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| Research Article

Analysis of Mangrove Forest Degradation and Mangrove Conservation Management in the Community Economy of Langkat Regency

Andre Iman Daniel Silaban[1], M Taufik Rahmadi[2]
[1]Department of Geography Education, Faculty of Social Sciences, Universitas Negeri Medan, Indonesia
[2]Geographic Information Science Study Program, Faculty of Social Sciences, Universitas Negeri Medan, Indonesia

Correspondence Email: andreidsilabansilaban@gmail.com

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Abstract: Mangrove ecosystems play a strategic role in maintaining coastal ecological balance while supporting local livelihoods through diverse ecosystem services. However, increasing mangrove degradation has threatened both ecological integrity and the socio-economic sustainability of coastal communities, including Selotong Village, Lalat Regency. This study analyzes the drivers of mangrove degradation, evaluates conservation management, and examines its socio-economic impacts. A qualitative approach was employed using purposive sampling involving 30 informants, including fishermen, pond farmers, village officials, community leaders, and coastal community groups. Data were collected through field observations, semi-structured interviews, and documentation, then analyzed using the Miles, Huberman, and Saldaña interactive model. The findings reveal that mangrove degradation is primarily driven by anthropogenic activities, including land conversion into aquaculture ponds and oil palm plantations, timber exploitation, and weak governance, compounded by coastal abrasion and hydrodynamic processes. These conditions have reduced fisheries productivity, increased fishing operational costs, and hindered the development of mangrove-based enterprises such as ecotourism and silvofishery. Effective conservation requires ecosystem-based and community-based management through ecosystem rehabilitation, institutional strengthening, multi-stakeholder collaboration, and community economic empowerment. This study proposes an integrated mangrove management model incorporating ecological, social, economic, and institutional dimensions to support sustainable coastal conservation policies.

Keywords: Mangrove Degradation; Community-Based Management; Coastal Community Economy; Langkat

1. INTRODUCTION

Mangrove ecosystems are among the most biologically productive coastal ecosystems in the world, playing a crucial role in maintaining coastal environmental stability while supporting local economic development (Permana et al., 2024). Mangroves function as natural coastal barriers against shoreline erosion, storm surges, extreme waves, and seawater intrusion, while simultaneously providing critical habitats, spawning grounds, nursery grounds, and feeding grounds for a wide range of fish, shrimp, crabs, mollusks, and other coastal organisms (Akram et al., 2023; Harefa et al., 2024). Beyond their ecological importance, mangrove ecosystems also generate substantial economic benefits through the provision of non-timber forest products, capture fisheries, aquaculture, blue carbon storage, and community-based ecotourism development (Dalimunte et al., 2026). In the context of global climate change mitigation, mangroves are recognized as one of the world's most efficient carbon sinks, possessing a carbon sequestration capacity that exceeds that of most terrestrial

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ecosystems. Consequently, mangrove conservation has become a major priority within international environmental and climate policy agendas (Chatting et al., 2022).

Indonesia possesses the largest extent of mangrove forests globally, accounting for approximately one-quarter to one-third of the world's total mangrove area. As the world's largest archipelagic nation, with a coastline exceeding 108,000 km, Indonesia relies heavily on mangrove ecosystems as strategic natural assets for enhancing coastal resilience and sustainable development (Prayogo et al., 2025). Mangrove forests are distributed throughout nearly all coastal regions of the country, including North Sumatra Province, where extensive mangrove ecosystems occur along the eastern coastline. This region is characterized by muddy coastal environments that provide highly favorable conditions for mangrove growth while simultaneously supporting fisheries, coastal agriculture, aquaculture, and various forms of natural resource utilization by surrounding communities (Basyuni et al., 2018; Sitio et al., 2023). Therefore, maintaining the sustainability of mangrove ecosystems in this region is essential not only for preserving ecological functions but also for safeguarding the socio-economic well-being of coastal populations. Despite their ecological and economic significance, mangrove ecosystems in Indonesia have experienced increasing anthropogenic pressure over recent decades. Similar to other coastal villages in Langkat Regency, such as Pasar Rawa and Kwala Serapuh, extensive land conversion for aquaculture ponds, oil palm plantations, and unsustainable timber harvesting has accelerated mangrove degradation (Dalimunte et al., 2025; Clarentia et al., 2026). This degradation is reflected not only in the reduction of mangrove cover but also in declining habitat quality, biodiversity loss, disruption of hydrological functions, increased vulnerability to coastal erosion and tidal flooding, and diminished carbon sequestration and storage capacity (Ginting et al., 2023). These ecological changes threaten the resilience of coastal ecosystems and reduce the ecosystem services upon which local communities depend.

Langkat Regency is one of the major coastal areas in North Sumatra Province with extensive mangrove forests that play a crucial role in supporting coastal livelihoods and regional economic activities. However, in recent years, the mangrove ecosystems in Langkat have faced severe degradation due to land-use change, uncontrolled resource exploitation, illegal logging, environmental pollution, and ineffective management practices (Syahputra & Fernando, 2024). One of the most critically affected areas is Selotong Village, where more than 90% of the mangrove forest has reportedly disappeared over the past decade. This alarming rate of mangrove loss indicates that ecosystem degradation has reached a critical stage, posing serious risks to the ecological stability and environmental sustainability of the coastal zone.

The decline in mangrove extent and quality in Langkat Regency has significant implications not only for environmental sustainability but also for the socio-economic conditions of communities whose livelihoods depend on coastal resources. Over the long term, continued mangrove degradation is expected to increase household economic vulnerability, as many local residents rely primarily on fisheries and the direct utilization of mangrove resources for their income and subsistence (Zu Ermgassen et al., 2021). Consequently, mangrove degradation should no longer be viewed solely as an ecological issue but rather as a multidimensional sustainable development challenge that directly affects ecosystem resilience, coastal livelihoods, and regional economic security.

This study aims to analyze the level of mangrove forest degradation in Langkat Regency, evaluate the implementation of existing mangrove conservation management practices, and examine the relationship between mangrove ecosystem conditions and the socio-economic welfare of coastal communities. The findings are expected to contribute to the development of an integrated mangrove management model that combines ecosystem conservation with community empowerment. Furthermore, this research seeks to provide scientific evidence to support more effective, sustainable, and inclusive coastal management policies that enhance community welfare while preserving the ecological integrity and long-term resilience of mangrove ecosystems.

2. RESEARCH METHODS

This study was conducted in Selotong Village, Secanggang District, Langkat Regency, North Sumatra Province, Indonesia, a coastal area located along the eastern coast of Sumatra. The village is characterized by extensive mangrove ecosystems that serve as vital ecological buffers while providing essential livelihood resources for local coastal communities. Langkat Regency contains approximately 9,250 ha of mangrove forests distributed across several coastal districts. Selotong Village was selected as the study site because it has experienced severe mangrove degradation resulting from land conversion for aquaculture ponds and oil palm

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plantations, uncontrolled mangrove logging, and environmental pollution. These disturbances have substantially reduced the ecological functions of the mangrove ecosystem, threatening the sustainability of coastal resources and the livelihoods of local communities, most of whom depend on fisheries and mangrove-related economic activities. These characteristics make Selotong Village a representative case for examining the relationships among mangrove forest degradation, conservation management, and the socio-economic conditions of coastal communities.

Research participants were selected using a purposive sampling technique to ensure that all informants possessed relevant knowledge, experience, and direct involvement in the utilization and management of mangrove ecosystems. A total of 30 informants participated in the study, including fishermen, aquaculture farmers, village officials, community leaders, members of coastal community organizations, and individuals actively involved in mangrove conservation initiatives. Informants were selected based on several criteria: (1) having resided in the study area for a considerable period, (2) depending on mangrove resources as a primary source of livelihood, (3) possessing knowledge of changes in the condition of the mangrove ecosystem over time, and (4) participating in or having adequate knowledge of local mangrove conservation activities. Data were collected through field observations, semi-structured interviews, and document analysis, enabling methodological triangulation to obtain comprehensive information on mangrove degradation, conservation management practices, and their impacts on the livelihoods of coastal communities.

The collected data were analyzed using the interactive model of Miles, Huberman, and Saldaña, which consists of three interconnected stages: data condensation, data display, and conclusion drawing and verification. All data obtained from observations, interviews, and documentation were first transcribed, organized, and coded according to research themes related to the extent of mangrove degradation, the implementation of conservation management, and the socio-economic conditions of local communities. The coded data were subsequently presented in matrices and narrative descriptions to facilitate the identification of patterns and relationships among the research variables. This analytical process enabled a comprehensive interpretation of the factors driving mangrove degradation, the effectiveness of conservation management strategies, and their implications for the economic sustainability of coastal communities. To ensure the trustworthiness of the findings, source triangulation, methodological triangulation, and member checking with key informants were employed, thereby enhancing the credibility and validity of the study's interpretations.

3. RESULTS AND DISCUSSION

Spatial Distribution of Mangrove Degradation in Selotong Village

The findings of this study indicate that the spatial distribution of mangrove degradation in Selotong Village, Secanggang District, Langkat Regency, is uneven and predominantly concentrated in areas experiencing intense anthropogenic pressure (Figure 1). Mangrove forests located adjacent to aquaculture ponds, oil palm plantations, and residential settlements exhibit significantly greater losses in vegetation cover than areas situated farther from human activities. This spatial pattern suggests that land-use change is the primary driver influencing the dynamics of mangrove ecosystems in the coastal region of Langkat Regency. The conversion of mangrove forests into aquaculture and agricultural land may provide short-term economic benefits for local communities; however, over the long term, it results in the degradation of critical ecosystem functions, including coastal protection against erosion and storm surges, provision of habitat and nursery grounds for aquatic species, and the sequestration and storage of blue carbon.

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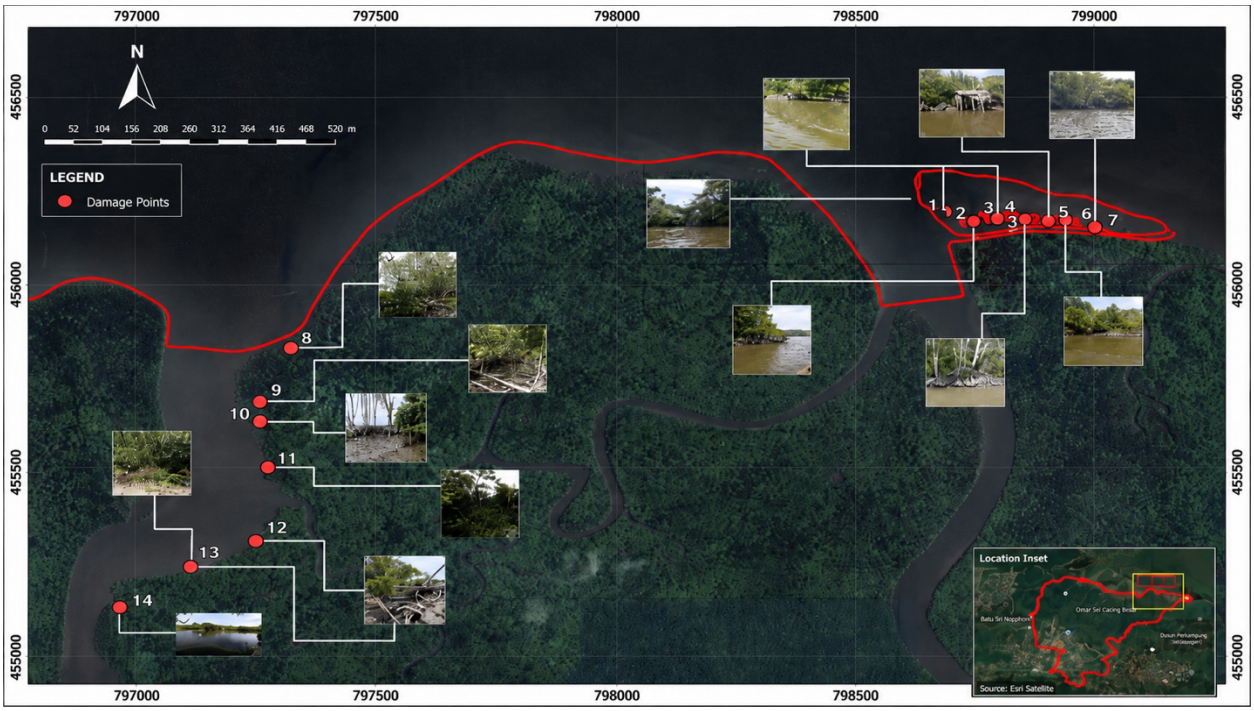

Figure 1. Spatial Distribution of Mangrove Degradation (Source: Data Processing, 2026)

Direct mangrove harvesting has also emerged as a significant factor accelerating degradation, in addition to land-use change. The extraction of mangrove timber for fuelwood, charcoal production, and construction materials has reduced vegetation density and hindered the natural regeneration of mangrove forests. Weak enforcement of protected area regulations and the limited implementation of local conservation policies have further intensified pressure on these ecosystems. This finding is consistent with the study by Ellison et al., (2020), which emphasizes that the success of mangrove conservation is largely determined by effective governance, adequate monitoring and enforcement, and the active participation of local communities in ecosystem management. Without stronger institutional capacity and community-based management mechanisms, mangrove rehabilitation efforts are likely to fail because anthropogenic pressures continue to persist.

The pattern of mangrove degradation driven by land-use change in Selotong Village is consistent with previous studies identifying coastal economic expansion as one of the principal drivers of mangrove loss in tropical regions. Bryan-Brown et al., (2020) reported that the conversion of mangrove forests for aquaculture and agriculture has been the dominant cause of global mangrove loss, particularly across Southeast Asia. Similarly, (Goldberg et al., 2020) demonstrated that anthropogenic pressures—including land-use change, coastal development, and natural resource exploitation have resulted in habitat fragmentation, thereby diminishing the ecological functions and resilience of mangrove ecosystems. The situation observed in Selotong Village reflects this broader trend, indicating that mangrove degradation is influenced not only by biophysical factors but also by the increasing demand for coastal land and natural resources driven by local socio-economic needs.

The spatial degradation of mangrove forests in Selotong Village has also produced substantial socio-economic consequences for coastal communities. The reduction in mangrove extent has degraded the habitat quality of economically important aquatic species, including fish, shrimp, and crabs, thereby reducing local fisheries productivity. Furthermore, the loss of mangrove cover has increased the operational costs incurred by fishermen, as fishing grounds have become more distant and fishery resources less abundant. These findings support the study by (Mhatre, 2024), which demonstrated that mangrove loss is significantly associated with declining coastal fisheries productivity due to the degradation of the ecological functions of mangroves as critical habitats, nursery grounds, and feeding areas for aquatic organisms. Consequently, continued mangrove

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degradation threatens not only ecosystem integrity but also the long-term livelihood security of coastal communities that depend heavily on these ecosystem services.

Factors Driving Mangrove Degradation

Mangrove degradation in Selotong Village is predominantly driven by anthropogenic factors that have occurred intensively and continuously over time. Land-use conversion for shrimp ponds, fish ponds, and oil palm plantations has become the primary factor contributing to the decline in mangrove cover and the alteration of coastal ecosystem structure. Similar findings have been reported in numerous studies across Indonesia, demonstrating that aquaculture expansion and land-use change are the dominant causes of mangrove loss, particularly in coastal areas experiencing strong economic pressures and high levels of human activity (Bhowmik et al., 2022). Likewise, (Hagger et al., 2022) reported that land-cover change associated with economic development is a major driver of mangrove decline because it reduces the natural regeneration capacity of mangrove forests and disrupts ecological connectivity among coastal habitats.

In addition to land conversion, the direct exploitation of mangrove resources has significantly accelerated ecosystem degradation in Selotong Village. Mangrove wood continues to be harvested by local communities for fuelwood, charcoal production, and construction materials due to their heavy dependence on coastal natural resources for their livelihoods. However, these extraction practices are generally not accompanied by sustainable management strategies, resulting in reduced vegetation density and impaired natural regeneration. Continuous harvesting of mangrove timber can alter forest community structure, reduce species diversity, and increase ecosystem vulnerability to external disturbances (Ferreira et al., 2024). Furthermore, weak law enforcement, limited implementation of environmental regulations, and inadequate public awareness regarding the ecological importance of mangrove ecosystems have further intensified pressures on these coastal environments.

Although anthropogenic activities constitute the principal drivers of mangrove degradation, natural factors also contribute to ecosystem deterioration in Selotong Village, albeit to a lesser extent. Coastal erosion, changes in ocean current patterns, tidal dynamics, and extreme weather events have caused physical damage to mangrove vegetation, particularly in areas where forest cover has already been substantially reduced. Mangrove forests fragmented by land-use change exhibit lower resilience to natural disturbances because the loss of interconnected root systems diminishes their capacity to trap sediments, stabilize shorelines, and protect coastal areas from erosion and wave action (Weaver & Stehno, 2024). Consequently, the combined effects of anthropogenic pressures and natural disturbances further accelerate the degradation of mangrove ecosystems and undermine their ecological resilience.

Effective Mangrove Conservation Management

The effectiveness of mangrove conservation management in Selotong Village continues to face significant challenges, particularly due to low community participation throughout the management process and the predominance of a top-down governance approach. Most mangrove rehabilitation programs remain largely focused on periodic replanting activities without adequate long-term maintenance, monitoring, and evaluation mechanisms. Consequently, rehabilitation success rates remain relatively low, as many planted seedlings fail to survive in areas that continue to experience pressure from land-use change, illegal logging, and coastal hydrodynamic disturbances. These findings suggest that successful mangrove conservation depends not only on the number of seedlings planted but also on the quality of governance, the consistency of monitoring and enforcement, and the active involvement of local communities as the primary users and stewards of mangrove resources.

The study further reveals that limited community participation is primarily driven by restricted public involvement in decision-making processes, insufficient institutional support, and the absence of tangible economic incentives derived from conservation activities. As a result, many local residents continue to perceive mangroves primarily as exploitable natural resources rather than as valuable ecological assets requiring sustainable management. Previous studies have demonstrated that community-based mangrove management significantly enhances conservation outcomes by strengthening local ownership, increasing compliance with community regulations, and improving the capacity of local stakeholders to manage coastal resources effectively. Similarly, Hai et al., (2020) emphasized that successful mangrove management across several Asian

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countries largely depends on the active participation of local communities throughout the planning, implementation, and monitoring stages of conservation programs.

Based on the findings of this study, the most appropriate conservation strategy for Selotong Village is an ecosystem-based management (EBM) approach that integrates ecological, economic, social, and institutional dimensions into a comprehensive management framework. Such a strategy should include rehabilitating severely degraded mangrove areas, implementing silvofishery systems that integrate mangrove conservation with sustainable aquaculture, developing community-based ecotourism, continuing environmental education programs, and strengthening local governance through village regulations and cross-sectoral collaboration. Among these strategies, the silvofishery system represents a particularly promising alternative because it balances environmental conservation with livelihood improvement by integrating aquaculture production with the preservation and restoration of mangrove vegetation.

Furthermore, the findings indicate that institutional strengthening is a critical determinant of long-term mangrove conservation success. Effective collaboration among local governments, village administrations, community organizations, universities, non-governmental organizations (NGOs), and the private sector is essential for establishing an adaptive and sustainable management system. Such collaboration may be implemented through the development of integrated management plans, the application of Geographic Information Systems (GIS) and remote sensing technologies for monitoring changes in mangrove cover, the establishment of payment for ecosystem services (PES) schemes, and the utilization of blue carbon initiatives as sustainable financing mechanisms for conservation activities. Therefore, mangrove management in Selotong Village should be transformed toward a community-based conservation model supported by strong institutional arrangements, technological innovation, and the diversification of local economic opportunities. Under this approach, mangrove conservation should no longer be perceived as a constraint on economic development but rather as a long-term investment in strengthening socio-ecological resilience and promoting sustainable coastal development.

Economic Impacts of Mangrove Degradation

Mangrove degradation in Selotong Village has had significant consequences for the economic sustainability of coastal communities. The decline in both the quality and extent of mangrove forests has diminished their ecological functions as nursery, spawning, and feeding grounds for various commercially valuable fish, shrimp, crabs, and other aquatic species. This ecological deterioration has directly affected the productivity of both capture fisheries and aquaculture, thereby reducing household incomes among communities whose livelihoods depend heavily on coastal resources. Many fishermen reported declining fish catches compared with previous years and were forced to travel farther offshore to obtain adequate harvests. Consequently, operational costs including fuel consumption, labor time, and fishing gear maintenance have increased, resulting in lower net economic returns. These findings demonstrate the strong interdependence between healthy mangrove ecosystems, fisheries productivity, and the economic stability of coastal communities.

The findings of this study are consistent with previous research indicating that mangrove degradation directly reduces the ecosystem services that support coastal livelihoods and economic activities. According to Arifanti et al., (2025), mangrove ecosystems provide a wide range of provisioning, regulating, supporting, and cultural ecosystem services that generate substantial economic value for coastal populations. The degradation of mangrove forests leads to reduced fisheries productivity, increased vulnerability to coastal hazards, and a decline in the overall economic value of coastal landscapes. Similarly, (Hochard et al., 2019) reported that mangrove loss in tropical regions contributes to declining fish stocks while reducing the capacity of coastal ecosystems to protect shorelines from erosion and tidal flooding. Therefore, mangrove degradation in Selotong Village not only reduces household income in the short term but also diminishes natural capital, which constitutes the foundation of long-term coastal economic development.

Beyond its impacts on the fisheries sector, mangrove degradation also constrains the development of alternative livelihood opportunities based on the sustainable use of coastal ecosystems. The potential for mangrove ecotourism, silvofisheries, mud crab aquaculture, and the utilization of non-timber forest products—including food products, beverages, natural dyes, mangrove honey, and handicrafts—has become increasingly limited due to declining environmental quality (Dogaru, 2021; Phelan et al., 2020). Previous research by

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Bhushan et al., (2024) demonstrated that mangrove-based economic diversification can simultaneously increase household incomes and strengthen ecosystem conservation. However, the situation in Selotong Village indicates that these economic opportunities have not been fully realized, as ecosystem degradation has reduced both the ecological quality and the attractiveness of the area, thereby limiting the development of sustainable mangrove-based enterprises and weakening the long-term economic resilience of coastal communities.

4. CONCLUSION

This study demonstrates that mangrove forest degradation in Selotong Village, Langkat Regency, is primarily driven by anthropogenic pressures, including land conversion into aquaculture ponds and oil palm plantations, excessive exploitation of mangrove timber resources, and weak coastal management governance. These human-induced disturbances are further exacerbated by natural processes, such as coastal erosion and dynamic hydrodynamic conditions along the shoreline. The interaction between anthropogenic and natural factors has significantly contributed to the decline of mangrove ecological functions, particularly their roles as habitats for aquatic organisms, natural coastal protection systems, and providers of essential ecosystem services that sustain coastal livelihoods. The degradation of mangrove ecosystems has consequently resulted in declining fisheries productivity, increased operational costs for local fishermen, and limited opportunities for developing sustainable mangrove-based economic activities, such as silvofishery, ecotourism, and the utilization of non-timber forest products. These findings highlight that the sustainability of coastal community livelihoods is strongly interconnected with the ecological integrity of mangrove ecosystems. As mangrove degradation progresses, the capacity of these ecosystems to support local economic activities and provide environmental protection continues to decline, ultimately reducing the socio-economic resilience of coastal communities. The loss of mangrove ecosystem services not only affects current livelihood conditions but also creates long-term vulnerabilities by increasing exposure to coastal hazards, reducing resource availability, and limiting opportunities for sustainable economic diversification. Therefore, mangrove degradation should be understood as a multidimensional challenge involving ecological deterioration, socio-economic instability, and governance limitations rather than merely an environmental issue.

The results further indicate that effective mangrove conservation cannot rely solely on vegetation rehabilitation efforts but requires an integrated management approach involving institutional strengthening, increased community participation, multi-stakeholder collaboration, and the development of sustainable alternative livelihoods. Integrating ecosystem-based management (EBM) with community-based mangrove management (CBMM) is a highly relevant strategy for balancing ecosystem conservation with improved local community welfare. Such an approach emphasizes involving local communities as active stakeholders in conservation processes, ensuring that restoration initiatives align with local socio-economic conditions, traditional knowledge, and long-term livelihood needs. The contribution of this research lies in developing a comprehensive mangrove management framework that integrates ecological, social, economic, and institutional dimensions as a foundation for sustainable coastal conservation policies. The findings provide important insights for policymakers and coastal managers in designing strategies that address both the causes and consequences of mangrove degradation. Future research is recommended to incorporate advanced spatial analyses using remote sensing techniques, ecosystem service valuation, and coupled socio-economic–ecological modeling approaches. These integrated methods would enable a more comprehensive assessment of mangrove management effectiveness and support evidence-based decision-making toward sustainable coastal development and enhanced resilience of coastal communities.

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