Evaluation of coastal area development sustainability of Banda Aceh post recovery

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Abstract. This study aims to determine the index value of the sustainable development status of the coastal area of Banda Aceh a decade after recovery. The method of evaluating the sustainability status is carried out through comparative reliability based on a number of attributes that were scored using the RAP-Fish software. The results of the sustainability analysis show that in a multidimensional manner, the sustainability status of the coastal area of Banda Aceh is less sustainable with a sustainability index value of 43.80%. There are 28 sensitive attributes that have a big effect on improving the sustainability status so that it needs to be maintained and 20 insensitive attributes with low influence so that it needs to be intervened so that the improvement of the sustainability status of the coastal area of Banda Aceh can run optimally.

1. Introduction
Banda Aceh is a seaside city in Aceh Province, Indonesia, with a 13.35-kilometer shoreline. Most of the land use in this coastal area is for aquaculture and fishermen’s settlements. The earthquake with a scale of 9 Mw and followed by a very large tsunami wave on December 26, 2004, had caused the entire region to experience destruction, both physically and non-physically. A year later, through Presidential Regulation No. 30/2005, the Rehabilitation and Reconstruction Agency (BRR) was formed, which was tasked with restoring the lives of the people of Aceh and Nias from the earthquake and tsunami disaster with a working period of four years (2005-2009). The fundamental change in the recovery of the area is a change in spatial patterns that consider the mitigation aspects of the possibility of a recurrence of the disaster more. Referring to the RTRW for Banda Aceh 2009-2029, the use of space in the coastal area is more directed as a low-density housing area. Fishermen’s housing growth is limited and only intended for residents who live and make a living on the coast, especially fishermen [1].

Currently, after one decade recovery of the city of Banda Aceh has developed quite rapidly, both physically and non-physically. This is inseparable from its role as the capital of the province, city of trade and services, and city of education. Physically, built-up land has increased by 2.5% compared to 15 years ago, while non-physically it can be seen by the increase in one of the important economic indicators, namely Gross Regional Domestic Product (GRDP) which has increased an average of 4.7%/year for the last 5 years. This condition is inversely proportional to the development of coastal areas, where the conversion of pond land to other land uses is 33.32%, while the area of residential land...
has increased by 22.67%. Reducing the area of the pond significantly results in a decrease in pond production by 46.74%, and will result in reduced income of fishermen and will reduce the level of GRDP if this is allowed to continue. The condition of Banda Aceh before the tsunami and after a decade of recovery can be seen in figure 1 and figure 2.

![Figure 1. Banda Aceh conditions one year after the tsunami. Source: Google satellite image.](image)

![Figure 2. Banda Aceh condition after a decade of recovery. Source: Google satellite image.](image)

Researchers from several countries have conducted different studies on sustainability. The Rapid Appraisal for Fisheries (RAP-Fish) method, which is based on the Multidimensional Scaling (MDS) approach, is one alternative way for evaluating sustainability. It is important to evaluate the sustainability of post-tsunami coastal area development to get an idea of the level of sustainability of the area after recovery so that policies taken in realizing sustainable development can be achieved as
expected. The purpose of this study was to determine the level of sustainability of the post-tsunami coastal area of Banda Aceh after the end of rehabilitation and reconstruction activities and subsequent development (2009-2019).

2. Materials and methods

2.1. Location
This research was done in four districts in Banda Aceh's coastline zones, namely: Kecamatan Meuraxa, Kecamatan Kuta Raja, Kecamatan Kuta Alam, and Kecamatan Syiah Kuala. The selection of the research location was determined purposively with the consideration that the four districts were the areas that suffered the most damage due to the tsunami disaster and were coastal areas that were dominated by fishermen settlements.

2.2. Population and sample
The subjects in this study were all fishermen in the coastal area of the four sub-districts of Banda Aceh. Purposive sampling was used, which means that samples taken based on specific criteria and considerations or quotas. The size of the sample size is determined using a technique developed by Isaac and Michael with an error rate of 10%, so using this formula the sample size is obtained as shown in table 1.

| District     | Number of fishermen | Number of samples |
|--------------|---------------------|-------------------|
| Meuraxa      | 152                 | 30                |
| Kuta Raja    | 54                  | 11                |
| Kuta Alam    | 43                  | 9                 |
| Syiah Kuala  | 152                 | 30                |
| **Total**    | **401**             | **80**            |

2.3. Procedure
MDS is a nonparametric multivariable analysis method with a simple approach that can be used to assess sustainability through comparative availability comparability based on several attributes scored utilizing computer-based statistical analysis techniques using RAP-Fish software developed by the Rapfish Group Fisheries Center University of British Columbia, Canada. The RAP-Fish approach is being used to assess the level of sustainable development in Banda Aceh's coastal area across five dimensions: ecological, economy, socio-culture, infrastructure, and technology, as well as law and institutions. The addition of two dimensions, namely infrastructure and technology, as well as law and institutions, because in the development of coastal areas, adequate infrastructure and technical support is needed and institutional and legal (regulatory) support to cover program activities and resolve conflicts of interest in the development of an area.

The analysis was carried out in several stages, including: (1) determining the attributes of spatial use in the coastal area of Banda Aceh, which include five dimensions: ecology, economy, socio-culture, infrastructure and technology, as well as law and institutions; (2) assessing each attribute on an ordinal scale based on the sustainability criteria of each dimension; and (3) compiling sustainability index and status. Scores for each attribute in each dimension are based on the scorer's experience and scientific judgment. Scores vary from 1 to 4, depending on the condition of each attribute stated, ranging from a very poor score of 1 to a very good score of 4. All of the attributes derived from the study's findings were examined in a multidimensional way. The calculation results of each dimension are expressed on a scale of 0% worst to best 100%, and separated into four categories of intervals or status categories, namely: 0-25% unsustainable, 25.01-50% less sustainable, 50.01-75% enough sustainable, and 75.01-100% very sustainable.
The MDS ordinance on the dimensions of the leverage factor analysis of the attributes based on the root mean square (RMS) on the x-axis is the next stage. The final step is to run a Monte Carlo simulation to see how errors in scoring affect the results. The more sensitive this feature is in the management of coastal areas, the larger the change in the RMS value. The correctness of the analysis is determined in MDS using the S-stress value obtained from the S and $R^2$ values to determine the goodness of fit. [4]-[10]-[11]. If the $R^2$ number is close to 1, the iteration process can be stopped. Low S values suggest good fit, whereas high S values imply poor fit. The Monte Carlo simulation of errors connected with the original assessment will reveal a considerable difference.

3. Results and discussion

3.1. Analysis of the sustainability of the ecological dimensions

The ecological dimension's sustainability index score was 59.75, with a sufficient (enough sustainable) status, per the results of the RAP-Fish analysis. The outcomes of the leverage analysis show that five attributes are sensitive to the value of the ecological dimension sustainability index, namely: (1) the condition of the aquaculture business road facilities; (2) the government's repair of ponds; (3) the condition of village road infrastructure; (4) the frequency of flood events; and (5) the intensity of pond habitat fragmentation. Attributes are sensitive to the ecological dimensions as shown in figure 3.

![Figure 3. Leverage of ten ecological attributes on sustainability score.](image)

3.2. Analysis of the sustainability of the economic dimension

According to the results of the RAP-Fish analysis, the economic dimension's sustainability index value was 40.79, indicating a less sustainable position. The leverage analysis reveals that five factors are sensitive to the economic dimension's sustainability index value: (1) the price of superior commodities; (2) profit from fishing business; (3) number of workers; (4) varieties of superior commodities; and (5) pond business feasibility. Attributes are sensitive to the economic dimensions as shown in figure 4.
3.3. Analysis of the sustainability of the socio-cultural dimension

The sustainability index value for the socio-cultural dimension was found to be 63.19, with a satisfactory (enough sustainable) status, based on the results of the RAP-Fish analysis. The leverage analysis yielded six attributes that were sensitive to the socio-cultural dimension of the sustainability index value: (1) the pattern of public relations in fisheries activities; (2) the number of villages with residents working in the agricultural sector; (3) the role of indigenous peoples in fisheries activities; (4) labor absorption rate; and (5) distance from sea level. Attributes are sensitive to the socio-cultural dimensions as shown in figure 5.

3.4. Analysis of the sustainability of the infrastructure and technology dimension

The sustainability index for the dimensions of infrastructure and technology was found to be 30.68, with a less sustainable status, based on the findings of the MDS analysis using the RAP-Fish. The leverage analysis identified five attributes that are sensitive to the value of the infrastructure and technology dimensions' sustainability index, namely: (1) standardization of fishery product quality, (2) availability of superior seed commodities, (3) application of fishery product certification, (4) availability of fishery processing industry, and (5) post-harvest handling. Attributes are sensitive to the infrastructure and technology dimensions as shown in figure 6.
3.5. Analysis of the sustainability of the legal and institutional dimensions
The sustainability index for the dimensions of legal and institutional aspects was obtained at 50.50 with a sufficient (enough sustainable) status based on the findings of the MDS analysis with the RAP-Fish. According to the results of the leverage analysis, there are seven sensitive features to the value of the legal and institutional components' sustainability index: (1) the existence of microfinance institutions; (2) availability of legal instruments; (3) the existence of a fishery extension center (BPP); (4) existence of fishermen groups; (5) existence of social institutions; (6) cross-sectoral mechanisms and development of coastal areas; and (7) availability of laws and regulations on the development of coastal areas. Attributes are sensitive to the legal and institutional dimensions as shown in figure 7.

3.6. Analysis of multidimensional sustainability
The index value for the sustainability of the ecological, economic, cultural, infrastructure and technology dimensions, law and institutional dimensions as shown on figure 8.
Based on the results of the MDS analysis with the RAP-Fish of the coastal area of Banda Aceh in the utilization of the coastal areas it can be concluded as follows: the status of the sustainability of the coastal area of Banda Aceh in each of its respective dimensions, namely: the ecological dimension is enough sustainable (59.75%), the economic dimension is less sustainable (40.79%), the socio-cultural dimension is enough sustainable (63.19%), the infrastructure and technology dimension is less sustainable (30.68%), and the legal and institutional dimensions is enough sustainable (50.50%), while in a multidimensional manner it is considered less sustainable with a sustainability index value of 43.80%. This means that when viewed from its sustainability status it can be said that the coastal area of Banda Aceh is included in the unsustainable category for the development of coastal areas, because there are still dimensions of sustainability that are in the less sustainable or unsustainable category, namely the economic, infrastructure and technological dimensions, as well as legal and institutional. The results of the analysis of the sustainability index value of the MDS analysis as shown in table 2.

Table 2. Results of RAP-Fish Analysis for sustainability development of the coastal area of Banda Aceh.

| Sustainability dimensions          | Sustainability index value | Sustainability level |
|-----------------------------------|-----------------------------|----------------------|
| Ecology                           | 59.75                       | Enough               |
| Economy                           | 40.79                       | Less                 |
| Socio-cultural                    | 63.19                       | Enough               |
| Infrastructure and technology     | 30.68                       | Less                 |
| Legal and institutional           | 50.50                       | Enough               |
| Multidimensional                  | 43.80                       | Less                 |

To determine if the attributes studied in the MDS analysis are carried out enough precisely and can be scientifically justified, as proven by the stress and coefficient of determination values ($R^2$). If the stress value of the analysis is less than 0.25 or 25% and the coefficient of determination ($R^2$) approaches 1.0 or 100%, the results are regarded accurate and responsible [7]. The MDS analysis reveals that all of the attributes investigated are quite accurate and can be justified. The stress value, which only ranges from 0.20 to 0.23, and the derived coefficient of determination ($R^2$) value, which ranges from 0.83 to 0.88, demonstrate this. The stress value and the coefficient of determination are shown in table 3.
Table 3. The results of the RAP-Fish analysis for the stress value and the coefficient of determination.

| Sustainability dimensions | MDS   | Stress | R²   | Iteration |
|---------------------------|-------|--------|------|-----------|
| Ecology                   | 59.75 | 0.209  | 0.88 | 3         |
| Economy                   | 40.79 | 0.214  | 0.87 | 3         |
| Socio-cultural            | 63.19 | 0.230  | 0.84 | 3         |
| Infrastructure and technology | 30.68 | 0.212  | 0.86 | 3         |
| Legal and institutional   | 50.50 | 0.203  | 0.83 | 4         |
| Multidimensional          | 43.80 | 0.155  | 0.94 | 2         |

4. Conclusions

The condition of the sustainable development of Banda Aceh's coastal area is still not sustainable, per the results of the multidimensional sustainability analysis, with a sustainability index value of 43.80%. Whereas in each dimension, namely the ecological dimension, the status index value is enough sustainable (59.75%), the economic dimension is less sustainable (40.79%), the socio-cultural dimension is enough sustainable (63.19%), the infrastructure dimension and technology is less sustainable (30.68%), and legal and institutional dimensions are enough sustainable (50.50%). The results of the analysis show that 28 sensitive attributes that have a major effect on improving the sustainability status so that it needs to be maintained and 20 insensitive attributes with low influence so that intervention (improvement) is needed so that the improvement of the sustainability status of the coastal area of Banda Aceh can run optimally.

There are five sensitive features found in the ecological dimension that have a significant impact on enhancing the status of sustainability. Three of the five attributes that need to be improved are the government's continuous improvement of ponds so that cultivation yields increase, reducing the intensity of pond land conversion into residential land even if necessary to prevent pond land conversion to other uses, and preventing tidal floods in certain months. While the other two features, namely the state of the aquaculture business road facilities and the state of the village road infrastructure, are still in good shape and require periodic maintenance, they must be maintained. Apart from the need for city government intervention to improve insensitive attributes so that the sustainability status improves, such as preventing changes in the ownership status (sales) of ponds to other parties (if necessary, the government controls the ponds land through Regional Owned Enterprises (BUMD), preventing ponds from experiencing drought by improving waterways, and ensuring the availability of water. Another feature that can be improved is the utilization of beaches for ecotourism activities, such as a combination of mangrove tourism, fishing villages, and gorgeous beaches, with local people serving as managers.

There are five sensitive attributes discovered in the economic dimension that have a significant impact on enhancing the status of sustainability. Two of the five attributes that need to be improved are maintaining the price of superior commodities and the profits of the fishery business, and expanding the market, particularly the fishery product market, so that other attributes, such as lowering the percentage of poor people and increasing the contribution of the fisheries sector to Banda Aceh's GDP, are automatically improved.

Among the other sustainability dimensions with moderately sustainable status, the socio-cultural dimension has the highest sustainability index value. There are six sensitive traits that can raise the sustainability index. This suggests that the socioeconomic situation of the people of Banda Aceh, particularly the population in the study region, is extremely favorable for the long-term use of coastal areas if properly maintained. The pattern of community relations in fishery activities is harmonious; many villages still have residents working in the fishery sector; ongoing community empowerment in fishery activities; high levels of employment; the distance between settlements and aquaculture businesses is very short; and the role of indigenous peoples in fishery activities is the basic capital in sustainable coastal redevelopment. The city government's task is to improve the insensitive attribute, namely the community's low level of environmental knowledge due to a lack of formal education,
through counseling and training, as well as providing the community with the widest possible access to integrated fisheries and other coastal businesses.

The infrastructure and technology dimensions have a moderately sustainable status with a fairly good sustainability index value. There are five sensitive attributes that need to be increased or maintained in value, and five insensitive attributes that need to be improved to improve sustainability status. The use of fishery product quality standardization and certification are sensitive features that must be maintained in order to sustain the quality of the products produced. Similarly, the availability of quality seed commodities, the fishery processing business, and post-harvest management must all be maintained in order for aquaculture to be viable. Furthermore, it is necessary to assist the city government in improving insensitive attributes, such as support for the availability of public facilities and infrastructure, connecting access, the availability of fisheries information technology, and the level of mastery of community aquaculture technology, which is still low, including reliance on water pumps, fertilization, and irrigation.

There are seven sensitive attributes in the legal and institutional dimensions that have a large impact on enhancing sustainability status, and two non-sensitive attributes that need to be changed to improve sustainability status. The backing of microfinance institutions and the Fisheries Extension Center (BPP), as well as the existence of groups of fishermen in a social organization tied by legal/religious instruments, are among the seven sensitive qualities. The existence of cross-sectoral mechanisms and the development of coastal areas, as well as the availability of laws and regulations on coastal area management so that the direction of coastal area development is more focused, are other sensitive attributes that contribute to improving the sustainability status. Meanwhile, the absence of regional collaboration and synchronization of central and regional policies are non-sensitive features that need to be rectified to improve the sustainability status.

Some of the suggestions in this research are that strengthening and empowering the community can be done by encouraging community business activities through capacity building, providing access to technology and information, capital, infrastructure, market guarantees, and other productive economic assets, so that sensitive attributes affect on big to increase the sustainability status can be maintained and the insensitive attributes can be fixed and improved. Improvement of one attribute in one dimension not only affects the improvement of other attributes in one dimension, but also increases the overall sustainability index in all dimensions so that the sustainable use of coastal areas can be achieved optimally.

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