The sustainability status of mangrove ecosystem management in the rehabilitation area of Sayung Coastal Zone, Demak Regency, Central Java Indonesia

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Abstract. This study aimed to analyze the sustainability status of the mangrove ecosystem management in the Sayung District coastal area, by integrating all the stakeholders' interests in a multidimensional analysis (ecological, economic, social, and institutional) and determining sensitive indicators in the sustainable management of mangrove ecosystems. The method used in this study was the multidimensional scalling (MDS) with the RAPFISH (Rapid Appraisal for Fisheries) software. The results showed that the multidimentional sustainable status of the mangrove ecosystem management in the coastal area of Sayung sub-district. The sustainability status of the mangrove ecosystem management is (1) very sustainable for the ecological dimension, in all villages (Bedono 72.17%, Timbulsloko 78.50%, Surodadi 91.11%); (2) sustainable for the economic dimension for all the villages (Bedono 74.73%, Timbulsloko 74.73%, Surodadi 52.74%); (3) very sustainable for the social dimension, for Timbulsloko (90,21%) but only sustainable for Bedono (63.05%) and Surodadi (74.58%); (4) very sustainable for the institutional dimension, in all villages (Timbulsloko 84.97%, Bedono 84.97%, Surodadi 87.90%). The mangrove ecosystem management is influenced by the following factors: coastal erosion, oceanographic conditions, average income of the community, local wisdom, community education level, participation in mangrove ecosystem management, monitoring and supervision and mangrove ecosystem management planning. By optimising the most sensitive indicators on each dimension, the sustainability of mangrove ecosystem management could be improved.
Key Words: multidimensional scalling, coastal erosion, sustainable management.

Introduction. Mangrove damage in Sayung coastal zone began in the 1980s, during a change in land use. The conversion of mangroves into ponds led to the loss of natural coastal protection (Marfai 2011; Fikriyani & Mussadun 2014; Putri et al 2014; Zaky et al 2012), worsening the Sayung coast exposure to the winds, waves, and currents. There was also a change in hydro-oceanographic patterns due to reclamation and buildings in the areas adjacent to the shore (Marfai 2012; Asiyah et al 2015; Putri et al 2014; Ervita & Marfai 2017). This created alterations in the coastlines which were influenced by high erosion. According to the Marine and Fisheries Ministry (2015), the area affected by coastal erosion was approximately 2,116.54 ha. It was further stated that the erosion occurred up to 5 km inland, with the worst effect in Bedono and Timbulsloko Villages (Irsadi et al 2019; Marfai 2012).

Furthermore, various efforts to overcome the coastal erosion were carried out by the public and the private sectors by constructing hard and soft structures. These

include: a beach belt with concrete buis, a wave breaker with used tire materials, a talud, an embankment, hybrid engineering, sediment enrichment, rehabilitation and mangrove planting. The mangrove rehabilitation effort succeeded in expanding the ecosystem. In addition, a rising awareness on the importance of coastal protection against erosion is experienced by the local community.

Besides, the management of mangrove ecosystems in the Sayung coastal zone faces many challenges such as ecological, economic, social and institutional issues. The study of the sustainability of mangrove ecosystems at the rehabilitation sites needs to be conducted by integrating and accommodating all aspects and interests in a multidimensional approach. In addition, the determination of sensitive indicators is also needed in order to improve the rehabilitated mangrove areas sustainability management. It is also expected to meet the needs and improve the welfare of the local community both in the present and in the future. The purpose of this study was to obtain a snapshot of the sustainability status of the mangrove ecosystem in the Sayung coastal zone and also to determine the leverage attributes or factors that influence its management.

Material and Method

Description of the research sites. This research was conducted from July to October 2019, in the coastal sub-district of Sayung, Demak Regency, Central Java Province, Indonesia, consisting of 3 villages, namely Bedono, Timbulslokoand Surodadi. The research site is shown in Figure 1.

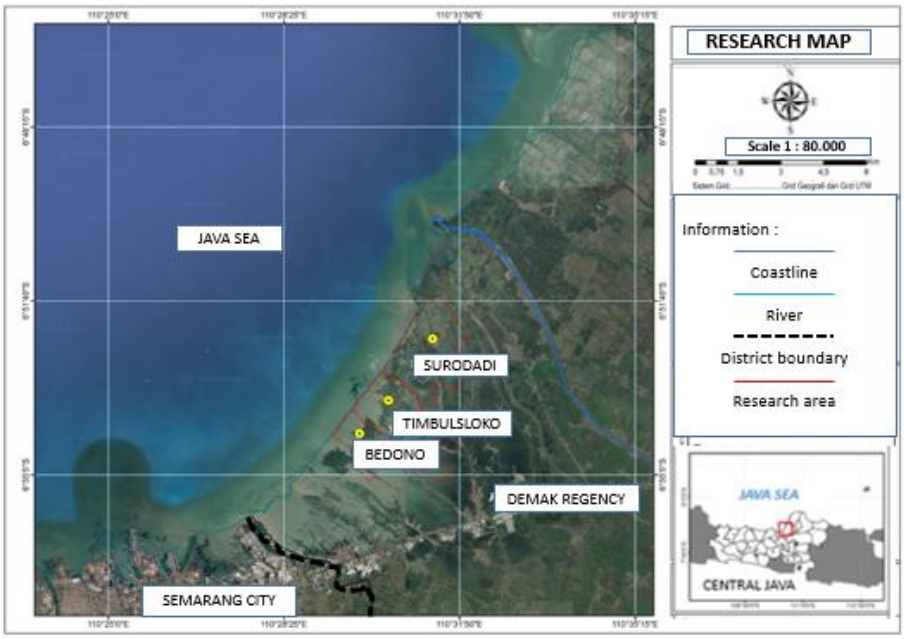

Figure 1. Research site.

Data and data collection. Primary and secondary data were collected by purposive sampling in the form of interviews and questionnaires, which were divided into two sections: one for experts and the other for the community. However, in order to acquire information from experts, in-depth interview techniques were carried out. The purpose of the extensive interviews was to establish indicators and also to score each sustainability measure. The respondents were major stakeholders of the Provincial Maritime and Fisheries Service, the District Maritime and Fisheries Service, the Environmental Service, Fisheries and Marine Instructors, academics from tertiary institutions, community leaders and NGOs concerned with the environment and natural resources. Secondary data was in the form of information relating to the sustainability and management of mangrove ecosystems. It was also obtained from literature studies, reports, and related research results.

Data analysis. The analysis of this study was carried out with the Multi Dimensional Scalling (MDS) approach using modified Rapid Appraisal for Fisheries (RAPFISH) software for mangrove management. RAPFISH is a rapid assessment technique designed to evaluate the sustainability of fisheries (Pitcher & Preikshot 2001). According to Yusuf et al (2016), the MDS-RAPFISH is a sustainability analysis tool to determine the status (level) and leverage attributes of a sustainability management. Pitcher et al (2013) added that RAPFISH is a rapid appraisal technique designed to allow an objective multi-disciplinary evaluation, but it does not intend to replace the conventional stock assessment for setting quotas. This study used the RAPFISH software for the implementation of the MDS approach, which will produce a comprehensive picture of the condition of mangrove ecosystem management so that it can be used as material to determine appropriate policies to achieve sustainable mangrove management (Figure 2).

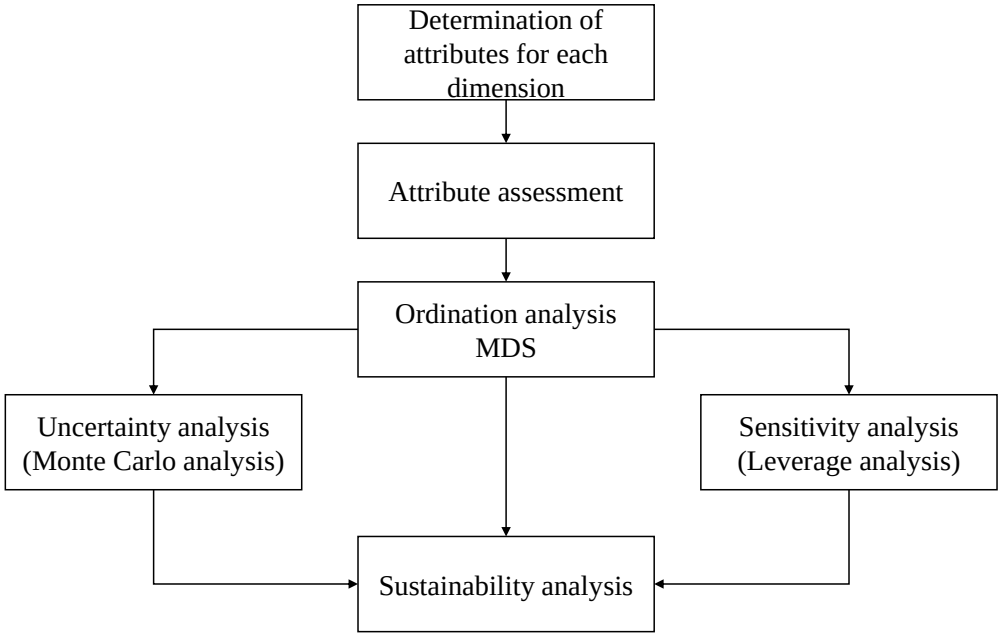

Figure 2. Stages in sustainability mangrove ecosystem management analysis (modified from Schaduw 2015).

The sustainability index scale has an interval of 0-100%. If the index value is more than 50%, then it can be categorized as sustainable. And if the index is less than 50%, then it is categorized as not or not yet sustainable. The sustainability index category is shown in Table 1.

Table 1

Sustainability index category (Fauzi & Anna 2005)

Value index	*Category*
0–25	Poor, not continuous
25.01–50	Less, less sustainable
50.01–75	Enough, quite sustainable
75.01–100	Good, very sustainable

The leverage analysis, in this study, was conducted to determine which attributes had a more dominant role or to which attribute, rather than than to the other features, the corresponding sustainability dimension was more sensitive. Furthermore, in order to evaluate the impact of random errors on all dimensions in the process and the estimation of the ordination value, the Monte Carlo analysis, and the scatter plot method were applied (Kavanagh 2001; Fauzi & Anna 2005). The validity level of the model was

obtained from the difference between the ordination value and the Monte Carlo analysis. The model is considered valid when the difference is below 5%.

Goodness of fit in MDS is reflected in the amount of S (Stress) and R^2. A good model is shown with the smaller value of S and R^2 close to 1. The stress value (standarized residual sum of square) is a measure of the incompatibility of the methods used for this research. Table 2 shows the stress value criteria.

Table 2

Stress value criteria (Laksana et al 2017)

Stress value (%)	*Goodness of fit criteria*
0-2.5	Perfect
2.5-5	Very good
5-10	Good
10-20	Enough
>20	Bad

Results

Sustainability indicators. Based on the result of literature studies and in-depth interviews with expert, 4 dimensions were determined with 26 indicators. Ecological dimension consist of 6 indicators, economy dimension consist of 5 indicators, social dimension consist of 7 indicators and institutional dimension consist of 8 indicators. Then an assessment of each indicator is conducted. Sustainability indicators and the scoring for each location are shown in table Table 3.

Table 3

Sustainability indicators in each dimension and scoring for each location

Sustainability indicators	*Description*	*Score*		
		Bedono	*Timbulsloko*	*Surodadi*
	Ecological			
Oceanographic condition	(0) not conducive, (1) medium, (2) conducive	0	0	1
Coastal erosion	(0) low, (1) medium, (2) high	2	1	0
Rehabilitation of mangrove ecosystem	(0) none, (1) exist, and well managed, (2) exist, but not managed properly	2	2	2
Mangrove density	(0) rare (<1000 tree ha^{-1}), (1) moderate (≥1000-1500 tree ha^{-1}), (2) dense (≥1500 tree ha^{-1})	2	2	2
Mangrove cover	(0) reduce, (1) fix, (2) increase	2	2	2
Sedimentation	(0) occured, (1) did not occur	1	1	1
	Economical			
Utilizaton of mangrove by local community	(0) low (<25% direct use of wood and fisheries), (1) moderate (≥25-50% direct use of wood and fisheries), (2) high (≥50% direct use of wood and fisheries)	2	2	0
Average community income from the regional minimum wage (UMR)	(0) lower than UMR, (1) the same as UMR, (2) above UMR	1	1	2

Sustainability indicators	*Description*	*Score*		
		Bedono	*Timbulsloko*	*Surodadi*
Government budget for mangrove management	(0) there is no budget, (1) low (lack of budget for management activities), (2) moderate (budget for mangrove management is sufficient, but still lacking, (3) high (budget for mangrove management is sufficient and exceeds the needs)	2	2	1
Funding support from NGO's and private sector	(0) no financial support, (1) there is little funding support, (2) there is financial support for management, large amount	2	2	1
Accessibility of mangrove areas	(0) low: location is difficult to access and infrastructure facilities are very poor, (1) medium: accessible location and inadequate infrastructure facilities, (2) high: location is easily accessible and infrastructure facilities are good	1	1	1
	Social			
Community perception of mangrove ecosystems	(0) bad, (1) medium, (2) good	2	2	2
Community education level	(0) not completing elementary school, (1) graduated elementary school, (2) graduated junior high school, (3) graduated senior high school (4) graduated college	2	2	2
Damage of mangrove ecosystem by local community	(0) large, (1) medium, (2) small	1	2	2
Public awareness of the importance of mangrove resources	(0) low (<50%), (1) moderate (50-75%), (2) high (75-100%)	1	2	2
Local wisdom	(0) none, (1) present, but not efficient, (2) present and efficient	2	2	2
Community participation in mangrove ecosystem management	(0) low (0-50%), (1) moderate (50-75%), (2) high (75-100%)	2	2	1
Conflict over mangrove resource use	(0) a lot (>5 times year^{-1}), (1) a few (2-5 times year^{-1}), (2) a little (<2 times year^{-1})	1	2	1
	Institutional			
Policy and planning of the mangrove ecosystem management	(0) none, (1) available, but not yet implemented, (2) available and implemented	2	2	1

Sustainability indicators	*Description*	*Score*		
		Bedono	*Timbulsloko*	*Surodadi*
Availability of rules and the role of non-formal institutions	(0) none, (1) present, but ineffective, (2) available and effective	2	2	2
Involvement of community institutions	(0) the community and community institutions are not involved, (1) community and community institutions involved, but only procedurally, (2) the community and community institutions are actively involved in providing information, processes and determining monitoring and evaluation mechanisms	2	2	2
Coordinations between institutions/stakeholders	(0) never been carried out, (1) rarely carried out, (2) always carried out	2	2	2
Availability of field officers	(0) none, (1) available but not effective, (2) available and effective	2	2	2
Compliance with management rules	(0) low (>5 times violation information), (1) medium (2-4 times violation information), (2) high (<2 times violation information)	2	2	2
Application of legal sanction for violators	(0) not implemented, (1) implemented but not effective, (2) implemented and effective	1	1	2
Monitoring and supervision	(0) no monitoring and supervision, (1) lack of monitoring and supervision, (2) monitoring and supervision are always carried out	1	1	1

Sustainability status. The MDS ordinance analysis results are shown below: for the ecological dimension in Figure 3, for the economic dimension in Figure 4, for the social dimension in Figure 5 and for the institutional dimension in Figure 6, where DT - Timbulsloko Village, DB - Bedono Village, DS - Surodadi Village. The sustainability index values, Monte-Carlo analysis and model validity are shown in Table 4.

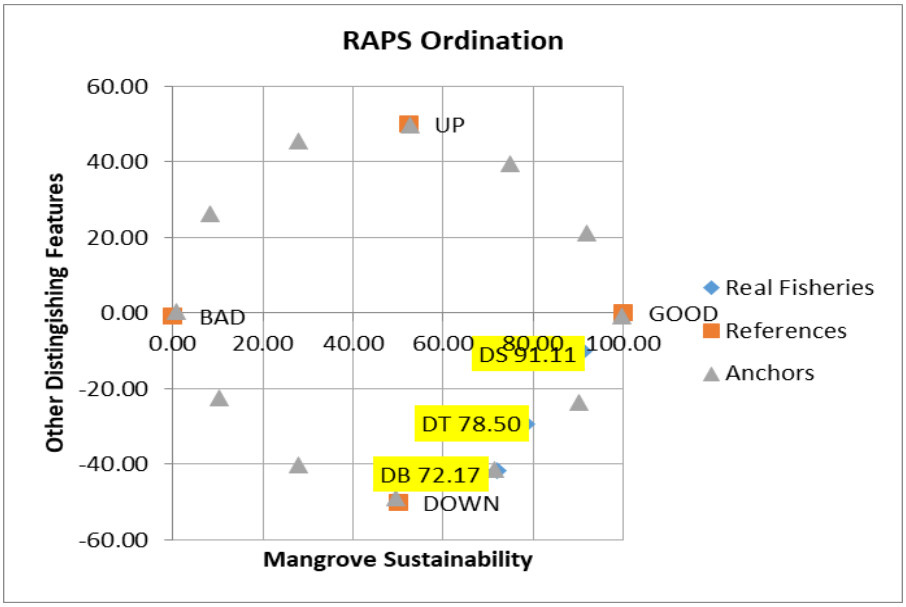

Figure 3. Sustainability ordinance in the ecological dimension.

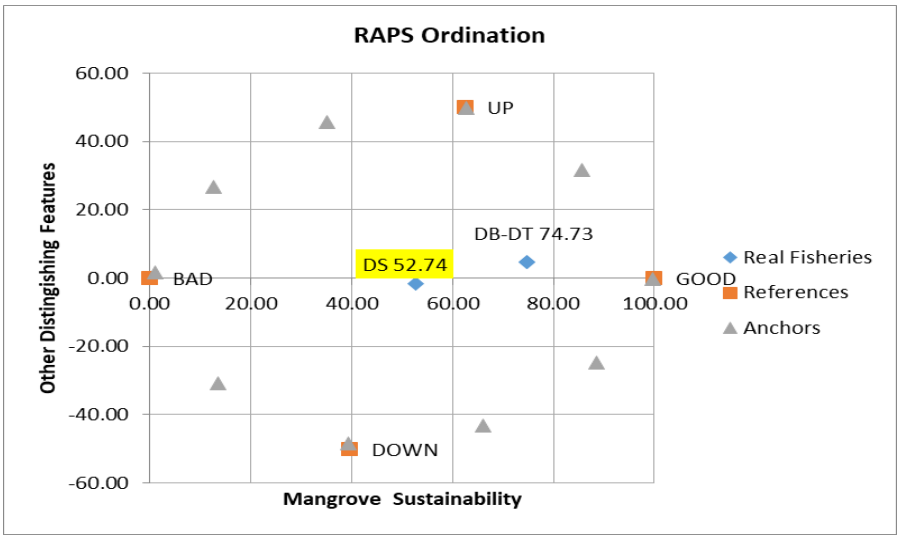

Figure 4. Sustainability ordinance in the economical dimension.

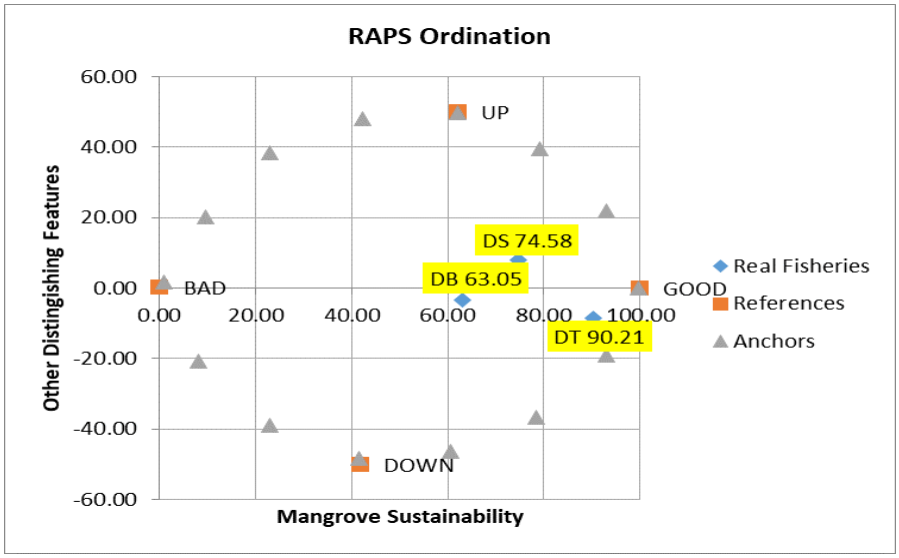

Figure 5. Sustainability ordinance in the social dimension.

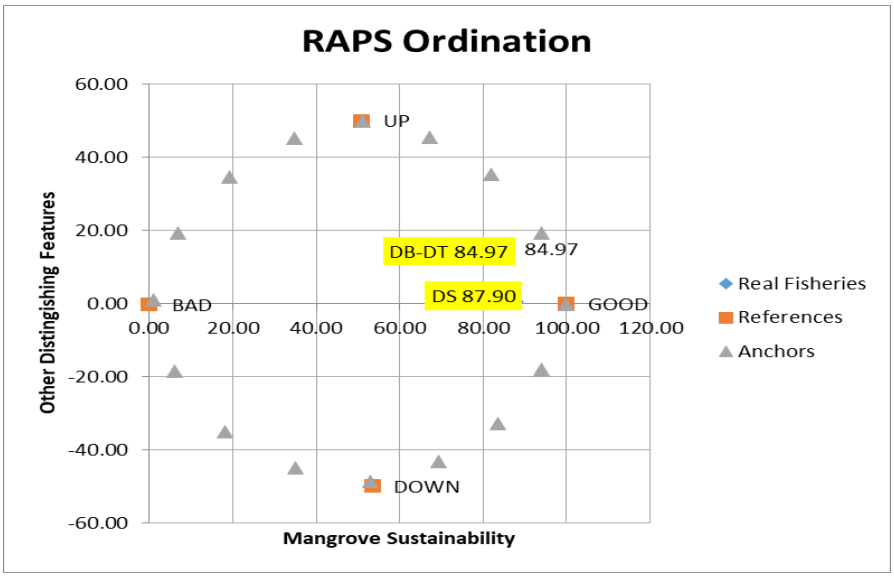

Figure 6. Sustainability ordinance in the institutional dimension.

Table 4

Sustainability index value and model validity

Dimension	*Location*	*Sustainability index (%)*	*Stress value (%)*	*R square*	*Monte Carlo analysis*		*Validity*
					Value (%)	*Diff*	
	Bedono	72.17			70.47	1.70	Valid
Ecological	Timbulsloko	78.50	14.29	95.09	76.60	1.90	Valid
	Surodadi	91.11			87.02	4.09	Valid
	Bedono	74.73			73.20	1.53	Valid
Economical	Timbulsloko	74.73	16.38	92.50	73.20	1.53	Valid
	Surodadi	52.74			52.28	0.46	Valid
	Bedono	63.05			62.25	0.80	Valid
Social	Timbulsloko	90.21	15.18	94.46	86.19	4.02	Valid
	Surodadi	74.58			72.71	1.87	Valid
	Bedono	84.97			82.66	2.31	Valid
Institutional	Timbulsloko	84.97	14.26	95.29	82.66	2.31	Valid
	Surodadi	87.90			84.19	3.71	Valid

Leverage attribute. The leverage attributes in each dimension at each village are displayed in Figures 7-18. Table 5 shows the leverage attribute or factors that affect the continuity of all dimensions.

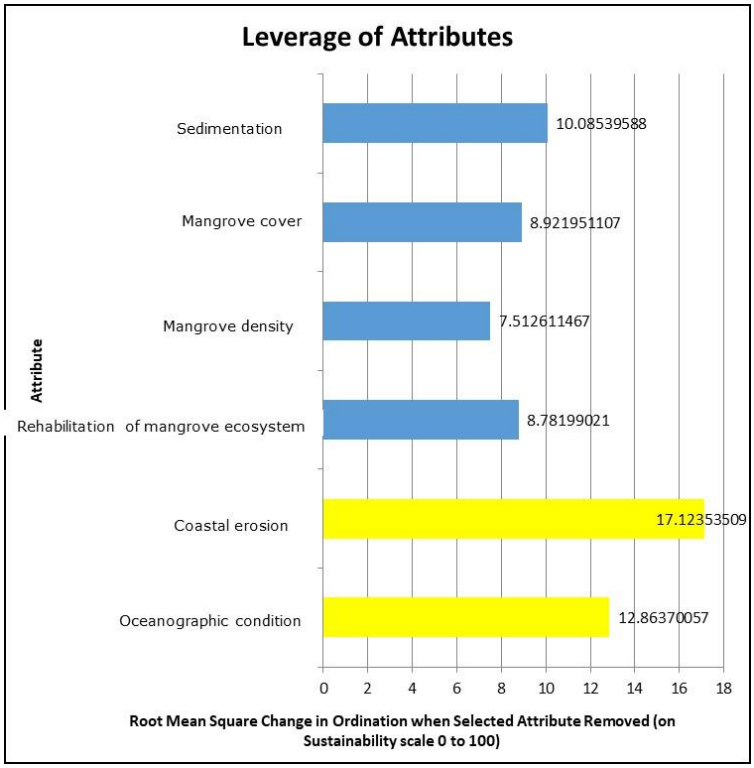

Figure 7. Leverage attribute of the ecological dimension in Bedono Village.

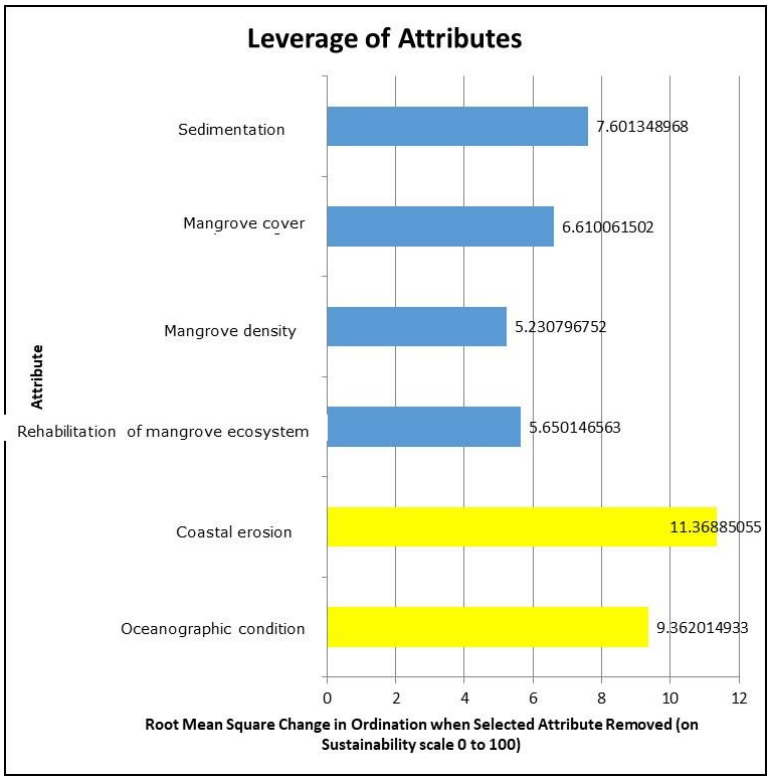

Figure 8. Leverage attribute of the ecological dimension in Timbulsloko Village.

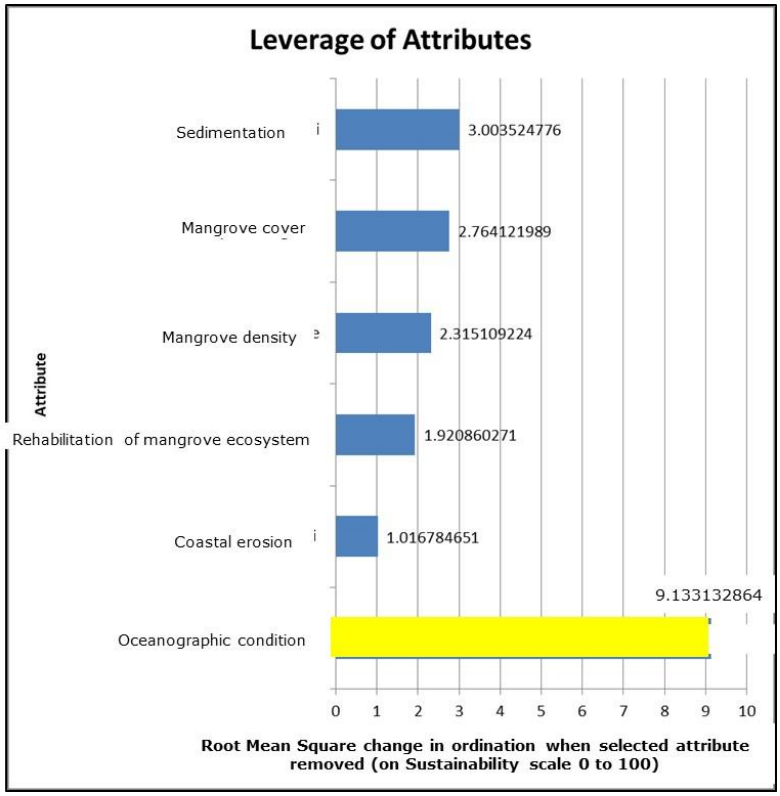

Figure 9. Leverage attribute of the ecological dimension in Surodadi Village.

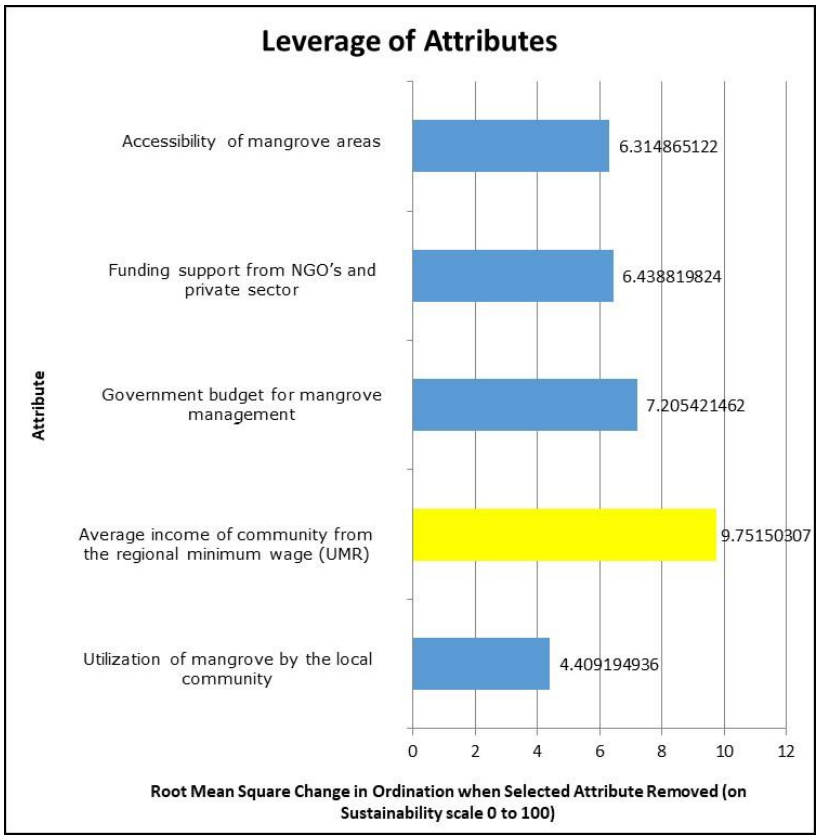

Figure 10. Leverage attribute of the economical dimension in Bedono Village.

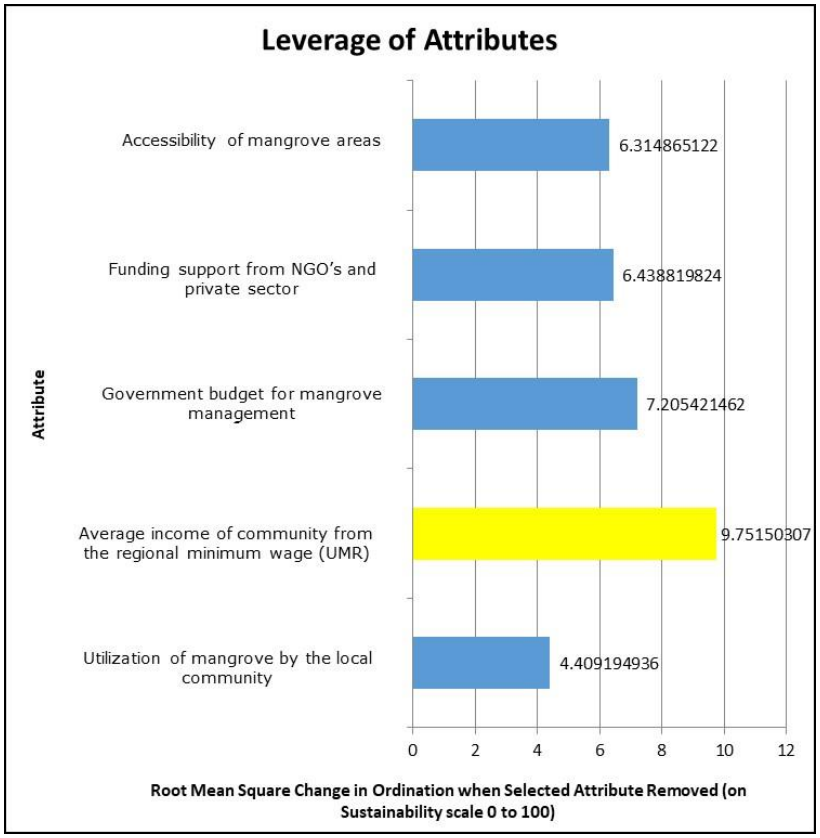

Figure 11. Leverage attribute of the economical dimension in Timbulsloko Village.

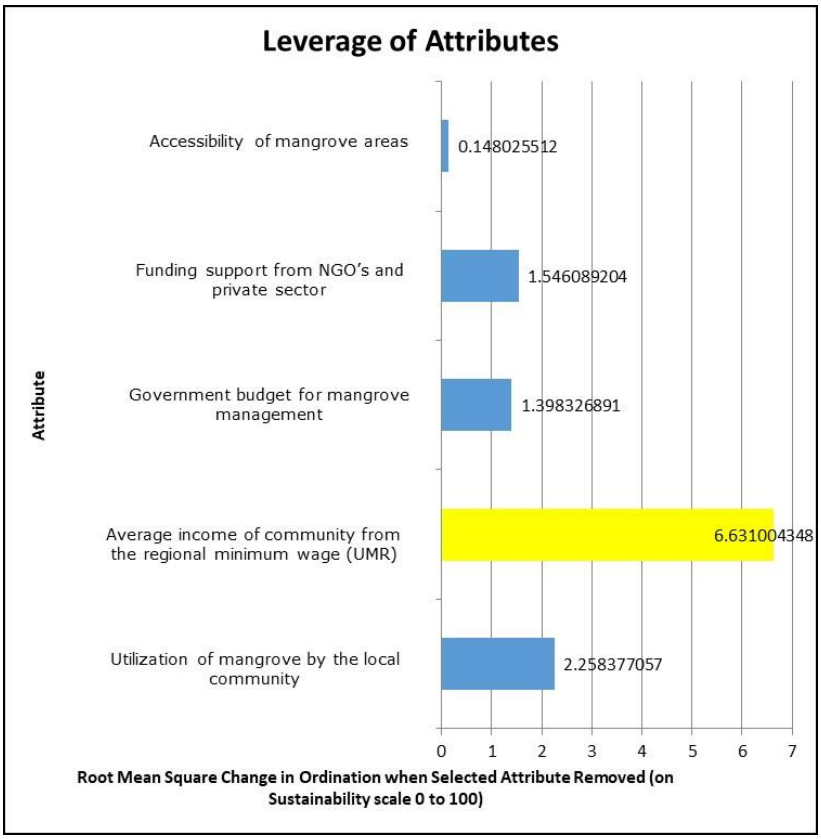

Figure 12. Leverage attribute of the economical dimension in Surodadi Village.

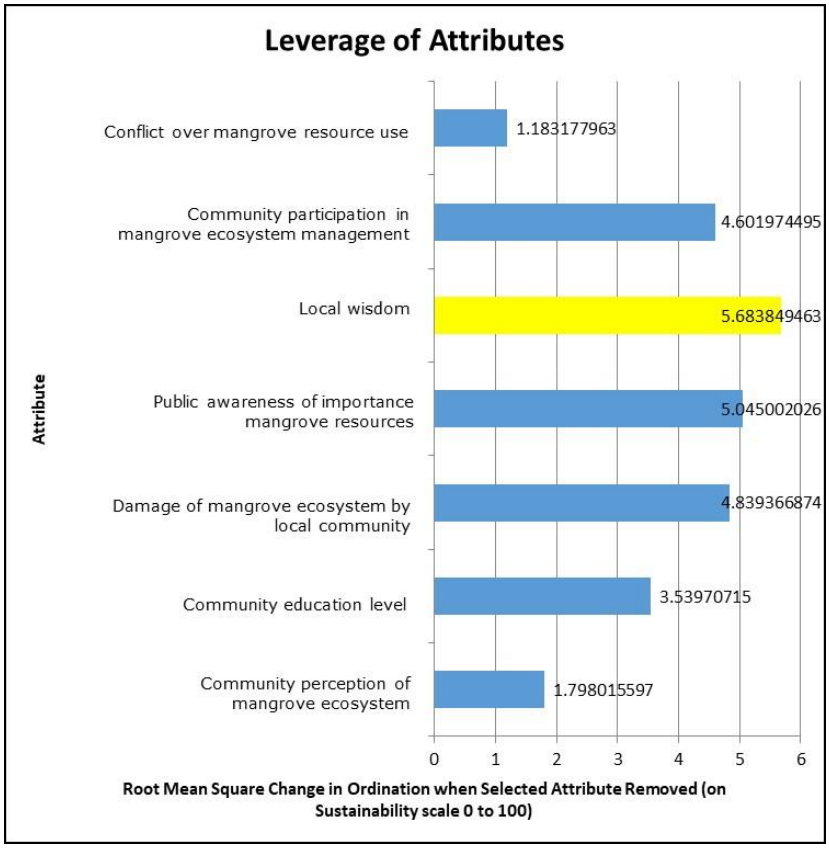

Figure 13. Leverage attribute of the social dimension in Bedono Village.

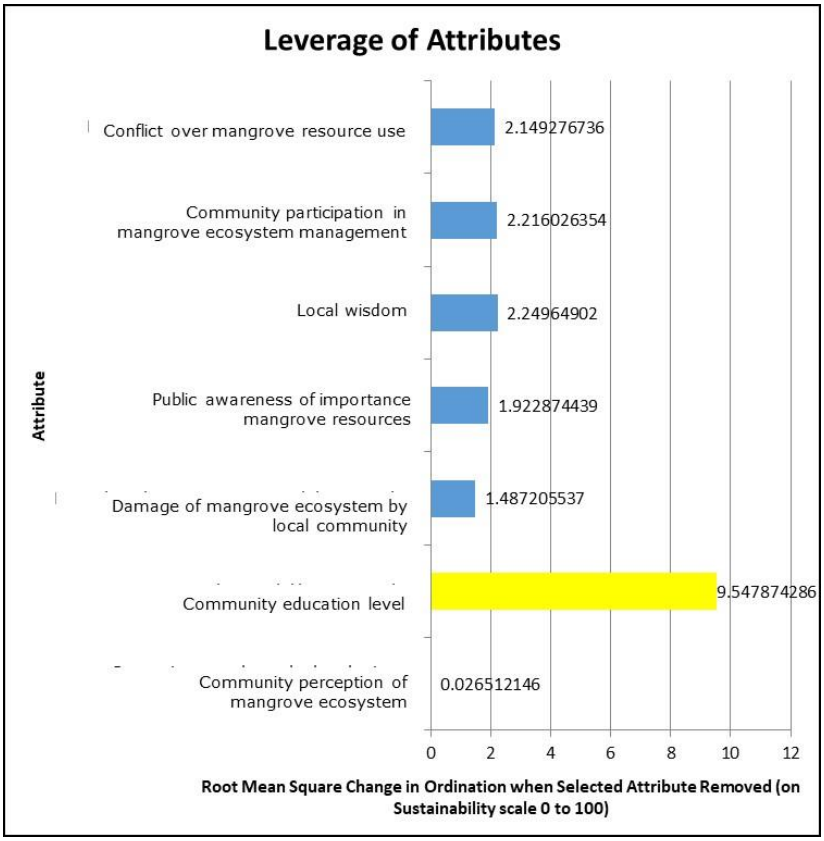

Figure 14. Leverage attribute of the social dimension in Timbulsloko Village.

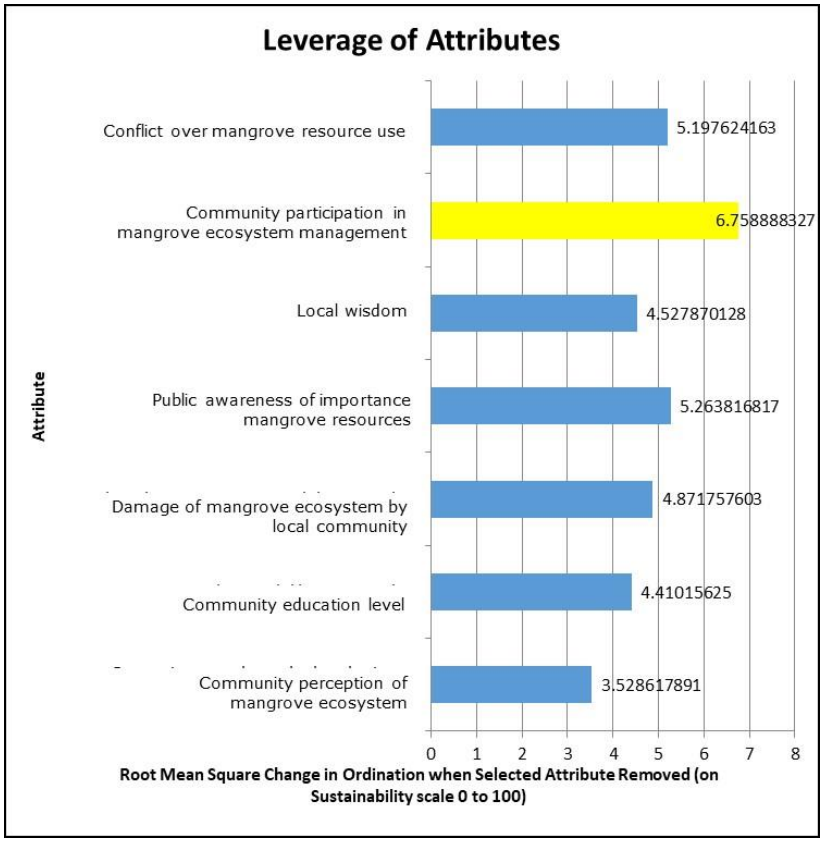

Figure 15. Leverage attribute of the social dimension in Surodadi Village.

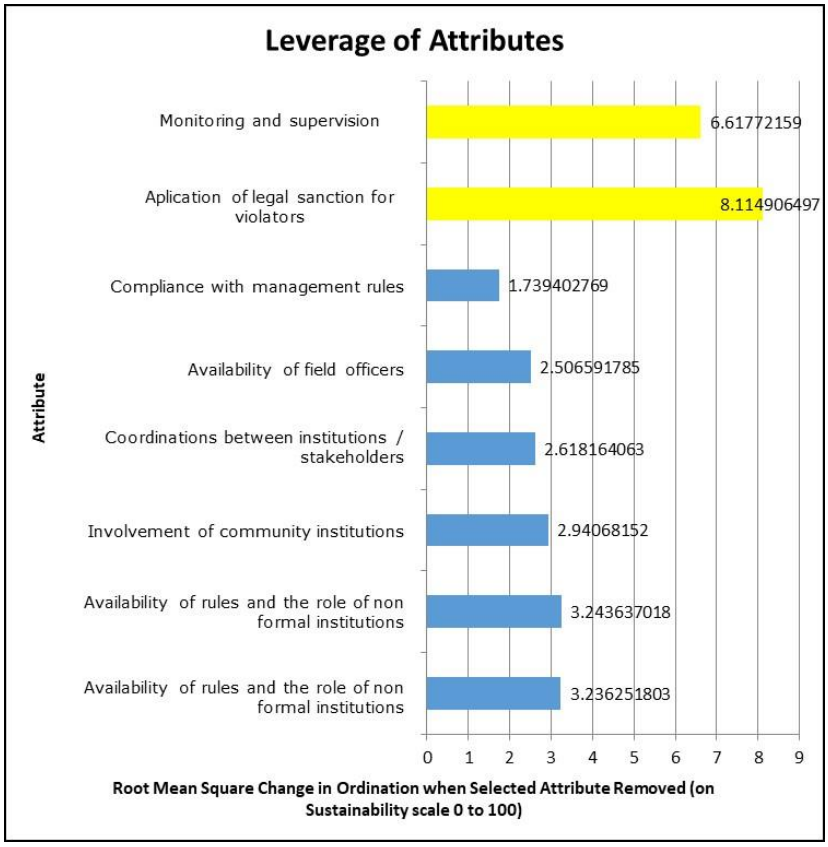

Figure 16. Leverage attribute of the institutional dimension in Bedono Village.

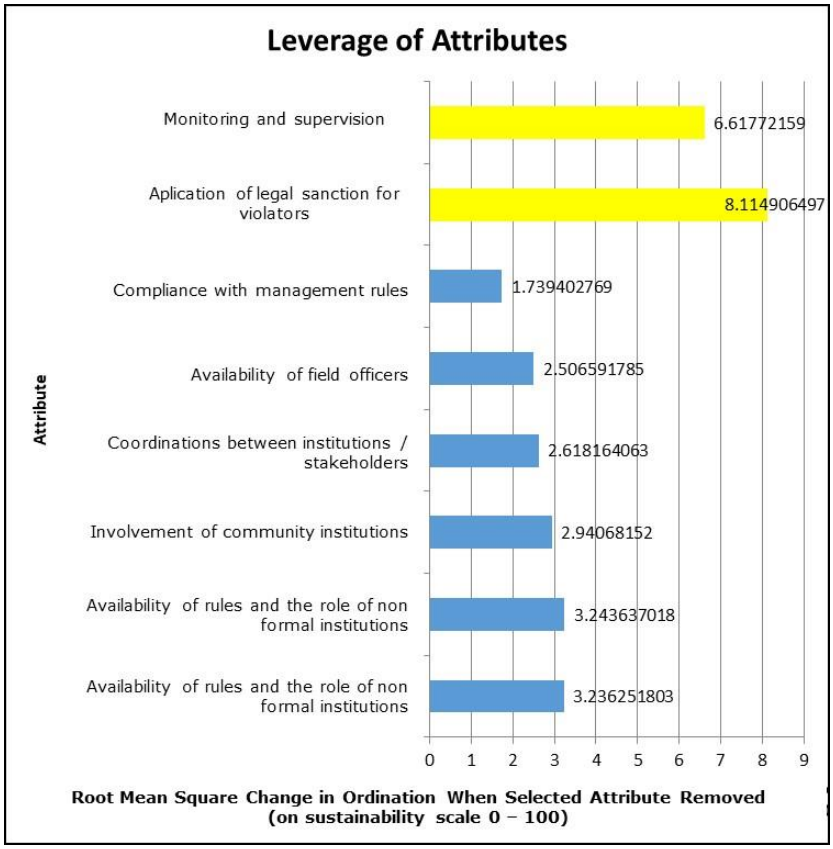

Figure 17. Leverage attribute of the institutional dimension in Timbulsloko Village.

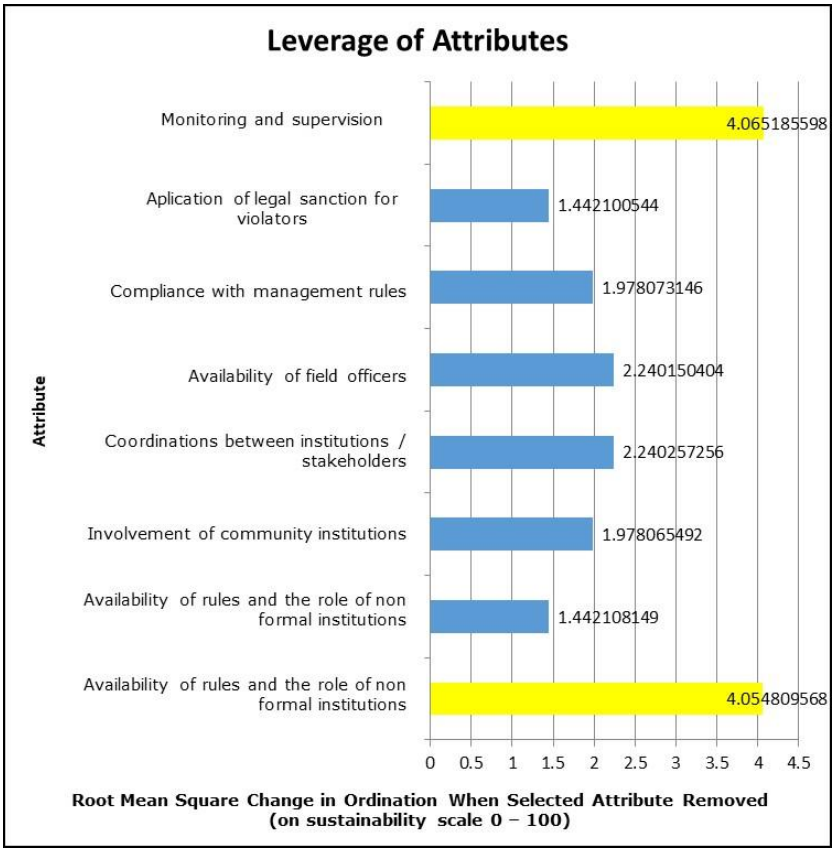

Figure 18. Leverage attribute of the institutional dimension in Surodadi Village.

Table 5

Leverage attribute on all dimension

Dimension	*Village*	*Leverage attribute*	*RMS value*
Ecological	Bedono	Coastal erosion	17.12
		Oceanographic condition	12.86
	Timbulsloko	Coastal erosion	11.36
		Oceanographic condition	9.36
	Surodadi	Oceanographic condition	9.13
Economical	Bedono	Average income of community from the regional minimum wage (UMR)	9.75
	Timbulsloko	Average income of community from the regional minimum wage (UMR)	9.75
	Surodadi	Average income of community from the regional minimum wage (UMR)	6.63
Social	Bedono	Local wisdom	5.60
	Timbulsloko	Community education level	9.54
	Surodadi	Community participation in mangrove ecosystem management	6.75
Institutional	Bedono	Monitoring and supervision	6.6
		Aplication of legal sanction for violators	8.11
	Timbulsloko	Monitoring and supervision	6.6
		Aplication of legal sanction for violators	8.11
	Surodadi	Monitoring and supervision	4.06
		Mangrove ecosystem management policies and planning	4.05

Sustainability trade-off. The sustainability trade-off is a depiction of its level in the various dimensions (ecology, economy, social and institutional) of the three villages. Sustainability trade off is shown in Figure 19.

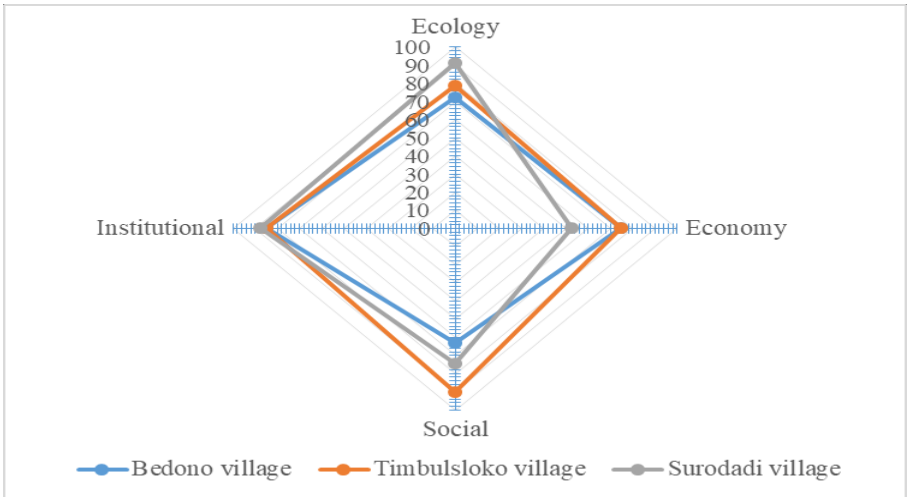

Figure 19. Mangrove ecosystem management sustainability trade off.

Discussion. The sustainability level of the ecological dimension in the Timbulsloko and Surodadi villages, was in the very sustainable category (78.50% and 91.11%), while for the Bedono village, it was classified as sustainable (72.17%). These conditions indicated that the level of mangrove management in the three villages was classified as good in terms of ecology. However, the leverage attributes on the ecological dimension were oceanographic conditions and coastal erosion. Therefore, to improve and maintain the sustainability status, it is necessary to pay attention to the leverage attributes.

The increase in mangrove areas indicated the success of its rehabilitation program and sustainability in the ecological dimension. In 2009, mangroves were only found in 4 coastal villages with a total area of 37.34 ha in the Sayung coastal zone. However, in 2019, they were distributed in 6 coastal villages with a total area of 226.17 ha (Table 6), which is in line with the research result of Fikriyani & Mussadun (2014); Faturrohmah & Marjuki (2017); Irsadi et al (2019); Puryono et al (2019).

Table 6

Changes of mangrove area in Sayung coastal zone

Village	*Mangrove area (ha)*	
	2009	*2019*
Sriwulan	0.3	0.15
Bedono	28.03	125.87
Timbulsloko	0.58	50.92
Suradadi	8.43	49.23
Sidogemah	-	10.26
Purwosari	-	8.91
Total	37.34	226.17

Mangrove area based on Landsat image analysis in 2009 and 2019.

The mangrove ecosystems have the ability to reduce the energy of seawater, minimize the scouring of the coast, decrease sediment movement, lessen surface winds, and shorten the re-formation of wind waves by 15% to 65% when passing through the roots and branches of the mangrove (Spalding et al 2014). These are efficient in reducing the impact of hurricanes or tsunamis (McKee & Faulker 2000). Its roots help produce and bind sediments which are positively correlated to the root. Also, approximately 70-80% of sediments from coastal waters are trapped in mangrove roots (Young & Harvey 1996; Furukawa et al 1997). Therefore, they tend to contribute to the reduction of erosion in coastal areas. Mangrove ecosystems are sometimes combined with other steps in achieving the desired level of protection (Gracia et al 2017).

According to Triatmodjo (1999), there are several methods to protect the coast, such as making it strong enough to withstand wave attacks, changing transport sediment rate, and reducing wave energy that reaches he shore and reclamation by increasing the sediment supply to the shore. Either soft or hard solutions can be deployed in order to overcome the damages and erosion that occur at the beach level due to the waves, by natural or artificial means. The soft solution method does not involve the building of any structure (non-structural). It is carried out in the form of planting mangrove plants, sand nourishment, maintenance of coral reefs and sand dunes on the beach, while the hard solution is handled by creating a structure to protect the beach, such as seawall, groin, jetty and breakwater.

MDS analysis showed that the sustainability from the economic perspective in the three villages was quite sustainable, with the ordination values of 74.73%, 74.73%, and 52.74% for Bedono, Timbulsloko, and Surodadi villages, respectively. These conditions indicated that the performance level of the mangrove management in the three villages was quite good in terms of economy. However, its level of sustainability in each of the villages was influenced by the same leverage attribute, which is the average income of the community, as determined from the Regional Minimum Wage (UMR).

The average income of the people at the research location was relatively small and below the regional minimum wage (UMR). Before the coastal erosion disaster, the main livelihood of the residents was the cultivation of crops and fish farming. In the previous decades, farmers experienced a glory period when the tiger shrimp was booming. However, the catastrophic coastal erosion and tidal waves that attacked the Sayung coast caused severe damages to the rice fields and ponds. They became unproductive and were not utilized anymore, resulting in a decrease in the community income (Marfai 2012; Damaywanti 2013; Asrofi et al 2017). In order to respond to this problem, the community had to adapt by changing its means of livelihood. Currently, the

major occupations are farming, industrial labor and fishing. Besides, the average income is one of the main factors that generally affect human activities in the use of natural resources in the vicinity, including the utilization of mangrove ecosystems. Therefore, an effort is needed in order to increase the average income. A viable solution would be to formulate alternative livelihoods in accordance with the interests, markets and conditions of both natural and human resources.

From the social perspective, the sustainability level in Timbulsloko Village was approximately 90.21% and was classified as very sustainable, while in the other two villages it was classified as quite sustainable, 63.05% in Bedono, 74.58% in Surodadi. These conditions indicated that the level of mangrove management in the three villages was quite good in terms of social aspects. The results of the leverage attribute analysis showed that the sustainability of the social aspects on the ecosystem was better in Bedono, due to the influence of the local wisdom. Conversely, Timbulsloko was influenced by the level of community education, while Surodadi was affected by the wider participation of the community to the mangrove ecosystem in management (Table 5).

Consequently, local wisdom and knowledge need to be adopted on a large scale by the management of the mangrove ecosystems. This is in accordance with the co-management approach to the resource management, which integrates the recognition of the rights and of the value of all stakeholders, for a well-balanced partnership (Adrianto 2011). According to Marfai et al (2015), the local wisdom of the Sayung coastal community precedes the regulation of mangrove management, beinginseparable from the beliefs, norms, and networks of the communities in the region. The local wisdom in the area includes the preservation of mangrove and natural resources, based on community norms that are fully managed by the inhabitants, related to the conservation of biological resources. An example is the prohibition of fishing and hunting birds, like herons, in around the tombs of Islamic warriors situated in the mangrove ecosystem.

Community education is also an important factor because its level tends to affect one's mindset and actions, related to the utilization of the surrounding natural resources. A poor education is an obstacle in the perception and participation of the inhabitants, ultimately affecting the community-based mangrove ecosystem management. Community participation in mangrove management in the Bedono and Timbulsloko villages was very high, while in Surodadi, it was classified as moderate. Therefore, increased community participation is needed in planning, implementing, utilizing, and monitoring evaluations (Gumilar 2012).

The results of the sustainability analysis showed that the institutional dimension was classified as sustainable with the ordination value of Bedono Village, approximately 84.97%, Timbulsloko Village was (84.97%), and Surodadi Village 87.90%. These conditions indicated that the level of mangrove management in the three villages was classified as very sustainable in terms of institutional dimension. The results of the leverage analysis showed that the attributes of the institutional aspects sustainability for each of the villages were the same, including the monitoring and supervision factors. The main leverage attributes of sustainability, including the monitoring and supervision factors, were the policy and planning determinants of the mangrove ecosystem management.

Monitoring and supervision in the three villages have not been effective, due to the lack of personnel resources tasked with carrying out these activities. Besides, participatory supervision involving the local communities is a solution to the problem. Furthermore, community supervisory groups (Pokmaswas) are formed by involving the inhabitants in supervising and controlling the use of mangrove resources responsibly, also supported by the governance regulations, which were accommodated from local wisdom. Bedono village has a Regulation No. 7/15/XII/2012 on Management of the Coastal and Sea Areas of the village. Timbulsloko Village has Regulation No. 145/236/IV/2014 on Management of the Coastal and Marine Areas of Timbulsloko Village. Likewise, Surodadi Village has Regulation No. 004/IX/GERHAN/2004 on the Conservation of Mangrove Forests.

Mangrove ecosystem management policies and planning are related to governance. According to Kooiman et al (2005), governance is the overall interaction

between the public and private sectors to solve community problems and create social opportunities. The concept of governance that is developed for the management of mangrove ecosystems is of an interactive type. It creates opportunities for other players such as NGOs, the private sector and local communities to actively participate to the sustainable development (Kooiman 2008).

The results from the trade-off graph showed that the three villages experienced relatively good conditions for all four dimensions of the management of the ecosystem. This condition was evidenced by the values of sustainability, all of which were above 50%, which means that the local mangrove management was classified as sustainable. In order to maintain the level of sustainability, all the leverage attributes of the management dimensions need to be adequately considered.

Conclusions. The sustainability level of the mangrove management from the ecological perspective was classified as sustainable, with the ordination values of 72.17%, 78.50%, and 91.11% for Bedono, Timbulsloko, and Surodadi Villages, respectively. The main leverage attributes were the beach erosion and the oceanographic conditions.

The sustainability level of the economic dimension of the mangrove management was classified as quite sustainable, with the ordination values 74.73%, 74.73%, and 52.74%, for Bedono, Timbulsloko, and Surodadi Villages, respectively. Its leverage attribute was the average income of the community from the UMR.

The level of social sustainability in the mangrove management was classified as sustainable or quite sustainable, with the ordination values of 63.05%, 90.21%, and 74.58% for Bedono, Timbulsloko and Surodadi Villages, respectively. Its leverage attributes were the local wisdom, the level of community education and the community participation in mangrove ecosystem management.

The sustainability level of the institutional perspective in mangrove was classified as sustainable, with the ordination values of 84.97%, 84.97%, and 87.90%, for Bedono, Timbulsloko, and Surodadi respectively. Its leverage attributes were the monitoring and supervision levels, the policy determinants and the appropriate planning of the mangrove ecosystem. In order to maintain and improve the sustainability status of the mangrove ecosystem management on the coast of Sayung Sub-district, the leverage attributes of each dimension need to be considered and enhanced.

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