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Sustainability level of mangrove forest management based on RAP-MForest approach in Pancer Cengkrong, Trenggalek District, Indonesia

AGRA DEWI SABRINA[1], ANANDA RILO RAMADHANDI[1], ALYA AFRA INAS NUR[1], NOR LIZA[2], SUTARNO[2], CHEE KONG YAP[3], MUHAMMAD INDRAWAN[1], AHMAD DWI SETYAWAN[1,4,♥]

[1]Department of Environmental Science, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret. Jl. Ir. Sutami 36A, Surakarta 57126, Central Java, Indonesia. Tel./fax.: +62-271-663375, ♥email: volatileoils@gmail.com

[2]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret. Jl. Ir. Sutami 36A, Surakarta 57126, Central Java, Indonesia

[3]Department of Biology, Faculty of Science, Universiti Putra Malaysia. 43400 UPM Serdang, Selangor, Malaysia

[4]Biodiversity Research Group, Universitas Sebelas Maret. Jl. Ir. Sutami 36A, Surakarta 57126, Central Java, Indonesia

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Abstract. *Sabrina AD, Ramadhandi AR, Nur AAI, Liza N, Sutarno, Yap CK, Indrawan M, Setyawan AD. 2022. Sustainability level of mangrove forest management based on RAP-MForest approach in Pancer Cengkrong, Trenggalek District, Indonesia. Intl J Bonorowo Wetlands 12: 82-88.* Mangrove forest area is a coastal resource that benefits the community's welfare. Protection and preservation of the mangrove ecosystem need to be carried out by taking into account various aspects to achieve sustainability. This study aims to analyze the level of sustainability of mangrove forest management and the contributing factors in the Pancer Cengkrong Mangrove Forest area in Karanggandu Village, Trenggalek District, East Java, Indonesia. This research was conducted in June 2022 through field interviews and literature studies. Three dimensions (ecological, economic, and social) were selected, along with their attributes. Each attribute was scored to indicate the status of sustainability. Then, the data obtained were processed by Multi-Dimensional Scaling (MDS) analysis using the Rapid Appraisal for Mangrove Forest (RAP-MForest) method. Furthermore, leverage analysis determines the sensitive attributes in each dimension. The results depicted that management in Pancer Cengkrong Mangrove Forest is less sustainable in the economic dimension and fairly sustainable in the two remaining dimensions. The social dimension achieved the highest sustainability index value at 72.92. Furthermore, knowledge of the sustainability index and sensitive factors can help provide recommendations for management in the Pancer Cengkrong mangrove area to achieve a sustainable level. In this case, the economic dimension should be more concerned with promoting environmentally sustainable development.

Keywords: Mangrove management, MDS, Pancer Cengkrong, RAP-MForest

INTRODUCTION

Mangroves are a distinctive community of tropical and subtropical coastal vegetation that grows and develops in tidal areas protected by mud or sandy mud substrates (Prihadi et al. 2018). In tropical and subtropical areas, mangrove forests grow in saline sediments in coastal and estuarine environments (Malik et al. 2017). Mangrove forest areas are known as coastal resources that play an important role in life. That is because the mangrove forest area has the potential to improve community welfare in 3 aspects, consisting economic, social, and environmental (Hamzah et al. 2020).

Mangrove forests have various benefits, including as a habitat for fish and crustaceans, effective sediment traps, and a role in nutrient recycling (Datta et al. 2012). Mangrove forests also play a role in protecting coastlines, supporting coastal fisheries, producing useful forest products, and as a place for a thriving ecotourism industry (Kusmana 2015). Another benefit that can be obtained from mangrove forests is that they can provide environmental services where mangrove forests can absorb more carbon than other plants on earth (Dinilhuda et al. 2018). That is useful in reducing the amount of carbon in the atmosphere, which shows the important role of mangrove areas in global warming mitigation (Senoaji and Hidayat 2016).

However, like other ecosystems, mangrove forests can also experience natural disturbances from nature and human anthropogenic activities (Alongi 2008). According to Abino et al. (2014), the mangrove area is one of the most threatened areas in the world. It can be experienced loss by a natural disaster, such as the tsunami that occurred in 1996 that affected more than 200 Ha mangrove degraded in Biak Island, Indonesia (Baigo et al. 2019). In addition, the location of the mangrove ecosystem, which is close to residential communities, makes the high level of utilization of mangrove forest products such as overfishing, extraction of wood for fuel, and other detrimental activities (Pattimahu et al. 2017). In Indonesia, it was reported that sand mining led to the decrease of carbon stock in the mangrove area (Slamet et al. 2020), and land use change to brackish water ponds and timber exploitation has been the main factor of the mangrove area degradation over the centuries in outside of Java Island (Ilman et al. 2016).

In managing mangrove forests, the economic, social, and ecological aspects must be maintained to create harmony and have no negative impact on other aspects. However, according to Mughofar et al. (2018), the community's knowledge about the Pancer Cengkrong mangrove forest area regarding the function of the mangrove forest is still very limited. That is evidenced by the decreasing area and community of mangrove forests caused by the exploitation of mangrove forests for fuel and household furniture. In the Pancer Cengkrong mangrove forest area, there are about 32 hectares in lightly damaged condition and about 5 hectares in heavily damaged condition (Dinas Kelautan Perikanan, 2016 in Paringsih et al. 2018). Therefore, this study aims to analyze the level of sustainability of mangrove forest management and the contributing factors in the Pancer Cengkrong Mangrove Forest area in Karanggandu Village, Watulimo Sub-district, Trenggalek District, East Java, Indonesia. This location was chosen because of the limited information about the analysis of the sustainability of mangrove forest management in this area. In contrast, the area has a profound potential to improve community welfare and promote ecological function. This study supposes that the condition of the mangrove forest in Karanggandu Village can be maintained and can support the welfare of the people who live around it.

MATERIALS AND METHODS

Study area

The research was conducted in the Pancer Cengkrong Mangrove Forest, situated in Karanggandu Village, Watulimo Sub-district, Trenggalek District, East Java, Indonesia (Figure 1), which is about 43 km from Trenggalek capital city. The Karanggandu Village is geographically located at coordinates 8º17'52' 'S 111º42'25"E. This research was done in June 2022.

Procedures

Data collection

The sustainability of Pancer Cengkrong Mangrove Forest in Karanggandu Village was examined based on three dimensions, consisting of ecological, economical, and social factors. A combination of literature study and interviews will gain data regarding ecological factors. At the same time, the remaining dimensions were investigated through interviews with the targeted informants. During the interview, respondents were asked about 22 attributes, including eight ecological, six economical, and eight social (Table 1). In this study, the attributes of the sustainability of the mangrove forest ecosystem refer to the previous research conducted by Melo et al. (2020) and Yuliasamaya (2021). Each attribute in each dimension is given a score indicating the sustainability of that dimension. Scores are given on an ordinal scale ranging from 0-2, which are interpreted as good to bad or low to high, depending on the sustainability criteria of each dimension. A bad value indicates an unsustainable condition, while a good value indicates a sustainable condition could be achieved. The scoring system refers to the previous research by Melo et al. (2020).

A purposive sampling method was used to choose the respondents who deeply correlated with the mangrove forest (Yuliasamaya 2021). As a result, researchers interviewed 40 informants: mangrove area managers, fishermen, traders, inhabitants surrounding the mangrove forest, and the Karanggandu Village's authorities. The respondents were 20-80 years old, with 20 men and 20 women.

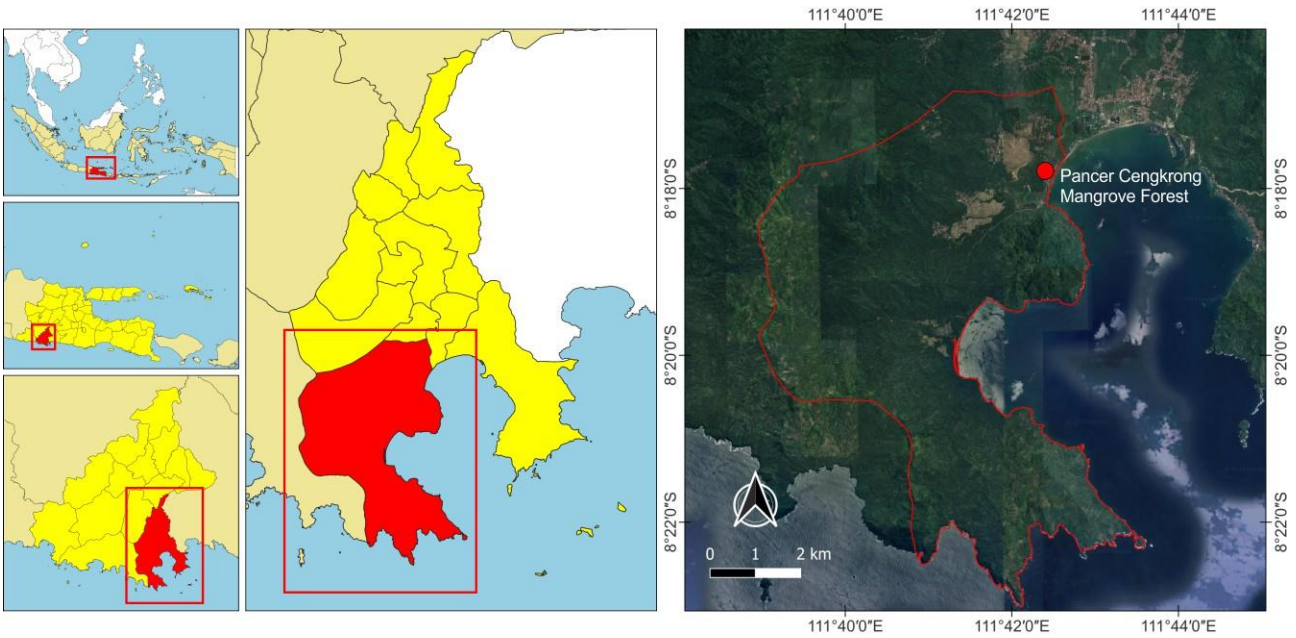

Figure 1. Research area in Pancer Cengkrong Mangrove Forest in Karanggandu Village, Trenggalek District, East Java, Indonesia

Table 1. Dimensions and attributes of the sustainability value index of Pancer Cengkrong Mangrove Forest management in Karanggandu Village, Watulimo Sub-district, Trenggalek District, East Java, Indonesia

Ecological dimension	Economical dimension	Social dimension
Mangrove density	Income to minimum wage	Participation in mangrove management
Mangrove cover	Land use zoning	Public awareness of the importance of mangroves
Mangrove land pressure	Mangrove usage by people	Local wisdom
Mangrove diversity	Direct economic value of mangrove	Community knowledge about mangroves
Mangrove ecosystem rehabilitation	Stakeholder engagement	Community education level
Mangrove fauna diversity	Mangrove utilization inventory	Community access to mangrove forests
Salinity level		Mangrove damage by the community
Coastline changes		Conflict over mangrove use

Table 2. Category of sustainability status of mangrove forest management (Sahputra et al. 2022)

Index value (%)	Category
0.00-25.00	Unsustainable
25.01-50.00	Less sustainable
50.01-75.00	Fairly sustainable
75.01-100.00	Sustainable

Table 3. The sustainability index from each dimension

Dimension	MDS result	Category
Ecology	56.50	Fairly sustainable
Economy	27.7	Less sustainable
Social	72.92	Fairly sustainable

Data analysis

The analysis used in this study was carried out by Multi-Dimensional Scaling (MDS) with the Rapid Appraisal for Mangrove Forest (RAP-MForest) method. This method enables us to see the sustainability level of the ecosystem by evaluating essential dimensions. Furthermore, it could show the important factors that play prominent roles in improving ecosystem conditions (Pitcher and Preikshot 2001).

After obtaining the scoring data, each was analyzed using Multi-Dimensional Scaling (MDS) to determine the relative position of mangrove forest management. The index scale for the sustainability of mangrove forest management ranges from 0-100% (Table 2). After that, the sustainability index value of each dimension is visualized in the form of a kite diagram, which is shaped as a triangle with symmetry determined by the index of each dimension. The angle with the greatest value indicates the most sensitive attribute. The last step is conducting the leverage analysis to determine the influencing aspects of each of the analyzed indicators (Melo et al. 2020).

RESULTS AND DISCUSSION

Results

This study managed to evaluate the sustainability condition of the Mangrove Forest in Karanggandu Village, from ecological, economical, and social dimensions. The assessment was done using Rapid Appraisal of Mangrove Forest (Rap-MForest) by examining 22 indicators from three dimensions. The study results in Figure 2 shows that the mangrove ecosystem management in Karanggandu Village tends to be more dominant in two aspects, namely the social and ecological aspects. Thus, the economic factor needs more attention to achieve sustainability. From the ecological perspective, it shows two main sensitive attributes with the highest value, namely the diversity of mangrove fauna with a value of 4.08 and the pressure of mangrove land with a value of 3.75 (Figure 3). The sustainability index value of the ecological dimension was 56.50 (fairly sustainable) (Table 3). In the economic dimension, there is the highest sensitive attribute, namely the inventory of mangrove utilization valued at 9.42. Another important sensitive attribute is the community's use of mangroves by 5.84 (Figure 4). The sustainability index value of the economic dimension was 27.7 (less sustainable) (Table 3). Lastly, the main sensitive attribute in the social dimension is local wisdom, with a score of 8.14, and community knowledge about mangroves scored 6.19 (Figure 5). Finally, the sustainability index value of social culture was 72.92 (fairly sustainable) (Table 3). From the given results, more consideration needs to be given to those significant attributes from every dimension to achieve the ecosystem's sustainability.

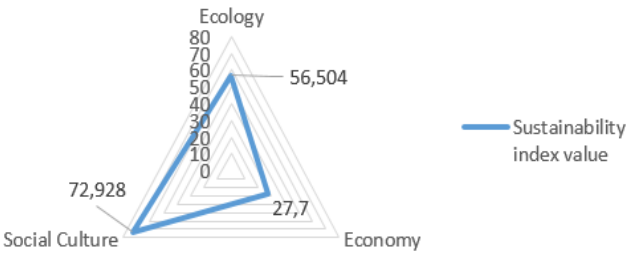

Figure 2. Kite diagram of mangrove management sustainability index values in Pancer Cengkrong Mangrove Forest, Indonesia

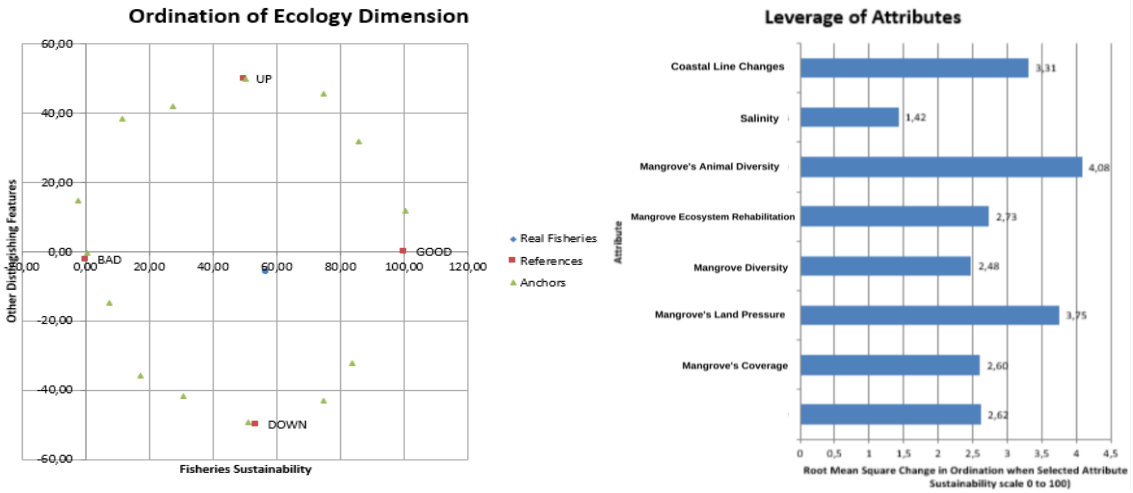

Figure 3. Sustainability index and attribute leverage in the ecological dimension

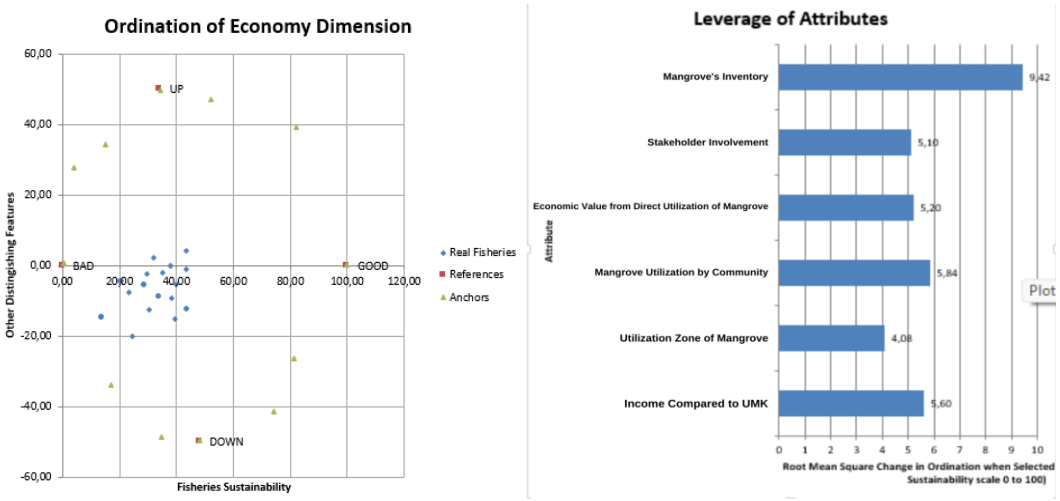

Figure 4. Sustainability index and attribute leverage in the economic dimension

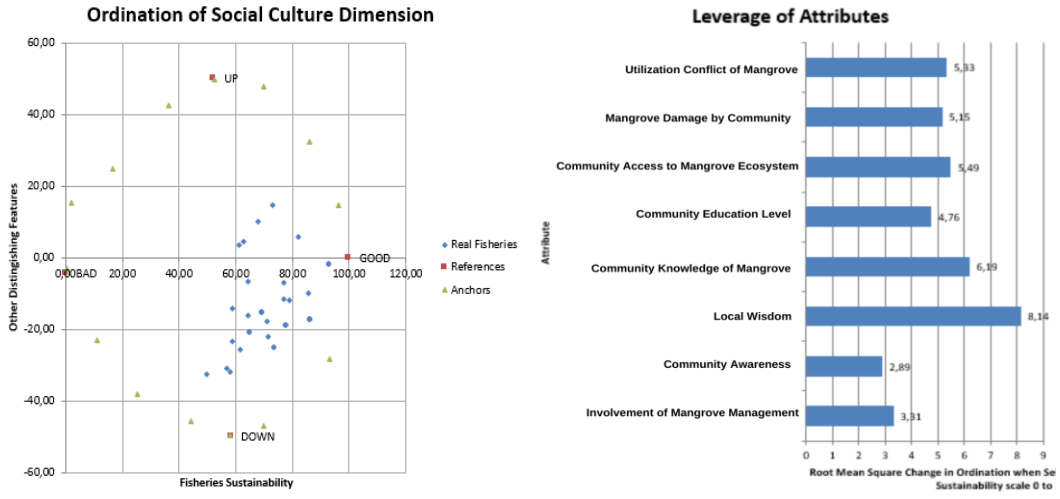

Figure 5. Sustainability index and attribute leverage in the social dimension

Discussion

Sustainable development has the principle of being able to meet human needs without impacting the environment. Using the RAP MForest method, the assessment of sustainability status produces a sustainability index value for each dimension. Therefore, at least three main dimensions will support it, namely the ecological, economic, and socio-cultural dimensions (Rahmayanti and Ananda 2017).

Mangrove ecosystem management status

The results of the RAP MForest analysis show that the mangrove ecosystem management in Karanggandu Village, Trenggalek District, is classified as less sustainable. That happened because the management of the mangrove ecosystem was not balanced yet in three sustainability aspects. Mangrove area management must proportionally consider the sustainability of three aspects; if there is a discrepancy in one of these aspects, it will cause an imbalance, leading to negative impacts on the others. The maintenance of the mangrove ecosystem in Karanggandu Village is routinely carried out by planting and repairing facilities to support ecotourism activities. Additionally, the local community has already reached a level of understanding about the importance of protecting the mangrove ecosystem. However, the existence of the Kadilangu mangrove cannot yet support the surrounding community's economic conditions. In addition, the pandemic conditions caused tourists to decline, so it impacted the economic conditions of parties related to the mangrove ecosystem. Based on the results in Figure 5, the social and ecological dimensions are considered quite sustainable, and the economic dimensions are considered less sustainable.

The highest sustainability index value in this study is the social dimension. Local involvement is considered the key factor in ecosystem management. Ouwor et al. (2019) said that communities have an essential view on this matter; thus, their participation in regulating is necessary. Raising their awareness to involve in conservation practices is a crucial aspect. Some determinant factor is needed to engage their willingness to participate in this activity (Roy 2014). Stone et al. (2008) study showed that the authority needs to provide the community with ecosystem services to promote conservation activity. In addition, the economic dimension with the lowest index needs to be considered. It requires cooperation between stakeholders in the development of economic activities such as ecotourism and entrepreneurship around the site to support economic sustainability.

Attributes from each dimension

The multi-dimensional analysis (ecology, economy, and social) of the Pancer Cengkrong Mangrove Forest ecosystem shows the sustainability level of various attributes as the assessment factors. Leverage analysis examined which attributes most influence sustainability management (Pitcher and Preikshot 2001). A great value showed the sensitive indicator in leverage analysis. Furthermore, management sustainability could be achieved by giving more attention to those important indicators (Melo et al. 2020).

The analysis of the ecological dimension leverage (Figure 3) shows the two highest influential attributes, namely the diversity of mangrove fauna with a value of 4.08 and mangrove pressure at 3.75. Regarding fauna diversity, Sawitri et al. (2019) reported that the fauna found in the Pancer Cengkrong mangrove Forest were 18 families with 30 species, spreading in mangrove and residential areas. This condition is in the moderate category, with *Faunus ater* as the highest Important Value Index species. The higher the diversity index, the better the level of mangrove health (Sari et al. 2019). It is because mangrove areas provide suitable habitats for fauna to thrive, such as breeding grounds and foraging areas (Zakaria and Rajpar 2015). For instance, canopy cover depletion could negatively impact the crab diversity in a mangrove forest in southern Kenya (Barbanera et al. 2022). Another major sensitive attribute is mangrove land pressure. Because the coastal communities in Pancer Cengkrong Mangrove Forest have been knowledgeable about the importance of this area to their livelihood, any damage from anthropogenic activities, for instance, land pressure, is uncommon. Another human activity that usually drives mangrove ecosystems in danger is the expansion of aquaculture and residential areas (Moschetto et al. 2021; Phan and Stive 2022). Land pressure profoundly contributes to threatening forest areas by increasing the critical land area (Kurnia et al. 2020).

Subsequently, the important factors in achieving sustainability from an economical dimension are mangrove utilization inventory and mangrove usage by people. The local authorities guide what kind of activities are allowed and prohibited in the mangrove area. That is reinforced by the application of fines and even imprisonment for violators of the rules. In addition, the locals of Karanggandu Village have achieved a level of understanding about protecting the mangrove ecosystem; thus, there is a minimal illegal activity in the mangrove area. The previous research proposed a similar result by Damastuti et al. (2022) in Central Java, Indonesia, which mentioned that the highest result of conservation effort in mangrove areas was achieved by applying a community-based mangrove management approach. Thus, the synergy between locals and the governments makes strong protection of the mangrove ecosystem, leading to a balance between human needs and nature.

Nearby communities around the Pancer Cengkrong Mangrove Forest benefit from the ecotourism it provides. The location of ecotourism in the mangrove area provides job opportunities for local residents, such as traders, managers, and fishermen. In addition, coastal inhabitants also gain a huge advantage from the fisheries sector. Therefore, the community realizes the importance of preserving the mangrove forest, so they gain more advantages provided by the mangrove, both economically and ecologically. Such as a finding in Mexico, more than 80% of coastal societies willingly participate in mangrove protection efforts because they assume that mangrove

ecosystem is essential and provides advantageous services to communities (Jadin and Rousseau 2022).

Lastly, the keystone attribute from the social dimension is local wisdom at 8,14. Local culture in the nearby Pancer Cengkrong is called "*labuh laut*," which is held annually. This activity is usually carried out at Prigi Beach, about 3.7 km from Pancer Cengkrong, by fisherman communities. The traditional ritual is conducted as a gratitude for the marine products provided by nature and a wish to be blessed. Before the traditional ceremony, the community makes traditional food (*Lodho*) in large quantities. The event's highlight was floating a giant *tumpeng* into the middle of the sea, which was participated by local people and tourists.

Community knowledge about mangroves became the second highest sensitive attribute, valued at 6,19. The people of Karanggandu are well aware of the benefits and applicable regulations related to the mangrove ecosystem. The use of mangroves as a support for economic activities such as ecotourism and protecting coastal areas as an ecological function of mangroves is one of the driving factors for conservation and increasing public knowledge about the mangrove ecosystem (Ritohardoyo and Ardi 2014). Therefore, community awareness towards conservation and sustainability of mangrove ecosystems because the community plays an important role in maintaining the stability of the mangrove ecosystem both in the ecological and social dimensions.

In conclusion, ecosystem management in the Pancer Cengkrong Mangrove Forest is fairly sustainable. Of the three aspects, namely economic, social and ecological, the economic aspect is the category with the lowest sustainability value. At the same time, the other two aspects are classified as fairly sustainable. The sustainability index is needed to determine the level of sustainability of mangrove forest management to preserve and support local communities welfare. Knowing the important factors in each dimension is also important to know the priority steps that must be taken to achieve sustainable management. Because every aspect in each dimension represents the factor in reaching the full potential and benefit of Pancer Cengkrong Mangrove Forest, based on the research that has been done, it can be seen that the economic factor still needs more attention to achieve the level of sustainability. The mangrove ecosystem management in Karanggandu Village tends to be more dominant in social and ecological dimensions. Thus, the policymakers and the locals should put a bigger effort into improving the economy without adverse impacts on environmental management. Local governments can release policies regarding the sustainable use of mangroves, and the communities can use mangroves to help their economic needs, such as for fish nurseries, manufacture of food products, and products made from mangrove trees.

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