Journal of Smart Agriculture and Environmental Technology
e-ISSN:3021-8802
Vol. 4, No. 2, August 2026
https://josaet.com | https://doi.org/10.60105/josaet.2026.4.2.73-81

Research Paper

Rehabilitation of the Ecological and Economic Functions of Urban Coastal Areas: A Mixed-Methods Assessment of Urban Aquaculture in Ketapang, Tangerang Regency, Indonesia

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Article History: Received: March 2, 2026, Accepted: June 22, 2026

Abstract
Mangrove-based ecotourism integrated with urban aquaculture has emerged as a promising strategy linking conservation with livelihood improvement in Indonesia's rapidly urbanizing coastal zones. However, empirical assessments that simultaneously address ecological, socio-economic, and governance dimensions remain limited. This study evaluates the Ketapang Urban Aquaculture (KUA) mangrove ecotourism site (14.5 ha) in Tangerang Regency, Banten Province, using a sequential exploratory mixed-method design that combines Sentinel-2 satellite imagery analysis with structured surveys (n = 9), semi-structured interviews with key informants, and field observations conducted between May 2025 and January 2026. Mangrove Vegetation Index (MVI) time-series analysis via Google Earth Engine revealed a 1639% increase in mangrove cover from 0.551 ha (2020) to 9.583 ha (2025), with a compound annual growth rate of approximately 77 to 78%. Despite this substantial areal expansion, the mangrove health index remains at a moderate level. Socio-economic findings indicate low and declining visitor numbers (5 to 10 on weekdays; 10 to 20 on weekends), closure of approximately 20 food stalls, and non-operational status of four formerly supported micro, small, and medium enterprise (MSME) groups. Community participation is largely confined to operational activities, with limited involvement in planning and decision-making. A welfare gap exists between internal management staff, who report relatively stable income, and vendors/MSME actors, whose livelihoods are directly affected by visitor decline. Annual operational costs (IDR 300 to 500 million) exceed tourism revenue, raising concerns about financial sustainability. The findings suggest that KUA has achieved notable ecological rehabilitation success but has not yet translated this into broad-based socio-economic benefits. Strengthening community-based governance, diversifying revenue streams, improving visitor infrastructure and digital promotion, and formalizing benefit-sharing mechanisms are recommended to advance the site toward a more sustainable and equitable ecotourism model.

Keywords
Benefit-sharing; Community well-being; Indonesia; Mangrove ecotourism; Peri-urban coastal management; Sentinel-2 remote sensing; Urban aquaculture

1. INTRODUCTION

Coastal ecosystems in tropical regions collectively constitute critical natural infrastructure that supports biodiversity, regulates biogeochemical cycles, and sustains the livelihoods of coastal-dependent communities, with their provisioning, regulating, and cultural services jointly determining the ecological and economic resilience of adjacent coastal settlements (Rumondang et al., 2024). Mangrove ecosystems occupy the intertidal zones of tropical and subtropical coasts and deliver irreplaceable ecological services, including shoreline protection against erosion and storm surges, sediment trapping, water quality regulation, nursery habitat provision for commercially important fishery species, and globally significant blue-carbon storage (Alongi, 2020; Howard et al., 2017; Macreadie et al., 2019). Indonesia historically held the world's largest mangrove extent, accounting for approximately 26 to 29% of the global total. Yet decades of aquaculture conversion, urbanisation, and overexploitation have reduced this area substantially, from an estimated 4.39 million ha in 2005-2006 to 3.06 million ha in 2011-2012 (Badan Informasi Geospasial, 2012).

In response, government-led and community-based mangrove rehabilitation programmes have accelerated across the archipelago, often linked to nature-based tourism as a mechanism for reconciling conservation with coastal livelihood improvement (Arifanti et al., 2022; Biswas et al., 2009; Yulianda, 2019). Ecotourism, defined as tourism that is nature-oriented, educationally enriching, and supportive of

conservation and local welfare, has been widely promoted as a sustainability strategy for rehabilitated mangrove areas (Seliari and Ikaputra, 2021; Yanti et al., 2022). However, ecotourism development that proceeds without adequate attention to carrying capacity, infrastructure quality, equitable benefit distribution, and community participation may generate environmental degradation and social conflict rather than the intended positive outcomes (Coccossis and Mexa, 2020; Lin and Yang, 2016).

A particularly novel variant of mangrove ecotourism is the integration of conservation with urban aquaculture (silvofishery), which involves the co-management of mangrove stands and aquaculture ponds within a shared landscape to create multifunctional coastal zones that simultaneously serve ecological, livelihood, and educational purposes (Hadi et al., 2022; Mahmudi, 2008). The Ketapang Urban Aquaculture (KUA) site in Ketapang Village, Mauk District, Tangerang Regency, Banten Province, exemplifies this approach. Developed from a formerly degraded and slum-prone fishing settlement under the local government's "Gebrak Pakumis Plus" and "Gerbang Mapan" programmes, KUA encompasses approximately 14.5 ha of rehabilitated coastal land with mangrove plantations, vannamei shrimp and milkfish ponds, and visitor facilities, and was inaugurated as an ecotourism destination in January 2023 (Azahra et al., 2024; Jonathan et al., 2023; Pemerintah Kabupaten Tangerang, 2022) . The broader coastal setting of Tangerang Regency, within which KUA is situated, has been characterised by persistent socio-ecological pressures on mangrove ecosystems driven by aquaculture conversion, population growth, and inadequate governance integration, with rehabilitation, ecotourism development, and silvofishery pond management identified as the priority policy responses (Mahardika et al., 2023).

Previous studies have examined KUA from various singular perspectives. Azahra et al. (2024) assessed mangrove health status and reported a moderate index value. Darmawan et al. (2025) described the implementation of ecotourism activities and their socio-economic benefits, while Apriliani et al. (2025) identified deficiencies in sanitation, inclusive facilities, and digital promotion using a SERVQUAL framework. Dewi and Berutu (2025) documented declining visitation after 2024, and Mulyawati et al. (2025) highlighted limited community roles in decision-making despite participation in economic activities. Romli and Purwanto (2024) emphasised the need for participatory communication strategies, and Yanuadi et al. (2024) found that amenities and institutional support require strengthening.

Despite these contributions, no prior study has simultaneously integrated (1) remote sensing-based temporal analysis of mangrove cover change, (2) assessment of community participation across the planning, implementation, and evaluation continuum, and (3) evaluation of multi-stakeholder well-being outcomes within a single analytical framework applied to KUA as a mangrove and urban aquaculture ecotourism model. Existing studies tend to focus on either ecological indicators, service quality, or governance in isolation (Apriliani et al., 2025; Azahra et al., 2024; Mulyawati et al., 2025). This fragmented evidence base is insufficient for diagnosing the systemic interdependencies that determine whether integrated mangrove ecotourism sites achieve sustainability.

This study addresses that gap by pursuing three objectives: (1) to quantify mangrove cover change at KUA over the period 2020-2025 using Sentinel-2 satellite imagery and the Mangrove Vegetation Index; (2) to assess the level and modes of local community participation in the planning, management, and monitoring of KUA; and (3) to evaluate the perceived impacts of KUA development on community well-being across economic, social, and environmental dimensions. Together, these objectives provide an integrated, evidence-based assessment of whether the KUA model delivers on its dual promise of ecological rehabilitation and inclusive livelihood improvement.

2. EXPERIMENTAL SECTION

2.1 Study Area

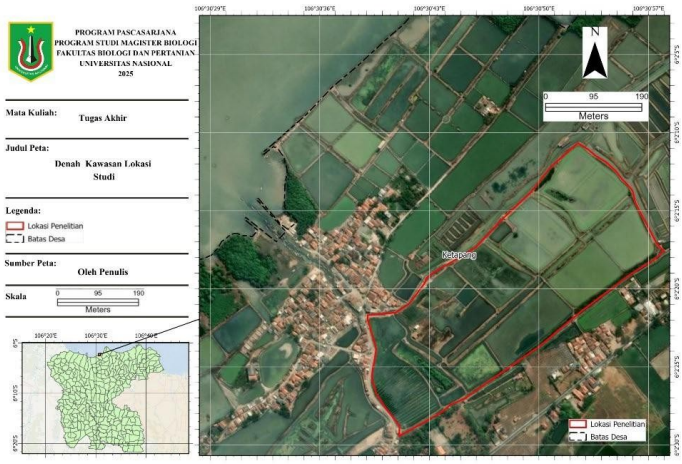

Figure 1. Location of the Ketapang Urban Aquaculture study site in Ketapang Village, Mauk District, Tangerang Regency, Banten Province, Indonesia

The study was conducted at Ketapang Urban Aquaculture (KUA), located in Ketapang Village (Desa Ketapang), Mauk District, Tangerang Regency, Banten Province, Indonesia (approximately 6°5′ S, 106°30′ E). The site covers approximately 14.5 ha of rehabilitated coastal land on the northern coast of Java, comprising zones of mangrove plantation, aquaculture ponds cultivating vannamei shrimp (*Litopenaeus vannamei*) and milkfish (*Chanos chanos*), revitalised fisher settlement, and visitor facilities including trekking paths, gazebos, and parking areas. KUA is managed by PT Mitra Kerta Raharja, a regionally owned enterprise (BUMD) assigned under Regent Regulation (Per-

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aturan Bupati) No. 69/2022 and No. 89/2022 (Pemerintah Kabupaten Tangerang, 2022).

2.2 Research Design

A sequential exploratory mixed-method design was employed (Creswell, 2014). Qualitative data were collected first to identify key contextual issues, followed by quantitative data collection to measure specific variables. The study was conducted from May 2025 to January 2026 and comprised three integrated components: (a) satellite-based mangrove cover analysis, (b) structured surveys, and (c) semi-structured interviews and field observations.

2.3 Satellite Image Analysis

Mangrove area change over the period 2020-2025 was estimated using Sentinel-2 Surface Reflectance imagery (COPERNICUS/S2SR; 10 m spatial resolution) processed on the Google Earth Engine (GEE) cloud computing platform. For each year (2020–2025), imagery was filtered by date range (1 January–31 December) and cloud cover (<20%). Cloud masking was performed using the Scene Classification Layer (SCL), excluding shadow, medium-probability cloud, high-probability cloud, and cirrus pixels, supplemented by masking pixels with cloud probability ≥20% (MSKCLDPRB). Reflectance values were normalised by dividing by 10 000. Annual median composites were generated to reduce temporal noise.

The Mangrove Vegetation Index (MVI), which has been validated for mangrove discrimination in tropical coastal environments (Baloloy et al., 2020), was computed for each annual composite. Mangrove pixels were classified using an empirically derived MVI threshold, and total mangrove area was calculated by summing classified pixels (each 100 m^2) within the KUA region of interest and converting to hectares. Annual growth rates and the overall change trajectory were computed from the time series.

2.4 Surveys

A structured questionnaire incorporating 5-point Likert-scale items and open-ended questions was administered to nine respondents purposively sampled across three stakeholder groups: internal management staff (n = 3), food vendors/MSME operators (n = 3), and visitors (n = 3). The questionnaire covered socio-demographic characteristics, participation in KUA activities, perceived economic-social-environmental benefits and challenges, and satisfaction with facilities and services. The small sample size reflects the purposive intent to capture depth and diversity of perspective across the three principal stakeholder categories in a site with very low daily visitor numbers and a limited pool of active vendors; the findings are therefore interpreted as indicative rather than statistically generalisable.

2.5 Interviews and Observations

Semi-structured interviews were conducted with key informants selected through purposive and snowball sampling, including the KUA site manager (PT Mitra Kerta Raharja), Ketapang Village officials, and community leaders. Interview guides were organised around five thematic domains: (1) history and objectives of KUA development; (2) the mangrove–aquaculture–tourism integration model; (3) institutional structure and partnerships; (4) community participation; and (5) impacts and sustainability challenges.

Field observations documented mangrove stand conditions (species composition, zonation, canopy status, visible disturbance), facility conditions (trekking paths, signage, sanitation, food stalls), aquaculture activities, and visitor-community interactions. Photographs and field notes were recorded systematically.

2.6 Data Analysis

Quantitative survey data were analysed descriptively (frequencies, means of Likert-scale scores). Satellite-derived mangrove area data were tabulated and visualised as a time series. Qualitative interview and observation data were analysed following the interactive model of Miles et al. (2014), involving data condensation (transcription, coding, memoing), data display (matrices, thematic summaries), and conclusion drawing/verification. Triangulation across data sources (satellite imagery, surveys, interviews, field observations, and secondary documents) was employed to enhance validity (Creswell, 2014).

2.7 Ethical Considerations

Informed verbal consent was obtained from all respondents and interviewees prior to data collection. Participation was voluntary, and respondent anonymity was maintained throughout analysis and reporting.

3. RESULTS

3.1 Mangrove Cover Change (2020–2025)

Sentinel-2 MVI analysis revealed substantial and sustained expansion of mangrove cover at KUA over the study period (Table 1). Mangrove area increased from 0.551 ha in 2020 to 9.583 ha in 2025, representing a cumulative increase of approximately 9.032 ha (1639%). The compound annual growth rate (CAGR) was approximately 77-78%.

Growth was most rapid during 2020–2022, exceeding 160% annually, indicating an accelerative early establishment phase. Growth decelerated markedly in 2022–2023 (14.9 %), then rebounded in 2023–2024 (64.5%) before moderating again in 2024–2025 31.0%. Spatial patterns indicate that mangrove expansion originated in the southwestern portion of the site and progressively extended toward the northeast, concentrated along rehabilitated pond margins and shoreline areas targeted by the restoration programme. Areas adjacent to settlements and visitor paths showed slower growth.

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Table 1. Changes in mangrove area at Ketapang Urban Aquaculture, 2020-2025 (Sentinel-2 MVI analysis).

Year	Mangrove Area (ha)	Annual Growth (%)
2020	0.551	—
2021	1.458	164.6
2022	3.871	165.5
2023	4.447	14.9
2024	7.313	64.5

Source: Sentinel-2 Surface Reflectance analysis via Google Earth Engine.

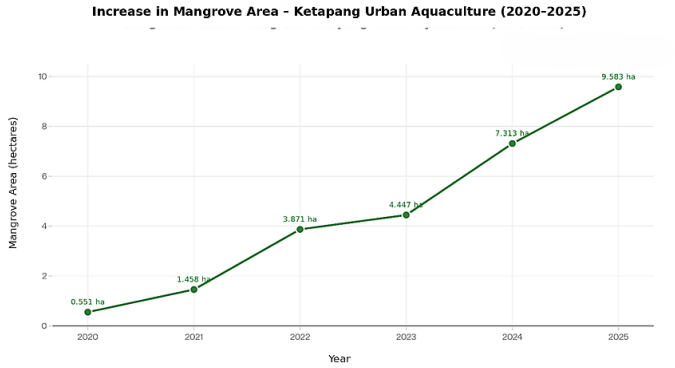

Figure 2. Line graph of mangrove area expansion 2020–2025

3.2 Mangrove Ecological Condition

Field observations identified five dominant mangrove genera at KUA: *Avicennia*, *Sonneratia*, *Rhizophora*, *Bruguiera*, and *Nypa*, distributed in a basic zonation pattern consistent with mangrove ecology along Java's north coast (Arifanti et al., 2022; Bengen, D. G., 2002). *Avicennia* and *Sonneratia* occupied the seaward fringe; *Rhizophora* dominated intermediate zones; *Bruguiera* and *Nypa* occurred in the more landward positions. Canopy closure was moderate in several planting blocks, and seedling establishment appeared successful in sheltered areas. However, signs of disturbance were noted near visitor paths, including damaged seedlings and litter accumulation, indicating localised anthropogenic pressure.

3.3 Visitor Numbers and Facility Condition

Current visitor numbers are low: approximately 5 to 10 persons on weekdays and 10 to 20 on weekends, with some days recording zero visitors. This is far below the expectations following the site's inauguration as a flagship ecotourism destination. Key infrastructure, including toilets, signage, and trekking paths, exhibits visible deterioration. Approximately 20 food stalls that previously operated have closed, and four MSME groups that received initial support are no longer operating optimally (Table 2).

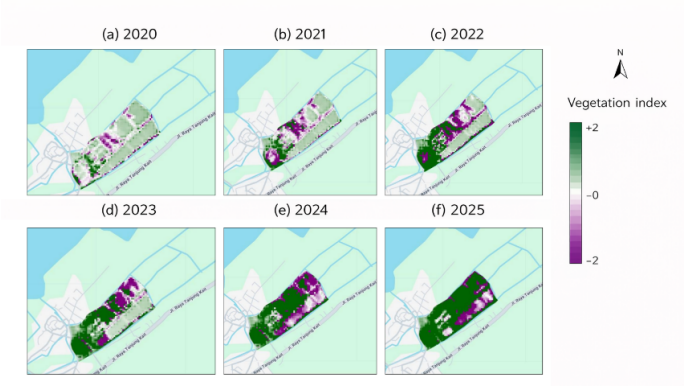

Figure 3. Spatial maps of annual mangrove cover 2020–2025

Table 2. Summary of visitor numbers and facility conditions at KUA.

Indicator	Observation
Weekday visitors	5-10 persons/day
Weekend visitors	10-20 persons/day
Days with zero visitors	Occasionally recorded
Toilet condition	Requires repair
Bench/seating condition	Requires repair
Lighting	Functional
Active food stalls	0 (of ∼20 previously active)

3.4 Community Participation

Survey and interview data indicate that community members participate in operational activities at KUA, including food vending, parking management, informal guiding, and casual labour during events. However, involvement in formal planning and decision-making processes is limited. Respondents reported that they are occasionally invited to attend meetings organised by the site management or village government, but their inputs are seldom incorporated into strategic decisions. The site manager acknowledged that enhancing community participation is constrained by low awareness and limited entrepreneurial literacy among some residents, particularly regarding value-added processing of mangrove-based products.

3.5 Perceived Well-being Impacts

The perceived impacts of KUA on community well-being are mixed and unevenly distributed across stakeholder

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Table 3. Summary of perceived well-being impacts by stakeholder group.

Dimension	Internal Staff	Vendors/MSME	Visitors
Economic	Relatively stable income; improved from pre-KUA period	Declining revenue due to low visitor numbers; high operational costs; stall closures	Entrance fee perceived as relatively high, reducing spending on local products
Social	Sense of professional identity; improved settlement conditions	Limited voice in decision-making; perception of unequal benefit distribution	Interest in educational experiences; some dissatisfaction with facility quality
Environmental	Appreciation of coastal protection from mangroves; reduced flooding	General awareness of environmental improvement	Positive perception of mangrove landscape aesthetics

groups (Table 3).

Internal management staff report improved livelihood stability compared to the period before KUA's establishment. In contrast, food vendors and MSME actors describe increasing difficulty sustaining their businesses as visitor numbers decline. The four formerly supported MSME groups are operating below capacity, and perceptions of inequitable benefit distribution between internal staff and external stakeholders were expressed in qualitative interviews.

3.6 Sustainability Challenges

The KUA management reported that annual operational costs range between IDR 300-500 million, while revenue from ticketing and routine activities is insufficient to cover these costs. Numerous government and NGO events hosted at KUA are conducted without rental fees, further reducing potential income. Financial sustainability therefore remains heavily dependent on government budget allocation and external partnerships. Additional challenges include limited human resources for marketing and product development, suboptimal digital promotion, and the absence of a transparent benefit-sharing scheme among the site management, village government, and community.

4. DISCUSSION

4.1 Mangrove Rehabilitation: Substantial Areal Gains, Ongoing Quality Challenges

The 1.639% increase in mangrove cover at KUA over five years represents one of the most rapid rates of rehabilitative expansion documented in the recent Indonesian literature. As a comparison, mangrove cover in Bengkulu Province expanded by 43.9% between 2015 and 2025 following community-led restoration efforts (Srifitriani et al., 2025). The accelerative pattern at KUA, characterised by rapid initial expansion (2020-2022) followed by growth moderation, is consistent with generalised rehabilitation dynamics observed in Southeast Asian mangrove restoration, where early canopy closure occurs rapidly in favourable substrate conditions before stands enter a stabilisation phase (Biswas et al., 2009; Arifanti et al., 2022).

However, the moderate mangrove health index reported by Azahra et al. (2024) and the localised disturbance signs observed during field work indicate that areal expansion has not yet been accompanied by full ecological maturation. This finding aligns with research demonstrating that mangrove species richness, structural complexity, and below-ground carbon stocks require considerably longer timescales, often exceeding a decade, to approximate reference-condition stands. The spatial pattern of slower growth near visitor paths and settlements further suggests that tourism-related trampling and waste accumulation pose localised risks that require management intervention (Basyuni et al., 2018). In Tangerang Regency more broadly, the dominant mangrove pioneer species at KUA, including *Avicennia marina*, *Sonneratia caseolaris*, and *Rhizophora mucronata*, are precisely the species documented by Mahardika et al. (2023) to colonise available substrates rapidly under favourable conditions, while exhibiting sensitivity to intensive land use change, waste inputs from aquaculture and settlements, and the loss of hydro-ecological connectivity, factors that likely underlie the growth deceleration observed at KUA during 2022 to 2023.

The satellite-based analysis demonstrates that KUA has achieved substantial ecological success in terms of mangrove area recovery. Nevertheless, the transition from area expansion to functional ecosystem restoration, encompassing canopy structure, biodiversity, and carbon sequestration capacity, remains ongoing and warrants long-term monitoring.

4.2 The Mangrove-Aquaculture-Ecotourism Integration Model: Concept versus Implementation

KUA's conceptual framework, which positions the site as a "living laboratory" where mangrove conservation, aquaculture, and ecotourism coexist within a shared landscape, is aligned with the silvofishery paradigm that has been

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advocated for sustainable coastal management in Indonesia (Hadi et al., 2022; Mahmudi, 2008). In principle, the integration model creates synergies: mangroves filter aquaculture effluent, provide natural feed for pond species, and stabilise substrates, while aquaculture provides livelihood alternatives that reduce pressure on wild fishery resources, and ecotourism generates non-extractive revenue that incentivises conservation (Datta et al., 2012; Lubis et al., 2024).

In practice, however, the current implementation at KUA reveals gaps between concept and reality. Documentation of aquaculture waste management, stocking density regulation, and water exchange protocols is limited, leaving the actual environmental footprint of the pond operations on mangrove water quality and health uncertain. This is a critical concern, as poorly managed aquaculture in mangrove landscapes has been identified as a primary driver of mangrove degradation across Southeast Asia. In contrast, the silvofishery model in Deli Serdang, North Sumatera, explicitly delineates production and conservation zones and regulates input use, thereby minimising ecological conflict (Basyuni et al., 2018).

The institutional arrangement whereby KUA is a government asset managed by a BUMD (PT Mitra Kerta Raharja) provides legal certainty and access to public funding but may inadvertently create a top-down governance structure that limits local ownership. Successful community-based mangrove ecotourism models in Indonesia, such as Mangrove Center Tuban, Wana Tirta in Kulon Progo, and Pulau Kemujan in Karimunjawa, demonstrate that co-management arrangements involving local governance structures (e.g., *kelompok sadar wisata*), village government, and external facilitators tend to produce stronger community buy-in and more equitable benefit distribution (Arrahmah and Wicaksono, 2022; Basyuni et al., 2018; Tia and Fitrianti, 2023).

4.3 Community Participation: Operational Engagement without Strategic Empowerment

The finding that community participation at KUA concentrates at the operational and utilisation stages, while strategic planning and evaluation remain dominated by the BUMD and government authorities, is consistent with a persistent pattern identified across community-based ecotourism initiatives in Indonesia (Mulyawati et al., 2025; Basyuni et al., 2018). When assessed against Arnstein's (1969) ladder of participation, the current mode at KUA would be classified as "consultation" or at best "placation," which are levels that fall short of genuine partnership or citizen control.

This limited participation has direct consequences for perceived equity and sustained community support. The welfare gap between internal staff and vendors/MSME actors, documented in both survey and interview data, mirrors concerns raised by Romli and Purwanto (2024) regarding the need for participatory communication and by Mulyawati et al. (2025) regarding the marginalisation of local voices. When economic benefits are perceived as accruing primarily to those closest to the management structure, community motivation to support conservation and tourism objectives erodes, a dynamic that threatens the long-term viability of the ecotourism model (Datta et al., 2012).

Experiences from community-based mangrove tourism in Banten Province itself demonstrate that community groups play critical roles in increasing conservation awareness and generating economic value through mangrove product diversification. These examples suggest that forming or strengthening a local *kelompok sadar wisata* at KUA and granting it a formal role in governance could shift participation from operational to strategic levels.

4.4 Visitor Decline and Financial Non-sustainability

The current visitation levels at KUA, ranging from zero to approximately 20 visitors per day, represent a critical sustainability challenge. Unlike mangrove ecotourism sites that have established partnerships with educational institutions for regular student visits (Yanti et al., 2022; Tia and Fitrianti, 2023), KUA has not yet diversified its visitor base beyond casual domestic tourists. The perceived high entrance fee, deteriorating infrastructure, and limited digital promotion collectively suppress demand (Apriliani et al., 2025; Dewi and Berutu, 2025; Yanuadi et al., 2024).

The financial gap, where annual operational costs of IDR 300 to 500 million exceed tourism revenue, means the site operates as a subsidised public facility rather than a self-sustaining ecotourism enterprise. While government subsidisation is not inherently problematic during an establishment phase, the absence of a credible trajectory toward revenue diversification raises questions about long-term viability should political priorities shift. Comparable sites that have achieved greater financial resilience typically combine ticketing with environmental education packages, mangrove product sales, event space rental at cost-recovery rates, and corporate social responsibility partnerships (Khakim et al., 2021; Yanti et al., 2022).

4.5 Novelty Defence

This study makes three distinct contributions. First, it provides the first Sentinel-2 MVI-based time-series analysis of mangrove cover change specifically for the KUA site, generating a quantitative baseline that was previously unavailable. Second, it is the first study to integrate ecological (remote sensing and field observation), socio-economic (survey and interview), and governance (participation assessment) dimensions within a single framework applied to KUA, enabling the identification of systemic disconnections between ecological success and socio-economic outcomes. Third, the findings contribute empirically to the nascent literature on BUMD-managed coastal ecotourism governance in Indonesia, a management modality that is increasing

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but has received limited scholarly attention compared to community-based or privately managed models.

4.6 Limitations and Bias Control

Several limitations should be acknowledged. First, the survey sample (n = 9) is small and purposive, precluding statistical generalisation; the findings are best interpreted as indicative patterns that warrant confirmation through larger-scale studies. Second, the ecological assessment is primarily descriptive; no density plots, diameter-at-breast-height measurements, or water quality parameters were collected, limiting the precision of ecological condition assessment. Third, the Sentinel-2 MVI analysis, while providing valuable areal change data, has inherent limitations related to pixel resolution (10 m), atmospheric conditions, and the distinction between true mangrove and other coastal vegetation, although the use of annual median composites and cloud masking mitigates some of these concerns. Fourth, the study is a single-site case study; cross-site comparisons with other mangrove ecotourism models would strengthen the generalisability of recommendations.

These limitations do not invalidate the principal conclusions because: (a) the satellite-derived areal change data are robust and independent of sample size constraints; (b) the qualitative findings are triangulated across interviews, observations, and secondary literature, with consistent patterns emerging; and (c) the study's primary contribution is diagnostic and framework-setting rather than hypothesis-testing, making its value proportionate to the depth of contextual understanding rather than statistical power.

5. CONCLUSION

This study demonstrates that Ketapang Urban Aquaculture has achieved remarkable success in mangrove area rehabilitation, expanding from 0.551 ha to 9.583 ha over five years, but has not yet translated this ecological achievement into a self-sustaining ecotourism model that delivers broad-based community well-being benefits. The principal disconnects lies between ecological recovery, which has been effective, and socio-economic and governance systems, which remain underdeveloped. Visitor numbers are low and declining, critical infrastructure is deteriorating, community participation is operationally confined, and economic benefits are unevenly distributed across stakeholder groups.

To advance toward sustainability, the following actions are recommended:

1. Ecological management: Implement routine mangrove stand monitoring (canopy cover, seedling survival, water quality near ponds) involving community members as citizen scientists; establish visitor impact zoning to protect vulnerable planting blocks.
2. Governance restructuring: Establish or formalise a local community group (kelompok sadar wisata) with defined roles in planning, monitoring, and evaluation; develop a transparent benefit-sharing agreement among PT Mitra Kerta Raharja, the village government, and community stakeholders.
3. Revenue diversification: Develop formal partnerships with schools, universities, and the Education Office for regular educational visits; create interpretive trail packages, mangrove product workshops, and event rental services at cost-recovery rates; invest in digital marketing infrastructure.
4. Infrastructure upgrading: Prioritise repair and improvement of sanitation, signage, and family-friendly spaces to improve visitor satisfaction and support demand recovery.
5. Aquaculture sustainability: Document and regulate aquaculture practices (stocking density, waste management, water exchange) to ensure compatibility with mangrove conservation objectives.

Future research should employ larger household surveys, quantitative ecological assessments (vegetation structure, biodiversity indices, carbon stocks), and comparative analyses with other mangrove ecotourism sites to evaluate the effectiveness of alternative governance and management strategies

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