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Analysis of Mangrove Carbon Economic Potential and Community Based Mangrove Management in Mojo Village, Pemalang Regency

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Abstract
Mangrove forests are vital for maintaining coastal ecosystem balance and mitigating climate change through blue carbon storage. This study present a novel integration of blue carbon economic valuation and community-Based mangrove Management (CBMM) assessment at the village scale, using mojo village, Indonesia as a case study. Mojo village was chosen as the research location because of the carbon potential that Mojo village has to be developed using the CBMM concept. A mixed-method approach combined secondary data analysis of mangrove carbon stocks with semi-structured interviews involving key members of the Pelita Bahari community group. The Mojo Village mangrove ecosystem demonstrated substantial blue carbon value, estimated between IDR 34.66 million and IDR 199.78 million per hectare under different carbon market scenarios, indicating substantial mitigation and financial potential. CBMM analysis reveals that strong local participation and institutional legitimacy support conservation outcomes; however, limited technical capacity, external dependence, and weak monitoring constrain readiness for carbon market participation. Analytically, the findings demonstrate that carbon valuation alone is insufficient without parallel governance strengthening. Community-based mangrove management supports the sustainability of coastal ecosystems and contributes to community welfare through the economic valorization of blue carbon. Beyond local benefits, this study contributes to the global blue carbon discourse by illustrating how village-level community management can inform scalable, socially inclusive pathways for integrating mangroves into national climate strategies, carbon markets, and international mitigation frameworks under the Paris Agreement.

Keywords: Carbon markets, Coastal resilience, Environmental governance, Local livelihoods, Participatory conservation.

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1. Introduction

Mangrove forests play a strategic role in mitigating global climate change through their ability to absorb and store large amounts of carbon in biomass and sediments (Alongi, 2014). This ecosystem is known as a major contributor to blue carbon because it can store up to five times more carbon than terrestrial forests (Duarte *et al.*, 2013). In addition to their ecological functions, mangroves also provide economic and social benefits to coastal communities, such as providing

fishery resources, ecotourism opportunities, and protection of coasts from abrasion and hydrometeorological disasters (Barbier *et al.,* 2011). These multiple functions position mangroves as socio-ecological systems in which climate mitigation, livelihood security, and coastal resilience are closely interconnected.

Indonesia controls around 24% of the world's total mangrove area, thus playing an important role in global efforts to reduce greenhouse gas emissions through mangrove conservation and restoration (Murdiyarso *et al.,* 2015). Mojo Village, Pemalang Regency, is one of the areas with the largest mangrove ecosystems in the region, covering an area of 120.93 hectares (Hariyati, *et. al.,* 2024). Mangroves in this area contribute to atmospheric carbon sequestration while supporting the livelihoods of coastal communities. Pressure from land conversion to ponds and settlements has reduced ecological functions and carbon sequestration capacity. Economic valuation of mangrove carbon stocks at the local level is still rarely conducted, even though this approach is important to support conservation policies and incentive schemes such as voluntary carbon markets and payment for ecosystem services (Siikamäki *et al.,* 2012; Barbier, 2016). Despite increasing international attention to blue carbon mechanisms, valuation studies at the village scale remain limited, even though this scale is critical for translating global climate commitments into locally implementable incentive instruments.

Research on community-based mangrove management in Indonesia has shown positive results. Mangrove rehabilitation in Singkawang, West Kalimantan, has been proven to increase biomass and carbon stocks through a community-based approach (Astiani *et al.,* 2024). A study on the coast of Demak confirmed the effectiveness of Community-Based Mangrove Management (CBMM) in protecting the area from abrasion (Nasution & Wijaya, 2024). Another study in Langkat, North Sumatra, found that active community participation played a major role in the success of rehabilitation while also providing economic benefits (Dinda *et al.,* 2020). However, most CBMM studies primarily emphasize ecological recovery or social participation, with limited integration of carbon economic valuation as a governance-relevant incentive for community-based conservation. The village of Mojo also has a Pelita Bahari group that has been active in conservation since 2008, but these efforts have not been fully supported by scientific data on the economic value of carbon. This study addresses this gap by explicitly integrating the economic valuation of blue carbon with an analysis of CBMM governance at the village scale. By combining carbon valuation with an assessment of community-based management practices across planning, implementation, and monitoring stages, this research moves beyond descriptive case studies and provides an analytical basis for linking local mangrove management with broader policy instruments, including payment for ecosystem services (PES), carbon market mechanisms, and Indonesia's FOLU Net Sink 2030 agenda. Furthermore, the Mojo Village case is positioned as a transferable example for other community-managed mangrove systems in tropical coastal regions facing similar socio-ecological challenges. Accordingly, this study aims to (1) estimate the economic value of blue carbon stored in the mangrove ecosystem of Mojo Village and (2) analyze community-based mangrove management practices using the CBMM framework. The results are expected to strengthen the scientific basis for inclusive, scalable, and policy-relevant blue carbon initiatives that connect local conservation efforts with national and global climate mitigation strategies.

2. Methods

The research location was in Mojo Village, Ulujami District, Pemalang Regency, which is a coastal area with the largest mangrove ecosystem in the region. The research was conducted from July to September 2025. The following map shows the geographical position of Mojo Village and the distribution of mangrove areas where data collection and field observations were carried out (Figure 1).

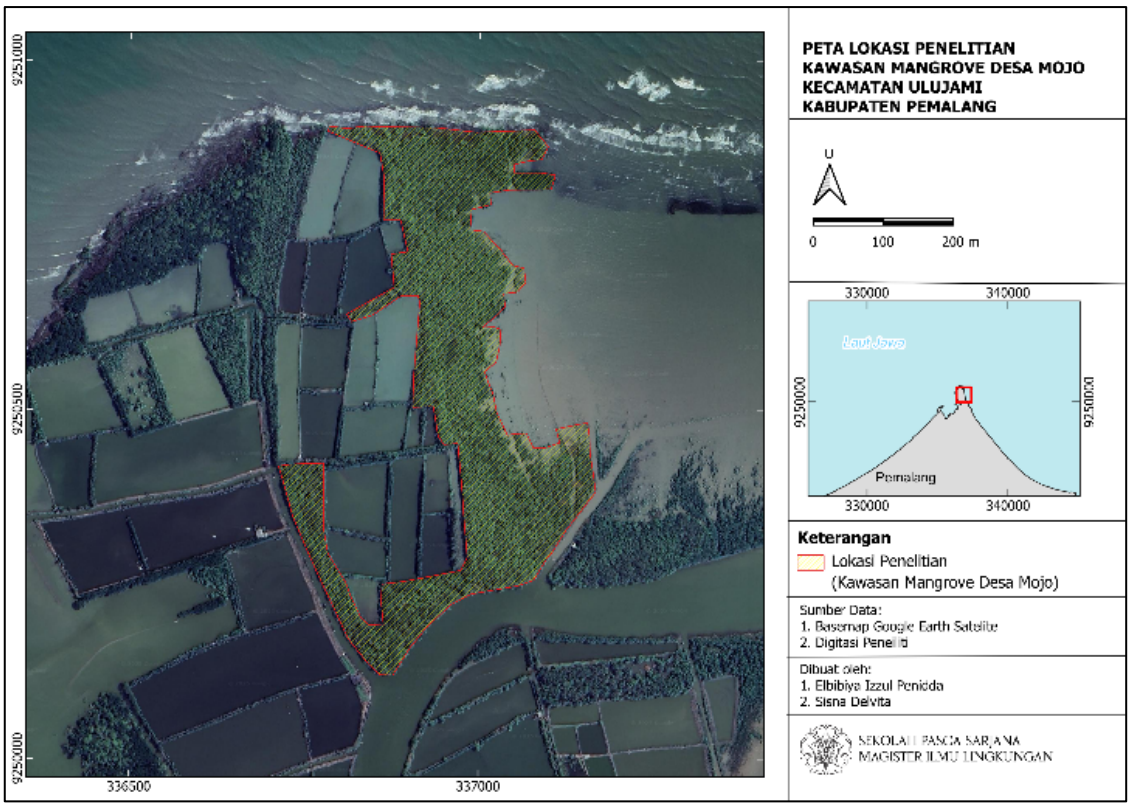


Figure 1. Map of the research location.

This study uses a mixed approach consisting of literature analysis for carbon stock estimation and qualitative interviews for community-based mangrove management (CBMM) in Mojo Village, Pemalang Regency. Mangrove carbon stock estimates were obtained from the study by Haryati *et al.* (2024), which quantified above- and below-ground biomass and sediment carbon stocks based on field measurements conducted across representative mangrove stands in Mojo Village. The data were selected because they represent the most recent, site-specific, and peer-reviewed carbon stock assessment available for the study area, making them suitable for village-scale valuation analysis. Nevertheless, the use of secondary carbon data entails uncertainty related to spatial heterogeneity, temporal variability, and methodological assumptions in biomass and sediment sampling, which may affect the precision of estimated carbon stocks. The reported carbon stocks range from 21.55–144.22 tons C/ha for biomass and 98.45–181.06 tons C/ha for sediments, resulting in a total of 112.43–247.98 tons C/ha with an average of 155.13 tons C/ha. These values were used to estimate the economic potential of blue carbon using three scenarios (minimum, average, and maximum) to avoid reliance on a single-point estimate and to better capture uncertainty and variability in carbon storage (Siikamäki *et al.,* 2012; Murdiyarso *et al.,* 2015). Conversion of carbon reserves into CO_2 equivalents using a factor of 3.67 based on the molecular mass ratio of CO_2 (44) to C atoms (12) (IPCC, 2006), using the formula:

$$CO_2e = C \times 3.67$$

Description:
CO_2e = Carbon dioxide equivalent
C = Carbon (mass)
3.67 = Conversion factor from C to CO_2 (44/12)

The economic value of carbon is calculated by multiplying the total CO_2 equivalents by the carbon price in three scenarios: (1) Social Cost of Carbon USD 50/tC (Environmental Defense

Fund, 2017), (2) voluntary carbon market price of IDR 84,000/tCO₂e, and (3) mandatory carbon market price (Clean Development Mechanism) of IDR 219,520/tCO₂e (Kepel *et al.,* 2017). These price scenarios were selected to reflect a wide range of possible market and policy contexts, acknowledging the volatility and uncertainty of carbon prices across regions and over time, particularly in international carbon markets. Accordingly, the valuation results should be interpreted as indicative estimates rather than fixed monetary values, intended to inform policy discussion rather than predict actual market revenues. Calculations were made on a per-hectare basis as the reporting standard (Donato *et al.,* 2011; Murdiyarso *et al.,* 2015).

Data collection on mangrove management was conducted through semi-structured interviews with one key informant, namely the Head of the Pelita Bahari Mangrove Group, who was selected using purposive sampling based on the relevance of the research objectives (Creswell & Poth, 2018). The selection of a single key informant was based on his long-term involvement in mangrove conservation activities, central role in decision-making processes, and comprehensive knowledge of the group's history, organizational structure, management practices, and interactions with government, non-governmental organizations, and private-sector partners. The use of a single key informant may introduce limitations related to subjective interpretation and potential bias. To mitigate these limitations, interview findings were cross-checked against secondary sources, including project reports, policy documents, and relevant literature, and were interpreted within an established CBMM analytical framework to enhance analytical robustness. Given the exploratory and governance-oriented nature of the study, the key informant approach was considered appropriate for capturing in-depth institutional and management insights at the community level (Patton, 2015). The aspects of data explored during the interviews are presented in Table 1.

Table 1. Aspects of community-based mangrove management explored through interviews based on the 5 Pillars of CBMM (Berkes, 2004; Armitage *et al.,* 2009).

Main Aspects	Focus of Study
Institutional & Governance	Group structure, local rules, coordination with government and external partners
Community Participation	The role of members and residents in conservation, rehabilitation, education, and ecotourism activities
Conservation & Utilization Strategies	Planting practices, maintenance, monitoring, and utilization of mangrove ecosystem services
Challenges & Barriers	Limited resources, funding, policy support, and land use conflicts
Opportunities & Potential	External support, integration with blue carbon programs, ecotourism potential, and CSR

The interview data were analyzed using thematic methods (Braun & Clarke, 2006) to identify the main patterns of the community's role in maintaining the sustainability of mangrove ecosystems and socio-economic benefits. The qualitative analysis was organized within the framework of Community-Based Mangrove Management (CBMM) (Berkes, 2004; Armitage *et al.,* 2009), which consists of five aspects: institutional and governance, community participation, conservation and utilization strategies, challenges and obstacles, and opportunities and potential. Using this framework, mangrove management practices can be systematically mapped to assess strengths, weaknesses, and prospects for sustainability at the local level.

In addition, the interviews also yielded information on the three stages of the management process, namely planning, implementation, and monitoring, which were then mapped in a conceptual chart in the results section to enrich the analysis. This analytical structure enhances the replicability of the approach, as the same combination of carbon valuation scenarios and CBMM governance assessment can be applied to other village-scale mangrove systems using locally available carbon data and key stakeholder interviews.

The integration of quantitative data (carbon valuation per hectare and total area) with qualitative data was carried out through a convergent parallel design, namely separate analyses that were linked at the final interpretation stage through triangulation (Creswell & Poth, 2018; Patton, 2015). This design allows the methodological framework to be transferable to other coastal regions by adapting data sources, carbon price assumptions, and governance contexts while maintaining analytical consistency.

3. Results and Discussion

3.1 Economic Valuation of Blue Carbon Reserves in the Mojo Village Mangrove Ecosystem

The mangrove ecosystem in Mojo Village has significant carbon storage capacity. Carbon stock estimates and economic value were calculated using three scenarios, namely minimum, average, and maximum, as shown in Table 2.

Table 2. Estimated carbon reserves and economic value of mangroves in Mojo Village

Scenario	Carbon Stock (tons C/Ha)	CO_2e (tons/Ha)	SCC Value (USD)	Voluntary Market (Rp)	Mandatory Market (Rp)
Minimum	112.43	412.62	5,621.50	34,659,920	90,577,925
Average	155.13	569.33	7,756.50	47,823,476	124,978,685
Maximum	247.98	910.09	12,399.00	76,447,274	199,782,210

Data Source: Carbon stock data per hectare adapted from Haryati et al. (2024), conversion of C to CO_2e using a factor of 3.67 (IPCC, 2006). Economic values were calculated based on three approaches: Social Cost of Carbon (Environmental Defense Fund, 2017), voluntary carbon market at Rp84,000/tCO_2e, and mandatory carbon market at Rp219,520/tCO_2e (Kepel et al., 2017).

Carbon stocks per hectare are comparable to the average carbon stocks of tropical mangroves, which are 174 tons C/ha (Donato *et al.*, 2011). This carbon storage potential is closely related to mangrove species composition and stand structure. Secondary data from Haryati *et al.* (2024) indicate that the mangrove stands in Mojo Village are dominated by common Indo–West Pacific species such as *Rhizophora* sp. and *Avicennia* sp., which are widely recognized for their high biomass accumulation and substantial below-ground carbon storage. In addition, relatively dense stand conditions reported in the study contribute to higher carbon stocks, as mangrove carbon storage is strongly influenced by tree density, basal area, and species-specific growth characteristics (Komiyama *et al.*, 2008; Donato *et al.*, 2011). These values substantially exceed carbon stocks of terrestrial forests, which typically range from 80 to 120 tons C/ha (IPCC, 2014). This comparison confirms the critical role of mangrove ecosystems in climate change mitigation through blue carbon storage, consistent with global assessments highlighting mangroves as among the most carbon-dense forest ecosystems. This finding aligns with Alongi (2014), who reported that mangroves can store up to four times more carbon than tropical terrestrial forests. When placed in an international context, the estimated carbon stocks in Mojo Village fall within the range reported for mangrove ecosystems in Southeast Asia and other tropical regions, such as mangroves in West Kalimantan, the Philippines, and parts of East Africa, which commonly store between 100 and 300 tons C/ha (Donato *et al.*, 2011; Alongi, 2020). This comparability suggests that village-scale mangrove systems, such as Mojo, represent globally relevant blue carbon assets rather than marginal or site-specific cases.

The variation in economic values across the three scenarios reflects differing levels of uncertainty. In the minimum scenario, estimated values provide a conservative baseline that reduces the risk of overestimation. In contrast, the maximum scenario yields substantially higher values but is associated with greater uncertainty due to its dependence on upper-bound carbon stocks and favorable market conditions. The average scenario offers a balanced reference point that may be more appropriate for policy discussion, as it reflects moderate assumptions while acknowledging inherent uncertainties in both carbon stocks and pricing. Rather than serving as

precise revenue projections, these valuation scenarios can inform the design of policy instruments such as payment for ecosystem services (PES) schemes, community-based benefit-sharing arrangements, and hybrid financing mechanisms that combine carbon revenues with public or donor support. In this context, blue carbon valuation should not be interpreted solely as a revenue estimate, but rather as an input for designing policy instruments such as payment for ecosystem services (PES) schemes and community-based benefit-sharing arrangements, which have been widely applied to align conservation incentives with local livelihoods in coastal and forest ecosystems worldwide (Muradian *et al.,* 2010; Wunder, 2015).

The implications of these findings extend beyond Mojo Village, where community-based mangrove conservation has been actively practiced since 2008. The integration of blue carbon valuation with community-based management aligns with Indonesia's FOLU Net Sink 2030 agenda, while also offering insights relevant to other tropical coastal regions seeking to link local conservation initiatives with global climate mitigation mechanisms. Studies from West Kalimantan (Astiani *et al.,* 2024) and the Demak coast (Nasution & Wijaya, 2024) similarly demonstrate that community-based mangrove management can enhance carbon stocks while generating socio-economic benefits. Taken together, these findings suggest that village-scale mangrove systems can play a meaningful role in global climate mitigation strategies when supported by appropriate governance frameworks, diversified incentive mechanisms, and safeguards against market uncertainty.

3.2 Community-Based Mangrove Ecosystem Management (CBMM)

Mangrove ecosystems are one of the most important coastal ecosystems with ecological, economic, and social functions. Mangroves act as barriers against abrasion and seawater intrusion while also absorbing blue carbon with high carbon storage capacity (Alongi, 2014; Donato *et al.,* 2011). Mangrove vegetation grows densely along the coastline, dominated by *Rhizophora mucronata* and *Avicennia alba* species. The following image shows the actual condition of the mangrove area, which is the location of community conservation and ecotourism activities (Figure 2).



Figure 2. View of the mangrove ecosystem in Mojo Village, Pemalang Regency.
Source: Field documentation (2025).

The mangrove area in Pemalang Regency has experienced significant degradation due to coastal erosion and land conversion into shrimp ponds, especially in Mojo Village. Rehabilitation efforts are carried out through the involvement of local communities with the support of external institutions, including NGOs and private companies through corporate social responsibility (CSR) programs. Mangrove management in Mojo Village takes place in three main stages, namely planning, implementation, and monitoring (Figure 3).

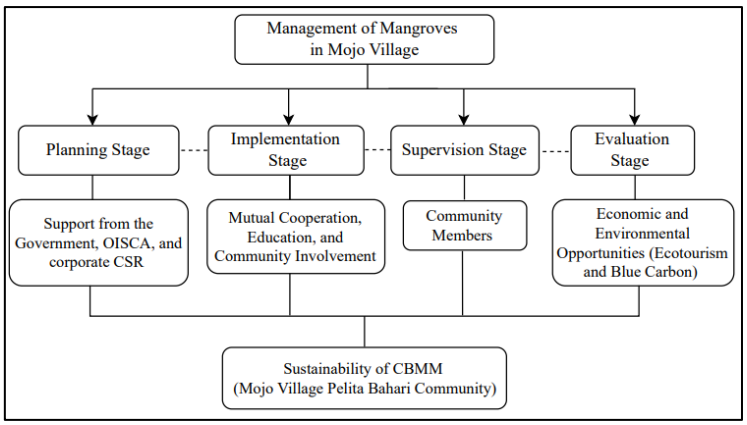


Figure 3. Stages of mangrove management by the Pelita Bahari Community.

The planning stage began in the 1990s with support from OISCA, the government, and corporate CSR programs. Activity planning was based on external programs involving community members in technical coordination, in accordance with collaborative principles that emphasize synergy between actors in ecosystem rehabilitation (Primavera, 2000; Walters, 2004).

The implementation phase included planting, maintenance, and outreach to the surrounding community. Activities were carried out collectively with funding from government programs and CSR. This collective work pattern reflected a form of community-based conservation that strengthened social cohesion and the sustainability of local resource management (Pretty, 1995; Berkes, 2004).

The monitoring phase is conducted informally and depends on the voluntary involvement of community members. Monitoring is mostly in the form of field observations without a standardized documentation system, a phenomenon similar to the weakness of technical capacity in community-based management in coastal areas (Armitage, 2005).

The evaluation aspect is more of a research analysis finding. The evaluation shows that CBMM practices in Mojo Village not only have an impact on ecological recovery, but also open up economic and mangrove-based ecotourism opportunities. This dimension points to the potential of blue carbon schemes as a long-term strategy, in line with the concept of socio-ecological resilience (Folke *et al.,* 2010). All stages culminate in the sustainability of CBMM implemented by the Pelita Bahari Community of Mojo Village.

Further analysis of mangrove ecosystem management in Mojo Village based on the local community was conducted using the five pillars of CBMM, namely institutional and governance, community participation, conservation and utilization strategies, challenges and obstacles, as well as opportunities and potential. This pillar framework allows for the systematic organization of data and provides a comprehensive overview of the socio-ecological dimensions of community-based mangrove management.

3.2 Institutional and Governance

The Pelita Bahari community was formed in the late 1990s through an OISCA labor-intensive program focused on mangrove rehabilitation. From the outset, mangrove management in Mojo Village was characterized by external intervention, which was later reinforced through the National Forest and Land Revitalization Movement program (2004–2006). This pattern shows a top-down initiative that was gradually internalized into the collective consciousness of the community to protect the coastal ecosystem. A similar phenomenon was also found in the context of community-based resource management in other coastal areas, where external initiatives acted as catalysts before internal institutionalization took place (Agrawal & Gibson, 1999; Adhikari & Goldey, 2010).

Community institutions developed with role diversification. The reforestation group focused on planting and maintaining mangroves, while the Tourism Awareness Group (Pokdarwis) and the Processing and Marketing Group (Poklasar) were also formed. Pokdarwis served as a forum for the development of mangrove ecotourism through the provision of boat tours, environmental guides, and conservation education for visitors. Poklasar plays a role in managing mangrove derivative products such as syrup, batik with natural dyes, and processed foods, as well as marketing these products to increase community income. This diversification is in line with the concept of institutional strengthening, which emphasizes the importance of expanding organizational capacity to manage ecological, economic, and social dimensions simultaneously (Berkes, 2004; Armitage, 2005).

Community leadership is centered on the figure of the chairperson, who acts as a knowledge broker and gatekeeper in bridging relationships with the government, NGOs, and the private sector. This central figure-based leadership structure strengthens internal cohesion, but also creates vulnerability in the event of a leadership change. This situation is consistent with Cleaver's (2002) findings that community institutions often depend on charismatic figures, so that the sustainability of the organization is influenced by leadership stability.

The community governance mechanism relies on mutual assistance practices, which are the main social capital of coastal communities. The documentation, monitoring, and supervision systems are still relatively weak because they are not yet supported by standard protocols, so institutional legitimacy is stronger at the local level than formal recognition by the government. This situation reflects an asymmetry of roles, in which communities are more often positioned as implementers of external programs than as equal partners in decision-making (Armitage *et al.,* 2009; Fabricius *et al.,* 2007).

Within the framework of Community-Based Mangrove Management (CBMM), the government acts as a regulator, facilitator, and coordinator that determines the effectiveness and sustainability of community-based mangrove management. Findings in Mojo Village show that the role of the government is still not optimal, especially in providing an institutional framework, cross-sector coordination, and operational policy support. A formal organizational structure within the mangrove community has not yet been established, so all monitoring activities are still carried out voluntarily by community members. This condition is in line with the findings of community-based coastal zone management in Kiluan, Tanggamus Regency, which show that weak government support and the absence of a formal institutional structure are the main obstacles to the sustainability of community-based management (Putriani *et al.,* 2024).

These institutional limitations are reflected in the high dependence of community institutions on the figure of the chairperson, weak internal coordination, and the absence of a clear membership structure and division of roles. A similar pattern is also found in various CBMM practices in Indonesia, where the dominance of key actors and the weak institutionalization of community organizations have an impact on the low effectiveness of management and program sustainability (Deciawarman *et al.,* 2024). A further impact of this condition is the lack of institutionalized mechanisms for benefit sharing and economic incentives, including in the development of blue carbon schemes. CBMM emphasizes that without the active role of the government in ensuring legal certainty, strengthening local institutional capacity, and performing mediation functions between actors, community-based management tends to depend on individual leadership and short-term projects, making it vulnerable to unsustainability (Putriani *et al.,* 2024; Deciawarman *et al.,* 2024).

This condition indicates a high dependence on the chairperson, while also creating organizational vulnerability in the event of a leadership change. In addition, the lack of human resources available to handle oversight creates the potential for a loss of program continuity and integrity, so that strategic decision-making often depends solely on the chairperson's personal initiative or external pressure.

3.3 Community Participation

Community participation in mangrove ecosystem management has grown out of ecological awareness that has emerged as a result of coastal communities' direct experience of the impacts of environmental degradation, such as tidal flooding, coastal erosion, and declining coastal resource productivity. Studies in coastal areas of Thailand show that repeated exposure to environmental risks encourages a shift in community perceptions from simply exploiting resources to actively participating in community-based mangrove protection and management (Dulyakasem *et al.,* 2025). This ecological awareness then encourages community involvement in the planning, implementation, and supervision of mangrove management through a community-based marine/natural resource management approach, which integrates conservation goals with the sustainability of local livelihoods.

Mangroves are perceived as protecting villages from the threat of the sea, thereby encouraging collective motivation to plant and care for them. This understanding is in line with Ostrom (1990), who asserts that collective action is built when the benefits of resources are felt tangibly by users.

Participation is realized through mass planting, vegetation maintenance, and socialization of the importance of mangrove ecosystems. The involvement of youth organizations and PKK (Family Empowerment and Welfare) expands the reach of community education, especially in environmental awareness activities. This role shows that local social groups can be important agents in building environmental awareness (Adger, 2003; Puspitasari *et al.,* 2020). Community involvement is also strengthened through PT PLN's corporate social responsibility (CSR) program, which facilitates joint planting activities, in line with findings that cross-actor partnerships can strengthen community-based conservation (Armitage, 2005; Rahmawati *et al.,* 2022).

Community participation remains volatile, increasing when there is financial support or facilities, but declining in routine activities without external incentives. Collective motivation tends to focus on short-term economic gains rather than internalizing ecological conservation values, so that sustainable participation has not been fully institutionalized (Pretty, 1995; Armitage, 2005). This condition emphasizes the need to strengthen internal institutions, involve local human resources, and develop incentive mechanisms that are not solely material-based in order to maintain the continuity and effectiveness of community-based mangrove management.

3.4 Conservation and Utilization Strategies

The mangrove ecosystem conservation strategy in Mojo Village is dominated by vegetation rehabilitation with a composition of Rhizophora mucronata (80.7%) and Avicennia alba (19.3%). The low vegetation diversity index (H' = 0.496) indicates the dominance of certain species, although the ecosystem's resilience is still classified as moderate to high thanks to its natural regeneration capacity and the support of replanting activities by the community. Conservation efforts include replanting in areas of abrasion, periodic vegetation monitoring, and environmental education facilitated by the community together with external partners. This pattern is consistent with the adaptive co-management approach that emphasizes the integration of ecological rehabilitation and social capacity building (Folke *et al.,* 2005; Armitage *et al.,* 2009).

External collaboration is a determining factor for sustainability. OISCA, Tokio Marine, and PLN play a role in providing seeds and financial support, while the community manages distribution and implementation of activities in the field. Dependence on external inputs remains strong, even though local awareness has become the basis for community participation.

Economic utilization is directed through ecotourism and mangrove-based derivative products managed by Poklasar (Fishery Product Processing and Marketing Group), including processed foods, syrups, and batik. Infrastructure and accessibility constraints hinder the optimization of ecotourism, as revealed by one of the community leaders who said that visitors often cancel their trips due to poor road conditions. This situation is consistent with the findings of Nasution and Wijaya (2024), who emphasize the close relationship between ecological and economic benefits in Community-Based Mangrove Management (CBMM). Walters *et al.* (2008) also assert that the sustainability of community-based programs is greatly influenced by local economic incentives,

while a study on the Demak coast shows the success of rehabilitation when combined with ecotourism and mangrove-based product diversification (Pribadi *et al.,* 2017).

Social dimensions and empowerment are integral elements in the management of the Mojo mangrove. Environmental education through World Environment Day celebrations, socialization in schools, and the involvement of youth organizations and PKK strengthen intergenerational knowledge transfer. These activities not only increase ecological awareness but also build social capacity that supports community resilience in the face of abrasion and tidal flooding. This perspective is in line with Dahdouh-Guebas *et al.* (2005), who emphasize that the success of mangrove management depends on the internalization of ecosystem values in community social practices. Giri *et al.* (2011) also emphasize the importance of investing in education and community empowerment as prerequisites for the sustainability of mangrove rehabilitation in Southeast Asia.

3.5 Challenges and Obstacles

Mangrove management in Mojo Village faces major ecological, social, and institutional challenges. Ecological degradation occurs due to land conversion to fish ponds, mangrove logging for firewood and animal feed, and abrasion that causes land ownership conflicts. Difficult access to the location adds to the obstacles to ecotourism development. Institutional and monitoring constraints are among the main challenges. A formal organizational structure within the mangrove community has not yet been established, so monitoring is carried out on a voluntary basis without standard technical procedures. The community leader has served on a voluntary basis since 2004, based on the decree establishing the Pelita Bahari Community, but the lack of human resources willing to manage monitoring activities has resulted in sporadic and incidental evaluation and documentation of activities. High dependence on the leader poses a risk in the event of a change in leadership.

Community participation is fluctuating, with enthusiasm increasing only when there is financial support or facilities from government programs or CSR. Routine activities without external incentives are often neglected, so that the sustainability of participation remains weak and has not been fully institutionalized. A summary of the main challenges and strategies implemented by the community and partners to overcome obstacles is presented in Table 3.

Table 3. Challenges and Resolution Strategies for Mangrove Management in Mojo Village

Challenges/Obstacles	Resolution Strategies
Land conversion due to fish ponds	Educational approach to raise community awareness
Logging of mangroves for firewood/animal feed	Educational approaches and socialization of the importance of preserving mangroves
Abrasion causes land ownership conflicts	Community education and discussion facilitation
Difficult access to locations hinders ecotourism	Technical support and infrastructure
Limited human resources for monitoring	Voluntary involvement of community members
Lack of evaluation protocol standards	Monitoring is carried out by community members on a voluntary basis
Weak supervision & dependence on volunteer leaders	Planning for internal institutional strengthening, human resource training, and voluntary leadership rotation

Challenges in mangrove ecosystem management have led to community dependence on government or CSR programs, as well as reduced continuity of community participation in routine activities. This situation reflects the complexity of obstacles that are not only ecological, but also socio-economic and institutional (Fabricius *et al.,* 2007; Armitage *et al.,* 2009). The solution strategy implemented combines educational approaches, technical support, and facilitation of mangrove-based businesses, including ecotourism, derivative products, and blue carbon schemes. This approach is in line with Barbier (2016), Pribadi *et al.* (2017), and Susanto *et al.* (2022), who

emphasize that the integration of education, infrastructure support, and local economic incentives is key to the success of CBMM.

3.6 Opportunities and Potential

Mangrove management in Mojo Village holds significant opportunities despite facing various obstacles. The development of mangrove-based ecotourism can be integrated with the village tourism agenda, providing alternative sources of income for the community while raising ecological awareness. Mangrove-derived products, such as syrup, eco-friendly batik, and bioactive mangrove-based food products, open up potential economic diversification to improve community welfare (Pribadi *et al.,* 2017; Nasution & Wijaya, 2024).

The link between conservation programs and the national FOLU Net Sink 2030 agenda positions mangrove ecosystems as an important pillar in climate change mitigation through greenhouse gas emission reduction. This strategy is in line with an integrative approach between local conservation and national policies that emphasize synergy between ecological benefits and economic incentives (Barbier, 2016; Friess *et al.,* 2019).

The economic potential of blue carbon provides opportunities for communities to access carbon market-based incentive schemes, which can increase motivation and sustainability of management. Alongi (2020) shows that mangrove carbon storage in Southeast Asia is among the highest in the world, so effective conservation not only has ecological impacts, but also contributes financially and to the global climate. The implementation of payment for ecosystem services (PES) mechanisms can strengthen community involvement, as found in mangrove rehabilitation studies in Indonesia and the Philippines (Dahdouh-Guebas *et al.,* 2005; Giri *et al.,* 2011).

Another opportunity arises from increasing local capacity through environmental education and the involvement of youth organizations, PKK (Family Welfare Movement), and Poklasar administrators in socialization and rehabilitation activities. This approach builds social capital and community adaptive capacity to the risks of abrasion and tidal flooding, so that ecological conservation and social empowerment proceed simultaneously (Folke *et al.,* 2005; Armitage *et al.,* 2005).

3.7 Implications of the Community-Based Mangrove Management (CBMM) Model in Coastal Areas

Various studies show that the Community-Based Mangrove Management (CBMM) model is an effective approach in supporting the sustainability of mangrove ecosystem management, especially when community participation is driven by direct experience of coastal environmental degradation. Research on the southern coast of Thailand shows that active community involvement in mangrove management develops in line with high dependence on mangrove ecosystem services, both as natural coastal protection and as a source of household livelihoods (Dulyakasem et al., 2025).

In line with this research, a study in the coastal region of Sri Lanka shows that the effectiveness of CBMM is also greatly influenced by the level of community participation in mangrove restoration and management activities. Empirical studies in coastal areas of Sri Lanka show that high community participation has a significant influence on the success of mangrove restoration, both in terms of increased vegetation cover and long-term management sustainability (Sathiyamoorthy, 2024). The results of this study emphasize that community involvement from the planning to monitoring stages is a key factor in the success of restoration, while also strengthening the sense of ownership of the mangrove ecosystem.

In addition to participation, the success of CBMM also depends heavily on institutional support and clear governance. A study on community-based management of marine areas in the Philippines shows that formal recognition of community management rights, accompanied by monitoring and enforcement mechanisms involving local communities, contributes significantly to improving the ecological condition and biodiversity of coastal waters (Marriott et al., 2021). This approach places the community as the main subject in the management decision-making process, not just as technical implementers of conservation activities. This condition shows that the effectiveness of community participation will be maximized if such involvement is integrated into an inclusive and adaptive governance system.

In the context of Mojo Village, the dynamics of community participation show similarities in terms of ecological awareness triggered by direct experiences of tidal flooding and coastal erosion. However,

compared to the cases in Thailand, Sri Lanka, and the Philippines, the implementation of CBMM in Mojo Village still faces limitations in terms of local institutional capacity and has not fully accommodated the role of the community in decision-making and monitoring. This condition limits the potential for CBMM to develop sustainably.

The main implication for expanding the CBMM model in coastal areas is the need for a contextual and gradual approach, including the need for Mojo Village to adjust the CBMM model to local social, economic, and institutional conditions. Without strengthening community capacity, clarifying the rights and roles of actors, and providing consistent policy support, CBMM risks becoming a short-term initiative that depends on external projects and is not sustainable. Therefore, the development of CBMM needs to be positioned as a gradual and adaptive socio-ecological transformation process in order to support the long-term sustainability of mangrove ecosystem management.

The following conceptual table from a successful CBMM study in Central Java shows that the sustainability of mangrove management is not only determined by the level of community participation, but also by the integration of community governance, rehabilitation strategies, institutional support, and the socio-economic benefits felt by the community.

Table 4. Conceptual Framework of CBMM in the Mangrove Management Phase and Its Implications for the Blue Carbon Scheme in Mojo Village

Main Pillars of CBMM	Management Stage	Successful CBMM Concept (Central Java Study)	The Condition of Mojo Village	Implications for the Blue Carbon Scheme & CBMM
institutional and governance	Planning & decision making	CBMM is most effective in villages with participatory decision-making and functioning local institutions, such as in Bedono, which demonstrates a combination of community-NGO partnerships and strong local legitimacy.	In Mojo Village, community participation still tends to be oriented towards the implementation of activities, with relatively limited space for strategic decision-making.	Strengthening the position of communities as decision-makers is a prerequisite for CBMM to support a sustainable blue carbon scheme.
Community participation	Implementation of rehabilitation	Active and voluntary participation contributes to a broader scale of rehabilitation and a higher success rate of restoration.	Participation in Mojo Village is socially strong, but it is not yet fully integrated into the long-term incentive system.	Blue carbon schemes can serve as an incentive mechanism to maintain sustainable community participation.
Conservation and utilization strategies	Rehabilitation & maintenance	The success of CBMM is determined by the selection of diverse species, large-scale rehabilitation, and long-term maintenance, not just initial planting.	Rehabilitation activities in Mojo Village are still focused on planting and have not been balanced with consistent maintenance strategies.	Integrating blue carbon stock targets requires a shift from a project-based approach to long-term adaptive management.
Challenges and obstacles	Protection & enforcement	Villages with clear local regulations that are accepted by the community	Local regulations exist in Mojo Village, but implementation and monitoring still	Blue carbon schemes require local regulatory certainty to ensure

		demonstrate higher levels of mangrove and biodiversity protection.	need to be strengthened.	the sustainability of ecological and economic benefits.
Opportunities and potential	Monitoring & sustainability	CBMM has successfully provided tangible benefits for livelihoods, thereby increasing community support for conservation.	The economic benefits of mangroves in Mojo Village have not been directly linked to carbon ecosystem services.	Blue carbon has the potential to bridge the gap between mangrove conservation and improved community welfare.

Source: Adapted and developed from Damastuti et al. (2022)

4. Conclusion

The mangrove ecosystem of Mojo Village shows significant blue carbon economic potential, with an estimated financial value per hectare ranging from IDR 34.66 million to IDR 199.78 million based on three different assessment scenarios and carbon market mechanisms. This value reflects the important contribution of mangroves as carbon sinks and a source of economic potential based on climate change mitigation. This study explicitly demonstrates the scientific novelty of integrating blue carbon economic valuation with Community-Based Mangrove Management (CBMM) analysis at the village scale, allowing ecological potential and governance capacity to be assessed simultaneously. Beyond the local context, these findings are relevant to tropical coastal communities worldwide seeking to align community-based mangrove conservation with global climate mitigation frameworks

CBMM in Mojo Village shows that, community institutions and participation play a central role in mangrove management, even though they still depend on outside actors. Conceptually, the Mojo Village case illustrates how successful community-based blue carbon schemes depend on the alignment between CBMM pillars (institutions, participation, conservation practices, monitoring, and external support) and management stages (planning, implementation, and monitoring). As a transferable example for other tropical regions, this case suggests the need for institutional strengthening, multi-actor contractual arrangements, and community-adapted monitoring, reporting, and verification (MRV) standards to enhance the scalability and sustainability of community-based blue carbon initiatives.

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6. Conflict of Interest Declaration

The authors declare that there is no conflict of interest regarding the publication of this article. The Authors confirmed that the paper was free of plagiarism.

7. Author Contribution Statement

All authors contributed equally to the research, data analysis, and writing and preparation of this scientific article.

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