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Sustainability status of ecological dimensions in mangrove forest management in the coastal of Pangkep regency: South Sulawesi

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Abstract
The mangrove forest ecosystem is one of the natural resources of the coastal area which has an important role from a social, economic and ecological point of view. Mangrove forest areas are considered to lack high economic value, so it is not uncommon for mangrove land to be converted into other uses such as settlements, ponds, and even industry and mining. This study aims to determine the sustainability status of the ecological dimensions of mangrove ecosystem management on the coast of Mangrove District. The research method uses Multidimensional Scaling (MDS) analysis with the Rap-MForest approach (Modified RAPFISH) to assess the ecological dimension of the sustainability status of mangrove forest management by conducting direct surveys.
Based on the results of the analysis, it was found that the sustainability status of the mangrove ecosystem on the ecological dimension was less sustainable. Based on the results of leverage analysis on Rap-MForest on the ecological dimension, it shows that the mangrove ecosystem diversity level indicator (X4) is the most sensitive to the sustainability of the mangrove ecosystem. This sensitive indicator is a lever factor in the ecological dimension, so that if improvements are made to this indicator it will leverage the value of the mangrove ecosystem sustainability index in the overall ecological dimension.

Keywords: Mangrove, Sustainability, Ecosystem, Ecology

Introduction
The mangrove forest ecosystem is one of the natural resources of the coastal area which has an important role from a social, economic and ecological point of view. The main function is to balance the ecosystem and provide various necessities of life for humans and other living things (Rangkuti *et al*., 2017) [7]. Mangrove forest areas are considered to lack high economic value, so it is not uncommon for mangrove land to be converted into other uses such as settlements, ponds, and even industry and mining (Purwowibowo, 2016) [5]. Even though the coastal or coastal area has a specific character compared to other areas. This region is an aggregation of various ecological and physical components that are interrelated and interact with each other (Jaya *et al*, 2020) [2].
The conversion of mangroves into other uses because they are considered more economically profitable will not only result in damage to the mangrove ecosystem, but will also result in a decline in the quality of other ecosystems. Such as estuary and marine ecosystems as well as the various ecosystems contained therein such as river estuaries, lagoons and canals. This decline in quality will then be followed by a decrease in ecosystem productivity which will directly limit the ecosystem's ability to produce various fish species that are important both ecologically and economically (Purnoyono, 2018). As one of the coastal ecosystems, the mangrove ecosystem is a unique and vulnerable ecosystem (Murdiyarso *et al*, 2015) [4]. On the basis of an understanding of the abovementioned mangrove forest problems, it is necessary to conduct a study regarding the status of sustainable management of mangrove forests on the coast of Pangkep Regency.

Research on the sustainability status of the ecological dimension is expected to provide an overview of the existing conditions as well as management scenarios that can be carried out in support of sustainable mangrove forest management in the Pangkep Coastal District.

Research Methods

This research was conducted in March - June 2022 in the coastal mangrove area of Pangkep Regency. This study uses a quantitative and qualitative approach with a longitudinal design because it is sustainable for a relatively long period of time and follows an interactive process of various variables. The sampling technique was carried out by purposive sampling according to the interests of analysis. The Rap-MForest approach Multidimensional Scaling (MDS) analysis method (Modified RAPFISH) to assess the ecological dimension of the sustainability status of mangrove forest management by conducting a direct survey.

Results and Discussion

Attributes of the ecological dimension considered capable of influencing the sustainability of mangrove forest management in the Pangkep Regency Coastal area consist of 6 (twelve) attributes, namely:

A. Changes in Habitat Diversity

Changes in habitat diversity occur due to excessive (destructive) utilization of mangrove ecosystems. The damage to the mangrove ecosystem that occurred in Pangkep Regency was predominantly caused by the conversion of the mangrove ecosystem into ponds for milkfish and shrimp cultivation and is still ongoing today. Based on the data it was found that there was a significant decrease in mangrove area due to the conversion of mangroves into ponds, so the score given to this attribute is 0 meaning that there have been many changes in habitat diversity.

B. Community Niche Structure

The condition of the community niche structure can be seen from the results of observations at the location and interviews with the surrounding community, that the community niche shows there has been a change, what can be seen is the decrease in the number of bird groups seen in the mangrove ecosystem compared to previous years, because their habitat has decreased in size, as a result of being converted into ponds. Thus the score given is 0, which means that there are many community niche structures that are damaged due to human activity.

C. Population Size and Demographic Structure of Mangrove Ecosystems

Based on the results of the analysis of Landzat TM satellite imagery for 1980 – 2020, it shows that there has been a very significant decrease in area, from 10,552.91 ha in 1980 to 312.60 ha in 2020. This decrease in area occurred due to the conversion of mangroves into ponds, only a small portion of which was remains, so that the population size and demographic structure of the mangrove ecosystem have changed greatly. Thus the score given is 0, which means there has been a significant change in population size and the demographic structure of the mangrove ecosystem.

D. Mangrove Ecosystem Species Diversity Level

Based on the results of identification in the field and review of the literature, it was found that there were 9 types of mangroves out of 19 species commonly found in South Sulawesi, namely Acantus ilicitifolius, Avicennia alba, Avicennia marina, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa, Sonneratia alba, Sonneratia ovate, and Lumnitzera racemosa. Based on the identification results, there were 6 species, namely Sonneratia spp, Rhizophora spp, Avicennia spp, Bruguiera spp, Aegiceras corniculatum, and Exocoecaria agallocha. Based on the identification results, the score given to this indicator is 1, which means it is quite diverse (4 - 9 types of mangroves).

E. Mangrove Ecosystem Rehabilitation

Based on field observations and interviews with the community, it was found that along the coast there were several rehabilitation points carried out, but many of the mangroves planted did not live because they were carried away by currents and lack of maintenance from the mangrove planting implementers. Therefore it needs monitoring and evaluation from the government and the involvement of all relevant stakeholders. Thus the score for this indicator is 1, which means that the implementation of rehabilitation is in moderate condition.

F. Mangrove Ecosystem Vegetation Density

Based on data from the Department of Maritime Affairs and Fisheries; Forestry and Plantation Services; and based on the results of field observations it was found that the average density of mangrove ecosystems in the Coastal Area of Pangkep Regency was 1,323 ind/ha, which means that the mangrove ecosystem has a moderate density. Thus the score for this indicator is 1, which means that the mangrove ecosystem has a density of 1000 – 1500 ind/ha.

Giving a score for the ecological dimension, with a score for each indicator of the ecological dimension obtained based on observations, data analysis results, literature review and interviews can be seen in Table 1 which is presented as follows.

Table 1: Indicator Scores on Ecological Sustainability Dimensions for Mangrove Ecosystems in Pangkep Regency

No.	Dimension and Indicator	Score	Description
Ecological dimention			
1	Changes in Habitat Diversity (X1)	0	Secondary Data
2	Community Niche Structure (X2)	0	Secondary Data and Interviews
3	Population Size and Demographic Structure of Mangrove Ecosystems (X3)	0	Secondary Data
4	Mangrove Ecosystem Diversity Level (X4)	1	Secondary Data
5	Mangrove Ecosystem Rehabilitation (X5)	1	Survey Data and Secondary Data
6	Mangrove Ecosystem Vegetation Density (X6)	1	Survey Data and Secondary Data

The score of the ecological dimension for the mangrove ecosystem was then analyzed using the Rap-MForest analysis

tool. The results obtained with the MDS method will show the mangrove ecosystem sustainability index value from the ecological dimension which can be seen in Figure 1. The analysis results show that the mangrove ecosystem sustainability index value for the ecological dimension is 32.60%, which means it is less sustainable.

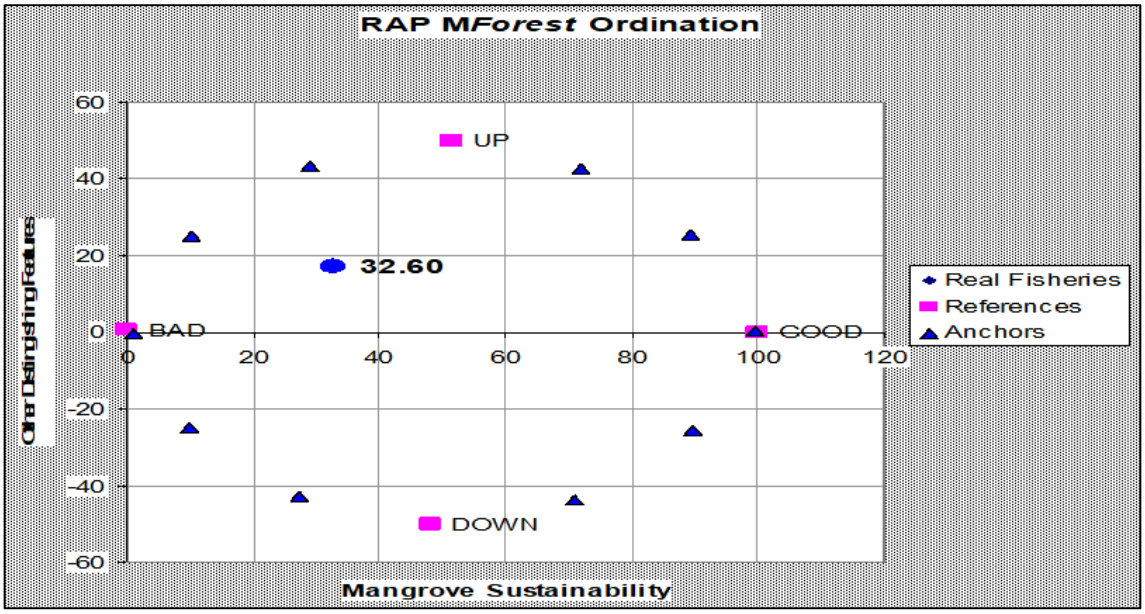

Fig 1: Status of Ecological Dimensions of Sustainability in Mangrove Ecosystems

Table 2: Statistical Values from Rap-MForest Analysis Results on Ecological Dimensions

No	statistical indicators	statistical value	percentage
1	Stress (S)	0.1419	14.91%
2	R^2	0.9461	94.61%

Furthermore, to see the level of stability of the results of this analysis, a Monte Carlo simulation was carried out. The stability of the ordinate values from Rap-MForest with this Monte Carlo simulation shows that the blue emission plots tend to converge (Figure 2). This shows that the errors in scoring each indicator and the procedural errors of the analytical method are small, the results of this Monte Carlo analysis support the determination of the ordination status of the sustainability studied.

The accuracy of determining this ordination is strengthened by the value of the squared correlation (R2) which is greater than 90%, namely 94.61%. Scientifically, this R2 value is considered high, which means the level of confidence (coefficient of determination) in Multi Dimensional Scaling (MDS) analysis can be trusted and accounted for. Furthermore, the measurement results are to see how precisely the configuration of a point can reflect the original data, the stress value (S) shows a low result, which is less than 25%, namely 14.91%. This shows that the analysis of the sustainability of the ecological dimension in this study is in the condition of goodness of fit with fair or sufficient qualifications. In the Rap-MForest model, the desired stress value is 25% smaller (Fauzi and Anna 2005). The results of this analysis can be seen in Table 2.

The sustainability status of the mangrove ecosystem on the ecological dimension is less sustainable. Indicators that influence the ecological dimension consist of five, namely: changes in Habitat Diversity (X1), community niche structure (X2), population size and demographic structure of mangrove ecosystems (X3), level of diversity of mangrove ecosystems (X4), rehabilitation of mangrove ecosystems (X5), and the vegetation density of the mangrove ecosystem (X6). Based on the results of leverage analysis on Rap-MForest on the ecological dimension, it shows that the mangrove ecosystem diversity level indicator (X4) is the most sensitive to the sustainability of the mangrove ecosystem. This sensitive indicator is a lever factor in the ecological dimension, so that if improvements are made to this indicator it will leverage the value of the mangrove ecosystem sustainability index in the overall ecological dimension. Based on the results of this analysis, it shows that the six indicators have values that are not too much different. This shows that the six indicators have almost the same effect on the level of sustainability of the mangrove ecosystem in Pangkep Regency. The six indicators have values that range between 5.99% and 7.32%, their contribution to the coordination of the sustainability status of the mangrove ecosystem on the ecological dimension, where according to Kavanagh and Pitcher (2004), if the indicator value is <8%, then no indicator is dominant in that dimension. Based on the results of the analysis, it was found that the six indicators on the ecological dimension had a value of <8%, this indicated that on the ecological dimension there were no indicators that had dominant sensitivity affecting the sustainability of the mangrove ecosystem. The results of the analysis can be seen in Figure 2.

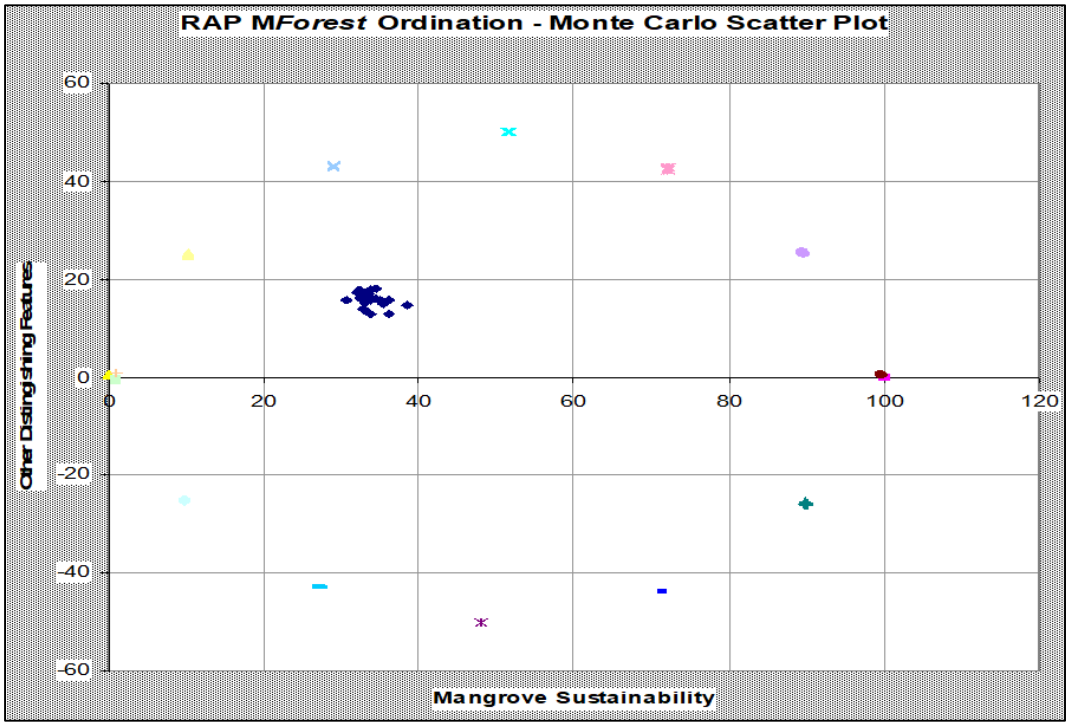

Fig 2: Results of Monte Carlo Analysis for Mangrove Ecosystems on Ecological Dimensions

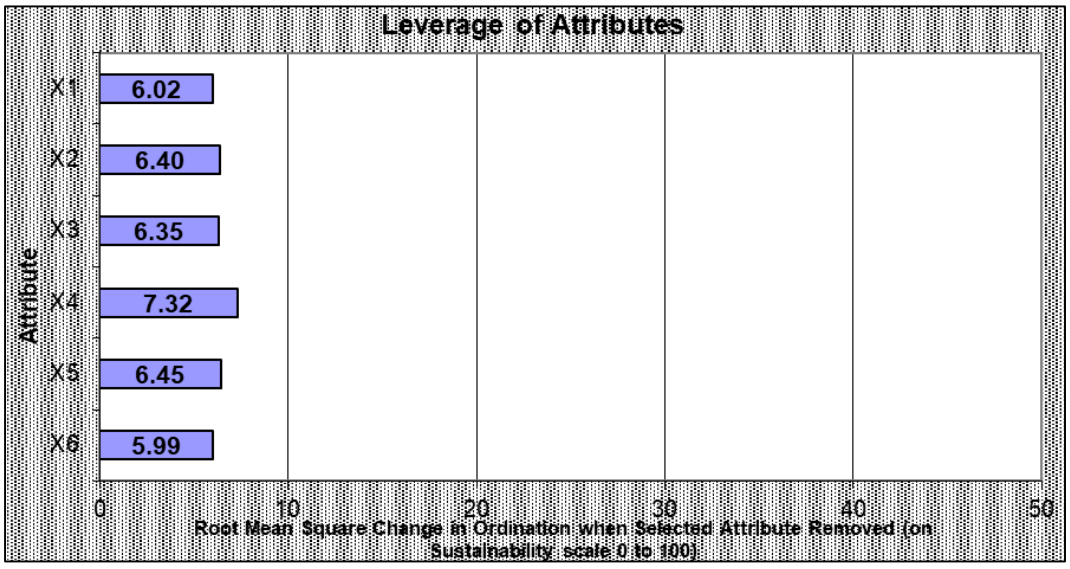

Fig 3: Results of Indicator Sensitivity Analysis for Mangrove Ecosystems on Ecological Dimensions

Based on the results of the ordination of the sustainability status of the ecological dimension which is classified as less sustainable, an ecological policy is needed to develop and manage it which leads to improvement of sensitive indicators on the ecological dimension. In this dimension, the indicator that has the highest sensitivity is the level of diversity of mangrove ecosystems. Based on the identification results in the field, it was found that the factors that disrupted the indicators on the ecological dimension were due to the conversion of mangroves into ponds. So to maintain the sustainability of the mangrove ecosystem, it is necessary to immediately control the conversion of the mangrove ecosystem which is still ongoing in Pangkep Regency.

Conclusion

Based on the results of the study, it can be concluded that the sustainability status of mangrove management on the coast of Pangkep Regency on the Ecological Dimension is classified as Less Sustainable with an index value of 32.60. Seeing its status which is still less sustainable, the existence of mangroves should continue to be disseminated to stakeholders so that later the existence of mangroves on the coast of Pangkep Regency is considered important and becomes a shared obligation to continue to preserve and even designate it as a conservation area.

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