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Research Article

Blue Carbon & Ecotourism: Empowering East Kalimantan's Coastal Communities

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Abstract

East Kalimantan's extensive mangrove forests represent globally significant blue carbon assets, yet their potential remains largely underutilised for community-based ecotourism. This study examines how integrating mangrove conservation with ecotourism development can advance climate change mitigation and economic empowerment for coastal communities in Berau and Tarakan, East Kalimantan, Indonesia. A convergent mixed-methods design was employed, combining structured surveys of 245 stakeholders, including local community members, tourism operators, government officials, conservation practitioners, and academics, with 32 semi-structured interviews, four focus group discussions, and participatory observation conducted between January 2024 and February 2025. Economic valuation integrated the Travel Cost Method (TCM) to estimate tourism demand and the Contingent Valuation Method (CVM) to assess willingness to preserve mangrove ecosystems, while carbon sequestration potential was quantified through biomass and soil organic carbon (SOC) analysis using validated allometric equations. Results indicate that optimised management of integrated ecotourism and blue carbon mechanisms could generate USD 18,400-22,800 per hectare annually, substantially exceeding returns from extractive land uses such as aquaculture or timber harvesting. However, realising this potential is constrained by significant implementation barriers, including inadequate visitor infrastructure, cited by 67% of stakeholders, and limited institutional capacity, reported by 72%, alongside financial and regulatory obstacles. Since Indonesia opened its domestic carbon exchange to international trading in January 2025, carbon credits have been valued at USD 5.8-8.7 per ton, offering a new and rapidly evolving revenue stream. To address governance fragmentation, this study proposes a quintuple helix framework that coordinates government, academia, the private sector, community organisations, and environmental NGOs. Strategic recommendations include phased infrastructure development, targeted capacity building, transparent benefit-sharing mechanisms, and digital platform adoption. Overall, this integrated approach demonstrates that mangrove ecotourism can simultaneously advance conservation objectives, national climate commitments, and sustainable livelihoods for coastal communities, offering a scalable model for other blue carbon regions in Indonesia and beyond.

Keywords

Blue Carbon, Mangrove Ecotourism, Community Empowerment, Economic Valuation, Carbon Trading, Sustainable Development, East Kalimantan, Climate Finance

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1. Introduction

Indonesia's coastal ecosystems represent critical natural capital for both global climate regulation and local economic development. As the world's largest archipelagic nation, Indonesia harbors approximately 3.2 million hectares of mangrove forests, accounting for nearly one-quarter of global mangrove coverage and storing an estimated 3 billion tons of carbon [1, 2]. These blue carbon ecosystems provide exceptional climate mitigation potential, with mangroves alone absorbing over 122 million tonnes of CO_2 annually while simultaneously supporting biodiversity conservation and coastal community livelihoods [3].

East Kalimantan province occupies a strategic position within Indonesia's blue carbon landscape, featuring extensive mangrove ecosystems along its 1,100-kilometer coastline. The province's mangroves encompass diverse geomorphological settings, including fringing, estuarine, and riverine systems, creating unique opportunities for integrated conservation and economic development [4]. Recent policy developments, particularly Indonesia's opening of international carbon markets in January 2025 and the establishment of bilateral trading partnerships, have fundamentally transformed the economic valuation framework for coastal ecosystem services [5, 6].

Despite this enormous potential, mangrove ecosystems throughout Southeast Asia face unprecedented degradation pressures. Expansion of commercial aquaculture, agricultural conversion, urban development, and climate change impacts have reduced global mangrove coverage from 18.8 million hectares in 1980 to 14.7 million hectares in 2020 [7, 8]. In East Kalimantan specifically, annual deforestation rates of 2.3-3.1% persist due to conflicting land use priorities, weak regulatory enforcement, and insufficient economic incentives for conservation [9].

Mangrove ecotourism has emerged as a promising mechanism to internalize ecosystem service values while generating sustainable livelihoods for coastal communities [10, 11]. Evidence from Tanzania's Amboni Mangrove Reserve demonstrates the transformative potential of strategic ecotourism development, with visitor numbers reaching 19,743 in fiscal year 2024/2025 and generating over 40 million Tanzanian shillings in revenue [12]. Similarly, successful implementations across Southeast Asia have stimulated infrastructure development, created employment opportunities, and motivated community-based conservation initiatives [13, 14].

However, realizing this potential requires addressing fundamental challenges in governance, infrastructure, capacity, and benefit distribution. Recent research emphasizes the critical importance of integrating institutional frameworks, community participation, and technological advancement in sustainable ecotourism development [15, 16]. The establishment of Indonesia's domestic carbon exchange (IDX Carbon) and evolving payment for ecosystem services mechanisms create unprecedented opportunities to link conservation outcomes with economic returns [17, 18].

This research addresses a critical knowledge gap regarding the integration of blue carbon mechanisms with community-based mangrove ecotourism in East Kalimantan. While existing literature examines ecotourism development and carbon valuation separately, limited empirical research explores their synergistic implementation within Indonesia's emerging policy framework. The study contributes to theoretical advancement by developing an integrated governance model while providing practical guidance for stakeholders navigating this evolving landscape.

The primary research objective examines how mangrove ecotourism development can simultaneously advance conservation goals and community economic empowerment in East Kalimantan. Specific aims include: (1) quantifying the economic potential of integrated ecotourism and blue carbon mechanisms, (2) identifying critical implementation barriers and success factors, (3) analyzing stakeholder perceptions and capacity requirements, and (4) developing a practical governance framework for sustainable implementation. Findings provide actionable insights for policymakers, conservation practitioners, and coastal communities seeking to leverage Indonesia's blue carbon leadership for sustainable development outcomes.

2. Materials and Methods

2.1. Study Area and Research Design

This research focuses on mangrove ecosystems in Berau and Tarakan districts, East Kalimantan province, Indonesia. These sites represent diverse geomorphological settings and development stages, enabling a comprehensive analysis of ecotourism potential. Berau Regency encompasses approximately 45,000 hectares of mangrove forests within the Berau Marine Conservation Area, recognized internationally for biodiversity richness. Tarakan Island features 8,500 hectares of urban-adjacent mangroves experiencing different anthropogenic pressures [19].

Research employed a convergent mixed-methods approach combining quantitative economic analysis with qualitative stakeholder perspectives during January-December 2024 and January-February 2025. This design enables triangulation of findings while capturing both measurable outcomes and contextual nuances essential for understanding complex socio-ecological systems [20]. The integrated methodology aligns with recommendations for assessing sustainable tourism development in coastal ecosystems [21].

2.2. Data Collection Methods

Primary data collection involved structured surveys

administered to 245 respondents across multiple stakeholder categories, including local community members (n=120), tourism operators (n=35), government officials (n=42), conservation practitioners (n=28), and academics (n=20). Survey instruments assessed perceptions regarding ecotourism potential, implementation barriers, willingness to participate, and benefit-sharing preferences. Sampling utilized stratified random selection within communities and purposive sampling for institutional stakeholders [22].

Qualitative methods included 32 semi-structured interviews with key informants representing diverse perspectives, four focus group discussions with community organizations, and participatory observation at existing ecotourism sites. Interview protocols explored governance challenges, capacity needs, traditional ecological knowledge, and stakeholder relationships. Focus groups facilitated collective problem-solving and validation of preliminary findings [23].

Secondary data sources comprised government statistical records, tourism visitor data, mangrove inventory reports, spatial datasets from remote sensing analysis, and economic indicators from district planning agencies. Carbon stock estimations utilized published allometric equations appropriate for regional mangrove species composition, validated through ground-truthing at representative plots [24, 25].

2.3. Economic Valuation Framework

Economic analysis integrated multiple valuation approaches to comprehensively assess mangrove ecosystem service values. Direct use values from ecotourism were estimated using the travel cost methodology and tourist expenditure surveys. Carbon sequestration values incorporated three pricing scenarios: Indonesia's domestic market rates (USD 4-5 per ton), international voluntary market prices (USD 8.7 per ton), and social cost of carbon estimates (USD 185-400 per ton), reflecting varied policy contexts [26, 27].

Total economic value calculations encompassed provisioning services, including fisheries support valued through replacement cost methods, regulating services, such as coastal protection, assessed via damage cost avoided approaches, and cultural services quantified through contingent valuation, capturing non-use values. Benefit-cost analysis evaluated ecotourism development scenarios over 20-year timeframes using 8% social discount rates consistent with Indonesian planning guidelines [28, 29].

2.4. Data Analysis Procedures

Quantitative data analysis employed descriptive statistics, comparative analysis across sites, and multivariate regression examining factors influencing stakeholder support and willingness to participate. Statistical software SPSS version 27 facilitated analysis with significance determined at $p<0.05$. Qualitative data underwent thematic analysis following systematic coding procedures, with NVivo 14 supporting data management and pattern identification [30].

Integration of quantitative and qualitative findings occurred through joint display matrices, enabling systematic comparison and synthesis. This approach enhanced validity by triangulating evidence from multiple sources while illuminating complementary insights unavailable from either method alone [31]. Ethical approval was obtained from the institutional review board protocols, with informed consent secured from all participants and confidentiality maintained throughout.

3. Results

3.1. Economic Potential of Integrated Mangrove Ecotourism

Economic valuation analysis reveals substantial financial potential from integrated mangrove ecotourism and carbon mechanisms in East Kalimantan. Total ecosystem service values range from USD 18,400 to USD 22,800 per hectare annually under optimized management scenarios, significantly exceeding returns from alternative land uses such as aquaculture (USD 3,200-4,500/ha) or timber extraction (USD 1,800-2,400/ha). This differential demonstrates compelling economic rationale for conservation-based development strategies.

Table 1 presents disaggregated economic values across service categories. Direct ecotourism revenues currently generate USD 2,400-3,800 per hectare in established sites, with substantial growth potential through infrastructure improvements and marketing investments. Fisheries support values, calculated through productivity enhancement in adjacent waters, contribute USD 4,200-5,600 per hectare. Coastal protection services provide USD 3,800-4,900 per hectare in avoided damage costs, particularly significant given increasing storm intensity under climate change scenarios [32].

Table 1. *Annual Economic Value of Mangrove Ecosystem Services in East Kalimantan (USD/hectare).*

Ecosystem Service Category	Current Value	Potential Value	Source
Ecotourism (direct)	1,200-2,400	2,400-3,800	[19, 33]
Fisheries support	3,800-4,600	4,200-5,600	[27, 34]

Ecosystem Service Category	Current Value	Potential Value	Source
Coastal protection	3,200-4,100	3,800-4,900	[32, 35]
Carbon sequestration (voluntary market)	600-1,200	2,800-4,200	[17, 26]
Water quality regulation	1,400-1,800	1,800-2,400	[36, 37]
Biodiversity habitat	800-1,200	1,400-1,900	[38, 39]
Total Annual Value	11,000-15,300	18,400-22,800	

Note: Values represent 2024 USD calculated using market prices, replacement costs, and contingent valuation methods. Potential values reflect optimized management with developed ecotourism infrastructure and carbon market participation.

Carbon sequestration represents particularly dynamic value streams given evolving market conditions. Indonesia's domestic carbon exchange (IDX Carbon), operational for international trading since January 2025, offers prices of USD 5.8-8.7 per ton for certified credits. At average sequestration rates of 380-520 tons CO_2 per hectare for mature mangrove stands, annual carbon revenues could reach USD 2,800-4,200 per hectare under voluntary market conditions [17, 40]. However, current low participation rates and procedural complexities limit the realization of this potential.

3.2. Implementation Barriers and Success Factors

Survey results identify multifaceted barriers constraining mangrove ecotourism development in East Kalimantan. Infrastructure deficiencies emerge as the most frequently cited challenge, with 67% of stakeholders rating this as critical. Existing mangrove sites lack basic visitor facilities, including boardwalks (present in only 23% of surveyed locations), interpretive signage (31%), restroom facilities (18%), and parking areas (42%). Transportation accessibility represents another significant constraint, with 58% of potential ecotourism sites located beyond 5 kilometers from paved roads [41].

Institutional capacity limitations affect multiple dimensions of implementation. Analysis reveals that 72% of local government officials and 81% of community organization leaders report insufficient training in ecotourism management, financial planning, or marketing strategies. Only 15% of surveyed communities have established formal tourism management structures with defined roles and accountability mechanisms. Regulatory complexity compounds these challenges, with overlapping jurisdictions between forestry, fisheries, tourism, and environmental agencies creating bureaucratic obstacles for permit acquisition and operational compliance [42].

Financial constraints inhibit both initial investment and sustained operations. Community members identify capital access as a primary barrier, with 84% lacking financial resources for infrastructure development and 76% unable to access formal credit due to collateral requirements or lending terms. Operational sustainability concerns persist even at established sites, where 63% report inconsistent visitor flows creating financial instability. Carbon market participation presents additional barriers, including verification costs (averaging USD 12,000-18,000 for initial certification), technical complexity of monitoring protocols, and lengthy approval timelines averaging 18-24 months [43].

Despite these challenges, the analysis identifies critical success factors from functioning sites. Strong community leadership correlates significantly with positive outcomes, with sites having dedicated management committees demonstrating 3.2 times higher visitor satisfaction scores and 2.8 times greater revenue per hectare. External partnership linkages prove essential, particularly relationships with conservation NGOs providing technical support and private sector entities facilitating market access. Sites maintaining active partnerships show 67% higher visitor numbers and 54% greater community participation rates [44].

Integration of traditional ecological knowledge enhances both conservation outcomes and cultural authenticity. Communities incorporating traditional management practices and cultural narratives into visitor experiences report 72% higher repeat visitation rates. Environmental education programs targeting both visitors and local youth strengthen conservation awareness while building long-term stewardship capacity. Sites implementing structured education initiatives demonstrate 48% lower incidence of degradation activities and 62% higher community support for conservation regulations [45].

4. Discussion

4.1. Economic Transformation Through Blue Carbon Integration

Research findings demonstrate that integrating blue carbon mechanisms with community-based ecotourism fundamentally transforms the economic calculus of mangrove conservation in East Kalimantan. The demonstrated potential values of USD 18,400-22,800 per hectare annually exceed extractive alternatives by factors of 4-8, providing compelling

economic rationale for conservation-based development. This aligns with emerging evidence globally documenting mangrove economic values ranging from USD 19,000-23,000 per hectare when ecosystem services are comprehensively monetized [46].

However, realizing this potential requires addressing critical implementation gaps. The substantial differential between current realized values (USD 11,000-15,300/ha) and optimal potential reflects systemic barriers in infrastructure, capacity, and institutional frameworks. International experiences offer instructive parallels. Tanzania's Amboni Mangrove Reserve achieved visitor growth from negligible levels to nearly 20,000 annually through strategic infrastructure investments in lighting and walkways, combined with educational programming. Similarly, successful Southeast Asian sites demonstrate that systematic capacity building and institutional strengthening precede sustainable tourism development [12, 13].

Indonesia's opening of international carbon markets in January 2025 creates unprecedented opportunities for financing conservation and development activities. However, current market participation remains minimal due to verification costs, technical complexity, and procedural barriers. Research from other blue carbon initiatives emphasizes the importance of simplified protocols, capacity building support, and equitable benefit-sharing mechanisms to ensure community participation [47, 48]. The establishment of regional carbon aggregation facilities and technical support services could significantly reduce transaction costs while maintaining verification standards.

4.2. Governance Architecture for Sustainable Implementation

Effective governance emerges as the foundational prerequisite for successful mangrove ecotourism development. Findings reveal that current fragmented institutional arrangements create inefficiencies, jurisdictional conflicts, and implementation barriers. The proposed quintuple helix framework addresses these challenges by systematically integrating government agencies, academic institutions, private sector entities, community organizations, and environmental NGOs within coordinated governance structures [49].

Government's role encompasses regulatory frameworks, spatial planning, infrastructure investment, and quality standards enforcement. Academic institutions contribute scientific expertise, monitoring protocols, capacity-building programs, and innovation. Private sector participation provides capital investment, marketing capabilities, operational expertise, and market linkages. Community organizations ensure local participation, traditional knowledge integration, and equitable benefit distribution. Environmental NGOs facilitate technical support, advocacy, monitoring, and certification assistance [50].

Implementation requires establishing formal coordination mechanisms, including joint management committees, regular stakeholder forums, transparent decision-making processes, and clear accountability structures. International experiences demonstrate that formalized multi-stakeholder platforms significantly improve coordination, resource efficiency, and outcome achievement. Malaysia's community-based mangrove management programs and Thailand's integrated coastal zone management initiatives provide relevant models adaptable to Indonesian contexts [51, 52].

Benefit-sharing mechanisms require particular attention to ensure equitable outcomes and sustained community support. Research findings indicate strong preferences for transparent revenue distribution formulas allocating a minimum 60% of direct tourism revenues to community members while designating specific portions for conservation activities, capacity building, and infrastructure maintenance. Successful implementations elsewhere employ community trusts, rotating leadership positions, skills-based employment prioritization, and regular participatory monitoring [53].

4.3. Strategic Pathways and Policy Implications

Findings support phased implementation strategies prioritizing foundational capacity building before intensive tourism development. Initial phases should focus on infrastructure essentials, organizational strengthening, and pilot demonstrations, building confidence and competencies. Intermediate phases can expand visitor facilities, diversify activity offerings, and strengthen marketing. Advanced phases integrate carbon finance mechanisms, regional branding, and international market connections [54].

Technology integration offers substantial opportunities for enhancing visitor experiences, operational efficiency, and conservation monitoring. Digital booking platforms, virtual reality previews, mobile applications for interpretive content, and real-time environmental monitoring systems can differentiate offerings while improving management. However, research indicates infrastructure limitations and digital literacy gaps require attention before technology investments yield anticipated benefits [55].

Policy implications span multiple governance levels. National policy priorities should include streamlined carbon market access procedures, capacity building infrastructure, and coordination mechanisms linking tourism, conservation, and climate policies. Provincial initiatives could establish regional ecotourism corridors, shared marketing platforms, and technical support services. District governments should prioritize spatial planning integration, infrastructure investment, and regulatory harmonization. Community-level actions encompass organizational development, skills training, and participatory management structures [56].

Research limitations include temporal constraints limiting longitudinal assessment of development trajectories, geographic focus potentially limiting generalizability, and

challenges monetizing certain ecosystem services. Future research should examine long-term socio-economic impacts, comparative effectiveness of different governance models, integration with blue food systems, and scaling mechanisms for regional replication. Monitoring visitor impacts, assessing cultural change dynamics, and evaluating carbon verification methodologies require ongoing investigation [57].

5. Conclusions

This research demonstrates that integrated mangrove ecotourism development offers transformative potential for simultaneously achieving conservation, climate mitigation, and community empowerment objectives in East Kalimantan. Economic analysis reveals substantial value generation potential of USD 18,400-22,800 per hectare annually when ecosystem services are comprehensively mobilized through coordinated tourism and blue carbon mechanisms. This represents 4-8 fold improvements over current extractive land uses, providing compelling economic rationale for conservation-based development strategies.

However, realizing this potential requires systematically addressing implementation barriers in infrastructure, institutional capacity, financial access, and governance coordination. Research findings identify critical success factors, including strong community leadership, external partnership linkages, traditional knowledge integration, and transparent benefit-sharing mechanisms. The proposed quintuple helix governance framework provides a practical architecture for coordinating diverse stakeholders while ensuring equitable participation and benefit distribution.

Indonesia's blue carbon leadership, exemplified by opening international carbon markets in January 2025, creates unprecedented opportunities for financing sustainable development while contributing to global climate goals. The country's 3.2 million hectares of mangroves, storing 3 billion tons of carbon, represent enormous potential for climate finance mobilization. Strategic implementation of integrated ecotourism and carbon mechanisms can demonstrate scalable models reconciling conservation imperatives with development aspirations.

Practical recommendations emphasize phased implementation, prioritizing foundational capacity building, transparent governance structures, equitable benefit distribution, and systematic monitoring. Infrastructure investments should focus on visitor essentials while maintaining ecosystem integrity. Capacity building must address technical, organizational, and financial management dimensions. Carbon market participation requires simplified procedures, aggregation facilities, and technical support systems to enable community engagement.

This research contributes empirical evidence demonstrating the economic viability of integrated conservation approaches while identifying implementation pathways appropriate for Indonesian contexts. The findings inform policy development at multiple governance levels while providing practical guidance for communities, conservation practitioners, and development agencies. As Indonesia advances its blue carbon agenda and climate commitments, mangrove ecotourism represents a scalable mechanism for translating ecological assets into sustainable prosperity for coastal communities while safeguarding critical ecosystems for future generations.

Abbreviations

CO	Carbon Dioxide
DXA	Direct Exchange Area
FOLU	Forestry and Other Land Use
IDX	Indonesia Stock Exchange
NDC	Nationally Determined Contributions
NGO	Non-Governmental Organization
USD	United States Dollar

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Author Contributions

Tamam Rosid: Conceptualization, Resources, Supervision, Writing – original draft

Abdul Hakim: Formal Analysis, Funding acquisition, Investigation, Validation.

Endah Susanti: Data curation, Methodology, Project administration, Software

Ma'rifah Yuliani: Writing – review & editing

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Certain data cannot be made publicly available due to privacy considerations and confidentiality agreements with participating communities.

Conflicts of Interest

The author declares no conflicts of interest.

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