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Short Communication: Mangrove forest management based on multi dimension scalling (RAP-Mforest) in Kwandang Sub-district, North Gorontalo District, Indonesia

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[2]Department of Silviculture, Faculty of Forestry, Institut Pertanian Bogor. Jl. Lingkar Akademik, Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia
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Abstract. *Melo RH, Kusmana C, Eriyatno, Nurrochmat DR. 2020. Short Communication: Mangrove forest management based on multi-dimension scalling (RAP-Mforest) in Kwandang Sub-district, North Gorontalo District, Indonesia. Biodiversitas 21: 1352-1357.* Management of mangrove forests is an important aspect in the effort to conserve the environment in coastal areas. Its management requires planning to ensure the sustainability of its function and benefit. This study aimed to analyze the sustainability level of the mangrove forest management in Kwandang Sub-district, North Gorontalo District, Gorontalo Province, Indonesia and to determine the factors that affected that sustainability. Data were collected through field measurement and interviews, and then analyzed using Rapid Appraisal of Mangrove Forest (Rap-Mforest) approach and Monte Carlo analysis. The results showed that mangrove management was fairly sustainable on the ecological criteria (60.43%), but less sustainable on the economic criteria (47.79%) and social criteria (42.22%). The result of leverage analysis indicated that 6 out of 20 indicators were categorized as sensitive indicators affecting the sustainability of mangrove management. These sensitive indicators should be given priority in increasing the sustainability index in the future.

Keywords: Mangrove forest, multidimensional scalling analysis, RAP-Mforest, sustainability

INTRODUCTION

In environmental management, including the management of mangrove, the Indonesian Law No. 32 of 2004 gives authority to the regional government as an autonomous region to mitigate damage to mangrove forests. Mangrove forest management is part of the overall coastal area development, so it should always consider wider interests and benefits, while still prioritizing community welfare in a sustainable manner.

Rational mangrove management must be conducted on a sustainable basis and for diverse purposes in accordance with its potential. Some truly undisturbed mangrove forest areas should be kept natural so that the virgin mangrove forest section can be saved if the management fails and causes damage or even loss of the managed mangrove. Mangrove ecosystems must be managed based on the ecological paradigm which includes the principles of interdependence among ecosystem elements, the nature of the cycle of ecological processes, flexibility, diversity, and co-evolution of organisms and their environment in a physical unit of the watershed (Damastuti and Groot 2017; Glaeser 2019).

Mangrove ecosystems are able to support a very complex food chain and support organisms at all trophic levels, because mangroves have high productivity and carrying capacity for aquatic biota (Islam and Haque 2004). Mangroves as an area of fish enlargement also have an important role in supporting commercial fisheries (Barbier 2000; Allen et al. 2012). The combination of land and water ecosystems makes mangrove ecosystems full of productive resources (Bouillon et al. 2008).

The implementation of sustainable mangrove forest management must take into account the ecological, social, and economic aspects, including aspirations of the community using coastal areas, as well as conflicts of interest that may exist (Chakraborty et al 2019). To quickly assess the sustainability status of mangrove forest management in North Gorontalo District, Indonesia this study used multidimensional scaling (MDS) analysis (Adiga et al. 2016). In this analysis, objects were presented visually based on previous research conducted to determine the sustainability status of management in the mangrove forest area in West Seram (Patimahu et al 2010). This MDS analysis on mangrove forest management in North Gorontalo District aimed to analyze the sustainability index value of each dimension and discover the balanced condition among each dimension. The results may be used to design policies on dimensions that are not sustainable and to pay attention to the leverage factors. Thus the results of this study can provide an overview of the existing conditions as well as the management strategy of mangrove forests in North Gorontalo District.

MATERIALS AND METHODS

Study area and time

The study was held from March to September 2018. The field research was conducted in Kwandang Sub-district, North Gorontalo District, Gorontalo Province, Indonesia in four villages, namely Katiaalada Village, Bulalo Village, Leboto Village, and Botunggobungo Village (Figure 1).

Procedures

Data of mangrove and its management were collected through field measurements and interviews. Then, applied Rap-Mforest approach was conducted through the following stages: (i) determining the indicators of sustainable mangrove forest ecosystem for each dimension (ecological, economic and social) and multidimensional, (ii) assessing each sustainable indicator using ordinal scale based on sustainability criteria for each dimension, and (iii) running ordination analysis based on multidimensional scaling (MDS) methods, showing the index and the sustainability status of mangrove forest management in North Gorontalo District.

For each indicator in each dimension, a score was given reflecting the sustainability conditions of the dimensions. The score range was determined based on criteria that could be found from the results of observations and analysis of secondary data. The score ranged from 0-2, depending on the state of each indicator that was interpreted from bad to good. Bad values reflected the most unfavorable conditions for sustainable management of mangrove forest ecosystems, whereas good values reflected the most favorable conditions. The sustainability attributes of mangrove forest management in North Gorontalo District consisted of 3 dimensions with a total of 20 attributes (Table 1). These dimensions and attributes were obtained from CIFOR and LEI literature studies related to Sustainable Forest Management (SFM), and based on observations in the field by the principles of sustainable development. In this study, four categories of sustainability status were arranged based on the basic scale 0-100 (Cisse et al. 2014) as stated in Table 2.

Figure 1. Study area in North Gorontalo District, Indonesia (24º16’58.96”S, 50º35’00.04”W). The status of this mangrove forest area is the limited production forest

Table 1. Dimension and attributes of sustainability value index of Mangrove Forest Management (MFP)

Ecological dimension	Economic dimension	Social dimension
Diversity of mangrove	Mangrove utilization by community	Coordination among institutions in MFP
Diversity of habitat	Mangrove forest financial management	Policy and planning in MFP
Water quality change	Zones of Mangrove utilization land	Community perception of MFP
Mangrove forest degradation	Mangrove forest rehabilitation finance	Community role in MFP
Diversity of fauna	Community income level around mangrove forest	Community preference for MFP
Mangrove planting activity	Mangrove roles on regional development	Informal institutional in MFP
Seed availability		
Flora fauna species existence		

Source: CIFOR and LEI in Pattimahu (2010)

Table 2. Category of sustainability status of mangrove forest management (Fauzi and Anna 2005)

Index value	Category
< 25	Unsustainable
25 < X < 50	Less Sustainable
50 < X < 75	Fairly Sustainable
75 < X < 100	Sustainable

In general, the Rap-MForest method is started by reviewing the indicators of sustainable mangrove forest ecosystems through literature studies and observations in the field. The next step is giving a score based on the conditions specified in Rap-MForest. After the scoring results are obtained, each indicator is analyzed using multidimensional scaling (MDS) to determine the relative position of mangrove forest management towards the ordination of good and bad. The next step is to analyze the value of stress using ALSCAL logarithms. From the results of ordination with MDS and stress values through ALSCAL algorithm, rotation is carried out to determine the position of management of mangrove forest ecosystems in ordinances of bad and good. The next step is to use Monte Carlo analysis to determine aspects of uncertainty and leverage analysis to determine the anomalous aspects of the indicators analyzed.

Data analysis

Each attribute was scored to determine the relative sustainability position between two reference points,' namely good and bad points using ordination analysis.

This Rap-MForest ordination process used the modified Rap-fish software from Kavanagh and Pitcher (2004) applicating the Rap-fish algorithm process, a technique called Multidimensional Scaling (MDS). The observed object or point is mapped in a two or three-dimensional space, so the object or point is attempted as close as possible to the origin. In other words, the same two points or objects are depicted with far apart points (Fauzi and Anna 2005). The ordinance (determination of distance) technique in MDS is based on the Euclidian Distance in dimensionless space n. The configuration or ordination of an object or point in MDS is then approximated by re-expressing *Euclidian* (d_{ij}) from point i to point j with the origin (d_{ij}) written in the following equation:

$$d_{ij} = a + bd_{ij} + e$$

Where:
D_{ij}) : Euclidean distance between two dimensions
a : *intercept*
b : *slope*
c : *error*

Furthermore, the ALSCAL algorithm was used, which is an appropriate method for Rap-fish and is easily available in almost every statistical software (SPSS and SAS). The ALSCAL method optimizes the square of the data in three dimensions.

Rap-fish software is the development of MDS contained in SPSS, for the rotation process, reverse position and several sensitivity analyses that have been integrated into one software. Through MDS, the position of the sustainability point can be visualized into two dimensions (horizontal and vertical axes). To project these points on a horizontal line rotation is carried out with a bad extreme with a score of 0% and a good extreme with a score of 100%. The position of the sustainability status of the system under study will be between these two extremes. This value is the index value of the sustainability of mangrove forest ecosystem management at this time. Illustration of the results of ordination of continuous index values can be seen in the picture.

The index value scale of the sustainability of mangrove forest management has a range of 0% to 100%. If the result of the analyzed system has a value of more than 50%, then the system is categorized as sustainable, and vice versa if the value is less than 50% then the system is categorized as unsustainable. This index value of each dimension was visualized through a kite diagram.

Sensitivity analysis was carried to identify the indicators that were sensitive in contributing to sustainability at the study site. The influence of each indicator is indicated in the form of "root mean square" (RMS) ordination changes, especially on the x-axis or scale of sustainability. The higher the value of the RMS changes due to the loss of a particular indicator, the greater the role of this indicator is in the formation of sustainability index, or in other words, this indicator is more sensitive in determining the sustainability of mangrove forest management at the research site.

To evaluate the effect of errors on the estimation process of the ordinance value of mangrove forest management, Monte Carlo analysis was used. According to (Kavanagh and Pitcher 2004) Monte Carlo analysis is also useful for assessing: (i) the effect of making indicator score errors caused by understanding imperfect conditions in the location of the study or misunderstanding of the indicators or how to score indicators, (ii) the effect of variations in scoring due to differences in opinions or judgments by different researchers, (iii) the stability of the iterative MDS analysis process, (iv) error entering data or missing data, and (v) the high-stress value resulted from Rap-MForest analysis (stress value is acceptable if <25%).

RESULTS AND DISCUSSION

Sustainability index

The assessment of the sustainability status using the analysis approach of Rapid Appraisal of Mangrove Forest (Rap-Mforest) produced index values of sustainability status in each dimension, namely the ecological, economic and social ones as shown in Table 3 and then was illustrated into Figure 2.

Some errors that can affect the entire analysis process with the MDS method have been assessed. Table 3 shows that the difference between the results of the analysis using the MDS and Monte Carlo methods is not more than 5% or very small. This shows the level of trust in the multidimensional total index and trust in the index value of each dimension, which means that the results of the analysis have been validated and are approaching the real situation.

Leverage of attributes

The results of leverage analysis on the ecological dimension as indicated in Figure 3 shows that the sustainability in ecological dimension was strongly influenced by the two main attributes, i.e., seed availability with a value of 5.83 and the presence of flora and fauna species with a value of 5.75. This means that to improve the sustainability status of the ecological dimension, it is necessary to pay attention to these two attributes.

The result of the Leverage analysis of economic dimensions (Figure 4) shows the two main sensitive attributes that had high leverage were the mangrove utilization by the community with a value of 6.75 and the role of mangroves in regional development with a value of 6.37. This means it is necessary to formulate work program efforts in order to improve the sustainability status of the economic dimension by considering these two attributes.

The results of the MDS analysis using Rap-MPforest showed that the sustainability index value on the social dimension was 42.22 (less sustainable). The most influential attribute in this dimension was structuring the boundaries of protected forests with a value of 6.85 and diversity management with a value of 6.43 (Figure 5).

Discussion

The result of Rap-MForest analysis, strengthened by Monte Carlo analysis, showed the index value of the current sustainability status for ecology dimension was 60.43, categorized as a fairly sustainable category. The index value for economic dimension was 45.79 categorized as less sustainable, and on the social dimension was 42.22 or less sustainable. These values were obtained based on the assessment of 20 indicators from three sustainable dimensions.

The main sensitive attribute in ecological dimension was the availability of mangrove seeds for mangrove forest area. In general, the mangrove seeds are provided by local government or District government. The mangrove seeds are given to the stakeholders which consist of Province Environmental Services and KPH Gorontalo Utara (Forest Management Unit of North Gorontalo), Fisheries and Marine Services. Mangrove seeds are also available naturally with the spread of seeds that fall from mangrove trees. The mangrove forest area was thin which means the mangrove abundance was low. There were 6 mangrove species, namely *Avicennia marina*, *Rhizophora mucronata*, *Rhizophora apiculata*, *Ceriops tagal*, *Sonneratia alba*, and *Avicennia alba*. The characteristic of this mangrove was the irregular zones, caused by the availability of mangrove seeds spread within all areas. There was a mangrove area encircling a hill, indicating that some mangrove trees grew on the dry land. Mangrove forest itself provides a place for natural seedlings area (Kuenzer et al. 2011; Sasidhar et al. 2013; Giri et al. 2015; Masood et al. 2015).

Tabel 3. The sustainability index value of each dimension

Dimension	MDS result	Monte Carlo	Differences (%)
Ecology	60.43	59.82	0.61
Economy	45.79	46.16	0.37
Social	42.22	42.87	0.65

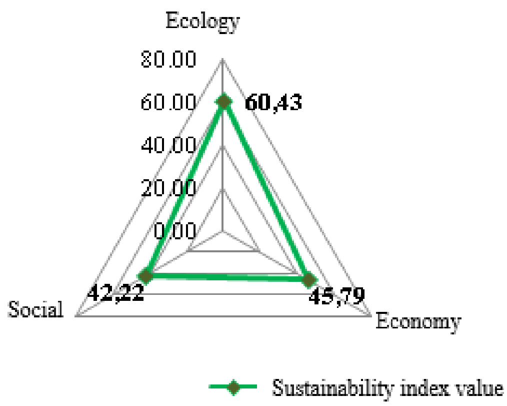

Figure 2. Sustainability status of mangrove forest management in North Gorontalo District, Indonesia

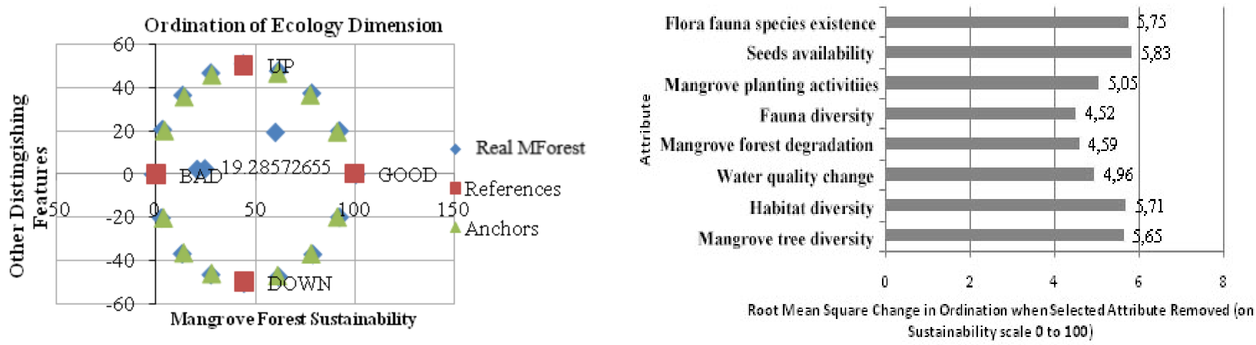

Figure 3. Sustainability index and leverage of attributes in ecological dimension

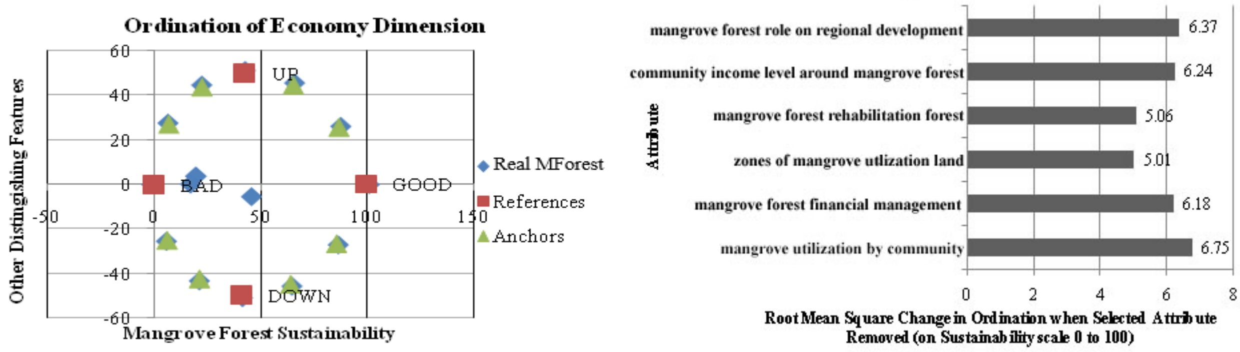

Figure 4. Sustainability index and leverage of attributes in economic dimension

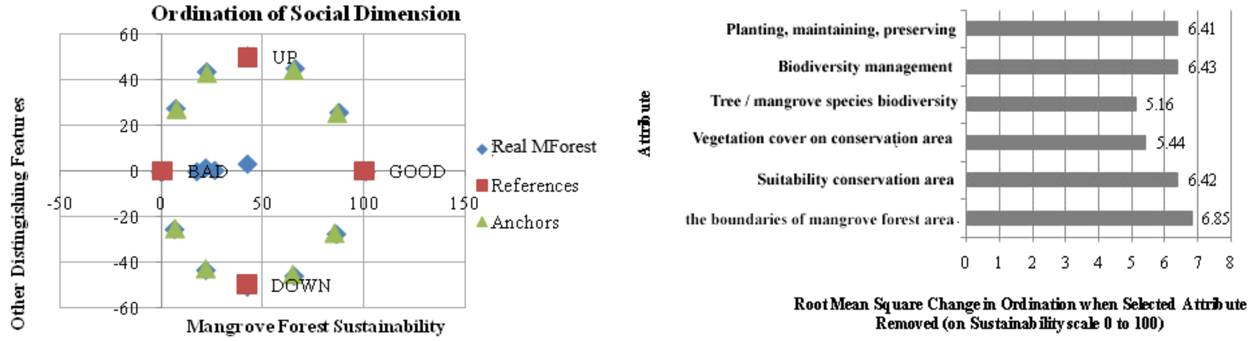

Figure 5. Sustainability index and leverage of attributes in social dimension

The other main sensitive attribute was flora and fauna existence. If the number of species is small and a single species is abundant, then that species dominates the community, resulting in low species diversity (Shirima et al 2015). Therefore, the species evenness should be maintained in order to keep the stability of mangrove forest ecosystem.

The main sensitive attribute in economy dimension was mangrove utilization. At present, the people who live around mangrove forest area get income from shrimp ponds developed in the mangrove forest area. Besides catching the shrimps, people can also catch a lot of fish which live there. The shrimp pond cultivation is still conducted traditionally, so the yield is still not optimal for the people. On the other hand, the mangrove is not well managed because the area is too accessible for other utilizations, such as logging. Excessive logging is a serious threat for mangrove forest ecosystem (Herbeck et al. 2020), and always results in the decrease of fish and shrimps catches on coastal sea waters around mangrove area (Martosubroto and Naamin 1977).

The other main sensitive attribute was mangrove forest area role in regional development. Therefore the regional development should pay attention to the sustainability of mangrove forest area, due to its high direct and indirect values. Indeed, mangrove forest management has a role directly and indirectly in socio-economicc aspects of community life around mangrove area (Umilia and Asbar 2016), i.e., providing food, medicines, recreation area, and sites and materials for education and research, harboring wildlife, settling mud, protecting coastal areas from tsunami, and sequestering carbon from the atmosphere.

The main sensitive attribute in social dimension was structuring the boundaries of mangrove forest areas, which was intended to optimize the function according to its characteristics and carrying capacity. Therefore, the area management unit can control the utilization and the government can supervise the conversion of area to other land uses. The boundaries of mangrove forest area in Kwandang, North Gorontalo make the mangrove accessible to local community who utilize it for several purposes. Forest resources have characteristic of the Common Resources which tend to degrade from time to time due to lack of understanding and sustainable management (Neumann et al 2016).

The other main sensitive attribute was biodiversity management. Biodiversity has an important function to maintain the stability of mangrove ecosystem. Therefore it should be maintained through the conservation, research and development programs. This study concluded that mangrove forest in Sub-district of Kwandang, District of North Gorontalo was categorized as sustainable, based on the ecological dimension, but less sustainable based on the economic and social dimensions.

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