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Sustainable Development Strategies for the West Coastal Mangrove Ecosystem in West Bangka Regency: A Socio-Ecological Systems Approach

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Received: 11-25-2024 **Revised:** 02-13-2025 **Accepted:** 02-28-2025

Citation: Falatehan, A. F., Sapanli, K., & Putra, A. H. (2025). Sustainable development strategies for the west coastal mangrove ecosystem in West Bangka Regency: A socio-ecological systems approach. *Chall. Sustain.*, *13*(1), 67-77. https://doi.org/10.56578/cis130105.

Abstract: Indonesia's commitment to reducing carbon emissions is reflected in its sustainable development agenda, with mangrove ecosystems playing a critical role due to their significant carbon sequestration capacity. However, extensive degradation has been observed in the Rambat Menduyung Mangrove Area, primarily driven by unregulated mining activities in the Bangka Belitung Islands Province. A socio-ecological systems approach is essential for understanding the complex interactions between ecological processes and socio-economic drivers in this region. This study aims to assess the socio-ecological conditions of the mangrove ecosystem and formulate an effective strategy for its sustainable development. A descriptive analysis was conducted to evaluate the ecological and socio-economic characteristics of the mangrove area, while Interpretative Structural Modeling (ISM) using Exsimpro software was employed to identify key strategic components for sustainable management. The findings indicate a persistent decline in mangrove coverage, leading to reduced fishery yields and economic losses for local communities. The current economic value of mangrove-related fisheries in the region is estimated at IDR 490,508,599,620 per year, while the potential economic value of carbon sequestration is approximately IDR 23,927,229,700 per year. The proposed development strategy underscores the necessity of strengthening policy enforcement, enhancing institutional capacity, and promoting community engagement. Key stakeholders, including the West Bangka Marine and Fisheries Department (DKP West Bangka), the Forest Management Unit of Rambat Menduyung (KPHP Rambat Menduyung), and the Belo Laut Village Government, must play a central role in implementing stricter conservation policies, enforcing environmental regulations, and fostering sustainable resource utilization. Through an integrated governance framework, the long-term resilience of mangrove ecosystems in West Bangka Regency can be ensured, thereby contributing to both ecological stability and economic sustainability.

Keywords: Mangrove degradation; Interpretative Structural Modeling (ISM); Institutional capacity; Environmental policy; Socio-ecological systems

1. Introduction

Indonesia has committed to addressing climate change through various global agreements. One effort to combat climate change is by implementing sustainable development. Sustainable development efforts focus on inclusive economic growth, improving social welfare, and strengthening environmental sustainability (Bappenas-National Development Planning Agency, 2020). Coastal ecosystems, including mangroves, seagrasses, and coral reefs, play a crucial role in the Sustainable Development Goals (SDGs). Mangrove ecosystems hold a significant role in achieving SDG 14, which focuses on sustainable coastal and marine management. Additionally, mangroves contribute to alleviating poverty and hunger (SDG 1 and SDG 2), ensuring livelihoods and economic growth (SDG 8), taking action against the impacts of climate change (SDG 13), and halting biodiversity loss (SDG 15) (Friess et al., 2019).

Mangrove ecosystems play essential roles in supporting sustainable development. One of the roles is contributing to the reduction of national carbon emissions due to their large carbon sequestration and storage functions (Lukman et al., 2022). Current mangrove ecosystem conservation activities are estimated to meet a quarter of the national emission reduction target at 26% by 2030 (Murdiyarso et al., 2015). However, mangroves are currently being harmed due to pressures and exploitation of coastal natural resources, like mining (Cahyaningsih et al., 2022).

Mining activities in the Bangka Belitung Islands Province become a threat to the mangrove ecosystem's sustainability in the coastal areas. The existence of mangrove natural resources is threatened by tin mining, as the main source of regional income. The impact of land clearing for tin mining has significantly reduced the mangrove carbon stock by more than 29.5 million tons of carbon (Haryati & Dariah, 2019).

One mangrove area that is potentially affected by mining is the Mangrove Rambat Menduyung Protected Forest Area in the Western Coastal Waters of West Bangka Regency. The waters of this area are a source of capture fisheries, producing shrimp, mullet, scallops, and blood cockles (Sapanli et al., 2023). In addition, these waters are also a mineral mining zone (KPU-TB-MN), according to the spatial plan for coastal areas and small islands (RZWP3K) of the Bangka Belitung Islands Province (Perda, 2020). Tin mining activities that have begun in these waters have impacted the condition of the mangrove ecosystem. One direct impact perceived by fishermen is the fishery yields decline due to tin mining (Febrianto et al., 2015). Tin mining activities in the Bangka Belitung Islands Province have led to significant damage to mangrove ecosystems, resulting in a substantial reduction in carbon stocks. According to Haryati & Dariah (2019), the clearing of land for tin mining caused mangrove carbon stocks to decline by more than 29.50 million tons. Furthermore, offshore tin mining has adversely affected the livelihoods of fishermen, reducing their incomes by up to 56%. On average, fishermen face total expenditures of IDR 3,400,000, with operational costs amounting to IDR 233,000 (Arnanda & Febrianto, 2021).

Sustainable management is needed in this area to prevent further degradation of mangroves, given their important role for both the community and the environment. Sustainable development needs to be approached comprehensively due to the complexity of mangrove management issues. This issue can be approached using the Social-Ecological System (SES) framework, which emphasizes the integrated relationship between humans and nature (Hafsaridewi et al., 2018). The interaction between social systems and ecological systems creates functional interdependencies, leading to simultaneous social and ecological changes (Muliani et al., 2018). Through this approach, the highly dynamic relationship between social and ecological changes in mangrove ecosystems can be comprehensively assessed, resulting in sustainable mangrove management recommendations (Handayani et al., 2021). Based on this condition, the main issue is the unsustainable management of mangrove areas due to economic interests being prioritized over environmental concerns. Therefore, the aim of this study is to analyze the socio-ecological conditions of the Mangrove Rambat Menduyung area and recommend a sustainable development model for the Western Coastal Mangrove Area of West Bangka Regency.

2. Methodology

This study was conducted in the Mangrove Coastal Area of West Bangka Regency, specifically in Belo Laut Village, Mentok District, West Bangka Regency. The mangrove forest area under investigation was the Mangrove Rambat Menduyung Protected Forest Area. The location was chosen purposively due to the onset of mangrove degradation in this area as a result of tin mining activities. This area, according to BBIPRR (n.d.), is classified as part of the Belo Sea Tin Mining Zone and the protected forest zone in the Coastal and Small Islands Zoning Plan (RZWP3K).

Data collection was carried out from January to April 2024. Sample selection in this study was determined using purposive sampling techniques, with respondents being parties directly involved in the management of the mangrove area. These respondents included representatives from fishermen groups, academics from the University of Bangka Belitung (UBB), and policymakers from the Regional Planning, Development, and Research Agency (Bappeda) of the Bangka Belitung Islands Province, the Regional Technical Implementation Unit of the Rambat Menduyung Production Forest Management Unit (UPTD KPHP), the Provincial Marine and Fisheries Department (DKP) of the Bangka Belitung Islands, and the Belo Laut Village Government.

This study used both primary and secondary data. Primary data were obtained from interviews concerning the socio-ecological conditions in the mangrove area and elite perspectives on sustainable development strategies. Secondary data included information on the ecological condition of the mangrove ecosystem, economic utilization outcomes of the area, regulations, and programs obtained from the Central Bureau of Statistics (BPS), UPTD KPHP Rambat Menduyung, DKP of West Bangka Regency, scientific publications, program reports, and research study reports.

The analysis of the socio-ecological conditions of the mangrove area was conducted using descriptive analysis of the socio-ecological components. This analysis referred to the framework by McGinnis & Ostrom (2014), which includes the components of the resource system, resource units, actors, and the governance system. The socio-ecological condition analysis involved identifying socio-ecological components, mapping the relationships

between socio-ecological components, and formulating necessary components to address issues based on the relationships between socio-ecological components.

The next phase of data analysis involved developing a sustainable coastal development model using ISM with Exsimpro software. The ISM analysis is utilized because it can comprehensively present the relationships between variables, from the input side to the expected output. The sample used consists of stakeholders involved in mangrove management activities. The ISM analysis consists of two main stages: hierarchy structuring and sub-element classification. Sub-elements at the lowest hierarchy level are key elements that can influence higher-level hierarchy elements (Rifaldi et al., 2021). The strategy elements discussed include the changes needed to support low-carbon development and the actor's involvement, based on the results of the socio-ecological analysis of the mangrove area.

3. Results

The Mangrove Rambat Menduyung Protected Forest area encompasses a total of 3,970 hectares. This mangrove area is located in Belo Laut Village, Muntok District, West Bangka Regency. The mangrove area falls under the protected forest category and is managed by the UPTD KPHP Rambat Menduyung. The availability of mangroves in this area presents opportunities for developing the local economy through activities such as capture fisheries and silvofishery systems. The majority of the local community around this mangrove area is engaged in capture fishing and blood cockle production. Additionally, there is potential for developing mangrove conservation and rehabilitation activities due to the economic value of mangrove carbon.

3.1 Socio-Ecological Condition of the Mangrove Area

The Mangrove Rambat Menduyung Protected Forest Area provides various ecosystem services, including serving as a breeding ground for aquatic biota and playing a significant role in high carbon absorption and storage. The mangrove ecosystem in this area is productive, providing marine biota and other ecosystem services that can be utilized by various stakeholders for economic activities and environmental conservation. The resources available around the Mangrove Coastal Area of West Bangka Regency are diverse. It is known that there are up to 30 species of fish and several aquatic biotas living in the area around the mangrove trees, which are captured by fishermen. This diversity of marine biota is due to the well-maintained mangrove ecosystem in this area. The resources in the mangrove area can be utilized by the local community for various economic activities, including capture fisheries and blood cockle farming.

The utilization of the mangrove ecosystem for fisheries activities has been conducted in an environmentally friendly manner. For capture fisheries, the fishing gear used includes nets and cast nets without using trawls that can damage the mangrove ecosystem. This fishing activity depends on the fishing season, so fishermen's income is not constant and depends on the season (Colwell et al., 2017). Additionally, mangrove degradation has led to a capture fisheries production decline (Haryanto et al., 2023). Another fishing activity is blood cockle farming, which has become a primary source of income for many local people as blood cockle farmers. However, currently, some farmers have stopped due to the unsuitability of the farming land. Farmers believe that the land for blood cockle farming is no longer suitable, with thick mud being a challenge for the cockles to survive. There is a need to identify the condition of the farming land, considering the potential of blood cockles in developing the economy in the mangrove area.

According to data from BPS of West Bangka Regency in 2024, the catch of marine biota in Mentok District, West Bangka Regency, in 2023 reached 10,491 tons, generating revenue of IDR 488,970,769,620. Meanwhile, the production of blood cockles reached 180.87 tons, which could gain a profit of IDR 1,537,830,000 (BPS West Bangka Regency-Central Bureau of Statistics, 2024).

Furthermore, the density of mangrove forests affects the ability of mangroves to absorb carbon (Henri et al., 2024). The function of carbon storage and absorption by mangroves can provide economic value, considering the economic value of mangrove carbon. The carbon function of mangroves can be monetized through schemes such as carbon trading. The economic value of carbon is obtained by multiplying the carbon absorption value by the agreed carbon price (PRRI, n.d.).

The carbon price in Indonesia varies between $2 and $18. Based on Bappenas-National Development Planning Agency (2014), the estimated average annual carbon absorption of mangroves is 20.78 tons CO2eq per hectare, resulting in an economic value of mangrove carbon of $42-$374 per hectare. Given the total area of the Mangrove Rambat Menduyung Protected Forest is 3,970 hectares, the total economic value of carbon is $164,976-$1,484,780 per year. Converted to Indonesian Rupiah at the exchange rate on June 10, 2024, of IDR 16,115.00, the total economic value of mangrove carbon reaches IDR 2,658,581,078 – IDR 23,927,229,700 per year.

The coastal waters of West Bangka Regency are prone to conflicts due to the presence of protected and conservation areas, which are part of the mining zone (Perda, 2020). Law enforcement and institutional capacity play a crucial role in managing this area. This area is managed by the UPTD KPHP Rambat Menduyung under the

supervision of the DLHK of the Bangka Belitung Islands Province. This institution routinely monitors and collaborates with the government and the community of Belo Laut Village to oversee and provide access to the mangrove area for community economic activities as long as they do not damage the mangroves. Meanwhile, fishing activities in this area are supervised by the DKP of the Bangka Belitung Islands Province because they are within the coastal waters area.

The UPTD KPHP Rambat Menduyung and the DKP of the Bangka Belitung Islands Province routinely conduct monitoring and outreach to the community to carry out environmentally friendly economic activities. However, in practice, there are still challenges from various cross-sectoral economic activities, particularly the increasing mining activities in this area, which puts pressure on mangrove resources. The onset of mangrove degradation has impacted the decline in fishermen's capture fisheries yields. The conflict between fishermen and marine mining is highly detrimental to small-scale fishermen, whose catches have declined since the advent of marine mining activities (Jihan et al., 2021).

Policies and mangrove management need to consider the complex dependencies between various components and the impact of human activities on the mangrove ecosystem. It is crucial to note that economic activities in the mangrove area must adhere to sustainability principles. This mangrove area implements co-management, requiring collaborative efforts between the government, local communities, NGOs, and other stakeholders to achieve sustainable management (Mahardika et al., 2023).

Based on the identification of socio-ecological conditions, there is connectivity or a relationship between the socio-ecological components found in the Mangrove Rambat Menduyung Coastal Area of West Bangka Regency. The connectivity of the socio-ecological system in this area is formed through complex interaction processes. Within the internal system of the area, social interactions are formed between actors and the governance system, while ecological interactions are formed between the mangrove ecosystem (resource system) and aquatic resources (resource units). Socio-ecological system interactions are formed through interactions between resource units and actors. The connectivity between socio-ecological components is illustrated in Figure 1.

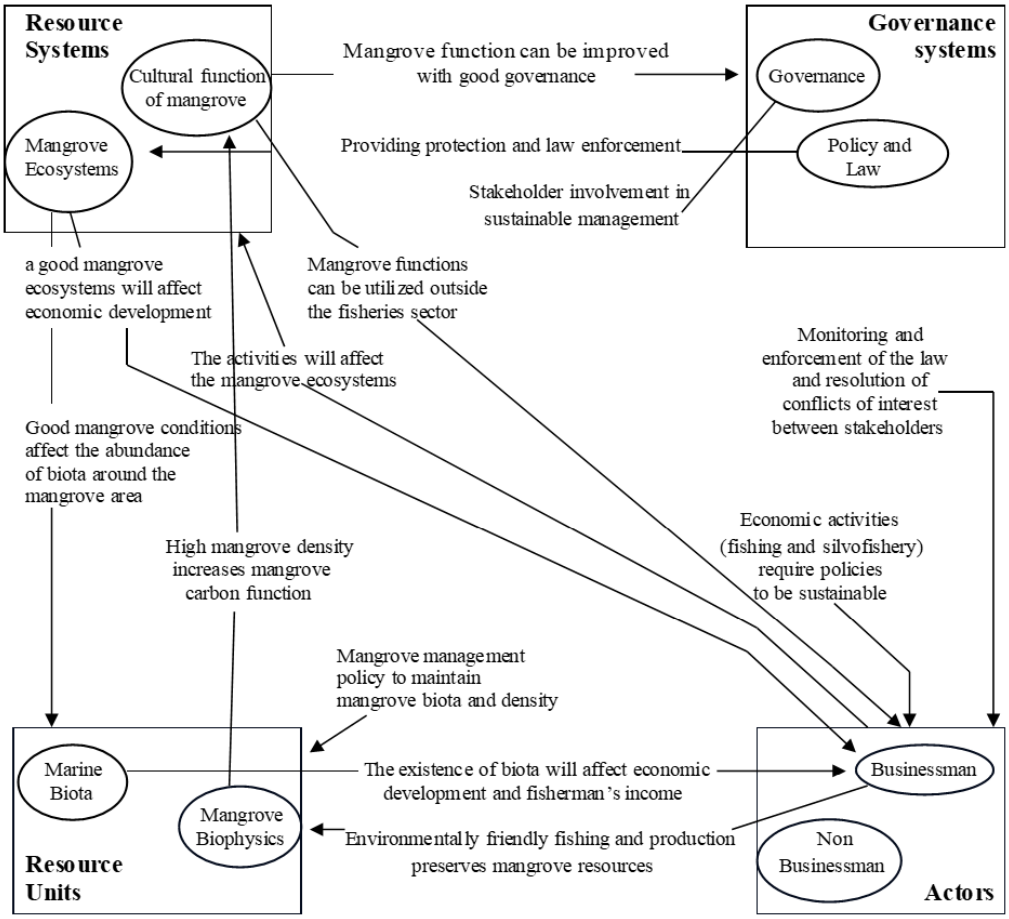

Figure 1. Connectivity between socio-ecological systems in the Mangrove Rambat Menduyung area

The connectivity between the resource system and the governance systems involves the authority to manage the mangrove ecosystem. Supervision and law enforcement are conducted to monitor the development of the

mangrove ecosystem and to determine appropriate strategies for its management. This policy is necessary to ensure the sustainable utilization of the mangrove ecosystem. Government agencies such as the UPTD KPHP Rambat Menduyung and the DKP of the Bangka Belitung Islands Province are also active in implementing mangrove conservation and rehabilitation programs. Furthermore, the community receives education on the sustainable use of mangrove forests and sustainable fishing practices in the Mangrove Rambat Menduyung area.

The resource system and the resource unit components have a very close inter-component connectivity. The condition of mangrove resources determines the success of economic development in the mangrove area. This can be seen from the diversity of marine biota around the mangrove ecosystem and the positive impact of environmentally friendly fishing practices on the mangrove ecosystem. Additionally, the density and types of mangroves affect their carbon function. Well-maintained mangroves will increase their carbon absorption and storage value (Henri et al., 2024).

The connectivity between the resource unit and the actors involves the stakeholders who utilize the resources either directly or indirectly. Economic activities include the capture of marine biota such as various fish, crabs, blue swimming crabs, shrimp, and other marine biota, as well as blood cockle farming. Other activities include mangrove conservation and rehabilitation by stakeholders. Academics from UBB also conduct research activities related to the mangrove ecosystem.

The connectivity between the resource system and the actors occurs both directly and indirectly. The condition of the mangroves, which affects the abundance of resources, impacts the income of those who utilize the mangrove ecosystem. The types of mangroves found in the Mangrove Rambat Menduyung Forest influence the forms of utilization by the community. This area is classified as a protected forest, so mangrove trees, leaves, and fruits cannot be directly utilized.

Low community awareness of the importance of the mangrove ecosystem adversely affects the coastal ecosystem balance and disrupts mangrove sustainability (Suharti et al., 2016). This can lead to conflicts and requires legal involvement to provide solutions. The connectivity between the governance systems and the actors allows for the creation of policies regulating all forms of mangrove ecosystem utilization activities. The governance systems have the authority to impose sanctions on community behaviors that damage the mangrove ecosystem.

The connectivity between the governance systems and the resource unit involves monitoring the utilization activities of the mangrove. The UPTD KPHP Rambat Menduyung and the DKP of the Bangka Belitung Islands Province support the development of carbon functions. The high economic value potential of mangrove carbon needs to be facilitated as it can increase community income.

Table 1. Relationships and required changes for sustainable development in the Rambat Menduyung Mangrove Forest Area

No.	Relationship	Sign	Changes Needed
1	Resource systems – Governance system	(+)(+)	- Strengthen protection policies and law enforcement against economic activities damaging mangroves. - Enhance institutional governance to promote sustainable economic activities and enforce penalties for mangrove-damaging activities.
2	Resource systems – Actors	(+)(-)	- Strictly regulate economic behaviors that harm mangrove ecosystems by resource actors. - Provide infrastructure and technological support to enable environmentally friendly economic activities.
3	Resource systems - Resource units	(+)(+)	- Manage cross-sectoral resource utilization sustainably to benefit all parties and minimize conflicts.
4	Resource units – Actors	(+)(-)	- Increase awareness among communities and stakeholders to actively participate in mangrove conservation, impacting economic activities positively. - Optimize mangrove resource utilization processes for sustainable community economic activities.
5	Resource units - Governance system	(+)(+)	- Direct supervision and enhanced implementation of mangrove conservation and rehabilitation programs with stakeholders. - Strengthen institutional capacities to efficiently and sustainably utilize mangrove resources.
6	Actors - Governance system	(+)(-)	- Increase government involvement in resolving community conflicts through complaint mechanisms and sanctions. - Strengthen local community institutions to manage ongoing programs collectively and clarify their roles.

Based on the analyzed socio-ecological connectivity, the relationship between the socio-ecological components in this mangrove area does not only provide positive impacts but also have negative effects on the community and resources (Rahman et al., 2020). The identified relationships and necessary changes for developing a sustainable

coastal development model in the Mangrove Rambat Menduyung Forest Area are presented in Table 1.

3.2 Coastal Sustainable Development Model

The coastal sustainable development model with a socio-ecological approach in the Rambat Menduyung Mangrove Area consists of strategies comprehensively structured based on the necessary changes and the actors or institutions involved to achieve sustainable development. The first model is based on the changes needed to support sustainable coastal development. The initial step is to enhance the governance and institutional capacity for mangrove area management (E3). The next steps involve strengthening law enforcement and policies for mangrove ecosystem protection (E1) and increasing community awareness, capacity, and participation in mangrove ecosystem management (E4). The final step is to improve infrastructure and the utilization of technology in managing the mangrove ecosystem (E2). This hierarchical structure model is illustrated in Figure 2.

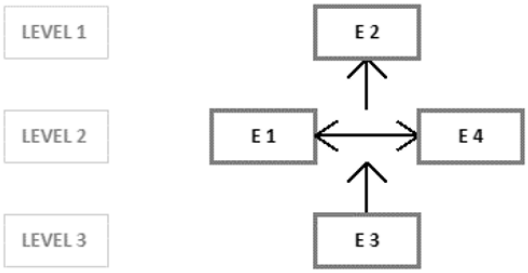

Figure 2. Model structure of the necessary changes for sustainable development

Enhancing governance in the utilization of mangrove areas for economic activities across the fisheries and mining sectors is crucial to minimize conflicts due to overlapping interests and negative impacts between sectors. For example, mining activities conducted near mangrove areas need to obtain strict environmental permits to reduce pollution impacts on the mangrove ecosystem. Additionally, the institutional capacity of stakeholders, especially those directly involved in economic utilization, should be improved through intensive assistance. This aims to ensure that both fishing and mangrove conservation activities provide high economic benefits and ensure the sustainable use of mangrove resources. Good governance can create synergy between the fisheries and mining sectors while preserving the mangrove environment (Mahardika et al., 2023).

Law enforcement needs to be strengthened through stricter monitoring and decisive actions against economic activities that damage mangrove areas. Currently, existing legal policies do not impose sufficiently strict sanctions, leading to the prevalence of illegal mining activities. In addition to relying on monitoring by related agencies, the local government and the community of Belo Laut Village can play a vital role in overseeing and reporting activities that damage these protected areas. Active participation from the local community will not only enhance monitoring but also increase collective awareness and responsibility for preserving the mangrove areas. Therefore, more effective law enforcement and active local community participation can significantly reduce environmentally destructive economic activities and support the sustainability of the mangrove ecosystem (Febryano et al., 2014).

As primary actors of the mangrove areas and the first to be affected by any damage, the community can increase their contribution through environmentally friendly economic activities. Conservation and rehabilitation efforts should be optimized as they will have a positive impact on increasing fishery yields and the economic value of carbon. To achieve these terms, more intensive socialization and assistance to the community are necessary (Santoso et al., 2021). Thus, the community can become active subjects in development, rather than passive objects. Direct involvement of the community will give them a greater role in enhancing the sustainable use of mangrove resources. Active community participation is a strong asset in supporting environmental preservation and improving economic welfare through sustainable and environmentally conscious economic practices (Alimin et al., 2024). One of the activities that can be carried out in the area to achieve sustainability is to make the area a tourist attraction, namely mangrove tourism. According to Safitri et al. (2024), mangrove ecotourism promises sustainable development that integrates aspects of environmental conservation, tourist attraction, and the utilization of ethnobotanical potential to improve public health. Meanwhile, according to Febryano et al. (2022), in Pahawang Island, Indonesia, most of the management of tourism on this island is carried out by the local community, with the help of the local government.

Adequate infrastructure and facilities support are crucial to optimize the utilization of mangroves for economic activities (Firdaus et al., 2023). Currently, the limited infrastructure supporting economic activities hinders the full utilization of mangrove resources. Therefore, optimizing the use of technology is a crucial step to enhance sustainable mangrove utilization. With the appropriate application of technology, productivity can be increased, and there is potential to shift from destructive economic activities to sustainable economic activities. The use of

technology not only helps in increasing efficiency and output but also in monitoring and preserving the mangrove ecosystem. Good infrastructure support and technological innovation will create synergy between economic growth and environmental preservation, ensuring long-term benefits for the community and the mangrove ecosystem.

The second model is structured based on the actors or institutions involved in coastal sustainable development. Cooperation and participation from various parties are essential to achieving low-carbon development goals. Among the seven identified actors or institutions involved, four are considered key: the policy makers of UPTD KPHP Rambat Menduyung (E4), DKP of the Bangka Belitung Islands Province (E3), and the Government of Belo Laut Village (E6). Community groups (E7) also play a significant role as actors of the mangrove area. Other involved actors include Bappeda of the Bangka Belitung Islands Province (E1), NGOs (E5), and academics (E2). The hierarchical structure model of the actors or institutions can be illustrated in Figure 3.

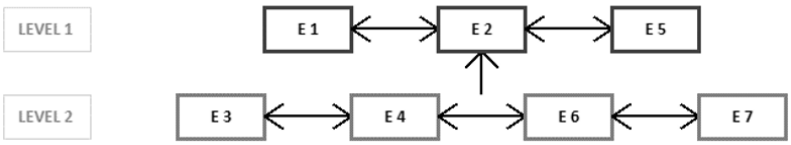

Figure 3. Model structure of the actors or institutions involved in sustainable development

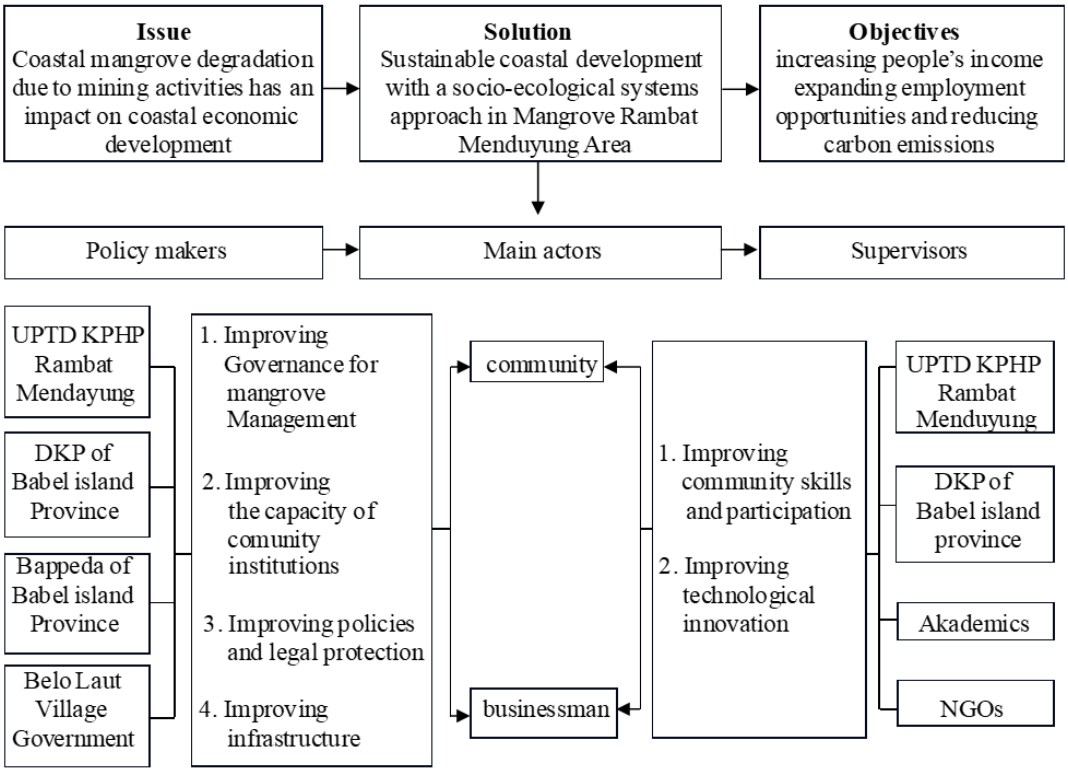

Figure 4. Sustainable coastal development model in the region

UPTD KPHP Rambat Menduyung and DKP of Bangka Belitung Islands Province play a primary role in managing and protecting the mangrove area. These institutions collaborate with the government and the community of Belo Laut Village to protect the area and enforce laws, particularly against activities that damage the mangrove area, such as illegal mining. DKP of Bangka Barat Regency also provides education, technical assistance, and infrastructure support for fishing activities, including advanced fishing gear and blood clam aquaculture technology.

The local institution, Belo Laut Village Government, can establish local regulations to ensure sustainable resource management. This institution must also actively collaborate with the community in monitoring and reporting violations, especially illegal mining in the mangrove area (Rudianto et al., 2020). Fisher groups and local communities are encouraged to implement sustainable principles in utilizing the mangrove area, such as silvofishery with blood clams, mangrove conservation, and rehabilitation activities.

In addition to these four institutions, three other entities also play significant roles in regional development planning and management by formulating sustainable development plans and identifying funding sources for mangrove area management. The role of academics from universities is crucial through research, education, and community service. NGOs can advocate for policies that support mangrove preservation and provide independent monitoring of policymakers based on concrete evidence in the field.

Based on the model of required changes and the actors or institutions involved in coastal sustainable development, the relationships can be illustrated in Figure 4.

Policy-makers play a crucial role in strengthening policies and laws, improving the governance of mangrove management, and enhancing community institutional capacities. They are also responsible for providing necessary infrastructure for mangrove ecosystem management. Extension officers from the Department of Marine and Fisheries (DKP) and the Forest Management Unit (KPHP) are tasked with educating communities around the area. Meanwhile, academics and NGOs can explore potentials through research and community empowerment programs using technological innovations to support sustainable development. Active involvement of policy makers and facilitators is expected to encourage key actors such as local communities residing around mangrove areas, fishermen groups, and miners to adopt sustainable development practices along the coastal areas. Sustainable development in these coastal areas is expected to increase community income, expand job opportunities, and reduce carbon emissions (Bappenas-National Development Planning Agency, 2022).

4. Discussion

The Mangrove Rambat Menduyung Protected Forest Area provides critical ecosystem services, such as serving as a breeding ground for aquatic biota and contributing significantly to carbon absorption and storage (Henri et al., 2024). This productive mangrove ecosystem supports a diverse range of marine biota, including up to 30 species of fish, which are vital for the livelihoods of local fishermen. The resources in this area are utilized for various economic activities, including capture fisheries and blood cockle farming, conducted in environmentally friendly ways to ensure sustainability. However, mangrove degradation has led to a decline in capture fisheries production, highlighting the need for careful management (Haryanto et al., 2023). Blood cockle farming, a primary income source for many local residents, faces challenges due to unsuitable farming land conditions, necessitating land condition assessments to optimize economic benefits from this activity.

The economic value of the mangrove ecosystem extends beyond fisheries. Mangroves' ability to absorb and store carbon offers significant economic potential through carbon trading schemes. For instance, the Mangrove Rambat Menduyung Protected Forest's carbon absorption translates to an economic value of between $164,976 and $1,484,780 annually, depending on carbon prices (Bappenas-National Development Planning Agency, 2014). Effective governance and law enforcement are crucial in managing this area, with institutions like UPTD KPHP Rambat Menduyung and DKP of the Bangka Belitung Islands Province playing key roles. These institutions collaborate with local communities and other stakeholders to ensure sustainable mangrove management, despite challenges such as increased mining activities (Jihan et al., 2021). Collaborative management practices, involving government, local communities, NGOs, and academics, are essential to address complex socio-ecological interactions and achieve SDGs for the mangrove ecosystem (Mahardika et al., 2023; Suharti et al., 2016; Rahman et al., 2020).

The coastal sustainable development model in the Rambat Menduyung Mangrove Area involves enhancing governance and institutional capacity, strengthening law enforcement and policies, increasing community awareness and participation, and improving infrastructure and technology to achieve sustainable development.

Enhancing governance in the utilization of mangrove areas for economic activities in both fisheries and mining sectors is crucial to minimize conflicts arising from overlapping interests and to mitigate the negative impacts between these sectors. For instance, mining activities conducted near mangrove areas must obtain strict environmental permits to reduce pollution impacts on the mangrove ecosystem. Additionally, the institutional capacity of stakeholders, particularly those directly involved in economic utilization, should be improved through intensive assistance. This aims to ensure that both fishing and mangrove conservation activities yield high economic benefits while ensuring the sustainable use of mangrove resources. Effective governance can foster synergy between the fisheries and mining sectors, ultimately preserving the mangrove environment (Mahardika et al., 2023).

Moreover, strengthening law enforcement is essential through stricter monitoring and decisive actions against economic activities that damage mangrove areas. Current legal policies often fail to impose sufficiently strict sanctions, allowing illegal mining activities to persist. Beyond monitoring by relevant agencies, local government and the community of Belo Laut Village play a vital role in overseeing and reporting activities that harm these protected areas. Active participation from the local community not only enhances monitoring but also increases collective awareness and responsibility for preserving the mangrove areas. Therefore, more effective law enforcement combined with active local community participation can significantly reduce environmentally destructive economic activities and support the sustainability of the mangrove ecosystem (Febryano et al., 2014).

UPTD KPHP Rambat Menduyung and DKP of Bangka Belitung Islands Province play a crucial role in managing and protecting the mangrove area, collaborating with the government and the community of Belo Laut Village to enforce laws, particularly against damaging activities like illegal mining. The DKP of Bangka Barat Regency also contributes by providing education, technical assistance, and infrastructure support for fishing activities, including advanced fishing gear and blood clam aquaculture technology. Additionally, the local Belo Laut Village Government can establish local regulations for sustainable resource management, actively collaborating with the community to monitor and report violations, and encouraging fisher groups and local communities to adopt sustainable practices such as silvofishery with blood clams and mangrove conservation and rehabilitation activities (Rudianto et al., 2020).

In addition to these primary institutions, other significant entities in regional development planning include academics, NGOs, and policymakers. Academics from universities contribute through research, education, and community service, while NGOs advocate for supportive policies and provide independent monitoring based on field evidence. Policymakers play a pivotal role in formulating sustainable development plans, improving governance, and enhancing community capacities, while also providing necessary infrastructure for mangrove ecosystem management. The active involvement of policymakers and facilitators is crucial in encouraging local communities, fishermen groups, and miners to adopt sustainable practices. This comprehensive approach is expected to increase community income, expand job opportunities, and reduce carbon emissions, thereby supporting sustainable development in coastal areas (Bappenas-National Development Planning Agency, 2022; Mahardika et al., 2023; Febryano et al., 2014).

5. Conclusions

The primary resources utilized sustainably by the Belo Laut Village community include marine biota harvesting and the potential carbon services as part of the resource system and unit. The Belo Laut Village community, KPH, and DKP of West Bangka are included as actors. Meanwhile, the governance systems consist of policies and mangrove management arrangements. The interconnection among these components yields both positive and negative impacts. Efforts for sustainable coastal development in this area involve enhancing law enforcement and policies for mangrove ecosystem protection, improving infrastructure and technology utilization, enhancing governance and institutional capacities, and increasing awareness, capacity, and community participation in mangrove ecosystem management. Policy-makers can strengthen existing regulations and governance by increasing community involvement. The Belo Laut Village government needs to enhance synergy with community groups to regularly monitor and support infrastructure needs required for community economic development. NGOs, academics, and community groups can enhance education for other communities, particularly those still engaged in mining, to transition to environmentally friendly economic activities.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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