Interaction of Social-Ecological Systems in Achieving Sustainable Mangrove Tourism in Mandar Village, Banyuwangi Regency, Indonesia

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Interaction of Social-Ecological Systems in Achieving Sustainable Mangrove Tourism in Mandar Village, Banyuwangi Regency, Indonesia

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Abstract

The interaction between ecology and society is crucial for achieving the sustainability of the mangrove ecosystem and the well-being of the multicultural Mandar Village community. This study aimed to examine the interaction within the social-ecological system of Mandar Village's mangrove tourism. The main mangrove species in the tourism area include Rhizophora mucronata, Sonneratia alba, and Avicennia marina. The Tourism Suitability Index (IKW) was 56.41% at station 1 and 58.97% at station 2, categorizing both as conditionally appropriate. The sustainability status is rated as moderately sustainable at 56.55%, influenced mostly by characteristics such as mangrove thickness, labor absorption, tourist perception, and management rules. The mangrove environment, nature tourism, the Fisheries Service, water quality, and fisheries extension workers are the most prominent nodes in the degree centrality of the social-ecological system's interactions. The primary elements linking the nodes are the mangrove ecosystem and ecotourism. The categorization illustrates the intricacy of the relationship, resulting in the establishment of seven groupings based on analogous traits. Managers must enhance their capacity to oversee mangroves, address ongoing community concerns regarding the removal of debris from these ecosystems, develop innovative educational tourism attractions centered on mangroves, and foster collaboration between the government and community to bolster mangrove sustainability and economic prospects for community welfare.

Keywords: Mangrove Tourism, Suitability, Sustainability, Interaction, Social-Ecological System

1. Introduction

Mangrove forests are natural resources in tropical regions that provide significant ecological and economic advantages. Indonesia is an archipelagic nation possessing the largest mangrove forests globally ((Ramena et al., 2020),(Aritonang et al., 2022)). The total amount of existing mangroves in Indonesia, according to the 2021 national mangrove mapping, is 3,364,080 hectares, whereas the area of potential mangrove habitat is 756,183 hectares, attributed to eroded areas, vacant land, degraded mangroves, ponds, and newly formed land. East Java encompasses 27,222 hectares of mangroves, with area percentages classified as dense at 47.26%, moderate at 46.08%, and sparse at 6.66%. Consequently, East Java is the region with the most extensive mangrove forests on the island of Java (Figure 1) (Ditjen PDASRH RI, 2021). The mangrove ecosystem serves as a green belt for coastal regions, playing a crucial role in sustaining environmental equilibrium, preventing erosion, offering habitat for diverse fauna, and delivering economic advantages to the community (Wulandari et al., 2024). It also contributes to climate change mitigation (Imburi et al., 2024) and possesses the capacity to sequester carbon ((Sulaiman, 2023),(Rani et al., 2023),(Asadi et al., 2024),(Choudhary et al., 2024),(Sidik et al., 2025)).

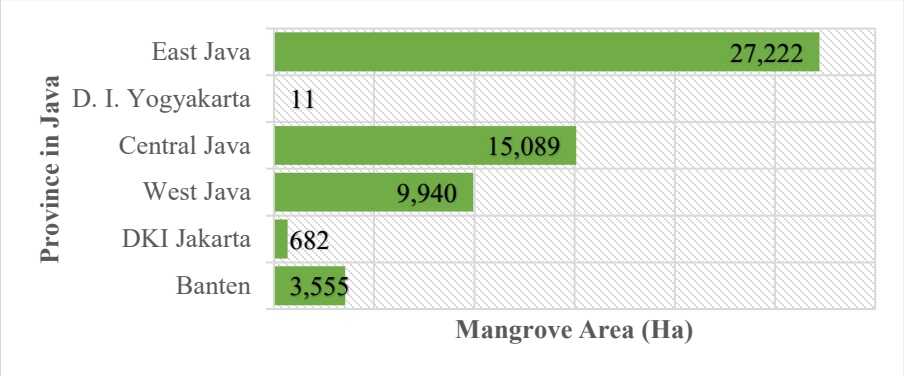


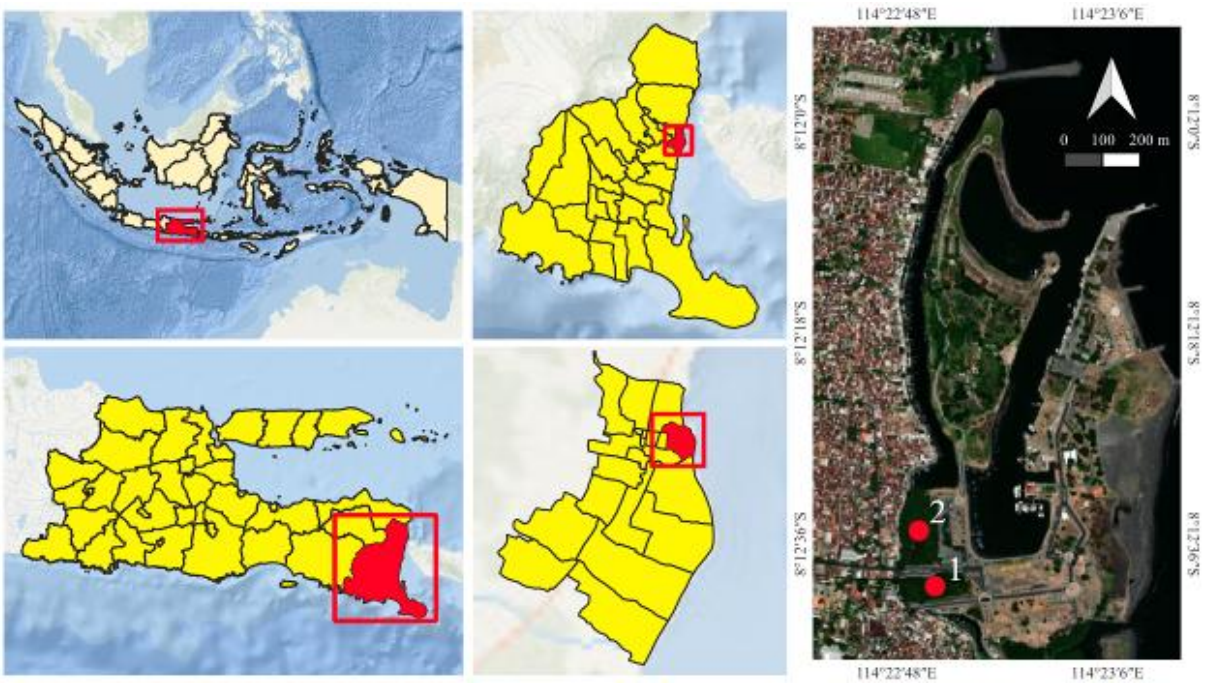
Figure 1. Mangrove Area Ecosystems on Java Island

Mangrove ecosystems have ecological advantages and can also be leveraged for tourism development (Fitrawahyudi & Sofyan, 2019). The attractiveness of diverse mangrove habitats attracts tourists and enhances understanding of their role in mitigating climate change effects (Prihadi et al., 2024). The utilization of mangrove ecosystems for tourism aligns with the transition from traditional tourism, characterized by mere travel, to contemporary tourism, which encompasses educational and conservation objectives (Syaifuddin et al., 2023). Management of sustainable tourism positively influences coastal habitats; yet, tourism activities may adversely affect these ecosystems if tourists engage in harmful behaviors (Fattah et al., 2023). The efficient administration of mangrove tourism through the engagement of coastal communities enhances the sense of ownership and is intrinsically linked to the mangrove ecosystem ((Hakim et al., 2017),(Fattah et al., 2019),(Mardianton et al., 2024)).

The management of Mandar Village mangrove tourism exemplifies the interplay between social dynamics and ecology, serving not just as a tourist attraction but also enhancing the local economy and promoting sustainable environmental conservation. Moreover, it necessitates cooperation and comprehension among stakeholders to guarantee equitable mangrove exploitation that reconciles commercial and ecological objectives. The ethnic diversity in Mandar Village, encompassing the Mandar, Osing, Javanese, Madurese, Chinese, and Arab communities, engenders distinctive socio-cultural dynamics in the stewardship of the mangrove ecosystem. Each ethnic group contributes local knowledge, values of wisdom, and diverse resource usage techniques to establish a multicultural community-based mangrove management system. This study aimed to examine the interaction within the socio-ecological system of Mandar Village's mangrove tourism.

2. Research Method

This study was carried out in the mangrove tourism region of Mandar Village, Banyuwangi Regency, from August 2024 to January 2025 (Figure 2). This study included expert sampling including 30 participants, including mangrove managers, representatives from the Culture and Tourism Office, the Animal Husbandry and Fisheries Office, Village Heads, community leaders, and relevant stakeholders. Data analysis was conducted to assess the viability of mangrove tourism utilizing the mangrove tourism suitability index (Table 1). Rapfish Multidimensional Scaling (MDS) was employed to evaluate the sustainability of mangrove tourism, while the socio-ecological system framework was applied to examine interactions in mangrove tourism management.



Gambar 2. Observation Station for Mangrove Tourism, Mandar Village (Station 1: 8°12'39.60" BT , 114°22'52.10" LU; Station 2: 8°12'36.71" BT , 114°22'53.08" LU)

Biota data acquisition was conducted utilizing visual techniques. Biota were immediately viewed at each observation site and captured using fishing apparatus. The collected biota were subsequently identified utilizing an identification manual (Latupapua et al., 2019). Species density refers to the quantity of individuals of species i inside a specified unit area, represented by the formula:

$$K = \frac{n_i}{A} \qquad (1)$$

Total density refers to the quantity of all mangrove individuals inside a specified unit area, represented by the following formula:

$$KT = \frac{\sum n}{A} \qquad (2)$$

Description:
K = Density of species-i
KT = Total density
A = Total area of sampling area (sample plot area)
ni = Total numbe of individuals of species-i
Σn = Total number of stands of all species

Table 1. Parameters, Weigths, Categories, and Ecotourism Suitability Scores

No	Parameters	Weights	Categories	Scores
1	Mangrove thickness (m)	5	> 500	3
			> 200-500	2
			50-200	1
			< 50	0
2	Mangrove density (100 m^2)	3	> 15-20	3
			> 10-15	2
			5-10	1
			< 5	0
3	Mangrove type	3	> 5	3
			3-5	2
			1-2	1
			0	0
4	Tides (m)	1	0-1	3
			> 1-2	2
			> 2-5	1

No	Parameters	Weights	Categories	Scores
			> 5	0
5	Biota objects	1	Fish, shrimp, crab, molluscs, reptiles, birds	3
			Fish, shrimp, crab, molluscs	2
			Fish, molluscs	1
			One of the aquatic biota	0

Source:(Yulius et al., 2018)

Tourism activities must be adapted to the conditions of natural resources and their utilization. The tourism suitability index serves to identify ecosystems suitable for tourism (Wahdaniar et al., 2019). The mangrove tourism category encompasses five elements with two assessment classifications:

$$IKW = \sum \left(\frac{N_i}{N_{maks}}\right) x100\%$$

Description:
IKW = Mangrove tourism suitability index
Maximum value: 39
Suitable: 75–100%
Conditionally suitable: 50–<75%
Not suitable: <50%
Ni = Value of the i-th parameter (weight x score)
Nmaks = Maximum value of a tourism category

The sustainability of mangrove tourism in Mandar Village, Banyuwangi Regency, Indonesia was evaluated across four dimensions utilizing a questionnaire administered to experts, with each indicator of the five dimensions rated on a scale from 1 (poor) to 3 (excellent). A higher score signifies that mangrove tourism is in a favorable state. The stages of analysis comprise the analytical process (Kavanagh & Pitcher, 2004):

1. *Multi-Dimensional Scaling (*MDS*):* This ordination technique is employed to assess the positioning of favorable and unfavorable spots.
2. *Monte Carlo* (MC): Monte Carlo analysis assesses the impact of stochastic errors employed to estimate the ordination value utilized.
3. *Leverage*: Utilize leverage analysis to identify the traits that are responsive to each dimension of sustainability–namely environment, economy, socio-culture, and governance–in enhancing the assessed index value.

The goodness of fit in MDS analysis is assessed using the S-stress value and the coefficient of determination (R^2). A low S-stress value signifies an excellent fit (Fauzi & Anna, 2005). The model is considered satisfactory if the study yields an S-stress value below 0.25 ($S < 0.25$) and an R^2 value nearing 1 (100%) (Tony J. Pitcher, 1999). An analysis utilizing the Rapfish software tool yielded the sustainability index value for Mandar Village Indonesia's mangrove tourism, as presented in Table 2, categorized into four sustainability status levels: none, low, adequate, and sustainable.

Table 2. Categories of Sustainability Status

Index Value	Category
0 – 25	unsustainable
>25 – 50	Less sustainable
>50 – 75	Sufficiently sustainable
>75 – 100	sustainable

Source: (T. J. Pitcher & Preikshot, 2001)

Connectivity analysis of the Social-Ecological System of mangrove tourism using RStudio program, encompassing degree centrality, betweenness centrality, and cluster centrality. The centrality measure indicates that nodes with a greater number of direct connections will exhibit greater dominance than those with fewer or no connections. Consequently, degree centrality (DC) is merely the degree of each node. The degree of a node refers to the quantity of connections it possesses with other nodes (Luke, 2015). The equation for degree centrality is as follows:

$$C_D(n_i) = \frac{\sum_1^j eij}{N-1}$$

Where:
$C_D(ni)$: centrality degree (ni) in the network (degree)
N : total number of nodes in the system

eij : the edge between node (i) and node (j)

Betweenness Centrality (BC) quantifies the extent to which a node lies on the shortest paths connecting other nodes in a network, necessitating that those paths traverse through that node. Consequently, nodes with elevated connectedness exhibit greater dominance as they are positioned to monitor or regulate the flow of information inside the network (Luke, 2015). The equation for betweenness centrality is as follows:

$$C_B(n_i) = \sum_{j<k} g_{jk}(n_i) / g_{jk}$$

Where:
$C_B(n_i)$: betweenness cetrality (ni) in the network (betweenness)
g_{jk} : the geodesic between nodes j and k
$g_{jk}(n_i)$: the number of geodesics between nodes j and k that contain node i

Cluster Centrality (Cc), or community discovery, is a method for quantifying centrality in a social network, emphasizing the proximity of an actor to all other actors. Cc will compute the centrality weight of a node by summing the shortest distances between node i and other nodes (Lestari et al., 2023). Community detection is assessed with the subsequent formula:

$$C_C = \frac{N-1}{\sum_{j\neq i}^{n} d(ni,nj)}$$

Where:
Cc : cluster centrality in the network
d (ni,nj) : distance between nodes (ni) and (nj)
N : the number of nodes in the network

3. Result and Discussion

3.1. Assessment of Mangrove Tourism Viability in Mandar Village

Mangrove tourism in Mandar Village (Figure 3) was initiated in 2023 by the Ministry of Maritime Affairs and Fisheries through the establishment of the Mandar Village Youth Community Supervisory Group (*Pokmaswas*) Number: 188/KEP/429.501.13/2023, chaired by Muhammad Fathoni. The objective of developing mangrove tourism is to save the mangrove ecosystems in the Mandar Village region via tourist and economic initiatives centered around mangroves. The mangrove tourist site is situated between residential areas and Boom Beach tourism, adjacent to a river flow. The mangrove area of station 1 is 1.76 hectares, whereas station 2 encompasses 1.14 hectares. (Zulia et al., 2019) assert that the proximity of mangroves to residential areas subjects them to pressure from local residents' activities, including illegal logging and trash.

Figure 3. Mangrove Tourism in Mandar Village

The amount of mangrove tourism in Mandar Village is quantified by a perpendicular line extending from the riverbank to the outermost mangrove vegetation adjacent to the sea. The proliferation of mangrove trees is a natural occurrence. Station 1 exhibits the greatest thickness at 164.83 m, whilst station 2 measures 96.52 m. Consequently, based on the mangrove thickness parameters at both stations, Mandar Village's mangrove tourism is deemed less suited for ecotourism, as the thickness falls between the range of 50-200 meters.

Table 3. Thickness of Mangrove Tourism in Mandar Village

Observation Station	Thickness (m)
1	164.83
2	96.52

Mangrove tourism in Mandar Village features three varieties of mangroves, including *Rhizophora mucronata* (Figure 4a), characterized by its lustrous leaves, broad elliptical shape with acuminate tips, and both supporting and aerial roots. Secondly, *Sonneratia alba* (Figure 4b) possesses distinctive features including green, oval-shaped leaves with rounded tips, respiratory roots, and spherical, flat, green fruit resembling apples. Third, *Avicennia marina* (Figure 4c) possesses oval or elliptical leaves, respiratory roots, and grayish-green fruit like a mango. The mangrove species commonly discovered and spread in mangrove tourism is *Avicennia marina* (Table 4).

Table 4. Varieties of Mangrove

No	Varieties of Mangrove	Station	
		I	II
1	*Rhizophora mucronata*	++	+
2	*Sonneratia alba*	+	++
3	*Avicennia marina*	+	+++

Description: (-) not found, (+) few = 1-10 individuals, (++) moderate = 11-20 individuals, (+++) many ≥ 20 individuals

a. *Rhizophora mucronate* b. *Sonneratia alba*

c. *Avicennia marina*

Figure 4. Varieties of Mangrove in Mandar Village

The mangrove environment exhibits varying species abundance (Table 5). The maximum density at station 2 is 45 trees per 100 m², while the minimum density at station 1 is 28 trees per 100 m². The rehabilitated mangrove area, initiated by the government, seeks to regulate community behavior to prevent littering and restore the compromised mangrove ecology. This mangrove habitat is in proximity to residential areas, culinary enterprises, processing businesses, Boom Beach tourism, and fishing boat docking facilities.

Table 5. Density of Mangrove Species in Mandar Village

No	Varieties of Mangrove	Tree level (per station)	
		I	II
1	*Rhizophora mucronata*	16	1
2	*Sonneratia alba*	6	17
3	*Avicennia marina*	6	27
	Jumlah	28	45
Total per Individual Station/ 100 m^2		9	15

The tidal conditions in the Mandar Village mangrove tourism region, as indicated by tidal data (Figure 3) from the Geospatial Information Agency (BIG), demonstrate that there are two high tides and two low tides each day, characterized by varying sea level elevations and durations. The peak tidal measurement of 1.142 m occurred in October 2024 (01:00 WIB), with an average tidal height of 0.88 m, for the period from October 2024 to January 2025. The minimum level was recorded in October at -1.144 m at 08:00 WIB, with an average of 0.99 m. The tidal conditions of the Mandar Village mangrove tourism area are classified as suitable, as they typically remain below 1 meter.

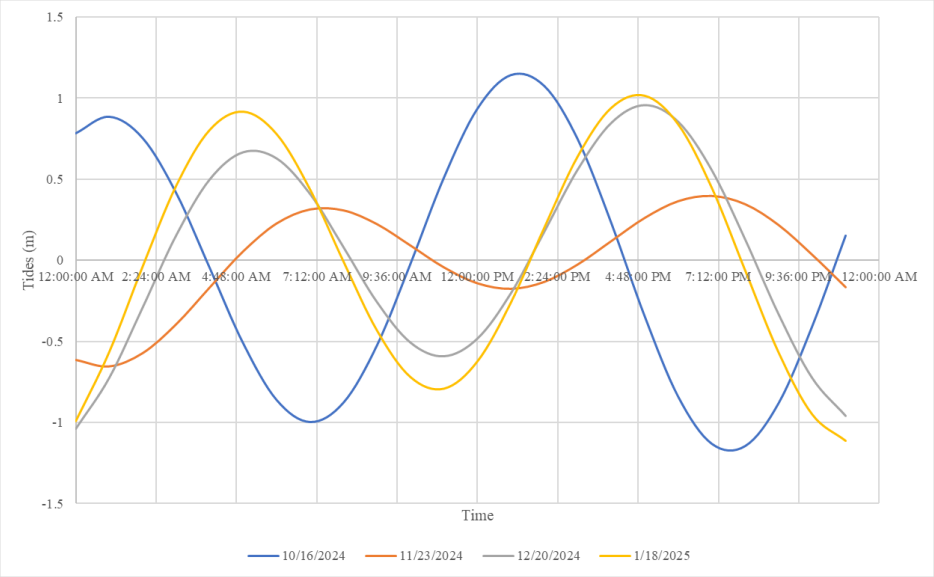


Figure 3. Tidal Patterns in Mandar Village

Mangrove biota encompasses mammals, birds, reptiles, amphibians, crustaceans, mollusks, and fish, all of which inhabit and interact within the mangrove ecosystem (Nugroho et al., 2019). The mangrove ecosystem serves as a feeding, spawning, and nursery ground, attracting fish and creating a conducive habitat for aquatic biota (Redjeki, 2013). Field observations and conversations with managers indicate that the Mandar Village mangrove tourism area encompasses diverse biota, including both aquatic and terrestrial species. In the research location, the predominant species of aquatic biota observed are mudskippers, mullet, kacang, kerong-kerong, and oysters (Table 6). Kacang fish are species that inhabit mangrove regions during high tide in search of sustenance. The terrestrial fauna associated with the species commonly identified is the great egret (*Egretta alba*). The reptilian species commonly observed at the research site includes monitor lizards (*Varanus salvator*).

Table 6. Categories of Mangrove Tourism Biota in Mandar Village

Type	Local Name	Scientific Name	Station	
			1	2
Fish	*Gelodok*	*Oxudercinae*	+	+
	Belanak	*Moolgarda seheli*	-	+
	Sliding	*Pempheris schwenkii*	-	+
	Mujair	*Oreochromis mossambicus*	+	-
	Kacangan	*Tylosurus crocodilus*	-	+
	Gabus	*Channa striata*	-	+
	Kerong-kerong	*Terapon sp*	-	+
Crustaceans	*Kepiting bakau*	*Scylla tranquebarica*	+	+
	Kepiting biola	*Uca*	+	+
	Ketam	*Varuna litterata*	+	+
	Udang putih	*Panaeus merguensis*	+	+
	Udang windu	*Penaeus monodon*	-	+
Molluscs	*Tiram*	*Crassostrea Gigas*	+	+
Reptiles	*Biawak*	*Varanus*	-	+
	Ular tambak	*Cerberus schneiderii*	-	+
	Kadal mangrove	*Emonia atrocostata*	-	+
Birds	*Kuntul besar*	*Egretta alba*	+	+
	Blekok sawah	*Ardeolla speciosa*	+	+

Description: (-) not found, (+) found

The density of the mangrove forest serves as an attraction for tourists, as both overly dense and sparse mangroves are conducive to mangrove tourism. Mangroves exhibiting greater biodiversity will undoubtedly be more appealing to visitors. Moderate tidal conditions are conducive to safe mangrove tourism for guests. Mangroves with diverse biotic elements possess more aesthetic value for visitors (Yulius et al., 2018). The mangrove tourism suitability index (IKW) at stations 1 and 2 in Mandar Village was 56.41% and 58.97% (Table 7), categorizing the mangrove tourism suitability as conditionally acceptable due to an index value ranging from

50-75%. The promotion of mangroves as a tourism attraction is an appropriate strategy to ensure the sustainability of the mangrove environment while delivering economic advantages to coastal communities. Mangrove tourism can incentivize both the community and government to conserve and sustain the mangrove ecosystem due to its economic benefits. Tourists not only appreciate the natural beauty but also receive information on the advantages of mangrove conservation to foster greater environmental consciousness. Furthermore, revenue generated from tourism activities may be designated for mangrove conservation and maintenance initiatives, including replanting and area restoration. The advancement of mangrove tourism serves as both a sustainable means to enhance community welfare and a strategic measure for preserving the integrity of the mangrove ecosystem.

Table 7. Suitability Index for Mangrove Tourism in Mandar Village

No	Parameters	Weights	Observation Station			
			1		2	
			Score	Value	Score	Value
1	Mangrove thickness	5	1	5	1	5
2	Mangrove density	3	2	6	2	6
3	Mangrove types	3	2	6	2	6
4	Tides	1	3	3	3	3
5	Biota objects	1	2	2	3	3
	Ni			22		23
	Value			56.41%		58.97%
	Category		Conditionally suitable		Conditionally suitable	

3.2. The Sustainability of Mangrove Tourism in Mandar Village

Tourists' preferences for visiting mangrove tourism areas encompass the quality of attractions, pricing, comprehensiveness and safety of tourism, sustainability of mangroves, and hospitable service (Fattah et al., 2021). The mangrove ecosystem in Mandar Village offers economic benefits through mangrove tourism and processed items derived from mangroves. This region features three species of mangroves that naturally proliferate along the river, creating an ecosystem that is crucial for the stability of coastal zones and serves as a habitat for many marine organisms. The mangroves in the Mandar Village region are currently deemed unsustainable at 43.69% due to land degradation, erosion, and anthropogenic activities, necessitating mangrove reforestation initiatives to restore the ecosystem, enhance coastal protection, and promote environmental sustainability and the livelihoods of coastal communities. The findings of the study (Fattah et al., 2025b) indicated that the river water quality, in terms of salinity, pH, and temperature, at three sampling locations in Mandar Village usually conformed to the quality standards for river or sea water. Nonetheless, levels of nitrite, nitrate, and orthophosphate frequently exceed safe thresholds. This is largely attributable to the river's closeness to heavily inhabited regions, where inappropriate disposal of domestic garbage exacerbates contamination.

The mangrove environment of Mandar Village possesses economic potential as a natural tourism site and a source of processed mangrove-derived products, rendering mangrove tourism in Mandar Village very sustainable at 64.36%. The mangrove ecosystem serves as a tourist destination, showcasing distinctive natural beauty and a variety of flora and wildlife. Tourists can engage in activities such as trekking, birdwatching, or boating, thereby enhancing their experience and augmenting local community revenue through tourism enterprises, including boat rentals, homestays, and souvenir sales. The study results (Fattah et al., 2025a) indicated that mangrove forests serve as a source of raw materials for various processed products, including syrup, nastar, kastengel, cookies, chocolate almonds, flowers, jam chopsticks, chocolate chopsticks, peanut cakes, and crispy brownies. These goods possess significant economic value and foster community innovation and entrepreneurship. The sustainable use of mangrove habitats can enhance economic welfare while preserving environmental sustainability.

Mandar Village is a multi-ethnic region comprising the Mandar, Osing, Javanese, Madurese, Chinese, and Arab ethnic groups. The mangrove ecosystem offers substantial social advantages for many ethnic groupings in the management of mangroves. The mangrove ecosystem not only sustains ecological life but also fortifies the social and cultural connections of the surrounding community, resulting in the classification of Mandar Village mangrove tourism as relatively sustainable at 58.64%. Mangrove conservation and management initiatives necessitate strong community engagement through planting, maintenance, and educational programs to foster a sense of belonging and cohesion between the community and organizations. Furthermore, the mangrove ecosystem serves as a platform for education and enhancing environmental consciousness among the youth through nature school initiatives or training programs. Managers can enhance partnerships and generate employment by collaborating with local people in the development of mangrove-based tourism or mangrove-processed industries. Consequently, the mangrove ecosystem not only sustains natural balance but also fosters harmony among ethnic groups and enhances community empowerment.

Efficient mangrove management necessitates the active participation of diverse stakeholders alongside explicit and stringent laws. The management of the mangrove environment in the Mandar Village region involves coordinated efforts to manage, maintain, and

utilize mangroves, resulting in a sustainability classification of 54.49% for Mandar Village mangrove tourism. The government is crucial in formulating explicit policies and regulations, including the designation of protected areas, oversight of development activities, management of resource utilization, enforcement of stringent penalties for infractions, and provision of incentives for communities engaged in mangrove conservation. Local communities, as the stakeholders nearest to the mangrove environment, actively engage in the planting, maintenance, and responsible utilization of mangrove resources. Collaboration with non-governmental groups, academia, and the corporate sector is essential for delivering technical help, finance, and education.

A sustainability number approaching 100 indicates a superior sustainability status, while conversely, a lower value signifies a diminished status. If it approaches zero, the sustainability status will deteriorate (Tjahjono et al., 2022). The evaluation of the sustainability state of Mandar Village mangrove tourism, based on four criteria (Figure 4), is 56.55%, indicating a moderate level of sustainability. Nonetheless, it necessitates development and more efficient administration to attain a greater degree of sustainability.

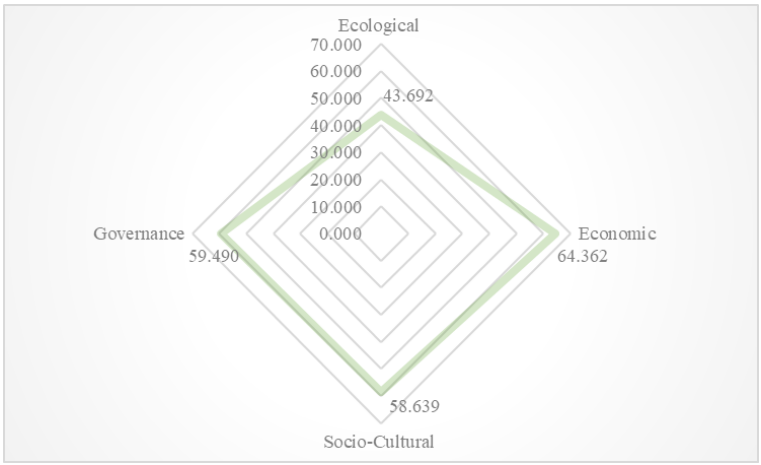


Figure 4. Multidimensional Sustainability of Mangrove Tourism

The development of Mandar Village mangrove tourism, grounded in ecological dimensions, takes into account key features such as mangrove thickness, area carrying capacity, and mangrove density (Figure 5). The primary factor in the development of Mandar Village mangrove tourism is mangrove thickness. The growing density of the mangrove serves as an attraction and experience for travelers due to its aesthetic appeal. The density of the mangrove offers an optimal habitat for diverse biota, including birds, crabs, reptiles, and fish, so attracting tourists. Mangrove tourism necessitates control through tourist limitations, scheduled visits, and education on the advantages of conserving the mangrove ecosystem to achieve sustainable tourism. The carrying capacity of the mangrove tourism region refers to the mangrove ecosystem's capability to support tourism activities without inflicting environmental harm, which could diminish tourist happiness. (Ardian et al., 2023) highlighted that the carrying capacity of an area is assessed to restrict the number of tourists to preserve the sustainability of the mangrove environment.

The carrying capacity of the Mandar Village mangrove tourism area defines its capability to support tourism activities without leading to ecological deterioration or a decline in the quality of the visitor experience. The primary elements influencing carrying capacity are mangrove forest area, plant density, water depth, and infrastructural availability. An excess of visitors above optimal capacity can exert pressure on the mangrove ecosystem, resulting in damage to mangrove roots, disruption of aquatic biota, garbage accumulation, and infrastructure deterioration, so diminishing the area's aesthetic appeal and sustainability. The tourist accommodation capacity in Mandar Village is relatively low. This is attributable to multiple constraints, including the restricted width of the tracking path, inadequate supporting infrastructure, and the biological carrying capacity of the mangrove region, which necessitates proper protection. The inadequately developed track path restricts the simultaneous accommodation of tourists, hence posing a risk of ecosystem disruption during peak visitation periods. Moreover, there exists a scarcity of amenities such as rest spaces, informational displays, and tourist management systems. The role of the Mandar Village mangrove density is to preserve coastal ecosystem stability, safeguard rivers from erosion, and enhance biodiversity. The optimal mangrove density is essential for sustaining ecosystems and facilitating eco-friendly tourism activities. Mangrove tourism in Mandar Village is situated near the river, making it susceptible to alterations in river flow that may diminish the productivity of the mangrove ecosystem, decrease biodiversity, impair its ecological role as a protector against erosion, impact both aquatic and terrestrial habitats, disrupt ecosystem equilibrium, and further reduce biodiversity. Moreover, excessive sedimentation downstream can diminish water quality and threaten the survival of aquatic creatures.

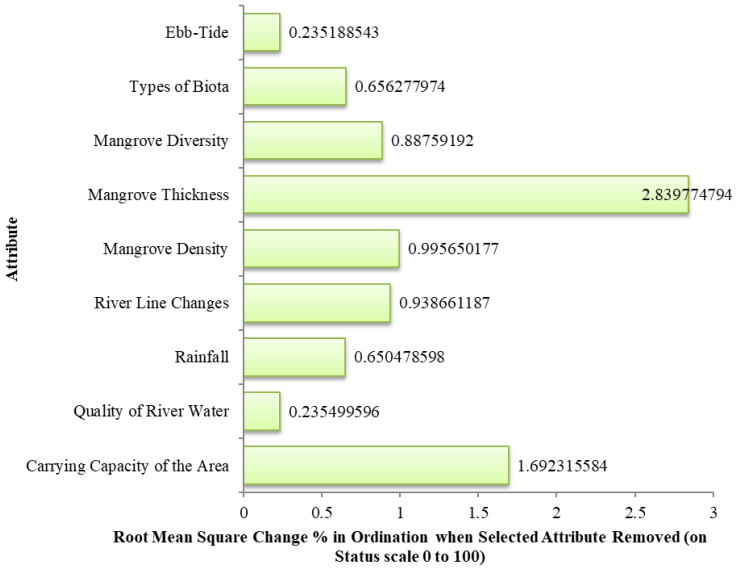


Figure 5. Leverage of Ecological Dimension

The primary factors in the economic aspect for achieving sustainable mangrove tourism in Mandar Village are labor absorption, management's capability to operate tourism, and governmental support (Figure 6). The mangrove ecosystem significantly contributes to the economy, particularly for employment opportunities. The conservation of the mangrove environment has ecological advantages and serves as a source of income for coastal people through the harvesting of economically valuable biota. The processing of mangrove-derived goods creates business opportunities for local populations. Mangrove ecosystem-based tourism also facilitates employment opportunities, including tour guides, homestay managers, and food vendors. Effective management of mangrove tourism is a crucial asset for enhancing the appeal and sustainability of tourist destinations based on mangrove ecosystems. Proficient managers can create appealing tour packages, including ecotourism, environmental education, and various tourism activities, to educate tourists on the significance of mangrove conservation while ensuring their comfort and satisfaction. Managers' comprehension of efficient destination promotion via social media or partnerships with relevant entities to access a broader market. Government support for the development of mangrove tourism substantially influences the economic, ecological, and social viability of coastal communities. Government contributions to the advancement of mangrove tourism typically involve the construction of supporting infrastructure, provision of financial assistance to local communities for the development of mangrove-based products, delivery of tourism management training, environmental education, and technical support to enhance community capacity for professional and sustainable tourism management.

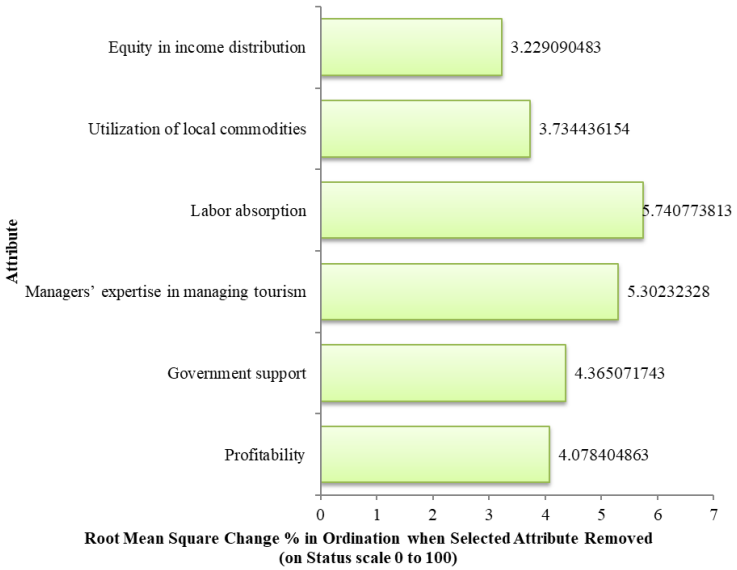


Figure 6. Leverage of Economic Dimension

Mangrove tourism in Mandar Village can achieve sustainable development through socio-cultural dimensions by addressing factors such as tourist perceptions, conflicts in tourism management, and the competence of managers in tourism operations (Figure 7). The opinion of tourists regarding mangrove tourism attractions is crucial in influencing their pleasure and intention to return. An engaging experience for tourists fosters opportunities for them to endorse the destination to others. Consequently, tourism managers must persist in enhancing the quality and diversity of attractions while ensuring sufficient facilities to maintain favorable tourist impressions and promote the sustainability of mangrove tourism. Conflicts between conservation concerns and economic exploitation of mangroves can adversely affect the growth of mangrove tourism. Regional development that neglects mangrove ecosystems, natural attractions, and biodiversity may lead to a deterioration in the quality of key mangrove tourism destinations. Conflicts among local communities, government, and the business sector can impede the construction of suitable tourism amenities and diminish community involvement in sustaining the mangrove ecosystem. Managers with a profound comprehension of mangrove ecology can facilitate the development of sustainable and instructive tourism initiatives. Furthermore, expertise in tourism management encompassing facilities management, marketing, and visitor services can enhance the overall experience for travelers. Managers must comprehend the principles of sustainability to mitigate the adverse effects of tourism activities on the mangrove ecosystem. The involvement of the multicultural community in Mandar Village, comprising Mandar, Osing, Javanese, Madurese, Chinese, and Arab ethnicities, has established a distinctive collaborative framework for managing mangrove tourism rooted in local wisdom through: complementary role distribution in ecosystem management, innovation of tourist attractions that integrate multiethnic cultural elements, and a conflict resolution mechanism based on inter-ethnic deliberation.

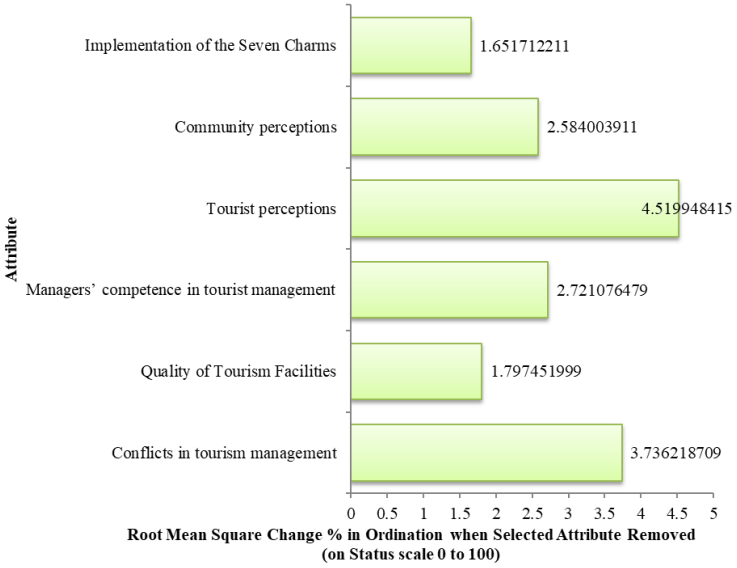


Figure 7. Leeverage of Socio-Cultural Dimension

The main governance components in the development of mangrove tourism include regulatory frameworks for tourism management, stakeholder involvement, and the promotion of sustainable tourism practices (Figure 8). Regulations governing the utilization of mangrove habitats as tourism attractions are essential to guarantee ecological, economic, and social viability. Explicit laws governing tourism activities can mitigate harm to mangrove ecosystems, disrupt animal habitats, and reduce environmental pollution from waste or refuse. Effective laws will establish limitations on visitor numbers, designate permissible places for visitation, and outline allowable tourism activities to mitigate pressure on the mangrove habitat. Moreover, rules might guarantee that tourism revenue is designated for the conservation and upkeep of mangroves. The involvement of stakeholders in the development of mangrove tourism is essential for fostering synergy and ensuring sustainability in destination management. The government, in its regulatory capacity, is tasked with formulating policies and regulations that promote mangrove conservation and facilitate the development of tourism infrastructure. Local communities, as the entities nearest to the mangrove ecosystem, play a crucial role in preserving environmental sustainability and are the primary participants in tourism activities. The private sector can participate by investing in and innovating facilities and promoting destinations. Furthermore, non-governmental organizations (NGOs) and scholars can offer technical assistance, teaching, and research to facilitate sustainable tourist management. Creating sustainable facilities by constructing pathways from materials that do not harm mangrove roots, utilizing solar panels for illumination, and implementing designated waste receptacles to mitigate pollution. Moreover, educational institutions such as information centers or interpretive signage regarding the mangrove ecosystem might enhance tourist awareness.

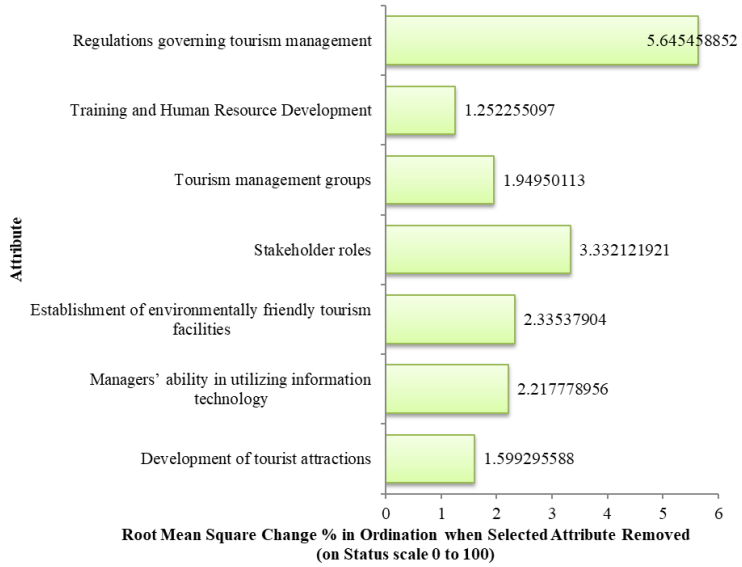


Figure 8. Leverage of Governance Dimension

Monte Carlo analysis is employed to assess the impact of stochastic errors on the estimation of the ordination value utilized. Monte Carlo analysis is valuable for examining the impact of attribute score inaccuracies, data entry mistakes, or absent data (Kurniawan et al., 2016). The outcomes of the Monte Carlo analysis reveal that the sustainability status value of Mandar Village mangrove tourism closely aligns with the findings derived from the MDS Rapfish research. The Monte Carlo analysis (Table 8) conducted in this study was performed 25 times, yielding little and minor differences in the results. This indicates that the ordination procedure has effectively mitigated random mistakes that may occur from discrepancies in researcher assessments or inaccuracies in data entry. Consequently, it can be inferred that the investigation into the sustainability of Mandar Village mangrove tourism has employed a robust and precise model.

The precision of the MDS Rapfish analysis is ascertained by the S-Stress value derived from the computation of the S value. A low S-Stress value signifies great precision (goodness of fit), whereas a high S-Stress value denotes the contrary. In this Rap-beachtour, an optimal model is characterized by an S-Stress value less than 0.25 (<25%) and a coefficient of determination (R^2) nearing 1.0 or 100%. Conversely, an S-Stress value exceeding 0.25 or 25% indicates low accuracy in the results of the Multidimensional Scaling (MDS) calculation (Suwarno et al., 2011). The S-stress value for the four dimensions of sustainability is below 0.25, with a squared correlation (RSQ) value nearing 1.00, namely within the range of 0.92 to 0.95. Consequently, it can be inferred that all variables employed in the investigation of the sustainability of Mandar Village mangrove tourism have proven beneficial, since they elucidate the four dimensions examined.

Table 8. Value of MDS, MC, Stress and RSQ

Dimensions	MDS	MC	Difference	Stress	RSQ (%)
Ecology	43.692	43.819	0.127	0.246	92.84
Economic	64.362	63.669	0.694	0.178	95.95
Socio-Cultural	58.639	58.078	0.562	0.221	94.45
Governance	59.490	59.033	0.456	0.233	93.72

3.3. Interaction of Social-Ecological Systems in Mangrove Tourism in Mandar Village

Centrality is one of the most widely used concepts in social network analysis. A centrality measure scores each node in the network in terms of its structural importance (Borgatti et al., 2013). The mangrove (Mangrv) and nature tourism (NatTouri) in Mandar Village have the highest degree centrality value of 10 (Figure 9), indicating that their presence has the greatest influence on other nodes. Mangrove protection has ecological advantages for organisms and serves as a tourist attraction. Mangrove forests are crucial for sustaining coastal ecological equilibrium by preventing erosion, sequestering carbon, and providing home for diverse kinds of fish, birds, and marine organisms. The diversity of mangrove and biota species renders it an appealing tourist destination. The Fisheries Service (Disperikan) plays a crucial role in advancing mangrove tourism, which has been operating at a consistent node of 8 degrees.

Disperikan plays a crucial role in sustaining the Mandar Village mangrove through training and mentoring initiatives. In 2023, the Ministry of Marine Affairs and Fisheries (KKP) facilitated the transformation of Mandar Village mangrove into a natural tourism site. Water quality (Klts_Ar) and extension workers (Pnylh) exert an influence on the third position, characterized by a node of 6 degrees. Subpar water quality resulting from environmental pollution diminishes aesthetic value, leads to organism mortality, and adversely affects the health of mangrove trees, potentially resulting in their demise. (Schaduw, 2018) explains that the volatility of these water quality factors would lead to a deterioration in quality and maybe the demise of mangroves.

Extension workers (Pnylh) play a crucial role in promoting the sustainability of the mangrove ecosystem through teaching, training, and support. Instruction delivered by extension workers enhances community awareness of the advantages of mangrove conservation, alongside technical instruction in planting and maintenance procedures to facilitate sustainable ecosystem management and mangrove-based processing for economic enhancement. Direct assistance aids the community in incorporating sustainability concepts into tourism activities, therefore mitigating adverse environmental impacts. The Department of Culture and Tourism (Disbudpar) is pivotal in the comprehensive development of mangrove tourism, serving not only as a natural attraction but also as an integral component of the gastronomic and cultural tourism of Mandar Village. The collaboration between extension workers and Disbudpar in integrating ecological considerations with tourism development exemplifies an effective multistakeholder strategy, using environmental conservation as a foundation for sustainable development.

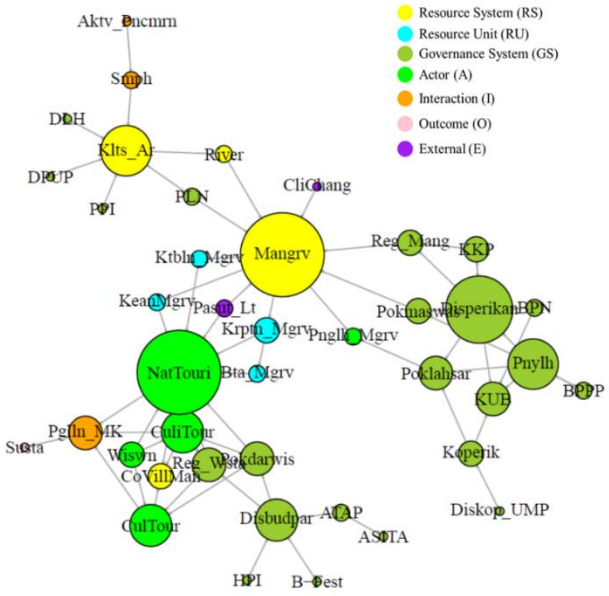


Figure 9. Interaction of the Social-Ecological System of Mangrove Tourism in Mandar Village

Betweenness – the share of times that a node is passed through in order to complete the connection between pairs of nodes via the shortest path (Wang & Cullinane, 2016). Betweenness indicates the node that serves as a link between two other nodes in a network, hence influencing the positioning of further nodes. The primary node, determined by betweenness, is mangrove (Mangrv), associated with nature tourism (NatTouri), with values of 144.5 and 74, respectively. Additionally, the river node (River) exhibits water quality (Klts_Air) values of 60 and 56, respectively. The actor node yielding the highest value is mangrove, establishing it as a pivotal player in mangrove tourism in Mandar Village (Figure 10). The presence of mangroves in Mandar Village offers ecological and economic advantages. Mangroves serve as natural coastal defenders against erosion, carbon sequestrators, and water quality regulators, while also providing home for diverse species of fish, crabs, birds, and other organisms. The economic management of mangrove ecosystems as nature-based tourism creates tourist attractions through activities such as river excursions, mangrove seedling planting, and wildlife observation. Local communities derive economic advantages from homestay enterprises, seafood gastronomy, and the selling of processed mangrove products, including syrup, handicrafts, and several other processed goods. The integration of environmental conservation and sustainable tourism fosters community revenue and enhances awareness of the significance of nature preservation.

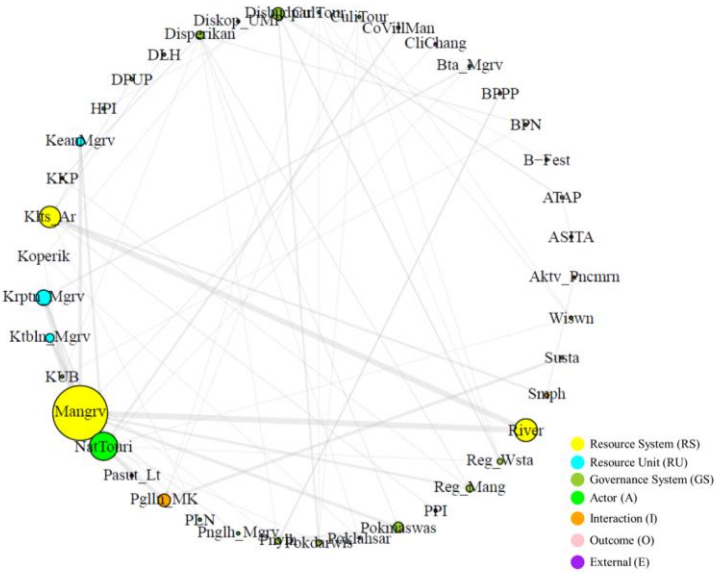


Figure 10. Betweenness Centrality Mangrove Ecotourism in Mandar Village

Cluster analysis is a set of techniques for assigning items into groups or classes based on the similarities or distances between them. Typically, these groups are mutually exclusive, forming a partition (Borgatti et al., 2013). Clustering is grouping nodes with commonalities as a cohesive force within a community. Mangrove tourism in Mandar Village is categorized into seven clusters:

a) Cluster 1 serves as a stakeholder in mangrove management, with the government, as the regulatory authority, responsible for developing policies and regulations that promote the conservation and sustainable utilization of mangroves. The local populations residing in the Mandar Village mangrove region are the principal agents in the preservation and traditional utilization of resources, while applying indigenous knowledge. Non-governmental groups and scholars contribute through research, teaching, and rehabilitation initiatives to enhance awareness of the significance of mangroves. The private sector, including the tourist and fishing industries, adopts sustainable practices and endorses conservation initiatives. Stakeholder collaboration is essential for effective mangrove management, biodiversity preservation, climate change mitigation, and enhancement of community welfare. In the absence of collaboration among all stakeholders, mangrove conservation initiatives will not function effectively.

b) Cluster 2 encompasses the mangrove habitat, which offers both economic and ecological advantages for various organisms. The mangrove ecosystem serves to safeguard the coastline form erosion, sequester carbon, and provide habitat for diverse species of fish, birds, and marine organisms. At the same time, the mangrove ecosystem presents economic opportunities through tourism, including ecotourism, educational tourism, and nature tourism.

c) Cluster 3 refers to pollution; the deterioration of water quality within the mangrove ecosystem is attributable to contamination by domestic waste, industrial activities, and oil spills, adversely affecting the growth of mangrove plants. Toxic chemicals, including heavy metals, pesticides, and plastic trash, contaminate aquatic environments, alter ecological equilibrium, diminish dissolved oxygen levels, and harm marine organisms integral to the mangrove food chain. Moreover, water contamination can diminish the appeal of tourism activities.

d) Cluster 4 refers to water quality management; the oversight of the Mandar Village River's water quality by relevant stakeholders has markedly improved the area's water quality. Initiatives undertaken include regular monitoring, management of domestic trash, and the planting of buffer vegetation along riverbanks to mitigate pollution and enhance water quality.

e) Cluster 5 prefers to tourism management, where sustainable mangrove tourism necessitates a holistic approach that emphasizes equilibrium between ecosystem preservation and economic exploitation. The active involvement of local people as primary managers yields economic advantages from tourism and fosters awareness for the preservation of mangrove sustainability. Furthermore, it is essential to implement stringent regulations concerning visitor numbers, the advancement of sustainable infrastructure, and the restriction of harmful activities such as deforestation or pollution.

f) Cluster 6 contains tourist management stakeholders, including the tourist Office, the Indonesian Tour Guide Association (HPI), and the Banyuwangi Festival, which play a pivotal role in advancement of mangrove tourism in Banyuwangi. The Tourism Office serves as a regulator and facilitator by developing integrated policies, supplying supporting infrastructure, and promoting mangrove locations via diverse marketing platforms. The Indonesian Tour Guide Association (HPI) enhances the quality of tourism human resources by training local tour guides to deliver mangrove conservation education and enrich tourist experiences through engaging ecological interpretation narratives. The Banyuwangi Festival serves as a tourism attraction by incorporating mangrove tourism into the national event program, drawing tourists with nature and culture-based tour packages.

g) Cluster 7 functions as a tour operator, serving a crucial role as an intermediary between mangrove areas and tourists, while also facilitating education and conservation efforts. In the realm of mangrove tourism, a meticulously organized trip not only offers an authentic natural experience but also enhances understanding of environmental sustainability.

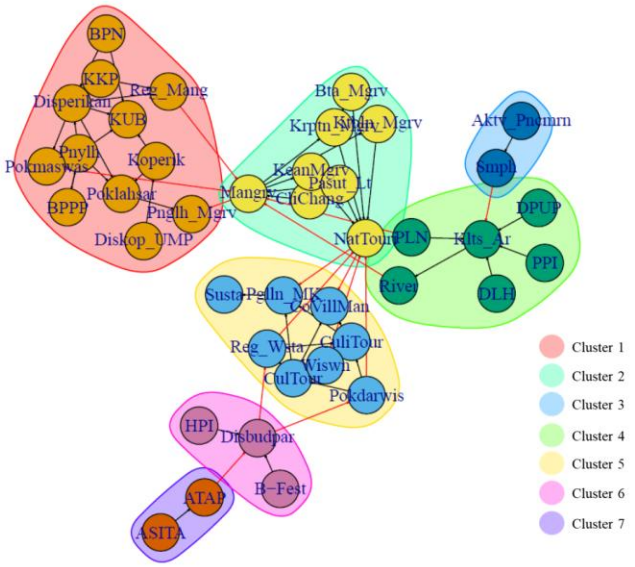


Figure 11. Mangrove Tourism Cluster in Mandar Village

The development of ecotourism fosters responsible tourism that aids in the preservation of nature and local culture by adhering to the principles of ecotourism: preservation, education, economy, participation, and tourism (Fattah et al., 2022). The primary stakeholders in the development of Mandar Village mangrove tourism are those involved in mangrove management, mangrove ecosystems, and tourism management, as these three elements are essential for the ecological and economic sustainability of the region. Mangrove management stakeholders, including the Fisheries Service and fisheries extension workers, are essential in policy formulation, technical assistance provision, and the implementation of suitable conservation techniques. In the absence of appropriate regulation and enforcement, the pressures from tourism activities may jeopardize the sustainability of mangroves. The mangrove environment is the primary draw for tourism; the state of the mangrove vegetation, water quality, and biodiversity influence visitor comfort and the tourism value, hence enhancing the destination's competitiveness. Third, effective tourist management is essential to reconcile conservation efforts with economic exploitation, encompassing visitor regulation, facility support, and local community engagement in labor absorption. An integrated approach that fosters collaboration among stakeholders, regular ecosystem monitoring, and the establishment of environmentally sustainable, multi-ethnic community-based tourism is essential for the enduring viability of Mandar Village mangrove tourism. The advancement of Mandar Village mangrove tourism is predicated on the interplay of social-ecological systems that take into account appropriateness and sustainability, encompassing:

1. Development of mangrove tourism attractions in the form of elevated restaurants that offer culinary items (cakes) and beverages (syrup, tea, and coffee) derived from mangrove resources, as well as fish and crabs sourced from the mangrove region, by implementing a minimum payment system, restricting visiting hours, and enforcing stringent regulations to preserve the sustainability of the mangrove ecosystem.
2. Enhancing managers' capacity to autonomously cultivate mangrove trees.
3. Extending the length of mangrove monitoring.
4. Research and development of processed mangrove derivatives.
5. Designing a secure and convenient parking facility for mangrove tourism patrons.
6. Developing instructional materials for the general populace or educational institutions concerning the roles and advantages of mangroves.
7. Implementing mangrove planting along the Mandar Village river on designated degraded land.
8. Executing the Environmental Service program via trash Management through the Banyuwangi Hijau initiative, enhancing TPS3R in Banywangi Regency, maximizing trash banks, and the Banyuwangi River Basin Care School (SEKARDADU).
9. Leveraging ethnic diversity to build culture-oriented mangrove tourism attractions.

4. Conclusion

Mangrove tourism in Mandar Village features three predominant species of mangroves: *Rhizophora mucronata, Sonneratia alba*, and *Avicennia marina*. The Tourism Suitability Index (IKW) for Mandar Village indicates that the area is conditionally appropriate

for development as a mangrove tourism site, with values of 56.41% and 58.97%. This suggests that while the potential for mangrove tourism is substantial, numerous elements of the physical, social, and management settings require additional focus to enhance the area's appropriateness. The sustainability condition of the Mandar Village mangrove tourism area is classified as fairly sustainable, with a score of 56.55%, signifying that the management system is not yet optimal in balancing resource usage and ecosystem preservation. Factors influencing sustainability include the density of mangrove vegetation, local labor absorption, favorable community and tourist impressions, and the presence of management laws. The interactions within the socio-ecological system indicate that the primary influencing nodes in the dynamics of mangrove tourist management are the mangrove ecosystem, nature tourism, the Fisheries Service, water quality, and fisheries extension personnel. The mangrove environment plays a pivotal role in tourism by offering both ecological and economic services, whereas nature tourism exemplifies conservation-oriented use elements. The participation of the Fisheries Service and fisheries extension workers underscores the significance of institutions and policies in executing participatory and sustainable management. Water quality, as an environmental indicator, is a critical determinant of the mangrove ecosystem's carrying capacity for tourism activities. The presence of these pivotal actors underscores the necessity for stakeholder coordination and the integration of ecological, economic, and social dimensions to enhance the viability and sustainability of mangrove ecotourism in a cohesive and sustainable fashion. Recommendations derived from the findings of this study include enhancing managerial competencies in mangrove management, fostering community awareness through ongoing participation in mangrove cleanup initiatives, developing innovative educational mangrove tourism attractions, and promoting collaboration between the government and the community to bolster mangrove sustainability and economic prospects for community welfare.

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Ethical
The study was conducted with the consent of all participants and relevant authorities.

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Conflict of Interest
The authors declare that there is no conflict of interest regarding the publication of this paper. All authors have contributed equally to the conception, design, data collection, analysis, and preparation of the manuscript. No financial or personal relationships have influenced the work reported in this study.

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