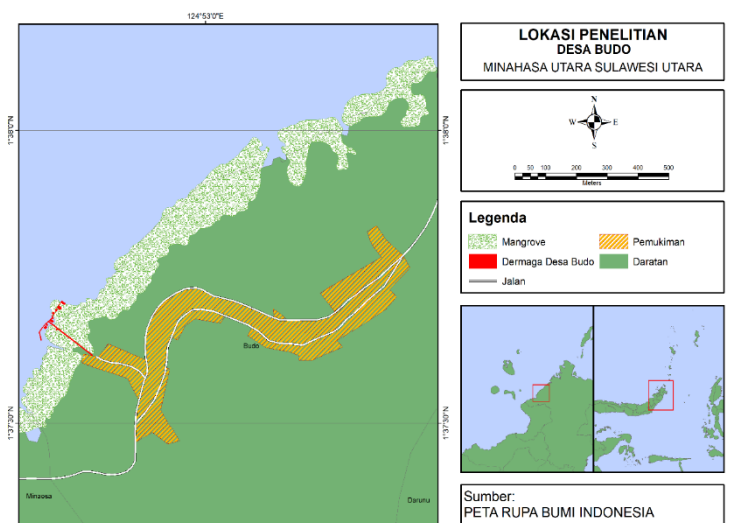


Figure 1: Research location

2.2 Data Collection

Data on the suitability of ecological resources were collected through a combination of methods, including:

1. Field surveys involving direct observations using the roaming method, interviews with the local community, and mangrove sampling.
2. Data searches from various relevant agencies and parties.
3. Processing and interpretation of Sentinel 2A imagery, as referenced in Abubakar et al. (19).

The data collected encompassed various parameters, including mangrove thickness, mangrove density, mangrove species, tides, and biota objects (12).

2.3 Data Analysis

The analysis of resource suitability was executed by calculating the Tourism Suitability Index, as outlined in Yulianda (12). Scoring and weighting were carried out based on all collected parameter data, guided by Table 1.

Table 1: Ecological Resource Suitability Matrix for Ecotourism in Mangrove Restoration Areas

No.	Parameters	Weight	Category	Score
1.	Mangrove thickness (m)	0.38	>500	3
			>200-500	2
			50-200	1
			<50	0
2.	Mangrove density (ind/100m) ²	0.25	>15-20	3
			>10-15	2
			5-10	1
			<5	0
3.	Mangrove type	0,15	>5	3
			3-5	2
			2-1	1
			0	0
4.	Low tide (m)	0,12	0-1	3
			>1-2	2
			>2-5	1
			>5	0
5.	Biota object	0,1	Fish, shrimp, crabs, mollusks, reptiles, birds	3
			Fish, shrimp, crab, mollusks	2
			Fish, mollusks	1
			One of the aquatic biota	0

The tourism suitability index was calculated as follows:

$$IKW = \sum (S_i \times B_i) \dots\dots\dots (1)$$

S_i= Score of i-th parameter

B_i= Weight of i-th parameter

Tourism suitability was categorized as follows:

Very Suitable = $IKW \geq 2.5$;

Suitable = $2.0 \leq IKW < 2.5$;

Not suitable = $1 \leq IKW < 2$;

Very Unsuitable = $IKW < 1$

The assessment of the area's carrying capacity (DDK), particularly in mangrove ecotourism, involved a multi-step calculation. It encompassed determining the ecological potential of visitors per unit area (k), followed by the ratio of the area's length that can be utilized (L_p) to the unit area for specific categories (L_t). It was further multiplied by the ratio of the time provided by the area for daily tourism activities (W_t) to the

time spent by visitors for each specific activity (W_p). The formulation for area carrying capacity analysis was adapted from Yulianda (12) and is expressed as:

$$DDK = k \times L_p/L_t \times W_t/W_p$$

Description:

DDK : Area Support Capacity (person/day)

K : Ecological potential of visitors per unit area (people)

L_p : Area/Length of area that can be utilized (m)

L_t : Unit area for a specific category (m)

W_t : Time provided by the area for tourism activities in one day (hours)

W_p : Time spent by visitors for each specific activity (hours)

The matrix illustrating the potential carrying capacity of mangrove ecotourism areas is presented in Table 5, developed from the works of Nugroho (12), Yulianda and Atmadipoera (20), and Winata et al. (21). This matrix was instrumental in identifying the activities with the potential for development in the tourist destination area, including tracking, fishing, boating, bird watching, picnicking, and camping.

Table 2: Mangrove Tourism Area Support Matrix

<i>Activity Type</i>	<i>Number of Travelers (person)</i>	<i>Unit Area (Lt)</i>	<i>Description</i>
Tracking	1	50 m	Calculated <i>track</i> length of each 1 person 50 m long
Fishing	1	25 m	1 person every 25 m distance with others
Boating	1	500 m	Maximum boating cycle 1 hour with a distance of 500 meters
Bird watching	1	67 m ²	1 person every 67m distance with others
Picnic	1	16 m ²	1 person every 16m distance with others
Camping	1	100 m ²	1 person every 100 m distance with others

3. Results

In this section, we explore the vital findings concerning the compatibility of ecological resources and the capacity for ecotourism in Budo Village's charming mangrove environment. We present the outcomes of our measurements and evaluations, shedding light on the ecological intricacies that form the basis for the sustainable development of this distinct tourist destination.

The results of measuring ecological resource suitability parameters for ecotourism in the mangrove area of Budo Village, North Minahasa Regency, Sulawesi Province, Indonesia, are summarized in Table 3. These parameters played a vital role in assessing the ecological suitability of the area for tourism activities.

Table 3: Measurement Results of Ecological Resource Suitability Parameters

<i>No.</i>	<i>Parameters</i>	<i>Measurement Results</i>
1.	Mangrove thickness (m)	189
2.	Mangrove density (ind/100m) ²	14
3.	Mangrove type	4

		<i>Avicennia marina</i> <i>Bruguiera gymnorhiza</i> <i>Rhizophora apiculata</i> <i>Sonneratia alba</i>
4.	Low tide (m)	3,7
5.	Biota object	Fish, shrimp, crab, mollusks

These initial measurement results were followed by an analysis of the suitability of ecological resources for ecotourism in Budo Village. The results of the ecological resource suitability analysis in Budo Village are presented in Table 4.

Table 4: Results of Ecological Resource Suitability Analysis for Ecotourism in the Mangrove Area of Budo Village

No.	Parameters	Measurement Results	Score (S)	Weight (B)	Value (SxB)
1.	Mangrove thickness (m)	189	1	0,38	0,38
2.	Mangrove density (Ind/100m) ²	14	2	0,25	0,5
3.	Mangrove type	4 <i>Avicennia marina</i> <i>Bruguiera gymnorhiza</i> <i>Rhizophora apiculata</i> <i>Sonneratia alba</i>	2	0,15	0,3
4.	Low tide (m)	3,7	1	0,12	0,12
5.	Object biota	Fish, shrimp, crab, mollusks	2	0,1	0,2
Total (Σ)					1,5

The ecological resource suitability analysis provided essential information on the suitability of the mangrove area for ecotourism. The total score of 1.5 indicates the overall suitability of the area, with a categorization that suggests areas of strength and areas that may require further attention.

Meanwhile, the calculation of ecotourism carrying capacity in Budo Village's mangrove area, detailed in Table 5, was rooted in activity types and ecological potential. Potential activities included tracking, fishing, boating, bird watching, picnicking, and camping.

Table 5: Carrying capacity of mangrove ecotourism in Budo Village

Activity Type	The Utilizable Mangrove Area of Budo (m)	Unit Area: Recommended Mangrove Area per Visitor (m/person)	Carrying Capacity of the Area (person/day)
Tracking	1680	50	33
Fishing	1680	25	67
Boating	1680	500	3

<i>Bird watching</i>	1680	67	25
Picnic	1680	16	105
<i>Camping</i>	1680	100	16

4. Discussion

The outcomes derived from this study provide a comprehensive understanding of the applicability of ecological resources for ecotourism endeavors in the mangrove region of Budo Village. These findings carry significant implications for the formulation and implementation of ecotourism strategies, underscoring the areas of proficiency and identifying potential sectors for enhancement. This discussion will further delve into these implications, providing a detailed analysis of the strengths and areas of improvement, thereby contributing to the development of sustainable ecotourism initiatives in the region.

4.1 Analyzing Suitability and Carrying Capacity

This study was conducted to analyze the suitability of mangrove ecotourism resources in the Budo Village mangrove tourism area and to assess its carrying capacity. By evaluating these parameters, we aimed to understand the impact of development on the mangrove area and to determine whether it remains suitable for its designation as an ecotourism destination. Additionally, our research sought to quantify the carrying capacity of the mangrove area, providing valuable insights into its potential for tourism activities.

Our measurements revealed that several ecological parameters fell below the ideal thresholds. Precisely, the mangrove thickness was measured at 189 meters, while the mangrove density was recorded at 14 individuals per 100 m². Furthermore, the mangrove area displayed limited species diversity, comprising *Avicennia marina*, *Bruguiera gymnorrhiza*, *Rhizophora apiculata*, and *Sonneratia alba*. The tidal range in the area reached 3.7 meters, and biota observations included fish, shrimp, crabs, and mollusks (7).

The assessment of these parameters led to the classification of the Tourism Suitability Index (IKW) for ecotourism in Budo Village as "Unsuitable" with an IKW score of 1.5. The primary contributors to this assessment were the low scores of two highly weighted parameters: mangrove thickness (0.38) and individual density (0.25). The former fell short of the ideal thickness for a tourist destination (500 meters), measuring only 189 meters, while the latter was below the desired range (15 to 20 individuals per 100 m²), with 14 individuals.

Additionally, the tidal range in the Budo mangrove area did not meet the ideal criteria for a high score (0-1 meter), registering a higher range (more than 1-2 meters). Mangrove species diversity and biota observations were rated average, with four mangrove species and biota objects limited to fish, shrimp, crabs, and mollusks. Ideally, the mangrove area should exhibit more than five types of mangroves and a more diverse range of biota objects, including reptiles and birds (7).

4.2 Mangrove Restoration and Sustainable Development

The results of these assessments collectively position the Budo mangrove area as unsuitable for ecological tourism. They raise concerns for the Budo Village government, responsible for managing the tourist attraction, and the North Minahasa district government, particularly the North Minahasa tourism office. To address these issues, we propose a comprehensive solution: mangrove restoration as a part of a sustainable ecotourism development approach.

Mangrove restoration and sustainable ecotourism development offer promising opportunities for coastal ecosystems. However, various challenges, risks, and barriers must be acknowledged and addressed (22–25). Restoration efforts require a long-term commitment, consistent funding, and multi-stakeholder coordination (23,25). Natural disasters and climate change impacts can hamper progress, as can competing resource uses and budget limitations (24). Additionally, increased tourism risks habitat damage and overuse unless carefully managed (22). Gaining support from local communities may be difficult if changes to traditional practices are perceived as top-down (22).

To maximize the chances of successful restoration and sustainable tourism development, it is vital to adapt plans and policies to address these risks and challenges (23,26–28). Integrated management approaches involving social capital and community participation can help overcome barriers (27,28). The economic and

ecological dimensions should be considered, focusing on sustainable sociocultural economic integration (26).

4.3 Restoration and Sustainable Tourism

Experiences in various Indonesian coastal areas have demonstrated that mangrove restoration can significantly increase the area, accelerate rehabilitation, and support the establishment of new community structures. In 2021, the Ministry of Environment and Forestry reported an increase in mangrove areas, highlighting the potential for rehabilitation and the expansion of natural mangroves (16,17).

Mangrove restoration efforts can restore the ecological aspects of this coastal natural resource while coexisting with Budo mangrove ecotourism activities. The restoration method chosen can affect the ability of restored mangroves to deliver various functions, including biogeochemical functions and wave dissipation (29). Also, effective mangrove restoration has the potential to impact the thickness and density of mangroves. It directly influences the presence and diversity of biota objects in the ecosystem (17).

Mangrove ecotourism, as a conservation strategy, prioritizes sustainable development, offering economic alternatives while supporting social development. It encourages responsible utilization of mangrove resources by local communities, as advocated by Ruru et al. in 2023 (18), allowing the community to benefit from the area's natural beauty, sociocultural traditions, and history, resulting in economic improvement, nature conservation, and community empowerment (30).

4.4 Budo Restoration and Sustainable Ecotourism Initiative

Therefore, to secure the long-term success of Budo Village as a tourist destination, it is urgent to launch a comprehensive Ecotourism and Sustainable Development Plan. This plan should start with thoroughly evaluating existing tourism activities, aiming to understand their environmental, social, and economic consequences. Involving key stakeholders, such as local communities, government bodies, tour operators, and environmental organizations, is vital to collect valuable insights and ensure a holistic approach. Subsequently, the plan can establish a set of region-specific ecotourism principles that highlight responsible tourism, cultural respect, and conservation tailored to the unique ecological and cultural attributes of the area.

The practical implementation of an ecotourism and sustainable development plan for a restored mangrove like Budo involves multiple crucial steps.

- Local community involvement in decision-making ensures respect for cultural traditions and ecological knowledge.
- Promoting responsible tourism includes waste management guidelines, wildlife protection, and educational programs.
- Creating economic incentives offers livelihood opportunities through guided tours, handicraft sales, and homestays.
- Integrating conservation efforts, such as mangrove restoration and wildlife monitoring, ensures long-term ecological health.

In short, mangrove ecotourism involves engaging communities, promoting responsibility, providing economic opportunities, and integrating conservation to preserve the mangrove ecosystem's natural beauty, cultural heritage, community empowerment, and economic growth.

An immediate and highly recommended practical action is implementing a mangrove planting program involving tourists, residents, community groups, and local governments. This restoration initiative should seamlessly integrate ecological principles into the area's development without disrupting tourism, ensuring sustainable utilization. Such an approach aligns with the core principles of ecotourism and sustainable development, effectively harmonizing economic interests with environmental sustainability.

4.5 Summary and Future Directions

To sum up, while the Budo mangrove area faces challenges in meeting ideal ecological tourism standards, the potential for restoration and sustainable development remains promising. By incorporating ecological principles and sustainable practices, this unique destination can continue to attract tourists and maintain its ecological value, contributing to the broader objectives of preserving our natural resources and promoting community welfare.

However, it is essential to acknowledge the limitations of this study. One limitation is the scope of the ecological parameters assessed, which offers opportunities for future research to explore additional ecological factors that impact the suitability of the mangrove area for ecotourism. Additionally, this study

primarily focuses on the ecological aspects without exploring the economic and social dimensions of ecotourism development. A more comprehensive analysis could consider these aspects as well.

5. Conclusion

Budo Village has achieved remarkable recognition, being among the top 50 recipients of the 2022 Indonesian Tourism Village Award and securing the coveted title in the digital and creative category. Its enchanting mangrove areas serve as a cornerstone for Budo's identity as a coastal tourist destination on the northern peninsula of Minahasa. However, a closer examination of the ecological suitability for ecotourism within the mangrove area paints a contrasting picture, classifying the Budo mangrove tourist destination as "unsuitable" with a Tourism Suitability Index (IKW) score of merely 1.5.

These findings demand the serious attention of the Budo village government, entrusted with the stewardship of the mangrove tourism destinations, and the North Minahasa district government, particularly the Tourism Office. Notably, none of the five parameters evaluating ecological suitability for mangrove tourism in Budo met the criteria of high value or ideal category.

Considering these challenges, the potential for mangrove restoration programs emerges as a viable solution to enhance the ecological suitability of mangrove resources as a tourist destination. Such restoration efforts should be seamlessly integrated with the development and refinement of the ecotourism model in the mangrove area. Mangrove ecotourism embodies a conservation strategy that prioritizes sustainable development, harmoniously combining environmental, economic, and socio-cultural facets. This careful management ensures the sustainable utilization of this precious resource while preserving its natural beauty and ecological value.

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