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Research Article

Analysis of mangrove ecosystem sustainability in the Biringkassi mangrove area, Pangkep District, Indonesia

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Abstract
Mangrove forests are found on coastlines in tropical and subtropical areas. The mangrove tree looks strange because its roots are partially above water, making it look like it is standing. Mangrove forests are coastal forests and critical habitats that act as nurseries and protect coasts from erosion. Determining the current status of sustainable management of mangroves is very important as a basis for planning future policies. The purpose of this study was to review the current status of mangroves and analyze the sustainability value of the mangrove ecosystem sustainability in the Biringkassi mangrove area, Pangkep district, Indonesia. This study is descriptive with a quantitative approach to conducting an inventory of mangrove ecosystems, including biophysical, social, economic and institutional data. Analysis of the sustainability of mangrove management The sustainability of the mangrove ecosystem was analyzed using the Rapid Assessment Fisheries (RAPFISH) software with the Multidimensional Scaling Method (MDS) method. The four aspects assessed were ecological, economic, social and institutional. The results of the sustainability analysis from the four dimensions showed that the ecological and institutional aspects have a moderate state of sustainability, but the economic and social aspects have a less sustainable state. Multidimensional analysis showed less sustainable management. Leverage analysis of 24 multidimensional attributes revealed eight highly influential attributes that can lead to change in management if not implemented correctly. Meanwhile, the analysis results should be maintained for properties that achieve low leverage so that the management value does not decrease.

Keywords: Mangrove, Multidimensional Scaling Method (MDS), Rapid Assessment Fisheries (RAPFISH), Sustainable status

INTRODUCTION

Mangrove ecosystems are among the most productive, with many natural resources and economic benefits (Azam and Unjah, 2017). They have many functions for the environment and society through their ecosystem services (Ke *et al*., 2022). In addition, They help to reduce environmental damage as they sequester carbon, control flooding and erosion, stabilize beaches and fish nurseries sea, anti-storm, filter pollution (Chow, 2018), resist strong sea winds and become a buffer zone for seawater intrusion (Larasati *et al*., 2022).

Mangrove ecosystems provide a variety of ecosystem services that are essential to human life, especially in coastal areas (Bimrah *et al*., 2022) and perform important functions in ecosystems (John, 2014). Therefore, the conservation and restoration of mangroves must be considered to maintain and enhance biodiversity (Basyuni *et al*., 2022; Cecep, 2015; Khairuddin *et al*., 2016).

Careless use of mangrove resources is linked to the degradation of the environment and the entire mangrove area (Sina *et al*., 2017). The global loss of mangroves is largely due to over-exploitation (Mbatha *et al*., 2022). The sustainable management of mangrove ecosystems is required to improve the state of the coastal environment (Asyiawati and Hindersah, 2020). The sustainable use of mangrove resources requires monitoring the condition of the forest over time (Mbatha *et al*., 2022; Valiela *et al*., 2001). To analyze the sustaina-

ble state of mangrove ecosystem management, a sustainability assessment was performed using Raffis technique to develop a more sustainable mangrove management strategy (Mbatha *et al*., 2022; Suryana *et al*., 2012).

Mangrove management in Biringkassi should aim to create productive and sustainable forests. Determining the current status of sustainable management of mangroves is very important as a basis for planning future policies. Suppose the mangrove status in Biringkassi is less than sustainable. It can be assumed that the political and institutional conditions for mangrove management in Biringkassi do not work well and vice versa (Kuvaini *et al*., 2019). The present study aimed to review the current status of mangroves and analyze the sustainability value of the mangrove ecosystem of the Biringkassi Mangrove area, Pangkep District, Indonesia.

MATERIALS AND METHODS

Study area

Sulawesi Island is an island located in the Eastern Region of Indonesia. South Sulawesi is a province located at the southern tip of Sulawesi Island with an area of 62,482.54 km². There are 21 districts in South Sulawesi and 3 cities. The Province of South Sulawesi is directly bordered by Central Sulawesi and West Sulawesi in the north, Bone Bay and Southeast Sulawesi in the east, Makassar Strait in the west, and the Flores Sea in the south.

Pangkajene and Kepulauan Regency is one of the regencies in South Sulawesi where Astronomically, Pangkajene dan Kepulauan Regency is located between 4°40' LS and 8°00' South latitude, and between 110° BT and 119°48'67" BT East longitude. In terms of geographic position, Pangkajene dan Kepulauan Regency has boundaries as follows: North – Barru Regency; South– Maros Regency; East – Maros Regency and Bone Regency; West – Makassar Strait. Pangkajene dan Kepulauan Regency has an area of 1,112.29 km2 and has 115 islands (Central Bureau of Statistics, 2022) . This research was conducted in the Biringkassi mangrove area, Bulu Cindea Village, Bungoro District, Pangkajene Kepulauan Regency of South Sulawesi Province. Study area is shown in Fig. 1. This research was carried out from September to December 2022.

Research approach and type

This research is descriptive with a quantitative approach with an aim to dig up facts on the location by using the observation method to carry out an inventory of the condition of the mangrove ecosystem, including biophysical, social, economic and institutional data.

Equipment and materials

Tools and equipment used included GPS (global positioning system), a roller to create cross-sections and determine the distance between cross-sections, a tape measure to measure tree circumference, a Digital camera and a questionnaire.

Data collection techniques

This study used two sources. Primary data was collected through observations and direct observations in the field as well as informants from the Department of Fisheries, the Department of Forestry, the Department of

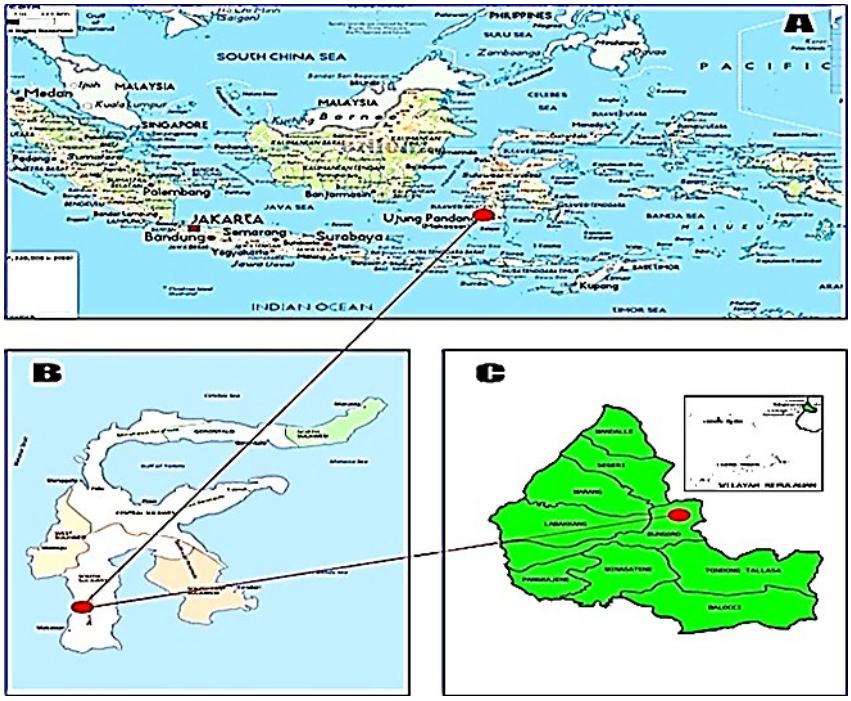

Fig. 1. *Study area of Pangkajene Kepulauan Regency, South Sulawesi Province, Indonesia.*

Environment, the village authorities, and the community sub-district Biringkassi of Pangkajene Kepulauan district. The researcher used observation as a basic method to conduct an inventory of the mangrove ecosystem's current status, including biophysical, social and economic data. Socioeconomic data was collected through interviews by purposeful sampling method.

Collecting data on mangrove vegetation

Mangrove data was collected using a composite method, namely cross-sections with nested right angles. This method aimed to find information about species composition, vegetation structure, community and distribution of species.

Collecting socioeconomic data of the community and determining the sustainability of the mangrove ecosystem

The Sustainable status of the mangrove ecosystem was determined using multidimensional scaling analysis through in-depth interviews with the required respondents (experts) based on their knowledge and competent experience. Respondents included the Director of the Fisheries Department, the Director of the Forestry Department, the Director of the Regional Development Planning Department (BAPPEDA), the Director of the Environment Department, the Head of Village, Scholars, Community Leaders and Non-Governmental Organizations (NGOs) . For secondary data obtained from research results and related documents. The identification of attribute data on RAPFISH referred to the assessment of RAPFISH by Pitcher *et al*. (2013) after being revised from the previous version, which was used to assess ecological and ecosystem factors such as those that will promote or hinder the sustainability of a resource.

Data analysis Analysis of the Mangrove Ecosystem

Ecological analysis was used to determine species density, relative density, species frequency, relative frequency, species dominance, relative dominance, and important value index (IVI) (Mueller-Dombois and Ellenberg, 1974). The importance value of a species ranges from 0 – 300 (Sambu *et al*., 2014). Important value index (INP) describes the influence or role of mangrove species in a mangrove community. An important value index was used to express its dominance and ecological success in an ecosystem (Nabi and Rao, 2012).

RESULTS AND DISCUSSION

Analysis of the sustainability of mangrove management

Analysis of the sustainability of mangrove ecosystems using Rapid Appraisal for Fisheries (RAPFISH) software with a Multidimensional scaling (MDS) method approach (Pitcher and Reikshot, 2001). The four dimensions assessed were ecological, economic, social, and institutional. The MDS method allows processing millions of data points with simple calculations by determining the position coordinates of each object in a multidimensional map so that the distance between mapping objects will correspond to the proximity value in the input data. The measure of closeness between pairs of objects is in the form of similarity values or dissimilarity values (Salami *et al*., 2012).

The RAPFISH method was carried out by determining the attributes of each dimension. Each attribute was given a value according to predetermined value criteria. The range of scores between 0 - 2 depended on each attribute's state, which was defined as "bad" and "good" values. Bad value was defined as the most unfavourable condition for sustainable mangrove ecosystem management. Meanwhile, good value was defined as the most favourable condition for sustainable mangrove management.

The data obtained from each attribute was then analyzed using RAPFISH software to determine the sustainability status of the resource. The status results describe the sustainability of each dimension assessed on a scale of 0 – 100 (Table 1). In the next stage, Monte Carlo simulation and leverage analysis were carried out. Monte Carlo simulation tests the confidence level of the total index value and each dimension (Pitcher and Preikshot 2001).

Sustainability of mangrove management in the Biringkassi mangrove area

The management of the mangrove ecosystem in the Biringkassi area is experiencing challenges ranging from ecological, economic, social and institutional problems. The sustainability of the mangrove ecosystem at the research location needs to be carried out by integrating all aspects and accommodating all multidimensional interests (ecological, economic, social and institutional). Analysis of the sustainability of the mangrove ecosystem in the Birangkassi area used the Multidimensional Scaling (MDS) method with the Rapid Appraisal analysis tool for the status of the mangrove Forest (Rap_Mforest). The dimensions analyzed in this study included ecological, economic, social and institutional dimensions. The ecological dimension consisted

Table 1. Categories of mangrove ecosystem management sustainability status based on the RAPFISH analysis index value

Index Value	Category
< 25	Not sustainable
26 – 50	Less sustainable
51 – 75	Quite sustainable
76 – 100	Sustainable

of 6 attributes: 6 of the economic, 6 of the social, and 6 of the institutional dimensions.

The value scale for the sustainability index of mangrove ecosystem management had a range of 0% to 100%. If the system under study had a value of more than 50%, then the system was categorized as sustainable and vice versa. The system was not categorised as sustainable if it was less than 50%. In this study, four categories of sustainability status were arranged based on a basic scale (0-100) (Cisse *et al*., 2014)

Ecology dimension

The attributes used in evaluating the ecological dimension were land use zoning, land pressure, rehabilitation, seed availability, abrasion and mangrove diversity. This shows that the ecological attributes in the ecological dimension are still sufficiently supportive to maintain the sustainability of mangrove ecosystem management in the Biringkassi mangrove area. The results of the ecological dimension sustainability index analysis are presented in Fig. 2

The environmental dimension in the form of mangrove diversity, land pressure, and abrasion does not negatively impact the sustainability of mangrove ecosystem management. The use of zoned mangrove land, rehabilitation, and availability of seeds support the sustainability of its management. Therefore, ecological attributes that positively impact the sustainability index value on the environmental dimension must be maintained to increase the sustainability index value on the environmental dimension. In the leverage analysis, three of the six attributes were considered leverage factors because their changes wre very sensitive to the value of the sustainability index on the environmental dimension. The results of the leverage analysis from the ecological dimensions are presented in Fig. 3.

The results of interviews with the village government and the local community said that the availability of natural seeds supports mangrove regeneration. This was due to the easy nature of mangroves to grow, especially in their habitat with suitable substrate characters. Naturally, the dominant species will continue to dominate the mangrove ecosystem, resulting in an imbalance of existing mangrove species. This can be seen from the observations in the field where the growth of the *Rizhopora mucronata* species dominates compared to other types of mangroves. The rehabilitation of mangroves at the research location was quite good. IT is just that this rehabilitation activity was less successful because it only involved the community in the implementation process. The community's non-involvement in the planning evaluation processes resulted in the rehabilitation activities being less than optimal. The optimal efforts are very important, so the mangrove is not degraded. Kusumaningtyas *et al*. (2019) stated that degraded mangroves cannot

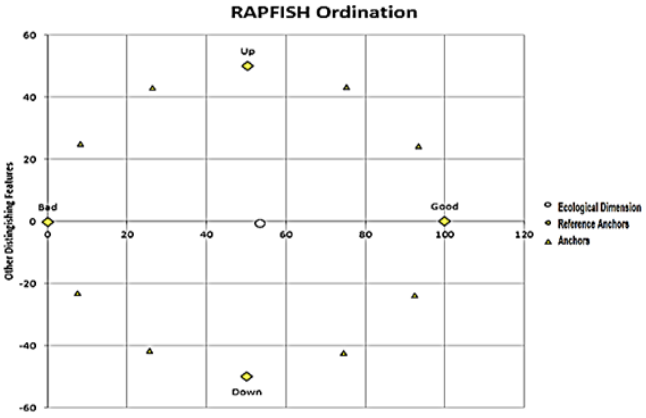

Fig. 2. *Ecological dimension sustainability index*

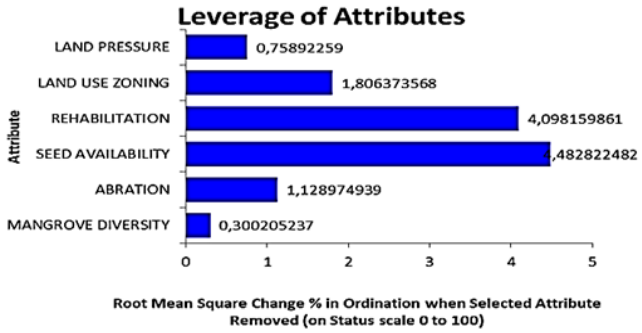

Fig. 3. *Attribute sensitivity values in the ecological dimension*

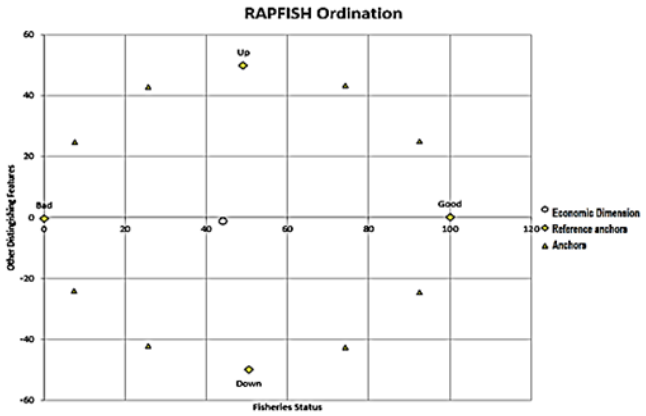

Fig. 4. *Economic dimension sustainability index*

maintain their surface elevation relative to seawater, resulting in increased abrasion. This extreme condition is a serious problem and must be addressed immediately so that the existence of mangrove forests can be well maintained (Lukman *et al.,* 2021). Therefore, an agreement between stakeholders and appropriate management efforts is needed to build a sustainable mangrove forest.

Economic dimension

Sustainability assessment on the economic dimension shows that the economic attributes in the economic dimension are less supportive of maintaining the sustainability of mangrove ecosystem management in the Biringkassi mangrove area. Attribute sensitivity values in the economic dimension are presented in Fig. 4.

The economic dimension factors in the form of area accessibility, the level of welfare of coastal communities, utilization of mangrove products, government budgets, other income, and the average minimum wage do not support the sustainability of mangrove ecosystem management at the study site. Based on the results of the leverage analysis presented in Fig. 5. It is known that the most sensitive attribute is the use of mangroves by the community, other income and government budgets for management

Community access to the Biringkassi mangrove area is relatively high. This can be seen from the large number of people who take wood and fishery products such as fish, crabs and shrimp from the mangrove forest. Open access to mangrove resources without clear regulations impacts damage to the mangrove ecosystem by the community. Besides that, people often use mangrove forests to benefit shrimp farming. Research by Do and Thuy (2022) has revealed that the productivity of shrimp pond cultivation would decrease if there were no mangrove ecosystems. The mangrove ecosystem can become a source of additional income for the local community by developing its potential. Community knowledge about the mangrove ecosystem must also be considered to increase sustainability. Low knowledge causes low understanding, participation, and community responsibility for managing mangrove ecosystems. Informal education needs to be provided about basic knowledge, counselling about processing mangrove products, and special assistance regarding nurseries and planting to increase sustainability status.

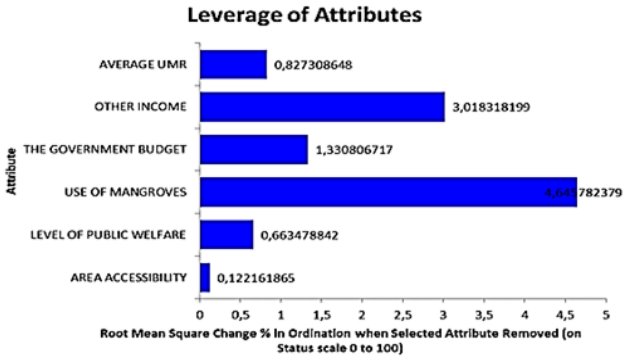

Fig. 5. *Value of attribute sensitivity in the economic dimension*

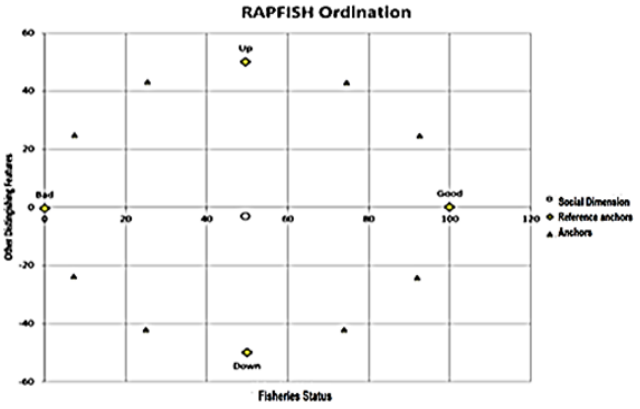

Fig. 6. *Social dimension sustainability index*

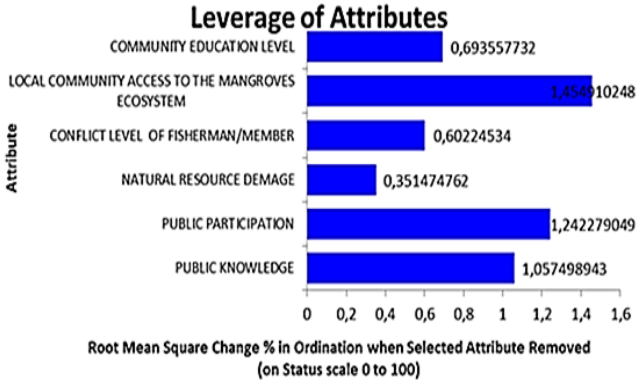

Fig. 7. *Attribute sensitivity value in the social dimension*

Social dimension

On the social dimension, six attributes influence the management of the mangrove ecosystem. Testing the sustainability status of mangrove management showed a sustainability index value of 49.78 (less sustainable). These attributes can have a negative impact if not managed properly in the future. The graph of social dimension sustainability coordination is presented in Fig. 6.

Of the 6 attributes of the social dimension analyzed, four attributes had a sensitive influence on the sustainability of mangrove ecosystem management. The results of the leverage analysis showed that the attributes that have a sensitive influence on managing mangrove ecosystems are local community access to mangrove ecosystems, participation, knowledge and level of education. The results of the leverage analysis on the social dimension are presented in Fig. 7.

Community access to the Biringkassi mangrove area was relatively high. This can be seen in the large numbers of people harvesting timber and fish products such as fish, crabs and shrimp from the mangroves. However, free access to mangrove resources without clear regulation damages communities in the mangrove ecosystem. This was due to the lack of ownership over the survival of the mangrove ecosystem. Community knowledge about mangrove ecosystems also needs to be considered to increase sustainability. Low level of education and lack of informal education lead to weak community understanding, participation and responsibility for mangrove ecosystem management. Treviño (2022) research reveals that the community is the subject who best understands the surrounding natural conditions, so managing mangrove ecosystems must be carried out in a complex manner by prioritizing the participation of local communities. Assistance and community development in mangrove conservation efforts can control the level of area degradation as a buffer for coastal areas and improve people's living standards in

an integrated and sustainable manner (Alves *et al*. 2020; Swangjang and Kornpiphat 2021; Buncag 2022). It is necessary to strengthen informal community education by providing basic knowledge, guidance on processing mangrove products and special support in nursery and planting forests to enhance sustainability.

Institutional dimension

In addition to the ecological, economic and social dimensions, the institutional dimension is also one of the most important factors in assessing the sustainability of mangrove ecosystems. The results of the institutional dimensions of the sustainability index on managing the Birangkassi mangroves showed an index value of 53.56. This condition explained that based on sustainability status, the institutional dimension was in the fairly sustainable category. The institutional dimension sustainability index is presented in Fig. 8.

The attributes used in evaluating the dimensions are: Area Legality, local government commitment, involvement of community institutions, availability of formal regulations, level of community compliance, and integration of management programs. Based on the leverage analysis, the three most sensitive attributes that affected the institutional dimension were obtained: the availability of formal regulations, the involvement of community institutions and coordination between stakeholders. The results of the leverage analysis on the institutional dimension are presented in Fig. 9.

The availability of formal regulations is very important so that all stakeholders and the community have strong guidelines in managing mangrove ecosystems (Firdaus *et al*., 2021). It agrees with Kaskoyo *et al*. (2017), who state that environmental policies will result in better decisions because the community has information that can be used to make decisions. This is very important so that the plan for mangrove ecosystem management activities can be carried out properly and there is no conflict of interest between parties. Therefore, coordination between institutions and stakeholders in managing mangrove ecosystems in the Biringkassi mangrove area must be increased, involving the participation of the community and community institutions.

Multidimensional sustainability status

The results of each aspect of the sustainability index analysis on the sustainability of mangrove ecosystem management in the Biringkassi mangrove area showed that there were alarming aspects of the status of ecosystem management of mangroves, and there are also aspects that show rather sustainable management. As shown in Fig. 10. Under these conditions, good management of the sensitive attributes of mangrove ecosystem management is required to prevent or avoid deterioration in sustainability and can also encourage and promote the sustainability of mangrove ecosystem

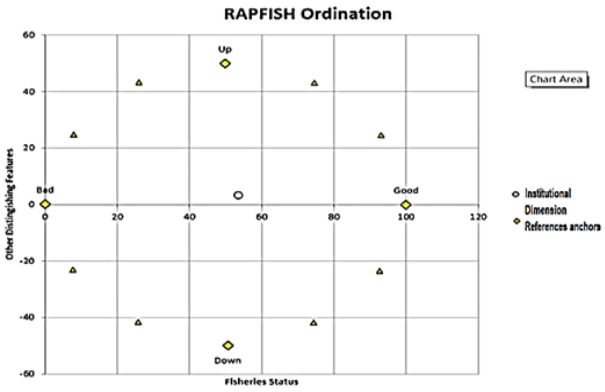

Fig. 8. *Institutional dimension sustainability index*

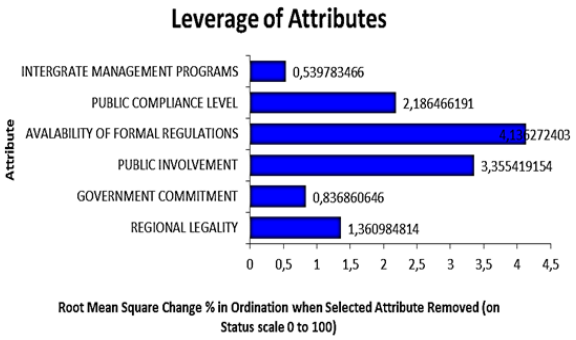

Fig. 9. *Values of attribute sensitivity in the institutional dimension*

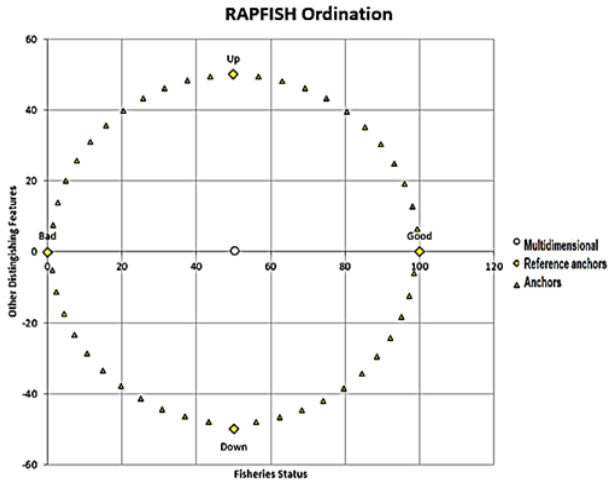

Fig. 10. *Multidimensional sustainability index*

management. The social-economic dimensions indicate unsustainable status, unlike the ecological and institutional dimensions, which indicate a fairly sustainable situation but involve sensitive attributes that may affect the sustainability of the ecological management of mangroves. This must be done to support improved sustainability and to prevent a decline in sustainability.

This value indicated that the management of mangrove ecosystems in the multidimensional mangrove area was in a less sustainable status. To increase the value of this sustainability index, various efforts must be made to increase the attributes that had a negative impact on the sustainability index value and maintain and

Table 2. Results of the RAPFISH analysis of the management of the Biringkassi mangrove ecosystem

Dimension	Sustainabilty index value %				
	Stress	R2	MDS	Monte Carlo	Difference
Ecology	0.15	0.94	53.56	52.82	-0.74
Economic	0.16	0.94	44.09	43.73	-0.36
Serial	0.17	0.94	49.78	49.53	-0.25
Institutional	0.16	0.94	53.57	53.18	-0.39
Multidimension	0.13	0.94	50.64	50.51	-0.13

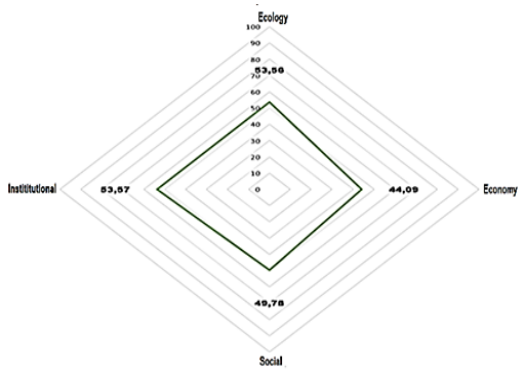

Fig. 11. *Mangrove Ecosystem sustainability fly chart*

even increase the attributes that have a positive impact on the sustainability index value.

Based on the results of the fly chart analysis (Fig. 11) on all dimensions, it is known that of the four dimensions analyzed, the economic dimension had the lowest level of sustainability. These results indicated that more attention is needed to manage the mangrove ecosystem from an economic point of view to improve the sustainability status and positively impact the economy of the people around the Biringkassi mangrove area. In addition to the economic dimension, paying attention to the social dimension, which is still classified as unsustainable, is also necessary.

Validity and accuracy of the MDS test

The validity test was carried out using Monte carlo analysis and MDS analysis at a 95% confidence level, indicating the index value of the sustainability of mangrove ecosystem management in the Biringkassi mangrove area. The results of the analysis showed that there was a difference between the two analyses. The difference between the four dimensions ranges below 1%. This condition indicated that the mangrove ecosystem management sustainability index does not experience a significant difference from the results of the Monte Carlo analysis. This difference in value indicated that errors in the analysis process can be minimized or avoided. Errors caused by scoring on each attribute, variations in scoring, errors in input values, and missing data can be avoided. Therefore, it can be concluded that the RAPFISH method can be used to evaluate the sustainability status of mangrove management in the Biringkassi area.

It can be seen from the stress value, coefficient of determination (R2), and confidence level in the built indicators. Based on Table 2, the highest sustainability index value was found in the Institutional dimension (53.57), while the lowest was found in the economic dimension (44.09). The economic and social dimensions are included in the less sustainable category because they have an index value between 25-50, while the ecology, institutional and multidimension are included in the fairly sustainable category because it has an index value between 51-75. It is known that the stress value is in the range of 13-16% or lower than 0.25 (25%), indicating the goodness of fit of the model built for the sustainability status of the dimension indicators presenting a good model. Based on the Monte Carlo analysis, the value of stress and R2 can be quite accurate and scientifically justifiable.

Conclusion

The analysis of four sustainability aspects showed that the ecological and institutional aspects have a fairly sustainable status, while the social and economic aspects have less sustainability value to support mangrove ecosystem management. The results of the multidimensional analysis showed that managing the mangrove ecosystem was still less sustainable, becoming a warning for the status and conditions of the mangrove ecosystem in the Biringkassi mangrove area of Pangkep District, Indonesia. The analysis results of the leverage effect of 24 multidimensional attributes yield eight highly influential attributes that can lead to changes in management if done incorrectly. Mangrove ecosystem management strategies that must be implemented include increasing coordination between stakeholders, creating formal regulations, increasing productivity and creativity of the community, developing an integrated Mangrove Ecosystem Management plan program, carrying out mangrove rehabilitation efforts, increasing the role of mangrove groups, and increasing the attention of researchers and academics.

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Conflict of interest

The authors declare that they have no conflict of interest.

REFERENCES

1. Alves, B., Angnuureng, D. B., Morand, P. & Almar, R. (2021). A review on coastal erosion and flooding risks and best management practices in West Africa: What has been done and should be done. *J Coast Conserv.,* 24 (38), 1-22. DOI: 10.1007/s11852-020-00755-7.
2. Asyiawati, Y. &, Hindersah, H. (2020). Sustainable mangrove ecosystem management policy in Muaragembong coastal area, Bekasi District - Indonesia. *Journal of Physics: Conference Series,* 1469(1). https://doi.org/10.1088/1742-6596/1469/1/012124.
3. Azam, S.N. &, Unjah, T. (2017). Innovative management of natural resources: Case study of Mangrove Area In Kuala Gula, Perak. Planning Malaysia: *Journal of the Malaysian Institut of Planners* 15 (4), 45–56.
4. Basyuni, M., Rizka Amelia., Dwi Suryanto., Ipanna Enggar Susetya & Yuntha Bimantara. (2022). Empowerment of abandoned ponds for sustainable mangrove rehabilitation activities in Percut Sei Tuan, Deli Serdang, Indonesia. *Journal of Sylva Indonesiana* 5(02), 137-147. https://doi.org/10.32734/jsi.v5i02.8727.
5. Bimrah, K., Dasgupta, R., Hashimoto, S., Saizen, I. & Dhyani, S. (2022). Ecosystem services of mangroves: A systematic review and synthesis of contemporary scientific literature. *Sustainability (Switzerland)* 14(19), 1-16. https://doi.org/10.3390/su141912051.
6. Buncag, M. J. J. (2022). Community based mangrove forest management sustainability analysis in Tagpait, Alborlan and Bancungan, Puerto Princesa City, Palawan, Philippines. *Environ Ecol Res* 10 (3), 325-333. DOI: 10.13189/eer.2022.100301.
7. Cecep, K. (2015). Integrated Sustainable Mangrove Forest Management. *Journal of Natural Resources and Environmental Management* 5(1), 1–6.
8. Central Bureau of Statistics (2022). Pangkajene Kepulauan Regency in Figures. *BPS-Statistics of Pangkajene Kepulauan Regency.* 2022
9. Chow, J. (2018). Mangrove management for climate change adaptation and sustainable development in coastal zones. *Journal of Sustainable Forestry* 37(2), 139-156. https://doi.org/10.1080/10549811.2017.1339615.
10. Cisse, A.A., Blanchard, F. & Guyader, O. (2014). Sustainability of tropical small-scale fisheries:Integrated assessment in French Guiana. *Marine Policy* 44, 397-405.
11. Do H.L., Thuy, T.D. (2022). Productivity response and production risk: A study of mangrove forest effects in aquaculture in the Mekong River Delta. *Ecol Econ* 194, 1-11. DOI: 10.1016/j.ecolecon.2021.107326.
12. Firdaus, M., Hatanaka, K. & Saville R. (2021). Mangrove forest restoration by fisheries communities in Lampung Bay: A study based on perceptions, willingness to pay, and management strategy. *For Soc* 5 (2): 224-244. DOI: 10.24259/fs.v5i2.12008. https://doi.org/10.19081/jpsl.2015.5.2.1 https://www.planningmalaysia.org/index.php /pmj/article/view/316.
13. Sina I., Maryunani., Batoro, J., Harahab, N. (2017). Analysis of total economic value of ecosystem mangrove forest in the Coastal Zone Pulokerto Village District of Kraton Pasuruan Regency. *International Journal of Ecosystem* 7 (4), 9. https://doi.org/10.5923/j.ije.20170701.01.
14. John, O. (2014). Sustainable Management Approach For Biodervisity Loss In The Mangrove Forest Swamps Of The Cross River Estuary Esin, *John O* 4(1), 53–63.
15. Kaskoyo, H., Mohammed, A. & Inoue M. (2017). Impact of community forest program in protection forest on livelihood outcomes: A case study of Lampung Province, Indonesia. *J Sustain For*, 36 (3): 250-263. DOI: 10.1080/10549811.2017.1296774.
16. Ke, G.-N., Utama, I. K. A. P., Wagner, T., Sweetman, A. K., Arshad, A., Nath, T. K., Neoh, J. Y., Muchamad, L. S. & Suroso, D. S. A. (2022). Influence of mangrove forests on subjective and psychological wellbeing of coastal communities: Case studies in Malaysia and Indonesia. *Frontiers in Public Health*, 10. https://doi.org/10.3389/fpubh.2022.898276..
17. Khairuddin, B., Yulianda, F., Kusmana, C. & . Y. (2016). Status Keberlanjutan dan Strategi Pengelolaan Ekosistem Mangrove Kabupaten Mempawah, Propinsi Kalimantan Barat. *Jurnal Segara* 12(1), 21. https://doi.org/10.15578/segara.v12i1.99.
18. Kusumaningtyas MA, Hutahaean AA, Fischer HW, Pérez-Mayo M, Pittauer D. & Jennerjahn TC. (2019). Variability in the organic carbon stocks, sources, and accumulation rates of Indonesian mangrove ecosystems. *Estuar Coast Shelf Sci*, 218, 310-323. DOI: 10.1016/j.ecss.2018.12.007.
19. Kuvaini, A., Hidayat, A., Kusmana, C. & Basuni, S. (2019). Teknik Penilaian Multidimensi untuk Mengevaluasi Keberlanjutan Pengelolaan Hutan Mangrove di Pulau Kangean Provinsi Jawa Timur. *Jurnal Wilayah dan Lingkungan* 7(3), 137–152. https://doi.org/10.14710/jwl.7.3.137-152.
20. Larasati, E., Karnati, N. & Muhab, S. (2022). International Journal of Social Science Research and Review. *Department of Education Management* 5(3), 260–27.
21. Lukman, K.M., Uchiyama, Y. & Kohsaka R. (2021). Sustainable aquaculture to ensure coexistence: Perceptions of aquaculture farmers in East Kalimantan, Indonesia. *Ocean Coast Management* 213, 1-9. DOI: 10.1016/j.ocecoaman.2021.105839.
22. Mbatha, A., Githaiga, M. N., Kiplagat, K., Kairo, J. & Mungai, F. (2022). How Sustainable is Mangrove Harvesting in Lamu: An Analysis of Forest Structure. *Journal of Sustainable Forestry*, 00(00), 1-20.
23. Mueller-Dombois and Ellemberg. (1974). Aims and Methods of Vegetation Ecology. *John Wiley and Sons, Inc.*
24. *Nabi, A., Rao, B,P. & Rama Prasad, A,V. (2012). Analysis of Mangrove Vegetation of Diviseema Region, Khrisna District, Andhra Pradesh. International Journal of Plant, Animal and Environmental Science 2 (4), 99-108.*
25. Pitcher, T. J., Lam, M. E., Ainsworth, C., Martindale, A., Nakamura, K., Perry, R. I. & Ward, T. (2013). Improve-

ments to Rapfish: A rapid evaluation technique for fisheries integrating ecological and human dimensionsa. *Journal of Fish Biology* 83(4), 865-889. https://doi.org/10.1111/jfb.12122.

26. Salami, A. T., Akinyede, J. & de Gier, A. (2010). A preliminary assessment of NigeriaSat-1 for sustainable mangrove forest monitoring. *International Journal of Applied Earth Observation and Geoinformation*, 12(SUPPL.1), 22-26. https://doi.org/10.1016/j.jag.2009.09.015.
27. Sambu, A.H., Rahmi & Khaeriyah, A. (2014). Analysis of Characteristics of and Use Value of Mangrove Ecosystem (Case Study in Samataring and Tongketongke Sub-Districts, Sinjai Regency). *Journal of Environment and Ecology* 5 (2), 222-233.
28. Suryana, A., Wiryawan, B., Monintja, D. & Wiyono, E. (2012). Analisis Keberlanjutan Rapfish Dalam Pengelolaan Sumber Daya, Ikan Kakap Merah Asep Suryana (Lutjanus Sp.) Di Perairan Tanjung Pandan. *Buletin PSP* 20(1)., 45–59.
29. Swangjang, K. & Kornpiphat P. (2021. Does ecotourism in a Mangrove area at Klong Kone, Thailand, conform to sustainable tourism? A case study using SWOT and DPSIR. *Environ Dev Sustain* 23, 15960-15985. DOI: 10.1007/s10668-021-01313-3.
30. Treviño, M. (2022). The mangrove is like a friend: Local perspectives of mangrove cultural ecosystem services among mangrove users in Northern Ecuador. *Human Ecol* 50 (5),1-16. DOI: 10.1007/s10745- 022-00358-w.
31. Valiela, I., Bowen, J. L. & York, J. K. (2001). Mangrove forests: One of the world's threatened major tropical environments. *BioScience* 51(10), 807–815. https://doi.org/10.1641/0006-3568(2001)051[0807:MFOOTW]2.0.CO;2.