Analysis of sustainability ecosystem mangrove management in Pangkah Wetan and Pangkah Kulon Villages Area, Ujungpangkah District, Gresik Regency, East Java Province

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Abstract. Mangroves provide several important functions such as gatherings, nurseries, living areas, and eating habitats. The best management plan designed for the conservation of mangrove wetlands must be considered as well as an ecological and social facility. The purpose of this study was to analyze the sustainability of mangrove ecosystem management from the ecological, economic, social, institutional and technological dimensions using the MDS (Multi Dimensional Scaling) method through the RAP-MANGROVE (Rapid Assessment for Mangrove) approach in Pangkah Wetan and Pangkah Kulon Villages, Ujungpangkah District, Gresik Regency, East Java Province. The results of the study show that the sustainability index of the mangrove ecosystem in the Pangkah Wetan Village for ecological, institutional, and technological dimensions are less sustainable, while for economic and social dimensions are sufficiently sustainable; while in the Pangkah Kulon Village for ecological, social, institutional, and technology dimensions are sufficiently sustainable, while for economic dimension is sustainable. Based on the results of leverage analysis, it shows attributes that are very sensitive to the sustainability status of mangrove ecosystems, for the ecological dimension are fauna diversity in mangrove ecosystems, and coastline changes. The sensitive attributes in the economic dimension are a type of direct use mangrove ecosystems for community, and contributions mangrove ecosystem to increasing labor; while in social dimension are mangrove ecosystems damaged by community and community access to utilize mangrove ecosystems. The sensitive attributes in the institutional dimension are involvement of community institutions regarding mangrove ecosystem management and the existence of sanctions for violating regulations in the mangrove ecosystem; while in technological dimension are processing techniques for mangrove products, and the techniques for capturing biota in mangrove ecosystems. The results of the Monte Carlo analysis show that the overall dimensions in this study are adequate and valid (indicated by the difference between MDS and Monte Carlo <5%), while the Goodness of Fit analysis shows an S-stress value of <0.25 for each dimension, so the RAP-MANGROVE model in this analysis is a good model and can be used to analyze the accuracy of the sustainability of mangrove ecosystem management.

Keywords: Mangrove, MDS (Multi-Dimensional Scaling), RAP-MANGROVE (Rapid Appraisal for Mangrove), Sustainable Analysis.

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1. Introduction
Mangroves have characteristics that are tolerant of salt, woody plants that are commonly found in the intertidal zone and located along tropical and subtropical coastlines (Polidoro et al. 2010) [1]. Mangroves are associated with a variety of fauna that have terrestrial and marine habitats, thus enhancing important ecological functions such as the provision of fisheries and biodiversity. Mangroves are connected to ecosystems adjacent to seagrass beds, coral reefs, estuaries, and others through physical, biochemical and biological interactions. Mangroves provide several important functions such as breeding and laying places, nurseries, residential areas, and eating habitats (Nagelkerken et al. 2008) [2]. Spalding et al. (2011) [3] said that mangrove diversity is currently low, namely only around 60–70 species classified in 40 genera, which are classified as very low for tropical forest ecosystems. Based on the results of previous studies on mangrove ecosystems, the benefits of mangroves are in the fields of fisheries, fuelwood, construction, medicine, etc (table 1). Another important benefit is as a carbon sink and overcoming the threat of climate change. Efficient carbon absorption from mangrove forests has become one of the detritus materials and exported to support coastal fisheries. Another function is to play a role in coastal protection of mangroves, which was highlighted when the Southeast Asian tsunami destroyed coastal communities in the Western Indo-Pacific and East Africa in 2004 (Primavera et al, 2019) [4].

Table 1. Mangrove Ecosystem Services

| Mangrove Ecosystem Services | Description |
|----------------------------|-------------|
| **Provisioning Services**   |             |
| Wood                       | Mangrove wood has a high calorific value, so it is great for firewood. Utilization of firewood in households is usually used as fuel for cooking. |
| Charcoal                   | Mangrove wood has a high-level density, especially for Rhizophora spp. The high level of wood density produces charcoal with very good quality. |
| Construction materials     | Mangrove wood, in general, has strong characteristics, durable, and doesn't rot easily, so it is very well utilized to make fishing equipment such as fish traps, ships, as well as one of the construction materials to make a residence. |
| Non-timber forest products | There are also have a non-wood benefit in the mangrove ecosystem, including honey, fruits, and others. |
| Dyes (tannins)             | For coloring fishing nets and cloth (batik cloth), and as a preservative for making drinks from coconut sap. Use Rhizophora, Ceriops, and other Rhizophoraceae bark. |
| Nipa palm (*Nypa fruticans*) | As the main base material for making rural housing in the tropical Asia region; but it can also be used to make vinegar, sugar from the sap, and cigarette wrappers from the leaflets. |
| Fisheries                  | Mangrove ecosystems are sanctuaries from fishing habitats and are one of the productive fishing grounds. |
| Pharmaceuticals            | Several types of plants and mangrove fruits have benefits for treating various diseases, one of which is diarrhea, epilepsy, rheumatism, asthma, and diabetes |
| **Regulating Services**     |             |
| Carbon absorption and storage | High primary productivity promotes Carbon sequestration while waterlogged anoxic sediment reduces mineralization. |
| Wave Barrier               | Mangroves can reduce the height of wind (wave height can be reduced by between 13% and 66% over 100m of mangroves. They can also reduce storm wave water levels by slowing water flow (5–50cm per km of mangrove width) and reducing surface waves (by >75% over 1km). |
| Coastal stabilization      | Mangroves can stabilize the coastline by reducing incoming seawater waves and preventing coastline sediments from being washed away and reducing erosion. |
| Water regulation           | Mangrove ecosystems have an important role in maintaining water quality by filtering sediment, minerals, and contaminants from river water and seawater. |
Mangrove Ecosystem Services | Description
--- | ---
Nutrient regulation | Mangrove ecosystems store and provide nutrients in the estuary, the conversion of mangrove ecosystem functions into urban areas, agriculture, and aquaculture shifts the influence of nutrients in dense estuaries.
Pollutant absorbent | Mangrove ecosystems are able to absorb many anthropogenic chemicals.

Supporting Services

Land formation | Mangrove ecosystems have the function to trap sediment (sedimentation) from river and seawater sources, as well as repair and form terrestrial land (accretion).

Ecosystem Service

Primary production | Mangrove ecosystem is a very productive ecosystem because it functions as an aquatic habitat that supports the fisheries sector to continue producing both primary and secondary products.
Nutrient cycling | Mangrove ecosystems can conserve and recycle nutrients.

Cultural Services

Ecotourism | The benefits of mangrove ecosystems for recreation and tourism to improve the economy of the community.
Education | Mangrove ecosystems are able to provide formal and informal education related to the environment and mangrove ecosystems.
Aesthetic | The beauty of nature and other landscapes offered by the mangrove ecosystem.
Spiritual and religious | Mangrove ecosystems have spiritual values, for example gratitude to God for the existence and benefits that are given by mangrove ecosystems.
Sense of place | The identity of indigenous groups is marked / derived from the mangrove ecosystem.
Heritage | Past cultural ties with an ecosystem.

Source: Primavera et al. (2019) [4]

Mangroves produce a variety of forest products, supporting the productivity of fisheries that depend on estuaries which are economically important. Economic constraints are usually in the form of capital available to fund changes in land use in coastal areas, as well as the development of watersheds. Cultural constraints are complex and determine the degree of environmental management and utilization of natural resources. Although mangrove wetlands have different levels of resilience to the impact of human activities, such as deforestation or major changes from the hydrological regime, they are persistent and can therefore be considered as some of the main causes of mangrove death and reduction of areas on a global scale (Rivera-Monroy et al., 2017b; Simard et al., 2019) [5,6]. Humans are part of all ecosystems, and natural resource management is a combination of policies that try to regulate community actions within the limitations provided by the environment. At present, a comprehensive ecosystem restoration program has been put in place to reduce impacts on natural processes and restore ecosystems (Jerath et al., 2016) [7].

The sustainability of mangrove ecosystems has become the main focus in several coastal areas, especially in Pangkah Wetan and Pangkah Wetan Villages, Ujung Pangkah District, Gresik Regency, East Java Province. The current mangrove ecosystem of Pangkah Wetan and Pangkah Wetan Villages has a problem, namely the use of land in the mangrove ecosystem for the economic activities of the local community. Furthermore, Prasetyo (2017) [8] said, ecosystem damage in Ujung Pangkah Subdistrict caused by coastal abrasion and deforestation, the trigger factor of deforestation in the mangrove ecosystem of Ujung Pangkah Subdistrict was the conversion of land into ponds which resulted in 732.78 ha of mangrove forest in 2006 disappearing, and to date is increasing. The purpose of this study was to analyze the sustainability of mangrove ecosystem management from the ecological, economic, social, and institutional dimensions. The results of this analysis are expected to provide an overview of the sustainability status of mangrove ecosystems and can be taken into consideration in making regulations on the preservation of mangrove ecosystems.
2. Methodology

2.1. Study site
This study focuses on the mangrove ecosystem and is located in Pangkah Kulon and Pangkah Wetan Villages, Ujung Pangkah District, Gresik Regency, East Java Province. The management and utilization of mangrove ecosystems in this location has a characteristic, especially those related to biodiversity (water birds) in the mangrove ecosystem. Until now there are still many people who consume waterbirds in the mangrove ecosystem.

2.2. Selection Respondent Method
Respondents in this study were selected by purposive sampling, namely stakeholders who have a direct relationship with the mangrove ecosystem both from the functions, tasks, and authority of stakeholders towards the mangrove ecosystem. According to Farrugia (2019) [9], purposive sampling is an approach that involves researchers who deliberately choose samples by considering the variables or the quality of respondents who are believed to be able to contribute to research.

2.3. Data Analysis
Data were analyzed descriptively and quantitatively. Descriptive data analysis is used to explain the activities of natural resource utilization and patterns of pond utilization. Quantitative data analysis using the RAPFISH / Multi-Dimensional Scaling (MDS) method. According to Papilo et al. (2018) [10], MDS is a data analysis technique with a statistical approach that is very useful for visualizing inequality from an aspect of study, which is quantitative and generally in 2 dimensions. While to measure the relationship between objects, the approach used is an approach from one object to another object. MDS analysis is used to find out what dimensions underlie respondents' perceptions of the sustainability of mangrove ecosystem management (Pitcher and Preikshot, 2001; Garmendia et al, 2010; Nicolas and Schaduw, 2015; Kholil et al, 2015; Adiga et al, 2016) [11,12,13,14,15].

RAPFISH was developed using five field evaluations, namely economic, ecological, technological, social and institutional. According to Pitcher and Preikshot (2001) [11], the economic field includes micro and macroeconomic factors, the field of ecology including parameters of population and environment, the field of technology including equipment used to utilize resources, social factors including social and anthropological factors, institutional fields including industry and communities. After all attributes have been obtained, RAPFISH uses statistical ordination techniques, Multi-Dimensional Scaling (MDS) to reduce fishery N × M matrix (N) and attribute (M) to produce N × 2 space dimensions that represent sustainability status (Kavanagh and Pitcher 2004) [16] RAPFISH or MDS analysis is done through several stages, namely: 1) reviewing the attributes in each dimension of sustainability and defining those attributes through field observations and literature studies. Overall, in this study, there were 33 attributes analyzed, consisting of 7 ecological dimension attributes, 6 economic dimension attributes, 6 social dimension attributes, 7 institutional dimension attributes, and 7 technological dimension attributes (appendix 1). Second, giving scores based on the results of field observations and stakeholder opinions in accordance with predetermined attributes. The range of scores given in this study ranges from 0 - 3, which is interpreted from "bad" to "good" or vice versa, depending on each rating of the attribute. Third, the results of the scores that have been given are analyzed, to determine the sustainability status of mangrove ecosystem management as shown in table 2 below. This MDS approach uses the RAPFISH approach, but because this study focuses on mangrove ecosystems, the approach used is RAP-MANGROVE (Rapid Appraisal Mangrove Ecosystem Management).
Table 2. Sustainability Index Category

| No. | Sustainability Index Range (SIR) (%) | Sustainability Index Category |
|-----|-------------------------------------|------------------------------|
| 1   | 0 < SIR ≤ 25                         | Bad                          |
| 2   | 25 < SIR ≤ 50                        | Less Sustainable             |
| 3   | 50 < SIR ≤ 75                        | Sufficiently Sustainable     |
| 4   | 75 < SIR ≤ 100                       | Sustainable                  |

Source: Thamrin et al. (2007) [17]

Leverage analysis of individual attributes in RAP-MANGROVE is done to determine how much each attribute influences the overall ordination score (Tesfamichael and Pitcher, 2006) [18]. Monte Carlo analysis is a statistical simulation method for evaluating the effects of random errors in a process, and for estimating 'true' values from statistics. Monte Carlo analysis can be done in 100 repetitions, adding zero errors that are normally distributed with a 95% confidence interval set up to 20% from the full range for each attribute to express uncertainty in each evaluation field. The estimated score for each dimension is expressed by the worst (bad) scale 0% to the best (good) 100%. Stress values less than 0.25 and R2 or RSQ values that are close to 1.0 are indicative of strong and said acceptable analytical results (Kavanagh and Pitcher, 2004) [16].

3. Results

3.1. Sustainability of Mangrove Ecosystems on the Ecological Dimension

Based on the results of the MDS analysis with the RAP-MANGROVE approach, the sustainability index value of the ecological dimension of the mangrove ecosystem in the Pangkah Wetan Village area was 45.80 percent, while in the Pangkah Kulon Village area it was 62.64 percent. This means that the ecological dimension in Pangkah Kulon Village is in a sufficiently sustainable category, while in Pangkah Wetan Village it is in the less sustainable category. This is because the condition of the mangrove ecosystem in Pangkah Kulon is better than Pangkah Wetan, besides that the mangrove rehabilitation activities in Pangkah Kulon Village are better. The mangrove rehabilitation activities in Pangkah Kulon Village are run by POKWASMAS in collaboration with the Gresik Regency Marine and Fisheries Agency (DKP), and there have even been many developments and innovations related to the empowerment and improvement of the mangrove ecosystem applied in Pangkah Kulon Village. Besides assistance from DKP, this POKWASMAS activity is also supported by CSR funds from private companies. The following is figure 1(a) which shows the sustainability index value of the ecological dimension of the mangrove ecosystem.

(a)

(b)

Figure 1. Sustainability Status (a) and RMS Value (%) Leverage Analysis (b) of Mangrove Ecosystem on Ecology Dimension of Pangkah Wetan and Pangkah Kulon Villages, Ujungpangkah District, Gresik Regency, East Java Province
Based on the results of the leverage analysis (figure 1(b)), the ecological dimension attributes have a sensitive influence on the increase or decrease in the sustainability status of the mangrove ecosystem. The greater the leverage factor value, the greater the role of these attributes to the sensitivity of the sustainability status of the mangrove ecosystem. The results of leverage analysis show that there are 3 (three) ecological dimension attributes that have the highest value (very sensitive for sustainability of mangrove ecosystems), including 1) fauna diversity in mangrove ecosystems, 2) coastline changes, 3) land pressure on mangrove ecosystems. This shows that fauna diversity in the mangrove ecosystem is very influential on the sustainability of the mangrove ecosystem, therefore, to improve the sustainability status of mangrove ecosystem management it is necessary to maintain and preserve the diversity of fauna in the mangrove ecosystem. Specific regulations are needed to protect the fauna in the mangrove ecosystem to reduce the degradation of fauna in the mangrove ecosystem Pangkah Wetan and Pangkah Kulon villages. Changes in coastline and land pressure in mangrove ecosystems occur due to the function conversion of land that is predominantly for aquaculture, the village government should in terms of area utilization refer to the regional spatial planning that has been established, so as not to damage the mangrove ecosystem.

3.2. Sustainability of Mangrove Ecosystems on the Economic Dimension

The results of the economic dimension sustainability analysis with 8 (eight) attributes on the mangrove ecosystem in Pangkah Kulon Village and Pangkah Wetan show that the value of the sustainability index of mangrove ecosystems from the economic dimension is 54.06 percent in Pangkah Wetan Village, and 78.19 percent in Pangkah Village Kulon. This value indicates that the mangrove ecosystem in Pangkah Kulon Village falls into the sustainable category, while in Pangkah Wetan Village falls into the sufficiently sustainable category. Most of the people in Pangkah Kulon Village and Pangkah Wetan mostly work as fishermen and pond farmers, where the community has interactions with the mangrove ecosystem. The existence of the mangrove ecosystem itself has a function for the fisheries sector, namely for feeding ground, nursery ground, and spawning ground. The function is indirectly useful and has an impact on the economic sector for fisheries commodities both capture fisheries and aquaculture. The fishermen's catch up to now is still said to be quite good, but according to the community when compared to when the mangrove ecosystem is still very good (around the 90s), there is currently a decline in catch, this is due to various factors, one of which is the effect of decreasing the quality of mangrove ecosystems. Next is figure 2(a) which shows the sustainability index value of the economic dimension of the mangrove ecosystem.

![Figure 2](image-url)

**Figure 2.** Sustainability Status (a) and RMS Value (%) Leverage Analysis (b) of Mangrove Ecosystem on Economic Dimension of Pangkah Wetan and Pangkah Kulon Villages, Ujungpangkah District, Gresik Regency, East Java Province

The results of leverage analysis (figure 2(b)) show that there are 3 (three) attributes of the economic dimension that very sensitive for sustainability of mangrove ecosystems, including 1) type of direct use mangrove ecosystems to community 2) contributions to increasing employment, 3) inventory results of
mangrove forest utilization. The results of the leverage analysis show that the attributes of the utilization of mangrove ecosystems to the community are very influential on the sustainability of mangrove ecosystems based on economic dimensions, this is because the more types of utilization of mangrove ecosystems, the higher economic benefits felt by the community, but it needs to be regulated regarding its utilization, so that the utilization process does not exceed the carrying capacity of the environment and does not damage the mangrove ecosystem.

3.3. Sustainability of Mangrove Ecosystems on the Social Dimension

The results of the social dimension sustainability analysis with 8 (eight) attributes on the mangrove ecosystem in Pangkah Wetan and Pangkah Kulon Villages obtained a sustainability index value from the social dimension of Pangkah Wetan Village at 50.21 percent in Pangkah Kulon Village at 67.82 percent. This value shows that the mangrove ecosystem of Pangkah Kulon and Pangkah Wetan Villages the sustainability of mangrove ecosystems seen from the social dimension fall into the sufficiently sustainable category. Community dependence on mangrove ecosystems is quite high, as seen from the pattern of life and habits of the community towards the use of mangrove ecosystems to fulfill their daily needs. Of course, social activities are also influenced by the condition of the community itself, such as understanding the importance of mangrove ecosystems for their lives. Next is figure 3(a) which shows the sustainability index value of the social dimension of the mangrove ecosystem.

![Figure 3(a)](image)

**Figure 3.** Sustainability Status (a) and RMS Value (%) Leverage Analysis (b) of Mangrove Ecosystem on Social Dimension of Pangkah Wetan and Pangkah Kulon Villages, Ujungpangkah District, Gresik Regency, East Java Province

The results of leverage analysis (figure 3(b)) show that there are 3 (three) attributes of the social dimension that very sensitive for sustainability of mangrove ecosystems, including 1) mangrove ecosystems damaged by community, 2) community access to mangrove ecosystems, 3) community participation in mangrove ecosystems management. Damage to the mangrove ecosystem resources by the community is a social dimension attribute that has the highest value, therefore, to improve the sustainability of the mangrove ecosystem must reduce/reduce damage to the mangrove ecosystem by the community. There needs to be rules that protect mangrove ecosystems and impose strict sanctions to prevent disturbance of mangrove ecosystems by the community. Subsequent attributes such as community access to mangrove ecosystems and community participation in the management of mangrove ecosystems affect the sustainability of mangrove ecosystems, community access to management will lead to the role of the community in managing the ecosystem, extension, assistance and incentives for the community to be involved community in protecting, and maintaining mangrove ecosystems to realize sustainable management of mangrove ecosystems.

3.4. Sustainability of Mangrove Ecosystems on the Institutional Dimension

The results of the institutional dimension sustainability analysis with 7 (seven) attributes on the mangrove ecosystem in Pangkah Wetan and Pangkah Kulon Villages indicate that the sustainability
index value of the institutional dimensions of each village is 47.70 in Pangkah Wetan Village, and 51.69 in the Village Pangkah Kulon. This value indicates that the sustainability status of the mangrove ecosystem in Pangkah Wetan Village is less sustainable, whereas in Pangkah Kulon Village it is sufficiently sustainable. The institutional management of the mangrove ecosystem in both Pangkah Wetan and Pangkah Kulon Villages is carried out by POKWASMAS, where the institution is still active in monitoring, monitoring, planting and maintaining mangroves. But there are differences in the programs/activities that have been carried out by the Pangkah Wetan Village and Pangkah Kulon Village. POKWASMAS Pangkah Wetan Village has not yet carried out mangrove rehabilitation activities, it is still in the form of economic development in the mangrove ecosystem area such as mangrove tourism sites, while POKWASMAS Pangkah Kulon Village has carried out mangrove tree nursery activities. POKWASMAS Pangkah Kulon Village nursery activities are the result of collaboration between POKWASMAS and DKP of Gresik Regency, in addition, some mangrove planting activities are the result of collaboration with private companies. Based on the facts of the field, it can be concluded that until now the preservation efforts of the mangrove ecosystem in Pangkah Wetan and Pangkah Kulon villages have not gone well. The government has made a regulation related to the protection of mangrove ecosystems, but it is only limited to the protection of water birds, such as the prohibition of hunting water birds, but the sanctions that have not been imposed for those who violate are only notices. The following is figure 4(a) which shows the sustainability index value of the institutional dimension of the mangrove ecosystem.

The results of leverage analysis (figure 4(b)) show that there are 3 (three) attributes of institutional dimensions that have the highest value (very sensitive for sustainability of mangrove ecosystems), including 1) involvement of community institutions regarding mangrove ecosystem management, 2) existence of sanctions for violating regulations in the mangrove ecosystem, 3) monitoring and supervision. The attributes of involvement of community institutions/stakeholders and the existence of sanctions violating regulations related to mangrove ecosystems are the most important things. The involvement of community/stakeholder institutions in the management of mangrove ecosystems indicates that the government, the community, and stakeholders are serious about protecting and protecting the mangrove ecosystem. This involvement can also create a rule of protection for mangrove ecosystems that are good and in terms of their application in accordance with established rules, to the imposition of sanctions for those who violate, thus monitoring and monitoring of mangrove ecosystems from upstream to downstream will be well established.

3.5. Sustainability of Mangrove Ecosystems on the Technology Dimension

The results of the sustainability analysis of the technology dimension with 9 (nine) attributes on the mangrove ecosystem indicate that the sustainability index value of the technology dimension for
Pangkah Wetan Village of 42.30 percent means that it is less sustainable, while for Pangkah Kulon Village, 60.15 percent means sufficiently sustainable. There is a difference in the results of the sustainability analysis between Pangkah Kulon Village and Pangkah Wetan, this is because of the conservation activities of the mangrove ecosystem in Pangkah Kulon Village are more developed technically compared to Pangkah Wetan Village. Preservation in Pangkah Kulon Village conducted by POKWASMAS is already a form of training, technological innovation in planting, maintenance and breeding. According to the DKP of Gresik Regency, his side is still collaborating and controlling the preservation of mangrove ecosystems, and even giving assistance in the form of marine vessels whose function is to facilitate POKWASMAS monitoring activities of existing mangrove ecosystems and new mangrove planting activities. The innovation and technological development activities for conservation and supervision activities also involve the participation of the community, especially pond farmers and fishermen so that the success of the mangrove ecosystem improvement program can be realized. Even so, seeing that the field conditions for the use of technology in the management of mangrove ecosystems have not gone well and still need to be improved, this is because the activities carried out by POKWASMAS are still tentative, and activities that have been run are not properly maintained. Next is figure 5(a) which shows the sustainability index value of the technology dimensions of mangrove ecosystems in Pangkah Wetan and Pangkah Kulon Villages, Ujungpangkah District, Gresik Regency, East Java Province.

![Figure 5](image)

**Figure 5.** Sustainability Status (a) and RMS Value (%) Leverage Analysis (b) of Mangrove Ecosystem on Technology Dimension of Pangkah Wetan and Pangkah Kulon Villages, Ujungpangkah District, Gresik Regency, East Java Province

The results of the leverage analysis (figure 5(b)) show that there are 3 (three) dimensions of technology attributes that very sensitive for sustainability of mangrove ecosystems, including 1) Processing techniques for mangrove products, 2) Techniques for capturing biota in mangrove ecosystems, 3) Techniques for planting mangroves. The attributes of the processing of mangrove products and capture of biota are the most important and sensitive influences on the sustainability status of mangrove ecosystems from the technological dimension, this is because these attributes are inherent attributes to the community because fishermen and pond farmers use resources within the mangrove ecosystem. It is necessary to improve the processing techniques of mangrove products and capture biota in mangrove ecosystems to increase production which can provide economic benefits to the community while reducing the risk of the impact of damage to the mangrove ecosystem due to the activity of utilizing mangrove ecosystems. Environmentally friendly technology improvements will influence and improve the sustainability of mangrove ecosystems in Pangkah Wetan and Pangkah Kulon Villages.

### 3.6. Monte Carlo Analysis

The RAP-MANGROVE model carried out in this study has been analyzed to see the error rate of the model using Monte Carlo analysis. This analysis was carried out at a 95 percent confidence level (Pitcher et al., 2013) [11]. The results of the Monte Carlo analysis are compared with the results of the MDS
analysis, if the difference between the two analyzes is <5%, then the results of the MDS analysis are adequate and valid (Alder et al., 2000) [19]. The analysis between MDS and Monte Carlo values in all dimensions in this study is <5%, meaning that the results of this research analysis are adequate and valid (table 3).

| Dimensions  | Village       | MDS (%) | Monte Carlo (%) | Difference (%) |
|-------------|---------------|---------|-----------------|----------------|
| Ecology     | Pangkah Wetan | 45.80   | 46.16           | 0.36           |
|             | Pangkah Kulon | 62.64   | 61.91           | 0.74           |
| Economic    | Pangkah Wetan | 54.06   | 53.62           | 0.44           |
|             | Pangkah Kulon | 76.33   | 78.19           | 1.86           |
| Social      | Pangkah Wetan | 50.21   | 49.64           | 0.57           |
|             | Pangkah Kulon | 67.82   | 67.00           | 0.82           |
| Institutional| Pangkah Wetan | 47.70   | 47.47           | 0.23           |
|             | Pangkah Kulon | 51.69   | 51.37           | 0.33           |
| Technology  | Pangkah Wetan | 42.30   | 42.70           | 0.40           |
|             | Pangkah Kulon | 60.15   | 59.19           | 0.97           |

3.7. Goodness of Fit Analysis

The assessment of the goodness of fit in the MDS analysis is determined by the resulting S-stress value. A good model is shown with a stress value of <0.25 and the value of R2 or RSQ is close to 1.0 (Kavanagh and Pitcher, 2004; Alder et al., 2000) [11,19]. The results of this analysis obtained S-stress values <0.25 for each dimension (table 4), so it can be concluded that the model in this analysis is a good model and can be used to analyze the accuracy of the sustainability of mangrove ecosystem management.

| Dimensions   | Stress | RSQ  | Iterations |
|--------------|--------|------|------------|
| Ecology      | 0.15   | 0.95 | 2          |
| Economic     | 0.17   | 0.94 | 2          |
| Social       | 0.15   | 0.94 | 2          |
| Institutional| 0.17   | 0.94 | 2          |
| Technology   | 0.15   | 0.94 | 2          |

4. General Discussion

Based on the analysis of the sustainability status of the management of mangrove ecosystems in Pangkah Wetan and Pangkah Kulon Villages using RAPMANGROVE, at least there are important factors/dimensions that should be considered to improve the sustainability status. The dimensions / factors that must be considered and improved to realize sustainable management of mangrove ecosystems are the ecological, institutional and technological dimensions. Ecological attributes that are very sensitive to the sustainability of mangrove ecosystems are the diversity of fauna in mangrove ecosystems and shoreline changes, this is consistent with the research of Karlina et al. (2016) [20] and Pudji et al. (2018) [21]; which states changes in the area of mangrove forests (scale and area) will affect the amount of fauna that can normally be utilized by the community such as crabs, shellfish, and other fish that have economic value. The institutional attributes that are very sensitive to the sustainability of mangrove ecosystems are the involvement of community institutions/stakeholders, and the existence of sanctions in violation of regulations related to mangrove ecosystems, this is in accordance with Mukhlisi et al. (2013) [22], Theresia et al. (2015) [23] and Schaduw (2018) [24] who stated that efforts to create sustainable management, especially in the institutional dimension, were determined by the involvement of community leaders and local communities and the consistency of law enforcement (rules to clear sanctions for violations). Technological attributes that are very sensitive to the sustainability of
mangrove ecosystems are mangrove yield processing techniques, and biota capture techniques in mangrove ecosystems, this is in accordance with the research of Alvi et al. (2018) [25] and Jaya (2019) [26] which state that technology and knowledge are very important in conserving mangrove ecosystems, especially in technologies related to aquaculture and capture fisheries, and ecosystem restoration/rehabilitation.

5. Conclusions

The status of the sustainability of the management of the mangrove ecosystem in Pangkah Wetan Village and Pangkah Kulon Village is mostly in the sufficiently sustainable category. Based on the results of leverage analysis, it shows attributes that are very sensitive to the sustainability status of mangrove ecosystems, for the ecological dimension are fauna diversity in mangrove ecosystems, and coastline changes. The sensitive attributes in the economic dimension are a type of direct use mangrove, culture and capture fisheries, and ecosystem distance to hurricane. The status of the sustainability of the management of the mangrove ecosystem in Pangkah Wetan Village and Pangkah Kulon Village is mostly in the sufficiently sustainable category. Based on the results of leverage analysis, it shows attributes that are very sensitive to the sustainability status of mangrove ecosystems, for the ecological dimension are fauna diversity in mangrove ecosystems, and coastline changes. The sensitive attributes in the economic dimension are a type of direct use mangrove, culture and capture fisheries, and ecosystem distance to hurricane.

6. References

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### Appendix 1. Attributes to Each Dimension of Sustainability Assessment

| Dimensions | Attribute | Good | Bad | Notes |
|------------|-----------|------|-----|-------|
| Ekologi    | 1. Mangrove Density | 2 | 0 | (0) <1000 mangrove trees/ha<br>(1) ≥1000-1500 mangrove trees/ha<br>(2) ≥1500 mangrove trees/ha<br>(3) ≥50% Mangrove cover<br>(4) ≥50%-75% Mangrove Cover<br>(5) ≥75% Mangrove Cover |
|            | 2. Mangrove Cover | 2 | 0 | (0) <50% Mangrove cover<br>(1) ≥50% Mangrove cover<br>(2) ≥75% Mangrove Cover |
|            | 3. Mangrove Diversity | 2 | 0 | (0) Low (H’=1-2)<br>(1) High (H’=3-4)<br>(2) Very High (H’ >4) |
|            | 4. Fauna diversity in mangrove ecosystems | 2 | 0 | (0) <2 Fauna diversity<br>(1) 2-10 Fauna diversity<br>(2) >10 Fauna diversity |
|            | 5. Land pressure on mangrove ecosystems | 0 | 2 | (0) No pressure in mangrove land area<br>(1) Pressure in mangrove land area is high<br>(2) Decreasing in coastlines area is very high |
|            | 6. Coastlines changes | 0 | 2 | (0) No decreasing in coastlines area<br>(1) Decreasing in coastlines area is high<br>(2) Decreasing in coastlines area is very high |
|            | 7. Rehabilitation on mangrove ecosystems | 2 | 0 | (0) Non-rehabilitation program<br>(1) Rehabilitation program exist, but not managed properly<br>(2) Rehabilitation program exist, with good management |
| Ekonomi    | 1. Contributions to Increasing Community Income | 2 | 0 | (0) <5%<br>(1) 5-10%<br>(2) >10% |
|            | 2. Total Economic Value of the Mangrove Ecosystem | 2 | 0 | (0) <5 billion/year<br>(1) 5-10 billion/year<br>(2) >10 billion/year |
|            | 3. Types of Direct use Mangrove Forests to Community | 2 | 0 | (0) <3 types of direct use<br>(1) 3-5 types of direct use<br>(2) >5 types of direct use |
|            | 4. Inventorization results of mangrove forest utilization | 2 | 0 | (0) Not available<br>(1) Exist, but not managed properly<br>(2) Exist, with good management |
|            | 5. Mangrove Utilization Zone | 2 | 0 | (0) Not available<br>(1) Available, but not yet obeyed<br>(2) Available and obeyed |
|            | 6. Contributions to Increasing Employment | 2 | 0 | (0) Low<br>(1) Moderate<br>(2) High |
| Social     | 1. Community knowledge about mangrove ecosystems | 2 | 0 | (0) Low<br>(1) Moderate<br>(2) High |
|            | 2. Community access to utilize mangrove ecosystems | 2 | 0 | (0) Do not have access at all<br>(1) Community access is low<br>(2) Community access is high |
|            | 3. Mangrove ecosystems damaged by community | 0 | 2 | (0) Low<br>(1) Moderate<br>(2) High |
|            | 4. Community awareness of the importance of mangrove ecosystems | 2 | 0 | (0) Low<br>(1) Moderate<br>(2) High |
|            | 5. Community participation in mangrove ecosystem management | 2 | 0 | (0) Low<br>(1) Moderate<br>(2) High |
|            | 6. Conflict of mangrove resource utilization | 0 | 2 | (0) <2 times/year<br>(1) 2-5 times/year<br>(2) >5 times/year |
| Dimensions                  | Attribute                                                                 | Good | Bad | Notes                                                                                                                                 |
|-----------------------------|---------------------------------------------------------------------------|------|-----|----------------------------------------------------------------------------------------------------------------------------------------|
| Institutional               | 1. Availability of Mangrove Protection Policies and Management Plans       | 2    | 0   | (0) Not available                                                                                                                    |
|                            |                                                                           |      |     | (1) exists, but is not implemented                                                                                                   |
|                            |                                                                           |      |     | (2) exists and is implemented                                                                                                          |
|                            | 2. Coordination between Institutions / Stakeholders Regarding Mangrove Ecosystem Management | 2    | 0   | (0) never implemented                                                                                                                |
|                            |                                                                           |      |     | (1) rarely implemented                                                                                                                |
|                            |                                                                           |      |     | (2) always carried out                                                                                                                |
|                            | 3. Involvement of Community Institutions Regarding Mangrove Ecosystem Management | 2    | 0   | (0) communities and community institutions are not involved in monitoring and evaluation                                           |
|                            |                                                                           |      |     | (1) community and community institutions involved but only procedurally;                                                             |
|                            |                                                                           |      |     | (2) communities and community institutions are actively involved in providing information, processes, and determination of monitoring and evaluation mechanisms |
|                            | 4. Compliance with the Rules for Mangrove Ecosystem Management            | 2    | 0   | (0) Low (>5 times violations)                                                                                                         |
|                            |                                                                           |      |     | (1) Moderate (2-4 times violations)                                                                                                   |
|                            |                                                                           |      |     | (2) High (<2 times violations)                                                                                                         |
|                            | 5. Availability of Extension Staff / Field Officers                       | 2    | 0   | (0) Not available                                                                                                                     |
|                            |                                                                           |      |     | (1) Exist, but doesn’t work effectively                                                                                               |
|                            |                                                                           |      |     | (2) Exist, and work effectively                                                                                                        |
|                            | 6. Existence of Sanctions for Violating Regulations in the Mangrove Ecosystem | 2    | 0   | (0) Not available                                                                                                                     |
|                            |                                                                           |      |     | (1) Exist, but not implemented                                                                                                         |
|                            |                                                                           |      |     | (2) Exist, and implemented properly                                                                                                   |
|                            | 7. Monitoring and Supervision                                             | 2    | 0   | (0) No supervision and monitoring                                                                                                      |
|                            |                                                                           |      |     | (1) Lack of supervision and monitoring                                                                                                 |
|                            |                                                                           |      |     | (2) Always monitored                                                                                                                  |
| Technology                 | 1. Mangrove Nursery Technique                                            | 2    | 0   | (0) Not available                                                                                                                     |
|                            |                                                                           |      |     | (1) Exist, but it’s not efficient                                                                                                      |
|                            |                                                                           |      |     | (2) Exist and efficient                                                                                                                |
|                            | 2. Mangrove Planting Techniques                                          | 2    | 0   | (0) planting relies on natural processes                                                                                               |
|                            |                                                                           |      |     | (1) planting of mangrove seeds (propagule) is done directly                                                                         |
|                            |                                                                           |      |     | (2) planting mangrove seeds through nurseries                                                                                          |
|                            | 3. Mangrove Maintenance Techniques                                       | 2    | 0   | (0) there is no                                                                                                                       |
|                            |                                                                           |      |     | (1) done naturally                                                                                                                     |
|                            |                                                                           |      |     | (2) based on studies/research                                                                                                          |
|                            | 4. Mangrove Processing Techniques                                       | 2    | 0   | (0) there is no                                                                                                                       |
|                            |                                                                           |      |     | (1) ever but not developed                                                                                                             |
|                            |                                                                           |      |     | (2) exists and developed                                                                                                               |
|                            | 5. Pest and Disease Control Techniques                                   | 2    | 0   | (0) there is no special treatment in controlling pests and diseases;                                                                   |
|                            |                                                                           |      |     | (1) control is carried out after the seed spreading using factory-made medicines;                                                     |
|                            |                                                                           |      |     | (2) eradication of pests and diseases carried out before stocking seeds without the use of factory-made drugs (organic pesticides) which can damage the mangrove ecosystem. |
|                            | 6. Biota Catching Techniques                                             | 2    | 0   | (0) catch hands                                                                                                                       |
|                            |                                                                           |      |     | (1) use a traditional tool                                                                                                             |
|                            |                                                                           |      |     | (2) using fish nets and traps                                                                                                          |
|                            | 7. Abrasion Control Techniques                                          | 2    | 0   | (0) there is no                                                                                                                       |
|                            |                                                                           |      |     | (1) exists, but is not developed                                                                                                       |
|                            |                                                                           |      |     | (2) exists, and is well developed                                                                                                      |