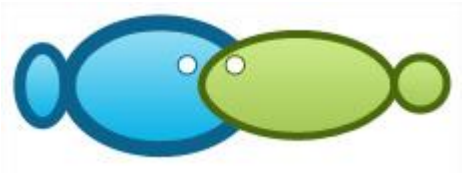

Sustainable status of mangrove forest ecosystem management in Langsa City, Aceh, Indonesia

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Abstract. Mangrove forest ecosystems have ecological, economic and physical or protective functions. Their management requires planning that can guarantee the sustainability of these functions and benefits. This study aims to determine the level of sustainability of mangrove ecosystem management and to determine indicator attributes that can be categorized as leverage factors in the management process. The data were analysed by multi-dimensional scaling (MDS) with Rap-Mangroveforest approach. The results showed that the management of the mangrove ecosystem of Langsa City had a less sustainable status, with a value of 46.75%. Leverage factors that influence the sustainability of mangrove forest management include: the number of mangrove working groups, formal and informal rules, counseling on mangrove management, management agencies, application of institutional rules, the existence of role models, facilitation and community assistance in the management of mangrove forest ecosystems, strengthening and enhancing the participation of local communities in management activities, conflict of utilization of mangrove resources and local wisdom.
Key Words: leverage factors, mangrove ecosystem, sustainability.

Introduction. Mangrove ecosystems have a biological function as a food source, spawning place and egg laying place for various marine biota like fish and shrimp. It is also as a habitat for fish that occupy coral reefs, sea grass beds, pelagic zones and other various types of wildlife. Furthermore, mangrove ecosystems have economic functions as producers of wood and non-timber products (honey, tannin), potential ecotourism services and also physical or protective functions, like protecting the shoreline, regulating sedimentation, improving water quality and controlling sea water intrusion for microclimate stability (Kusmana 2014; Giri et al 2015; Askornkoae & Kato 2011; Spalding et al 2010; Kathiresan & Bingham 2001).

Mangroves grow in 124 tropical and sub-tropical countries in the world, and have an area around 15.2 million ha. Indonesia and four other countries (Australia, Brazil, Nigeria and Mexico) contain 48% of the world's mangrove forests (Lavieren 2012). Based on One Map Mangrove data, the area of mangrove ecosystems in Indonesia is 3.5 million ha, consisting of 2.2 million ha in the forest area and 1.3 million ha outside the forest area. Some of the mangrove ecosystems have been damaged (Kusmana 2014).

The phenomenon of mangrove forest damage has also occurred in Langsa City (MFAD 2013). Many people who use mangroves for different purposes do not consider environmental sustainability. This caused the decrease of the quality and quantity of mangrove ecosystems. If left untreated, it can threaten the sustainability of mangrove forests as a habitat for flora and fauna.

The main factors that cause damage to mangrove forests in Langsa City are the conversion of mangrove land to other uses, the opening of new settlements, illegal logging, pests and diseases, pollution and the expansion of ponds and unsustainable cultivation practices as well (MFAD 2013). These activities cause the deforestation of coastal ecosystems and decrease water quality in Langsa City. The reduced size of

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mangrove forests has led to environmental changes that consequently led to an increase in the concentration of greenhouse gases (GHGs) in the atmosphere, influencing climate change (Pendleton 2012).

The research objective was to assess the sustainability status of mangrove forest ecosystem management in Langsa City based on ecological, economic, social and institutional dimensions and determining indicator attributes that can be categorized as leverage factors in the management of Langsa City's mangrove forest ecosystem.

Material and Method

Location and time of the study. The study was conducted in Langsa City, Aceh, Indonesia, from December 2015 until April 2016. The data was collected using purposive sampling technique. Data collected during the study was primary and secondary data. Primary data was directly obtained from key persons through Focus Group Discussion (FGD). To obtain and analyze information and knowledge from experts, an expert survey was carried out by in-depth interview techniques. The expert survey is carried out by the stages of the RAPFISH procedure, the purpose of which is to set indicators and provide scores on each sustainability indicator. The tool used is the Rap-Mangroveforest technique as a modified approach from the RAPFISH (Rapid Appraisal for Fisheries).

The respondents were 7 people, consisting of: the Head of the Aceh Provincial Forestry Service; the Head of Regional Planning and Development Agency (Bappeda) of Aceh Province; the Head of Langsa City Bappeda; the Head of Langsa City Marine, Fisheries and Agriculture Office; the Head of the Environmental, Gardening and Hygiene Agency of Langsa City; academics from Pantee Kulu Banda Aceh College of Forestry, and Balee Jurong Non-Governmental Organizations (NGOs). The secondary data was obtained from the documentation studies and research results, related literature, and monographical data on the study location.

Data analysis. The assessment of the sustainability status of mangrove forest ecosystem management in Langsa City was carried out using the Multi-Dimensional Scaling (MDS) technique. The tool used is the Rap-Mangroveforest technique as a modified approach from the RAPFISH (Rapid Appraisal for Fisheries) program developed by the Fisheries Center, University of British Columbia. MDS is a statistical analysis technique that attempts to carry out multidimensional transformations into simpler dimensions (Kavanagh & Pitcher 2004).

Rap-Mangroveforest modification is carried out on the dimensions and attributes in the analysis, in accordance with the research objectives. MDS is used to assess the sustainability status index and identify the most sensitive attributes of each sustainability dimension (from the ecological, economic, social and institutional dimensions) through leverage analysis. The stages of sustainability analysis using Rap-Mangroveforest are presented in Figure 1.

The evaluation of the sustainability of mangrove forest ecosystem management using the MDS method is carried out through several stages:

1. The determination of management attributes of sustainable mangrove forest ecosystems for each dimension. In this study, four dimensions of sustainable development were used: ecological, economic, social and institutional dimensions.

2. The evaluation of each attribute in an ordinal scale (scoring) based on the sustainability criteria of each dimension. The appraisal of the attributes was carried out using questionnaires with information from several respondents to determine the scores of each attribute from each dimension. The assessment is based on an ordinal scale that reflects bad and good values, where the range of scores depends on the state of each attribute. Bad values reflect the most unfavourable conditions for the sustainability of mangrove ecosystem management, while good values reflect the most favourable conditions in supporting the management of sustainable mangrove ecosystems in Langsa City. Between these two extreme values, there are one or more intermediate values, depending on the number of ranks for each attribute.

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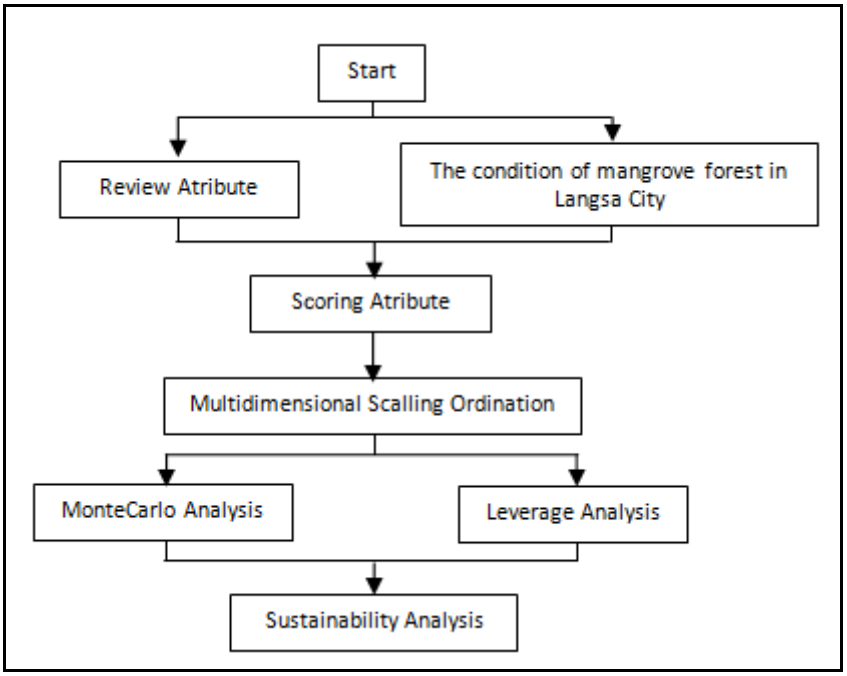

Figure 1. The stages of the sustainability analysis using Rap-Mangroveforest.

3. Analysis of Rap-Mangroveforest ordination with the MDS method to determine the position of the sustainability status in each dimension, on the sustainability index scale.

4. Assessing the index and sustainability status in each dimension. The sustainability index value of each dimension can be visualized in the form of a kite diagram. Symmetrical kite diagrams are determined by the sustainability index of each dimension (ecological, economic, social and institutional). This sustainability index value is analyzed multi-dimensionally to determine the point that reflects the position of the sustainability of mangrove ecosystem management relative to the reference point, both good and bad. The sustainability status category of the mangrove ecosystem management in Langsa City based on the index value of Rap-Mangroveforest analysis results is presented in Table 1.

Table 1

Category of the sustainable status based on the index value analysis by Rap-Mangroveforest

Index value (%)	*Category*
0.00–25.00	Unsustainable
25.01–50.00	Less sustainable
50.01–75.00	Fairly sustainable
75.00–100.00	Sustainable

Note: the source is Kavanagh & Pitcher (2004).

5. Conducting a sensitivity analysis (Leverage analysis) to determine which sensitive variables affect sustainability. Sensitive variables are attributes that have leverage factors and contribute to the sustainability index of the mangrove forest management in Langsa City. The determination of sustainable management leverage attributes of mangrove forest ecosystems is based on the value of the "root mean square" (RMS). The RMS value indicates the importance of the role of each attribute towards the sensitivity of the sustainability index (Kavanagh & Pitcher 2004).

6. The greater the value of the RMS changes due to the loss of a certain attribute, the greater the role of these attributes in the formation of a sustainability index value on the scale of sustainability is.

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7. The Monte Carlo analysis was performed to take into account the dimensions of uncertainty (Kavanagh & Pitcher 2004). This analysis observes and evaluates the effect of errors by assessing ordination. The effect of errors can be caused by various conditions, such as mistakes in calculating scores due to the imperfect understanding of attributes or field conditions, variations in scores due to differences in opinion or judgment of researchers, repetitive MDS analysis processes, errors in data entry or missing data, iterative stability, and high stress values (stress values are acceptable if the value is <25%) (Pitcher & Preikshot 2001). The goodness of fit on MDS is reflected in the number of S-stress values calculated based on the values of S and R^2. A lower stress value indicates a condition of suitability and a high S value indicates the opposite. Through the Rap-Mangroveforest approach, a good model can be obtained from stress values that are smaller or less than 0.25 (S<0.25) and good R^2 values close to 1.0 (Kavanagh & Pitcher 2004).

Results and Discussion

The compilation of attributes of the mangrove forest ecosystem management. The assessment of the sustainability of mangrove forest ecosystem management in Langsa City covered four dimensions, namely ecological, economic, social and institutional dimensions. Each dimension consists of several attributes. Based on the extraction result, a total of thirty attributes were obtained for all dimensions assessed (Table 2).

Table 2
Dimensions and attributes of mangrove forest ecosystem sustainability in Langsa City

Dimension	*Attributes*	*Total*
Ecology	Types of land use, crown density, soil resistance to abrasion, changes in water quality, food chains and ecosystems, effort to preserve mangrove forest ecosystems, availability of seeds for rehabilitation and critical level of mangrove forest.	8
Economy	Average income of the community, availability of funds for rehabilitation of mangrove forests, number of businesses created and coordinated, improvement of alternative livelihoods, percentage of population living below the poverty line, utilization of mangroves by the community, employment and income from mangrove tourism services.	8
Social	Understanding to the environment, community knowledge about mangrove forests, community participation in mangrove forest management, work ethic, facilitation and community assistance in the management of mangrove forest ecosystems, strengthening and enhancing the participation of local communities in management activities, conflict of utilization of mangrove resources and local wisdom.	8
Institutional	The number of mangrove working groups, formal and informal rules, counseling on mangrove management, management agency, application of institutional rules and the existence of role models	6

Note: the sources are: Pitcher & Preikshot (2001); Machado et al (2015); Karlina et al (2016).

Sustainability status of mangrove forest ecosystem management. The management of the mangrove forest ecosystems requires integrated sectors and the interests of stakeholders. In order to realize a sustainable management of the mangrove forest ecosystems, the four dimensions of study become the main indicators of

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sustainability. The result of the index value assessment, which indicated the sustainability status of the mangrove forest ecosystem management in Langsa City is presented in Table 3 and the kite diagram of the sustainability index value of Langsa City mangrove forest management is presented in Figure 2.

Table 3

The result of the index value assessment

No	*Dimension*	*Index Value*
1	Ecology	52.51
2	Economy	49.72
3	Social	45.27
4	Institutional	44.89
	MDS Average	48.10

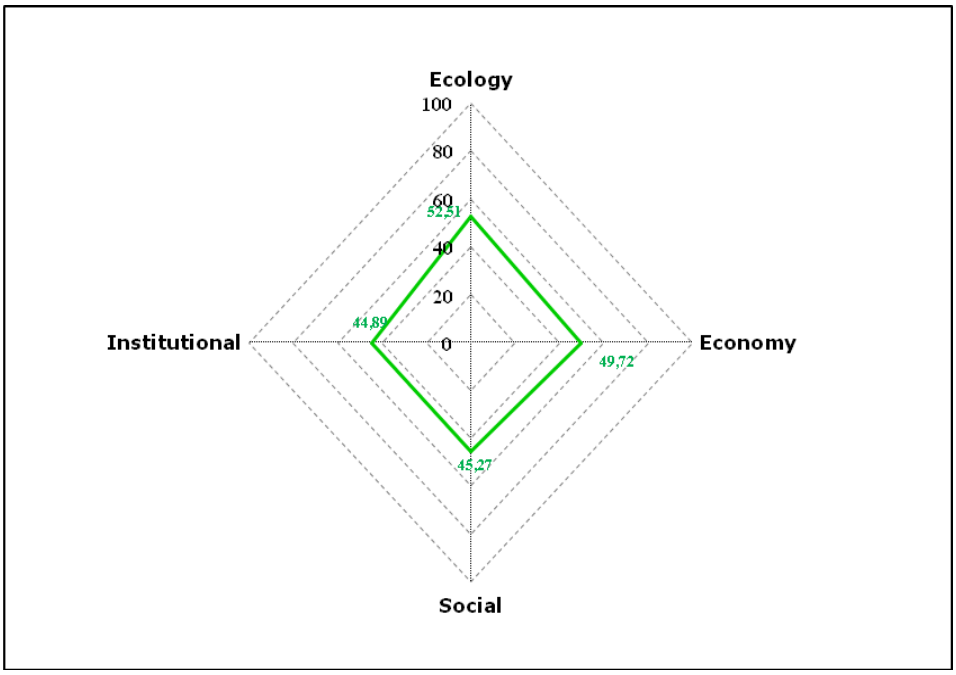

Figure 2. Kite diagram of the sustainability index value.

The result of the sustainability status assessment shows that the average management of mangrove forest ecosystems was categorized as sustainable, by the score of 48.51%. The results of the sustainability index value analysis of each dimension of the sustainability of mangrove forest ecosystem management in Langsa City indicated that the economic dimension, social dimension and institutional dimension of the status are less sustainable and are a warning to the situation of mangrove forest management in Langsa City. The ecological dimension had the highest percentage, which means that it is sustainable. Each dimension should become sustainable in the future, therefore the attributes of existing conditions of each sensitive dimension need to be corrected by different interventions.

The leverage analysis (Figure 3) of ecological attributes shows that there were three attributes that became leverage factors due to their sensitivity to the changes of sustainability index values, namely: availability of seeds for rehabilitation, types of land use and the critical level of mangrove forests. Changes to these three factors would easily influence the increase or decrease of the sustainability index value in the ecological dimension.

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The critical condition of mangrove forests will remove the ecological, economic and social functions of the forest (Polidoro et al 2010; Valiela et al 2001). Mangrove land use management through rehabilitation of critical mangrove lands can have positive impacts on the environment, which in turn can improve the welfare of the community (Sudtongkong & Webb 2008; Janmaimool 2016). On the other hand, the availability of seeds from several species of mangrove plants from time to time is one of the supporting factors of the success of planting in the rehabilitation of critical mangrove forests (Rusdiana et al 2015; Nguyen et al 2016). In many cases, the failure of mangrove rehabilitation is caused by errors in the selection of planting sites and inappropriate mangrove species (Jusoff 2013; Primavera & Esteban 2008).

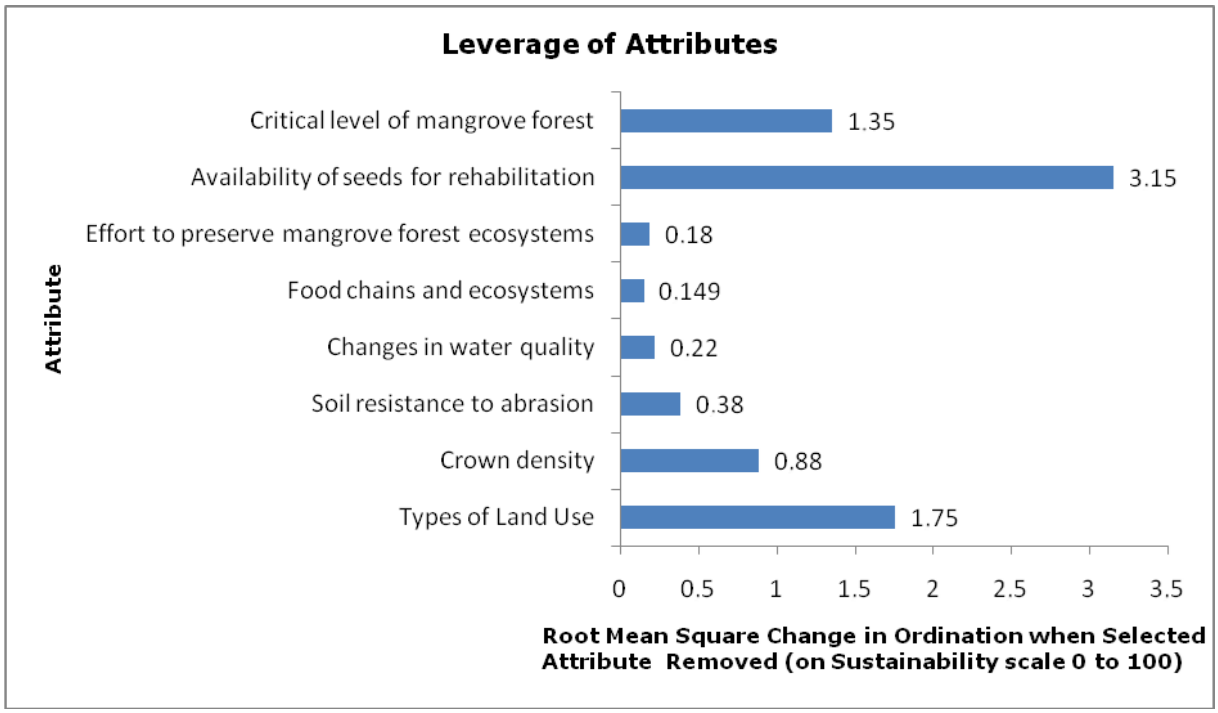

Figure 3. Leverage analysis of ecological attributes.

The land cover in the research location is represented by mangrove forests (protected forest areas, other use areas, conversion production forests and production forests), ponds, residential areas and port areas. Most mangrove areas, as land resources, have been converted and used for agriculture, fisheries, urbanization, mining, and salt ponds. In some places, over-exploitation and reclamation of mangrove land has resulted in the degradation and loss of mangroves (Romanach et al 2018). The main causes of the deforestation of mangrove forests in South Asia are the conversion to agriculture, shrimp ponds and settlement development (Giri et al 2015). The main drivers for the loss of mangroves in Southeast Asia are the conversion of mangroves to aquaculture, agriculture and oil palm plantations (Richards & Friess 2016; Thomas et al 2017).

Based on the leverage analysis of the economic attributes (Figure 4), there were three attributes which were the most sensitive in influencing the mangrove forest ecosystem management, namely: the increasing or improvement of alternative livelihoods, the percentage of the population living below the poverty line and the utilization of mangroves by the community. Changes to these three factors will easily influence the index value of sustainable economic dimension.

The improvement of alternative livelihood can be done by involving community groups in the management of mangrove forest ecosystems at the research sites and training them in the cultivation of green mussels. The ecological conditions of the waters of Kuala Langsa estuary can be utilized for the cultivation of green mussels (Sagita et al 2017). Green mussel cultivation is known to be environmentally friendly, can be carried

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out throughout the year and it is cost effective for a cultivation system (Soon & Rangsangan 2014).

Based on projected data in 2016, the total population of Langsa City was 168820 people. The percentage of poor people in Langsa City in 2016 amounted to 11.09%, with a poverty line of 23.72 USD per/capita/month. Kuala Langsa Village in West Langsa sub-district is one of the villages in Langsa City with a high proportion of poor people (CSB 2017).

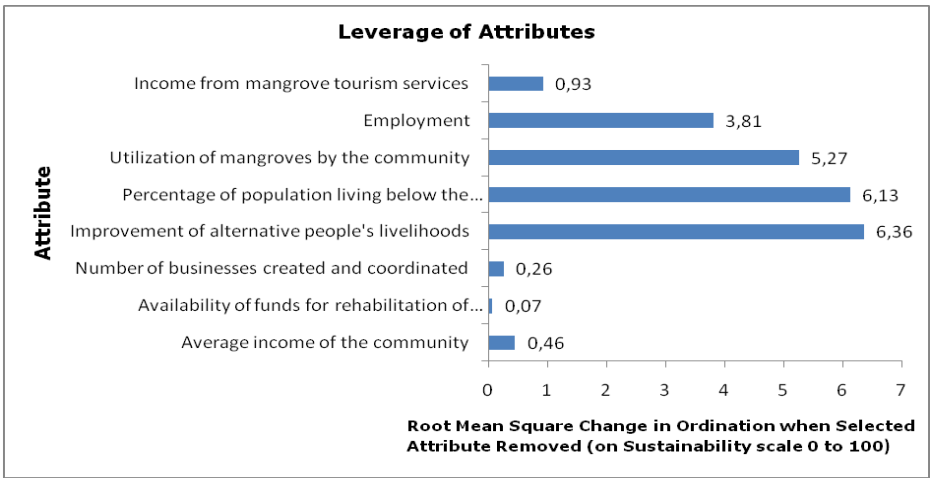

Figure 4. Leverage analysis of economy attributes.

In Langsa City, there have been already community groups who started small businesses by making sweet cakes and sugars from the *Nypa fruticans* fruits. However, due to a lack of business capital and a small market share, these businesses went bankrupt. There are also some people who work as mangrove honey collectors. This activity is a seasonal work depending on the flowering mangrove season. Several types of mangroves can be easily planted and grown in hydroponic media or in pots, with the potential to be used as ornamental plants. Mangrove species that can be used as ornamental plants are *Rhizophora apiculata*, *Rhizophora stylosa* and *Bruguiera gymnorrhiza.*

Based on the leverage analysis of the social dimension (Figure 5), there were two attributes most sensitive to influence mangrove forest ecosystems management, namely: work ethic and understanding of the environment. Changes in these two factors will easily influence index value of the social dimension of sustainability index value. From the attributes of work ethic, in the research location, there were already community groups fostered by the NGO Balee Jurong who volunteered to collect mangrove propagules, which were then planted in nurseries in the Kuala Langsa mangrove tourist site.

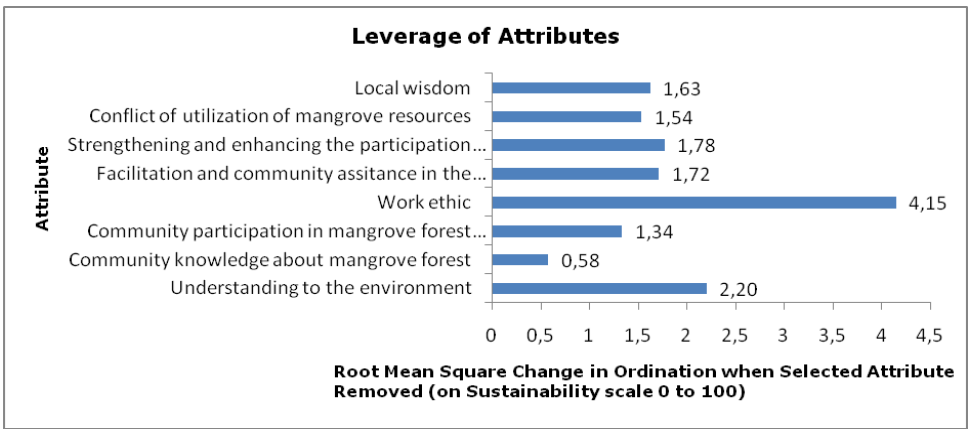

Figure 5. Leverage analysis of social attributes.

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The results of leverage analysis of the institutional dimension (Figure 6), show that there were four attributes that were most sensitive to mangrove forest ecosystem management, namely: management agency, counselling on mangrove management, the existence of role models and the number of mangrove working groups. Due to the sensitivity of these attributes, good governance efforts on institutional dimension attributes can maintain the sustainability of mangrove forest ecosystem management.

The formation of a coastal area management institution in Langsa City is also required. It should involve the government, such as Langsa City Government, Environmental and forestry services (DLHK) Aceh Province, Aceh Province Bapedda (Local Planning Institution), law enforcement officers and the community, with the roles of controlling, monitoring, evaluating, supervising and sanctioning any felony. Government and community institutions in the management of existing mangrove ecosystems have not yet developed or functioned optimally.

A community discussion forum to express their aspirations and consolidate the implementation drivers for mangrove forest management is also needed. It is important to socialize laws and regulation related to mangrove forest ecosystem management. Socialization of laws and regulations related to coastal management is needed for all stakeholders, and the substance of the rules and sanctions needs to be socialized more detailed as well (Askornkoae & Kato 2011). For example, installing rule and sanction boards in strategic places.

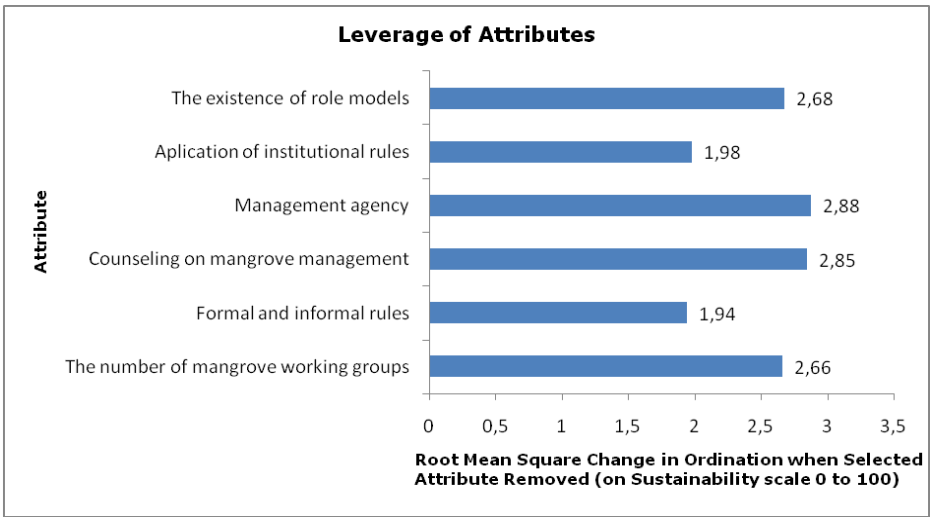

Figure 6. Leverage analysis on institutional attributes

There has been a public consultation on the protection and preservation of mangroves in Langsa City initiated by the World Wildlife Foundation (WWF) Indonesia Programme, Langsa City Government and Region III Aceh Forest Management Unit (FMU) on the 20th October 2017, through the Shared Resources Joint Solutions (SRJS) Program, funded by International Union for Conservation of Nature (IUCN), WWF and the Dutch Ministry of Foreign Affairs. However, until now there has been no formation of mangrove working groups in Langsa City.

The lack of capacity of central and regional governments and related stakeholders in interpreting and implementing policies on mangrove forests management can threaten the sustainability of these ecosystems. It is in line with the national policy, which states that the capacity of the regional government in carrying out the authority and obligation to manage mangrove ecosystems in accordance with local conditions and aspirations is increased (MF 2013).

Multidimensional sustainability index and level. Rap-Mangroveforest analysis results for the multidimensional sustainability of mangrove forest ecosystem management in Langsa City based on existing conditions, rendered an index value of 46.75%, which

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includes it in the status of "less sustainable". This value is obtained based on the assessment of 30 attributes from 4 dimensions (ecological, economic, social and institutional dimensions). To improve this sustainability index, efforts must be made to improve the attributes that have a negative impact on the sustainability index value and maintain or even improve the attributes that have a positive impact on the sustainability index value of the mangrove forest management activities that have been carried out.

10 sensitive attributes contribute to the multidimensional sustainability index value based on the results of the leverage analysis of the four dimensions in the management of mangrove forest ecosystems in Langsa City (Figure 7). The ten attributes are: number of mangrove working groups, formal and informal rules, counselling in mangrove management, management agency, application of institutional rules and the existence of role models, facilitation and community assistance in the management of mangrove forest ecosystems, strengthening and enhancing the participation of local communities in management activities, conflict of utilization of mangrove resources and local wisdom. The ten attributes can be used as leverage factors in improving the sustainability status of mangrove forest ecosystem management, through various policies implemented in supporting the implementation of mangrove forest management activities in Langsa City.

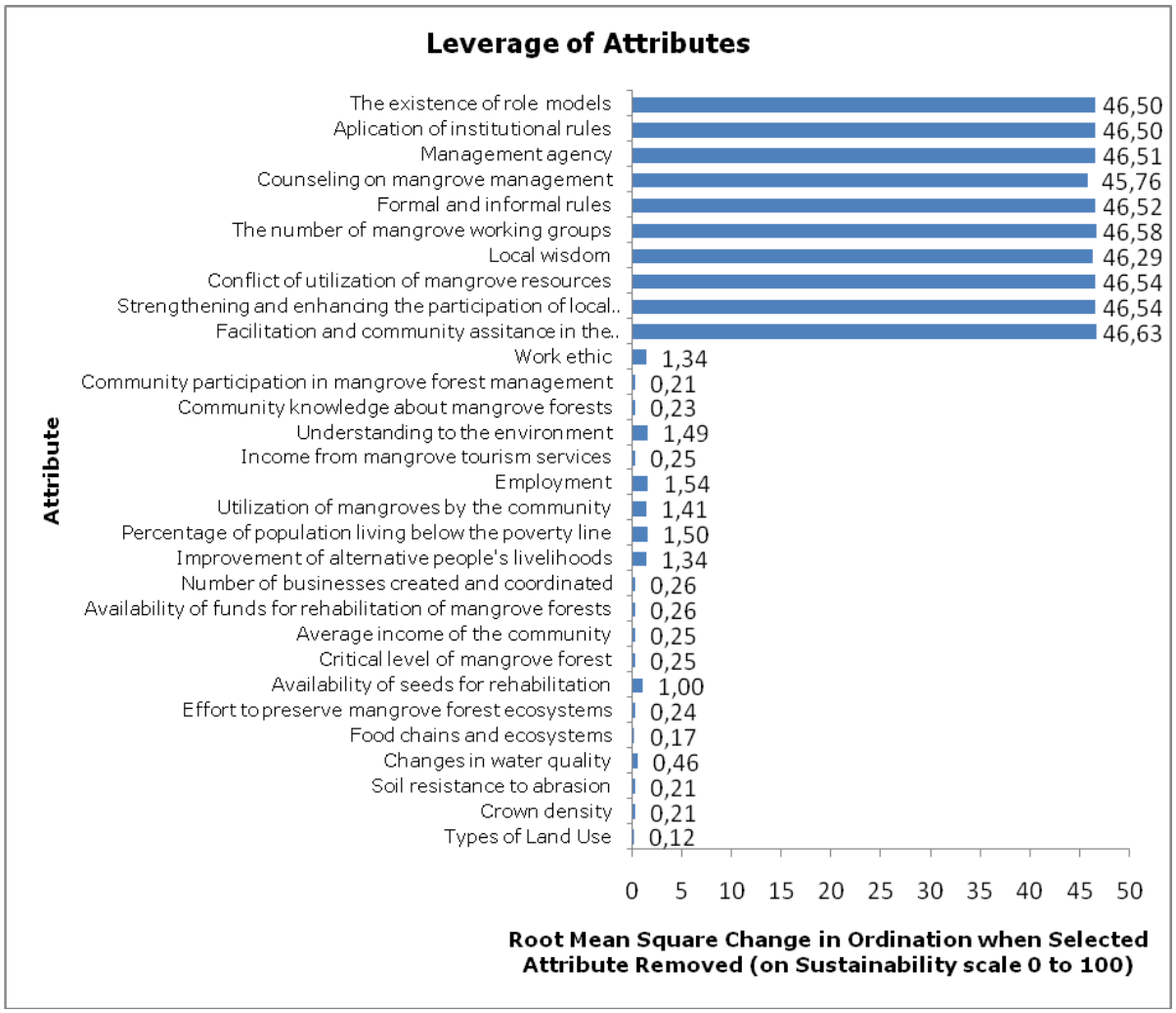

Figure 7. Leverage analysis of multidimensional attributes.

Validity and reliability test. The validity test was carried out using the Monte Carlo analysis and MDS analysis at a 95% level of confidence. The differences in all dimensions between the two analyses are below 1%. This condition indicates that the MDS analysis is

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sufficient to estimate the index value of the sustainability of mangrove forest management in Langsa City. This difference indicates that errors in the analysis process can be minimized or avoided. Errors were caused by the scoring each attribute. Variations in giving a multidimensional scoring because of differences in opinion were relatively small, the repetition process in data analysis was relatively stable, and errors in inputting lost data and data can be avoided. The difference in the value of the sustainability index between the results of MDS and Monte Carlo is presented in Table 4.

From the results of Rap-Mangroveforest analysis, the coefficient of determination (R^2) ranged from 0.94 to 0.95, greater than 0.80 or close to 1.00. This value indicates that the sustainability index estimation model was good and adequate (Kavanagh & Pitcher 2004). The stress value in Rap-Mangroveforest analysis ranged from 0.13 to 0.14 or smaller than 0.25, therefore the MDS analysis model obtained had a high degree of accuracy to assess the sustainability index of mangrove forest ecosystem management in Langsa City. The value of stress and the coefficient of determination from the Rap-Mangroveforest analysis can be seen in Table 5.

Table 4

The difference in the value of the sustainability index between the results of MDS and Monte Carlo

Sustainability Dimension	*Sustainability Value Index (%)*		
	MDS	Monte Carlo	Difference
Ecology	52.51	52.63	-0.12
Economy	49.72	49.77	-0.05
Social	45.27	45.99	-0.71
Institutional	44.89	45.09	-0.20
Multidimensional combination	46.75	47.80	-0.33

Note: MDS – multi-dimensional scaling.

Table 5

The value of stress and the coefficient of determination from the Rap-Mangroveforest analysis

Parameter	*Sustainability Dimension*			
	Ecology	Economy	Social	Institutional
Stress	0.14	0.13	0.14	0.14
R^2	0.94	0.95	0.94	0.94
Iteration	3	2	3	3

Conclusions. The sustainability of mangrove forest ecosystem management in Langsa City has an important role for the sustainability of the east coast region of Aceh. Overall, the sustainability level of the management of Langsa City's mangrove forest ecosystem based on existing conditions is less sustainable. Sensitive attributes contribute to the sustainability index value and need to improved are: the number of mangrove working groups; formal and informal rules; counseling in mangrove management; management agencies; application of institutional rules; the existence of role models; facilitation and community assistance in the management of mangrove forest ecosystems; strengthening and enhancing the participation of local communities in management activities; conflict of utilization of mangrove resources; and local wisdom.

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