Conceptual framework for assessing the ecotourism carrying capacity of mangrove areas at ujung piring beach, Mlonggo

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Abstract. The mangrove ecosystem plays a crucial role in maintaining biodiversity and ecological functions in coastal areas. This conceptual article explores the potential of mangrove ecosystems as ecotourism destinations, focusing on the suitability assessment of the area and tourism support capacity on Kemujan Island, Karimunjawa National Park, Indonesia. The study employs land suitability evaluation and tourism capacity analysis to assess the condition of mangrove forests as natural tourist destinations. The assessment results indicate that the mangrove forests in the region have high biodiversity and facilities that support various ecotourism activities, such as trekking, nature photography, and wildlife observation. The tourism capacity evaluation also identifies that the area can accommodate a number of visitors, considering factors such as area size, types of activities, and visit duration. In conclusion, developing mangrove ecotourism could provide significant economic benefits while promoting environmental conservation, though careful management is required to ensure the sustainability of the ecosystem and the well-being of local communities.

1 Introduction

Coastal habitats, which support over 40% of the world's population, are highly productive ecosystems. However, rapid socio-economic development and global changes have significantly impacted these areas, leading to degradation and even the collapse of some coastal ecosystems. Therefore, sustainable coastal zone development has become a global priority [1]. Carrying capacity was initially defined as the maximum number of individuals that a habitat can support, and this concept has since expanded to include various types such as population, resource, environmental, and ecological carrying capacities [2].

Human activities include coastal reclamation, marine aquaculture, and environmental protection measures [3]. Current research has made progress in Carrying Capacity Assessment (CCA), but most of the focus has been on terrestrial areas, with limited systematic research on coastal regions. Existing Marine Eco-environmental Carrying Capacity Assessment (MECCA) studies often concentrate on single elements of carrying capacity, which do not fully reflect the coastal ecological status [4]. MECCA is still in its

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its early and immature stages. Integrated MECCA research that includes comprehensive assessment systems is rare and needs to be strengthened. Analytical methods such as Analytic Hierarchy Process, expert assessments, and Principal Component Analysis (PCA) have limitations, including subjectivity and difficulty in determining accurate carrying capacity in coastal areas. Analytical techniques for CCA, such as ecological footprints, index evaluations, system dynamics, fuzzy comprehensive assessment, and material element expansion methods, have limitations due to their terrestrial orientation and complexity [4]. Therefore, further exploration is needed for feasible and rational evaluation methods for marine ecological carrying capacity to support coastal management and ensure sustainable coastal zone development.

Mangroves provide numerous vital ecosystem services, including nutrient and carbon cycling, and offer various goods and services to coastal human communities [5]. However, mangrove forests worldwide have experienced significant degradation, with 35-50% damaged in the past three decades, particularly in Asia [5]. This damage releases carbon, exacerbates global warming, decreases water quality, reduces biodiversity, and destroys coastal habitats. Mangroves continue to face threats from natural hazards and human activities. Therefore, tools are needed to prevent or mitigate these hazards, which rely on accurate information about ecosystem vulnerability. Vulnerability assessments help identify potential pressures and estimate damage caused by destructive events.

Mangrove ecosystems are valuable coastal ecological units with unique characteristics [6]. Mangroves are known for their ability to retain and store various materials from sea currents, including organic waste and debris from land, due to their fertile environment. Mangroves are located in the transitional zone between seawater and freshwater, influenced by tidal dynamics, and support diverse biota that live in extreme and dynamic conditions [7]. While aquatic species are more common in mangroves, some terrestrial species also inhabit the mangrove ecosystem and surrounding areas. Previous studies have largely focused on the impacts of climate change, such as sea-level rise and temperature increases. However, for comprehensive management strategies, it is also crucial to consider the impacts of human activities, such as land use changes that disrupt freshwater flow to mangroves [4].

The degradation of mangrove ecosystems in Jepara reflects serious challenges for coastal environmental sustainability and the well-being of local communities. Human activities such as land clearing for shrimp and fish ponds, and the development of residential and industrial areas, have led to mangrove forest degradation and deforestation. Industrial, household, and shrimp pond waste that contaminates the water also damages the surrounding environmental quality, disrupting mangrove growth and the life of dependent biota.

Mangroves play a critical ecological role in protecting coastal environments from threats such as tsunamis, erosion, and seawater intrusion, and in supporting terrestrial biodiversity. In aquatic environments, mangroves serve as important habitats, breeding grounds, and nurseries for marine life, providing food and protection [5]. Additionally, mangrove forests, like those found in the Mlonggo coastal waters, have the potential to be developed as ecotourism destinations. Ecotourism, which focuses on natural experiences and ecological sustainability, can provide economic benefits to local communities while supporting conservation efforts and raising environmental awareness.

Ujung Piring Beach, with its mangrove ecosystem, is dedicated to protecting marine ecosystems, including coral reefs. The aim is for the development of mangroves at Ujung Piring Beach to not only preserve biodiversity but also to support education, research, recreation, and ecotourism. Overall, the research aims to evaluate the suitability of the mangrove ecosystem for ecotourism and assess the tourism capacity in the area.

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2 Methods

The article employs a combination of primary and secondary data collection methods to assess the ecotourism potential of a mangrove forest ecosystem. The primary data, such as species diversity, vegetation structure, and fauna, are measured using field observations and vegetation analysis, while secondary data come from documents like land coverage reports and community interactions. The study also uses Geographic Information System (GIS) image analysis to evaluate tree density, mangrove strip length, and inundation levels. In terms of analysis, various formulas are applied to calculate vegetation parameters like density, frequency, and dominance of species. The Tourism Suitability Index (TSI) and Tourism Carrying Capacity (TCC) calculations provide insights into the feasibility of mangrove areas for ecotourism, integrating natural factors and human impact to determine the maximum number of visitors an area can sustain without damaging the ecosystem.

2.1 Research location

The research location is the Marine Conservation Reserve Area in Desa Jambu (K-25), covering an area of 366.168 hectares in Jepara Regency, Central Java. This area holds significant potential as a center for environmental conservation and ecotourism. Situated along the shores of the Java Sea, its presence is crucial for maintaining marine ecosystems and biodiversity. The strategic coastal position of Desa Jambu makes it a key focus for environmental preservation and the development of ecotourism in the region.

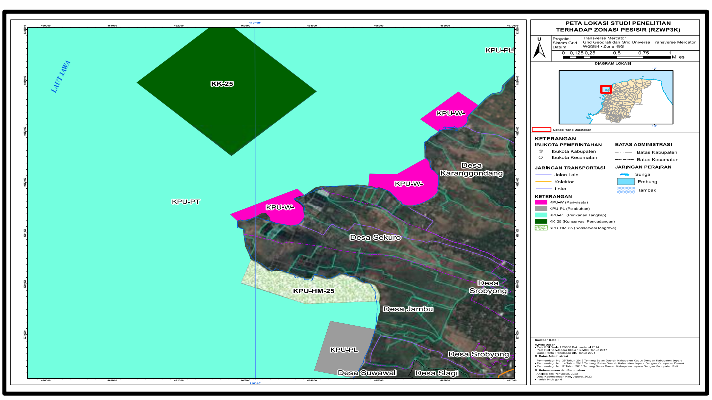

Fig. 1. Location map of kp-25 in relation to the rzwp3-k regulation of Central Java Province 2018-2038

2.2 Materials and methods

The relationship between various components of the mangrove ecosystem, the impacts of human activities, the feasibility of the ecosystem for ecotourism, and its carrying capacity is illustrated in Fig. 2.

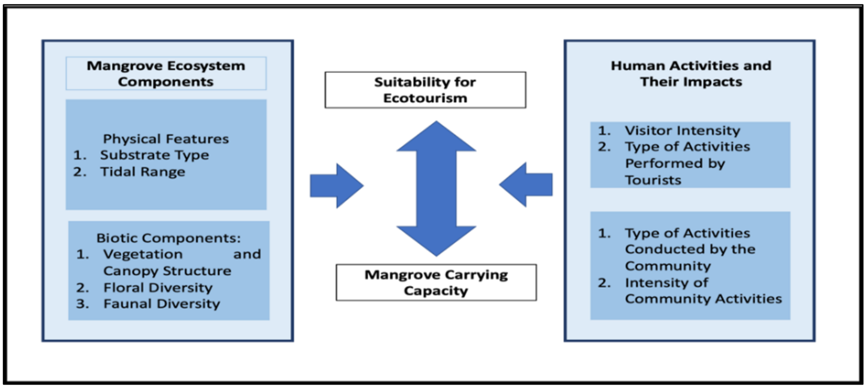

Fig. 2. Conceptual framework for assessing the ecotourism carrying capacity of mangroves at Ujung Piring beach, Mlonggo

2.3 Land suitability assessment

The assessment of mangrove forest land suitability for ecotourism (Table 1) is conducted using a matrix adapted from [7]. The primary attraction of mangrove ecotourism is the extent of the forest. Therefore, maintaining the mangrove environment in optimal condition is crucial to provide an enjoyable experience for visitors exploring the area under the canopy of mangrove trees. The mangrove trails in this area range from 50 to 200 meters, which is a reasonable distance for tourists to walk and observe the transition zone between land and sea. Additionally, the moderate tree density allows more sunlight to reach the ground, showcasing various root systems and mangrove fauna to visitors, providing sufficient natural light for photography. Furthermore, moderate density helps prevent excessive sunlight from making the temperature along the trails too hot.

High species diversity of plants and animals, along with various taxonomic groups available for exploration in the mangrove area, is valuable as an ecotourism attraction. Additionally, the presence of important flora and fauna species, categorized as endemic (E), rare (R), threatened (T), or protected (P) under applicable laws, is particularly noteworthy as these species underscore the importance of conserving the biodiversity of the mangrove ecosystem. The potential of the forest for ecotourism activities allows for the planning of various recreational activities for tourists, such as trekking (nature walks in the forest), nature photography, picnicking, birdwatching or wildlife observation, eco-education, camping, and fishing. Different levels of inundation are observed to record possible zonal variations in substrate and vegetation. It is assumed that greater zonal variation in this area indicates higher expected biodiversity in the ecosystem.

Table 1. Land suitability assessment matrix for mangrove forest in kp-25 for ecotourism purposes adapted from winata (2020).

Parameters	Weights	Good, score=3	Acceptable, score=2	Substandard, score=1	Poor, score=0
Mangrove strip length	5	50-200 m	200-500 m	>500m	<50m
Tree density (trees per 100 m-2)	4	5-10 trees	10-20 trees	>20 trees	< 5 trees
Floral diversity (∑ spp)	5	>10 spp	6-10 spp	2-5 spp	1sp
Important Plant Species (E/R/T/P)	3	>3spp	2-3 spp	1 sp	0

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Parameters	Weights	Good, score=3	Acceptable, score=2	Substandard, score=1	Poor, score=0
Fauna diversity (∑ spp)	5	>10 spp	6-10 spp	2-5 spp	1 sp
Important Animal Species (E/R/T/P)	3	>3spp	2-3 spp	1 sp	0
Diversity of animal taxa (mammals, birds, herpetofauna, fish, crustaceans, molluscs, etc.)	4	>4 taxa	3-4	2	1
Possible ecotourism activities offered	4	>7	4-7	2-3	1
Inundation level	2	Submerged by any current	Submerged for 10-19 days per month	Submerged for 5-9 days per month	Submerged for <5 days per month

2.4 Types and measurement of data

Data for this study is categorized into primary and secondary data. Primary data include species diversity and vegetation structure in the mangrove forest, fauna diversity, and various types of substrates along with related environmental conditions (substrate types and inundation levels during high tides) in the area. Secondary data encompass supporting information related to land coverage, annual forest reports, visitor perceptions, park ranger reports, and other relevant information necessary for supporting the analysis and conclusions of this study, including local community interactions with the mangrove forest (Table 2).

Table 2. Summary of research parameters and methodology adopted in this study.

Parameter	Metode	Instrumen
Mangrove strip length	GIS image analysis	GIS
Tree density (trees per 100 m-2)	Vegetation analysis	Grid Cells
Floral diversity (∑ spp)	Conducting an inventory of plant species inside and outside the vegetation analysis plot.	Grid Cells. Exploration
Important Plant Species (E/R/T/P)		
Fauna diversity (∑ spp)	Conducting an inventory of fauna species inside and outside the vegetation analysis plot.	
Important Animal Species (E/R/T/P)		Grid Cells, concentration calculation; Exploration
Diversity of animal taxa (mammals, birds, herpetofauna, fish, crustaceans, molluscs, etc.)	Document analysis, interviews, observations	
Possible ecotourism activities offered	Document analysis, interviews	Review of existing reports and records from

Parameter	Metode	Instrumen
		relevant authorities and visitors
Inundation level	GIS image analysis	Review of existing reports and records from relevant authorities, field observations

Vegetation data are analyzed using the following formulas:

1. Density of a species (D_e) (plants ha-1):

$$\frac{Number\ of\ individuals\ of\ a\ species}{Size\ of\ sampling\ plot\ (ha)} \quad (1)$$

2. Relative density (RDe):

$$\frac{Density\ of\ a\ species\ Density\ x}{total\ of\ all\ species}\ x\ 100 \quad (2)$$

3. Frequency of a species (F):

$$\frac{Number\ of\ plots\ where\ the\ species\ was\ found}{Total\ number\ of\ sampling\ plots} \quad (3)$$

4. Relative Frequency (RF):

$$\frac{Frequency\ of\ a\ species\ x}{Frequency\ of\ all\ species}\ x\ 100 \quad (4)$$

5. Dominance of a species (D_o)

$$\frac{Total\ basal\ area\ of\ a\ species}{Total\ area\ of\ sampling\ plots} \quad (5)$$

6. Relative Dominance (RD_o)

$$\frac{Dominance\ of\ a\ species\ x}{Total\ dominance\ of\ all\ species}\ x\ 100 \quad (6)$$

7. Important Value (IV)

$$IV = RD_e + RF + RD_o \quad (7)$$

2.5 Fauna diversity

Data on mangrove fauna are presented in a tabulated format, categorizing all observed species based on their taxa (e.g., class, order, family). The relative abundance or proportion of abundance for bird species in mangrove areas is estimated using the IPA (Indices Ponctuel d'Abondance) method, which applies a simple statistical equation for analysis.
Important Flora and Fauna

Important flora and fauna for conservation are categorized based on their conservation status, which includes species that are endemic (E), rare (R), threatened (T), or protected (P) under Indonesian law. The conservation status is primarily referenced from the IUCN Red List of Threatened Species and may also cross-reference with CITES appendices to assess their protection status.

2.5.1 Assessment of area suitability for ecotourism

The area suitability index used for tourism assessment, known as the Tourism Suitability Index (TSI), is applied in this research following the equation provided by Muflih et al. (2015):

$$TSI = (\Sigma\ Vi / Vmax) \times 100\% \quad (8)$$

Where:
AAA = Attractiveness of the area (e.g., natural beauty, biodiversity, accessibility)
BBB = Existing facilities and infrastructure for tourism (e.g., pathways, observation points, guides)
CCC = Conservation value of the area (e.g., importance for ecosystem preservation, endangered species habitat)
DDD = Degree of human impact or disturbance (e.g., pollution, encroachment)

This index helps to evaluate the overall suitability of a mangrove area for ecotourism, considering both the natural and man-made factors that influence its potential as a tourist destination.

2.5.2 Classification of TSI values

The Tourism Suitability Index (TSI) is classified into one of three categories based on its percentage value:

1. Highly suitable: TSI > 75%
2. Moderately suitable: 50% < TSI ≤ 75%
3. Not suitable: TSI ≤ 50%

2.6 Assessment of ecotourism carrying capacity

The ecotourism carrying capacity (TCC) of a location refers to the maximum number of visitors that can be accommodated in an area within a specific time period without adversely affecting the natural and social environment of the area. This formula helps in determining the sustainable number of visitors that the site can support while maintaining its ecological balance and social harmony. The TCC is measured using a modified version of the formula from Muflih et al. (2015):

$$TCC = A_v \times (S_a/S_v) \times (T_a/T_v) \quad (9)$$

Where:
TCC : Tourism Carrying Capacity of an area
A_v : The smallest unit of activity that can be conducted by visitors in the area (people)
S_a : The width or size of space available for visitor activities (in meters or square meters)
S_v : Minimum spatial unit required for specific activity categories by visitors (in meters or square meters)
T_a : Time period designated for a particular tourism activity per day (hours)
T_v : Average time spent by visitors on each tourism activity (hours)

The TCC assessment, based on the values of Av, Sa, Ta, and Tv, developed by various studies on the types of tourism activities that can be promoted in mangrove forests, is presented in Table 3 below.

Table 3. Assessment of carrying capacity for specific tourism activities (winata, 2020).

Activities	A_y	S_a	T_a	T_y
Trackking	1	50m	8	2
Bird Watching	1	67m^2	8	2

Activities	A_y	S_a	T_a	T_y
Picnic	1	16m^2	8	2
Camping	5	100m^2	24	24

3 Results and conclusions

The findings from this research underscore the significant ecological value of the mangrove ecosystem at Pantai Ujung Piring and highlight several key implications for its management and development.

1. First and foremost, there is a pressing need for robust conservation strategies to preserve the rich biodiversity of this ecosystem. Effective management practices must be implemented to safeguard critical species and habitats from further degradation caused by development or pollution. This includes regular monitoring of environmental conditions, as well as proactive measures to mitigate human impacts and ensure the long-term health of the mangrove forest.
2. The strong potential for ecotourism development at this site presents an opportunity to enhance both environmental conservation and local economic benefits. Investment in infrastructure that supports sustainable tourism activities is crucial. This involves creating eco-friendly trails, providing educational signage, and ensuring that tourism operations do not disturb the delicate balance of the ecosystem. By developing ecotourism thoughtfully, it is possible to offer enriching experiences to visitors while simultaneously promoting conservation awareness and stewardship.
3. Economic benefits for local communities are a significant implication of this research. The introduction of ecotourism can lead to direct economic advantages for residents through job creation and increased revenue from tourism activities. Involving local residents in the tourism sector and decision-making processes can improve livelihoods and foster a supportive attitude towards conservation efforts. Training and capacity-building programs are essential to equip locals with the skills required for roles in ecotourism and related fields.
4. Managing the sustainability of tourism activities is critical to avoid overexploitation of the mangrove ecosystem. The tourism carrying capacity (TCC) analysis suggests the need for guidelines to regulate visitor numbers and ensure that tourism remains within the ecosystem's sustainable limits. This approach will help maintain ecological balance and prevent negative impacts on both the environment and the local community.
5. Effective policy and planning are necessary to guide the development of ecotourism in mangrove areas. Policies should harmonize conservation goals with tourism objectives, ensuring a balanced approach that supports both. Collaboration among government agencies, conservation organizations, and local stakeholders is essential to create and implement comprehensive strategies for sustainable mangrove management.
6. Public awareness and education play a crucial role in supporting the conservation and sustainable use of mangrove ecosystems. Educational programs for visitors and local communities should emphasize the importance of mangroves, conservation practices, and the benefits of ecotourism. Increasing environmental education can foster a culture of stewardship and enhance support for ongoing conservation initiatives.

Based on the above concepts, it can be concluded the mangrove ecosystem holds significant potential for development into an ecotourism destination due to its rich biodiversity and ecological importance. The high species diversity of both flora and fauna, including key conservation species, underpins its value as a unique natural attraction. Ecotourism in mangrove areas offers not only a distinctive experience for visitors but also the opportunity for substantial economic benefits for local communities.

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Assessment of the area's suitability for ecotourism, through metrics such as vegetation diversity, the presence of important species, and the availability of facilities for activities like trekking, nature photography, picnicking, bird-watching, and ecological education, indicates that Pantai Ujung Piring mangrove forest is highly suitable. Furthermore, the tourism carrying capacity (TCC) evaluation suggests that the area can accommodate a significant number of visitors while considering factors like the size of the area, types of activities, and duration of visits. Additionally, the Tourism Carrying Capacity (TCC) assessment to be conducted can reveal whether the area has the capacity to accommodate a certain number of visitors, considering factors such as area size, types of activities offered, and visit duration. This is crucial to ensure that ecotourism growth can be achieved sustainably without disturbing the natural and social environment of the area.

The local inhabitants in Mlonggo Jepara gain a great deal economically from ecotourism at Ujung Piring Beach. It can make money by advertising nearby establishments that provide guided tours, lodging, dining services, and handcrafted goods. Local employment rises as a result of job opportunities created in industries like tour guiding, hotels, and conservation. Furthermore, ecotourism stimulates the market for goods and services generated locally, bolstering the local economy.

Impacts from society and culture can be advantageous as well as difficult. Because tourists are interested in local customs and support historical preservation, ecotourism can increase a community's sense of pride in its culture. But it might also result in the commercialization of cultural activities, which could change how authentically local rituals are practiced. When a community adjusts to tourism, its way of life may alter as well, sometimes prioritizing the demands of visitors over more customary pursuits.

Resource conflicts can arise, particularly when traditional livelihoods such as fishing, agriculture, or mangrove forest use are in competition with tourism. There may be conflict between the growth of tourism and local needs as a result of conservation initiatives or the building of tourist facilities that restrict locals' access to natural resources. It's crucial to resolve these disputes if ecotourism is to protect local jobs.

xInteractions between visitors and the local population can promote environmental awareness and cross-cultural exchange. Overtourism, however, has the potential to upset local life and irritate locals if it is not properly controlled. Managing the influx of tourists while ensuring the welfare of the community is essential to preserving good relations between tourists and residents.

Overall, the potential for mangrove ecotourism is promising as a sustainable source of income for local communities while fostering environmental conservation and awareness. However, effective planning and management are crucial to ensure that ecotourism activities positively contribute to the sustainability of the mangrove ecosystem and the well-being of local residents.

Finally, ongoing research and monitoring are vital to understanding the long-term impacts of ecotourism and other human activities on the mangrove ecosystem. Future research should focus on evaluating the effectiveness of conservation measures, tracking changes in biodiversity, and refining management practices based on empirical evidence. This continuous feedback loop will help ensure that ecotourism development remains sustainable and beneficial for both the environment and local communities.

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