Strategies for optimizing mangrove ecosystem management in the rehabilitation area of Sayung coastal zone, Demak Regency, Central Java

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Abstract. *Sayung coast is experienced very high coastal erosion and has a huge impact on the lives of the surrounding communities. One of the efforts in handling coastal erosion is the rehabilitation of the mangrove ecosystem. The purpose of this study was to prioritize mangrove ecosystem management strategies in rehabilitation areas. Data were collected from three coastal villages, namely, Bedono, Timbulsloko, and Surodadi, through in-depth interviews, questionnaires, and field observations. The data analysis was carried out using the Analytical Network Process (ANP) method. The result showed that the priority problems in the mangrove ecosystem management on the Sayung coast were: conversion of mangrove land, failure of mangroves to grow, lack of monitoring and supervision. Therefore, the priority solution for optimizing mangrove ecosystem management is rehabilitation and conservation, increasing community participation, and monitoring by involving the community.*

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PENDAHULUAN

Sayung Coastal Zone in Demak Regency is one of the areas experiencing the highest coastal erosion in Central Java. Coastal erosion on Sayung Coastal Zone reaches 5 km inland with an area of 2 116.54 ha (KKP, 2015). The government and the private sector have made efforts to overcome coastal erosion with hard and soft structures, including the construction of a coastal belt with concrete cylinder (buis beton), construction of breakwater, construction of a wave breaker using used tires, construction of embankments, manufacture of Hybrid Engineering, and mangrove rehabilitation (Handayani *et al.*, 2020a).

Mangrove rehabilitation is an effort to restore the function of the degraded mangrove ecosystem to a condition that is considered good and capable of carrying out its ecological and economic functions. Rehabilitation through mangrove planting on Sayung Coastal Zone is carried out by various community elements, including government institutions, private sector, universities, domestic and foreign NGOs.

Mangrove rehabilitation efforts have paid off, as evidenced by the increase in mangrove areas on Sayung Coastal Zone (Handayani *et al*., 2020a; Irsadi *et al*., 2019; Faturrohmah and Marjuki, 2017).

Mangrove ecosystem services on Sayung Coastal Zone are grouped into supporting services, provider services, regulatory services, and cultural services. In mitigating coastal erosion, mangrove ecosystems have services such as retaining currents and waves, retaining strong winds, and trapping sediments (Handayani *et al*., 2020b). Mangrove ecosystems have a strong root system that can reduce wave energy, retain sediment (Nontji, 2002), and function as a trap and sediment stabilizer (Kusmana, 2003). Mangroves can reduce energy, thereby reducing the speed of water flow entering the mangrove area and reducing the risk of coastal erosion (Roza, 2016). Sugiarto and Ekayanto (1996) added that mangroves could keep the coastline stable.

Given the importance of the mangrove ecosystem on Sayung Coastal Zone, it is necessary to optimize the management of mangrove ecosystems in the rehabilitation area. Optimal management strategies are expected to provide the sustainability of the mangrove ecosystem and continue to provide ecosystem services, especially those related to coastal protection. This study aims to develop a strategic priority for mangrove ecosystem management in the rehabilitation area.

METHOD

Study Area and Period

This research was conducted from September to November 2020. The study area covers Sayung coastal zone, Demak Regency, Central Java, consisting of three villages, namely Bedono Village, Timbulsloko Village, and Surodadi Village.

Data Collection

Data collection covers primary and secondary data. Primary data collection is obtained through in-depth interviews and filling out questionnaires. In-depth interviews were conducted to explore information, problems, and solutions in mangrove ecosystems management. Respondents came from academia, government, and practitioners. While, Secondary data is gathered from data and information related to managing mangrove ecosystems on Sayung Coastal Zone.

Data Analysis

Management priorities were analyzed using the Analytical Network Process (ANP) method through Super Decision 2.6 software to obtain a management strategy. ANP is a relative measurement theory used to derive composite priority ratios from individual ratio scales that reflect the relative measurement of the influence of interacting elements (Saaty, 1999). ANP is a development of the Analytical Hierarchy Process (AHP). The ANP method can improve the weakness of AHP, which can accommodate the interrelationships between criteria or alternatives. The stages in the ANP analysis are (1) model construction, (2) model quantification, and (3) synthesis and analysis of results.

The construction of the ANP model is based on a literature review, in-depth interviews with experts, community leaders, and relevant stakeholders who know the problems that exist in the management of the mangrove ecosystem on Sayung Coastal Zone. Ecological, economic, social, and institutional problems are formulated in the ANP model in Figure 1. Solutions in dealing with problems in various aspects are also formulated in the model.

This stage uses questions in the ANP questionnaire in pair comparisons between elements in the cluster. This stage determines the dominant influence between components and how big the difference is through a numerical scale of 1-9. Verbal scale and numerical scale in pair comparisons are presented in Table 1.

Table 1 Comparison of verbal scales and numerical scales

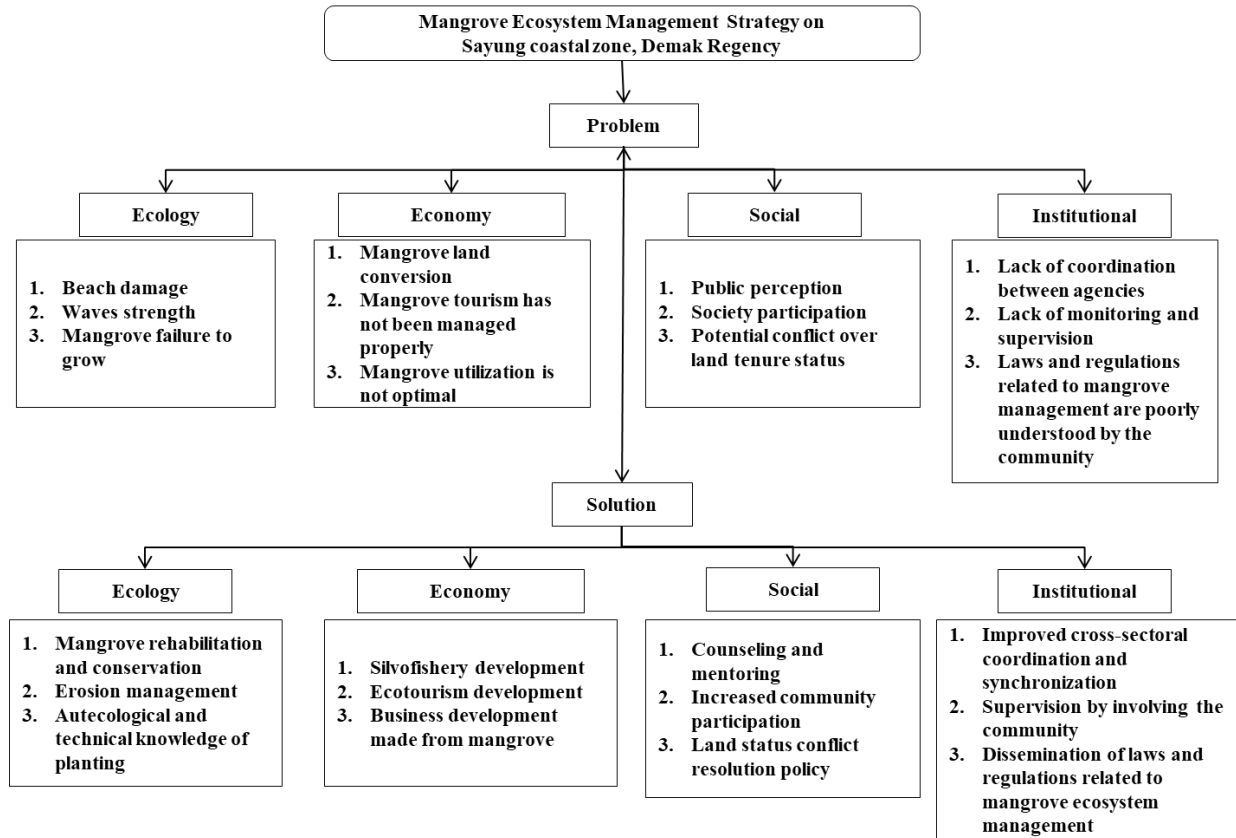| Verbal Scale	Numerical Scale
Extreme	9.8
Very Strong	7.6
Strong	5.4
Moderate	3.2
Equal	1

Source: Saaty (1999)

Figure 1 Construction of the ANP model for mangrove ecosystem management

The questionnaire that the respondent has filled out is then inputted into the super decision software. The next step is to calculate the value of Kendall's coefficient of concordance, a measuring tool for calculating rater agreement using Microsoft Excel. Rater Agreement is a measure that shows the level of conformity (agreement) of the respondents (R1-Rn) to a problem in one cluster. Kendall's coefficient concordance tool used to measure rater agreement (W; 0<W≤1). To calculate the value of W, do the following steps:

Calculate the average value (U) of the total rank of each cluster:
$$U = (T_1 + T_2 + T_P) / p$$

Calculate the value of the sum of the squares of the deviation (S), with the formula:
$$S = (T_1 - U)^2 + (T_2 - U)^2 + \ldots + (T_P - U)^2$$

Calculate the maximum value of the square of deviation (Max S), with the formula:

$$\text{Max S} = (n - U)^2 + (2n - U)^2 + \ldots + (pn - U)^2$$

Determine the value of W in the rater agreement calculation with the formula:

$$W = S/ \text{Max S}$$

Notes:

U = Average rating of each criterion

S = Square of deviation

W = Kendall's Coefficient

P = Number of criteria

n = Number of respondents

$T_{1,2,p}$= Total ranking of criteria 1, 2, …p

If the value of W = 1 indicates that the respondents' assessments have a perfect agreement, whereas if W= 0 or close to 0, it indicates disagreement between respondents' answers or varied answers (Ascarya, 2005).

RESULTS AND DISCUSSION

From the results of the ANP analysis, Kendall's coefficient of concordance (W) value is 0.64. This value indicates that the level of agreement between the resource persons is quite high on priority problems and solutions for mangrove ecosystem management. Determining the priority of problems and solutions can facilitate the government in formulating strategies for managing mangrove ecosystems in Sayung Coastal Zone.

Mangrove Ecosystem Management Problems

The results of the ANP analysis for priority problems are shown in Table 2. It can be seen that the main priority problem in ecosystem management on Sayung Coastal Zone is the conversion of mangrove land. The second priority is the failure of mangroves to grow, and the third priority is the lack of monitoring and supervision.

Table 2 ANP results on priority problems

Aspect	Problem	Normalized by Cluster	Ranking
Ecology	Mangrove failure to grow	0.3877	2
	Beach damage	0.3458	5
	Waves strength	0.2665	12
Economy	Mangrove land conversion	0.4324	1
	Mangrove utilization is not optimal	0.2670	11
	Mangrove tourism has not been managed properly	0.3006	9
Institutional	Lack of coordination between agencies	0.3289	7
	Lack of monitoring and supervision	0.3642	3
	Legislation is not understood by the public	0.3069	8
Social	Public perception	0.3612	4
	Society participation	0.3432	6
	Potential conflict over land tenure status	0.2956	10

The results of the ANP analysis show that from the four aspects of the problem, each has its own priority. The priority of solutions in each aspect can be seen in Figure 2. In the ecological aspect, the priority problem is the failure of mangroves to grow. Improper planting techniques can cause the failure of mangroves to grow. In planting mangroves, it is necessary to pay attention to ecological conditions (substrate, water flow, species) and autecology of the ecological characteristics of mangrove species. Site selection is also an important thing in mangrove planting. The currents and waves on Sayung Coastal Zone are relatively large, so the newly planted mangroves are prone to be uprooted by the waves. Planting should be in a protected area either naturally or behind coastal structures. Community involvement in rehabilitation is also very important, not only in the implementation of planting but also in post-planting maintenance.
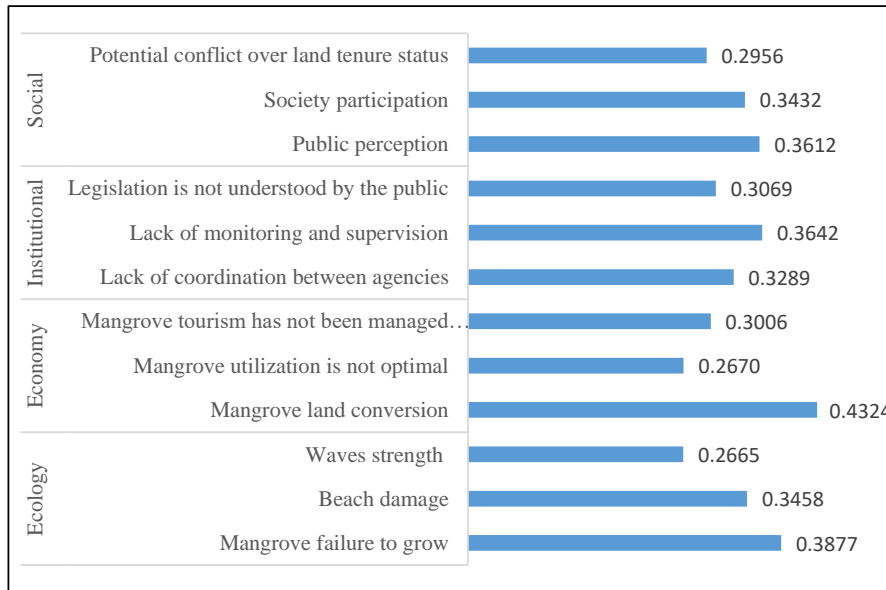

Figure 2 Priority of problems in each aspect

The priority problem in the economic aspect is the conversion of mangrove land. Land conversion is a change in the function of part or all of an area from its original function to another function. Conversion of mangrove land by cutting down trees and shifting their functions to other uses can have a comprehensive impact. Conversion of mangrove land can give results to people's incomes and opportunities to increase employment. Still, on the other hand, there is a decrease in mangrove areas which can cause ecosystem damage (Rusdianti and Sunito, 2012). Further, Rahman *et al*. (2020b) explain that the conversion of mangrove land impacts reducing the area and density of the mangrove ecosystem, thus affecting the structure and density status of the mangrove ecosystem.

Conversion of mangrove land into ponds is one of the causes of damage to the mangrove ecosystem. The conversion of mangrove land into ponds on Sayung Coastal Zone occurred in the 1980s (Marfai, 2011; Fikriyani and Mussadun, 2014; Putri *et al*., 2014). In the absence of natural protection, waves and currents attack the coast directly. This is one of the causes of coastal erosion on Sayung Coastal Zone (Marfai, 2011; Fikriyani and Mussadun, 2014). Coastal erosion is exacerbated by the inundation of seawater resulting in the decline of very large land functions in residential areas, rice fields, and ponds. Damage to rice fields and ponds has an impact on decreasing people's income and livelihoods. The conversion of mangrove land is currently no longer happening on Sayung Coastal Zone, but we need to be careful so that this activity does not happen again.

In the social aspect, the priority problem that arises is public perception. Perception in general, is often interpreted as the perspective of society or a person towards an object, be it physical or social objects (Setiawan *et al*., 2017). The community's perception of the mangrove ecosystem is very important because it

will relate to their attitude in interacting with mangroves. As users who are in direct contact with the ecosystem every day, the community is expected to have good knowledge about the mangrove ecosystem. Thus the mangrove ecosystem can grow and provide optimal benefits to the community.

The priority problem in the institutional aspect is the lack of monitoring and supervision. Supervision and monitoring of the mangrove ecosystem on Sayung Coastal Zone has not been maximized, this is due to the lack of personnel on duty. The government needs individuals or groups that can actively maintain, monitor, and supervise mangroves from various destructive utilization activities.

Priority Solutions for Mangrove Ecosystem Management

The results of the ANP, which show the priority solutions in the management of the mangrove ecosystem on Sayung Coastal Zone are presented in Table 3. The first priority solution is the rehabilitation and conservation of the mangrove ecosystem. The second priority is increasing community participation. The third priority is supervision and monitoring by involving local communities.

Table 3 ANP results on priority solutions

| Aspect	Solution	Normalized by cluster	Ranking
Ecology	Erosion management	0.2938	8
	Autecological and technical knowledge of planting	0.2445	11
	Mangrove rehabilitation and conservation	0.4616	1
Economy	Ecotourism development	0.4023	4
	Silvofishery development	0.2870	9
	Business development made from mangroves	0.3107	7
Institutional	Supervision by involving the community	0.4108	3
	Improved cross-sectoral coordination	0.3185	6
	Socialization of laws and regulations	0.2707	10
Social	Land status conflict resolution policy	0.2272	12
	Counseling and mentoring	0.3394	5
	Increased community participation	0.4335	2
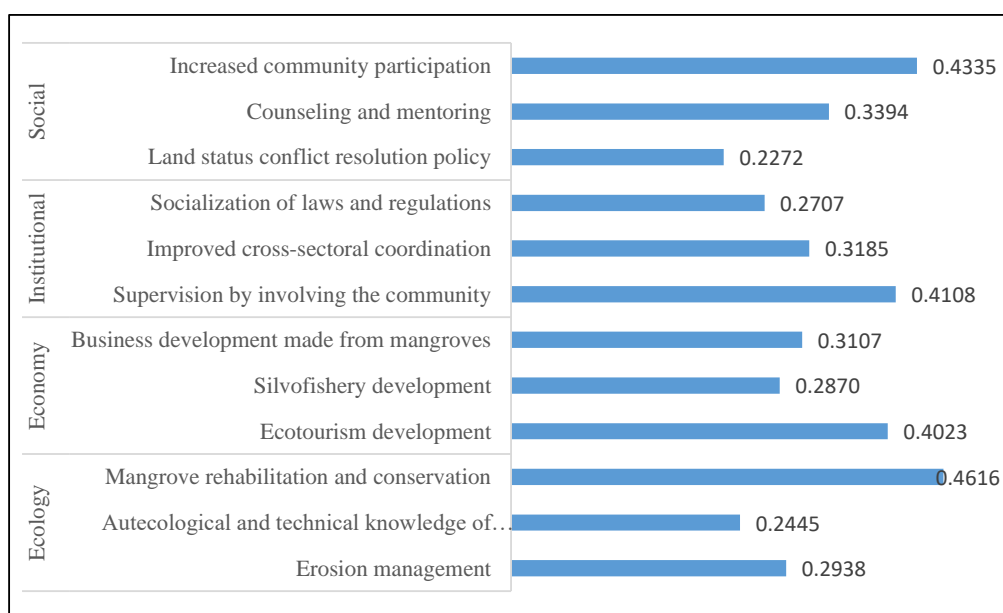
Figure 3 Priority of solutions in each aspect

Figure 3 shows the priority problems in each aspect. In the ecological aspect, the priority solution is the rehabilitation and conservation of mangrove ecosystems. Rehabilitation is an activity that aims to change the damaged ecosystem to a more balanced alternative (Brown, 2006). Rehabilitation activities are carried out to restore damaged mangrove conditions so that the mangrove ecosystem can carry out its functions properly. This is in accordance with Bengen (2001a) that the main concept that can be applied in managing and preserving mangrove ecosystems is the protection and rehabilitation of mangrove forests. One way that can be done to protect the existence of the mangrove ecosystem is to make it a conservation area or green belt along the coast.

The best defense to protect an area from abrasion is the mangrove forest (Bengen, 2001b). The results of the study by Handayani *et al.* (2020b) stated that mangrove rehabilitation on Sayung Coastal Zone needs to be continued to improve the quality and quantity of the mangrove ecosystem, this is because services related to coastal erosion control are in a position that tends to be in deficit. Rehabilitation or planting of mangroves on Sayung Coastal Zone needs to be combined with coastal buildings. This is because the oceanographic conditions on Sayung Coastal Zone are relatively strong. Coastal structures or breakwaters function to reduce currents and waves, capture sediment, and protect newly planted mangroves from the waves. Mangroves that successfully grow and develop will hold mud or fine sediment so that the mangrove land becomes wider and accelerates the formation of soil or sediment deposits. The results of Ismanto's research (2018) state that the highest ability to exist coastal structures to capture transport sediments on Sayung Coastal Zone is breakwater and coastal belts.

In preparing the rehabilitation plan, physical, biological, and social approaches are used (DKP, 2008). The physical approach is done by building physical buildings to reduce the strong oceanographic factor. As the results of previous studies, improving the sustainability of mangrove ecosystem management in Sayung on the ecological dimension is to pay attention to oceanographic conditions and prevention of coastal erosion. The biological approach is carried out by planting mangroves as a natural protector of the coast. The social approach is carried out by increasing community participation in preventing coastal erosion and managing mangrove ecosystems.

The priority solution in the economic aspect is the development of mangrove eco-tourism. Eco-tourism is a concept of utilizing natural resources with a conservation approach for tourism development (Yulianda, 2019). Eco-tourism is an alternative program that can be applied to improve the welfare of local communities and efforts to anticipate damage to the mangrove ecosystem (Wardhani, 2011). Eco-tourism activities also support biodiversity knowledge and protection. Based on the definition and concept of eco-tourism, the development of eco-tourism should be able to ensure the sustainability of the mangrove ecosystem and provide economic and social benefits for the local community.

Bedono Village currently has mangrove tourism in 2 locations, namely mangrove tourism, integrated with cultural tourism in Tambaksari Hamlet, and mangrove tracking in Bedono Hamlet. At this location, there are still many shortcomings that must be addressed, including road access to the location, tracking in mud and other facilities. Eco-tourism development on Sayung Coastal Zone should be supported by natural attractions, infrastructure, transportation, accommodation, adequate infrastructure, and optimal visitor services to attract visitors and tourists. Surodadi and Timbulsloko villages do not yet have mangrove tourism. The mangrove ecosystem in the village has the potential to be developed into eco-tourism, supported by the residents' desire to have mangrove tourism. The development of mangrove eco-tourism at each location should have certain characteristics and special attractions. In the management of mangrove eco-tourism, the management agency should come from the local mangrove group. In this case, the local government plays a role in directing policies in eco-tourism and conservation. The development of mangrove eco-tourism must be planned properly so as not to cause damage to the mangrove ecosystem.

On the social aspect, the priority solution is to increase community participation. The success of the rehabilitation and conservation of mangrove ecosystems is determined by the participation of the local community. This is because the local community has a direct interest in the mangrove ecosystem and its

ecosystem services. Rahman *et al.* (2020a) added that the management of mangrove ecosystems could not be separated from the role of the community because the community is the actor and target of management. According to Nurrohmah *et al.* (2016) a participatory approach to natural resource management is expected to strengthen the capacity of communities living around natural resources to manage these resources. It is also a way to ensure that the community is part of the beneficiary. The results of previous research showed that community participation in Bedono Village and Timbulsloko Village was in the high category, while Surodadi Village was in the sufficient category. The assessment of community participation in Sayung Coastal Zone is carried out in 4 aspects, namely (1) Participation in decision making, (2) Participation in program implementation, (3) Participation in enjoying the results or benefits, and (4) Participation in program evaluation. In general, community participation in Sayung Coastal Zone is in the high category. Although participation is in the high category, the community needs continuous assistance and direction so that participation can increase. Increased community participation will contribute positively to sustainable mangrove management.

In the institutional aspect, the priority of the solution is supervision and monitoring by involving the community. Rehabilitation and conservation activities require continuous monitoring, monitoring and maintenance. Participatory supervision involving the local community can solve the lack of human resources for the apparatus on duty. Communities as users who live and are in direct contact with the ecosystem are expected to be able to monitor the sustainability of the mangrove ecosystem. The Sayung community's concern for mangrove conservation is relatively high. This can be seen from the community's attitude when they see someone logging or destroying mangroves; they reprimand and give advice. Participatory monitoring can be done by maximizing the role of existing community groups. The coastal community groups in the research location include the Marine Mangrove Group and the Bina Karya Group in Bedono Village, the Barokah Mangrove Group in Timbulsloko Village, and the Natural Blessing Group Surodadi Village. The village government strongly supports the supervision and monitoring of the mangrove ecosystem in their area. This can be seen from the issuance of regulations on mangrove management which are accommodated from local wisdom. In Bedono Village there is Village Regulation No. No. 7/15/XII/2012 of 2012 concerning the Management of the Coastal and Marine Areas of Bedono Village. Timbulsloko Village has Village Regulation No.145/236/IV/2014 of 2014 concerning the Management of Coastal and Marine Areas of Timbulsloko Village. Similarly, Surodadi Village has Village Regulation No. 004/IX/GERHAN/2004 of 2004 concerning Conservation of Mangrove Forests.

CONCLUSION

In this study, priority problems and solutions for managing mangrove ecosystems on Sayung Coastal Zone were identified in four aspects: ecological, economic, social, and institutional. The results showed that the optimization strategy of mangrove ecosystem management on Sayung Coastal Zone could be achieved by focusing on strategic priorities, namely: 1) rehabilitation and conservation of mangrove ecosystems; 2) increasing community participation; 3) monitoring and monitoring involving the community; 4) developing mangrove eco-tourism. Optimal mangrove ecosystem management strategies can be achieved if there is good coordination between all parties. Optimal management will ensure the sustainability of the mangrove ecosystem to provide ecosystem benefits/services for the surrounding community.

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