Multidimensional scaling approach to evaluate sustainability status of belawan watershed management

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Abstract. Sustainability is currently a global issue, population growth and damage to natural resources, and environmental quality issues. This study will evaluate the sustainability of Belawan watershed management to develop sustainable watershed management planning. Watershed sustainability evaluation uses the MDS approach with rapfish (Rapid Appraisal for Fisheries) program modification to 5 dimensions and 42 attributes. From the assessment, the sustainability status of the Belawan watershed for ecological, economic, social culture, institution and legal dimensions is less sustainable. In contrast, the level of technology dimension is not sustainable. With the scenario of moderate improvement obtained, the status of sustainability ecological dimension, economic dimension, social culture dimension, and institutions legal dimension are reasonably sustainable. In contrast, the technology dimension is less sustainable. For optimistic improvement scenarios, all dimensions are reasonably sustainable. Sustainable watershed management needs to be done in an integrated manner that covers all institutions and related stakeholders.

1. 1. Introduction

1.1. Background

Today’s Sustainability issues are global issues with population growth and depletion of natural resources, and environmental quality problems.

Sustainable development is the world's agenda to respond to sustainability problems in natural resource management[1]. Sustainable development movement is implemented in almost all sectors, especially related to natural resource management.

The existence and condition of watershed ecosystems are one of the national issues in recent years because one of the variables of floods and landslides is the condition of damaged watersheds.

One of the causes is the storage of land use.

This condition causes reduced catchment areas as a buffer against the burden of significant flooding due to high rainfall. Currently, watershed damage is increasing due to land needs in line with the increasing population.

Increasing interests in sectoral and regional development resulting in changes in forest areas status, function, and allocation are the cause.
In Indonesia, there are 17,076 watersheds with an area of 189 million ha, 14.3 million ha is critical land that must be rehabilitated.

This watershed damage requires proper management by the conditions of government administration, institutional, social and biophysical.

1.2. Objective
Evaluate the sustainability Belawan Watershed to develop a strategic plan for sustainable watershed management comprehensively.

Belawan Watershed sustainability is evaluated from several aspects or dimensions, ecology, social culture, economy, technology, and institution and legal.

The sustainability analysis is based on the Multidimensional Scaling Method and the modified Rapfish (Rapid Appraisal for Fisheries) program. The research was using five dimensions and 42 attributes.

2. Material and Method

2.1. Description of Area Study
Belawan watershed is located in Deli Serdang Regency, Medan City, and Langkat Regency, with an area of 41,346.10 Ha. The geographical location of the Belawan watershed is at coordinates 98°29'26" - 98°43'13" East Longitude and 03°50'56"-03°15'54" North Latitude.

Belawan watershed topography conditions vary, from sloping to very steep. Most of the sloping (71.16 %), flat (12.70 %), somewhat steep (12.10 %), steep (2.63 %) and very steep (1.39 %).

Land cover conditions, mostly (56.45%) used dryland farming, used Plantation 10.39 %, used settlement 9.66 %.

There are 32 various industrial activities located in the Belawan watershed, which is located along the Belawan river. This has an impact on the environment in the watershed as well as the water quality of the Belawan river.

In general, the condition of the Belawan watershed has been disrupted its hydrological function, seen from the condition of land cover and land use and frequent flooding during the rainy season.

This research was conducted from September 2019 – March 2020.
2.2. Data Collection

The Watershed sustainability analysis uses the Multidimensional Scaling (MDS) method, using a modified Rapfish program. MDS analysis is carried out on five dimensions/aspects of sustainability, namely:

- The ecological dimension,
- The economic dimension,
- The social & cultural dimension,
- The technological dimension,
- The institutional & legal dimension.

The sustainability index calculation uses the Rapfish (Rapid Appraisal for Fisheries) software developed by the Rapfish Group Fisheries Center University of British Columbia, Canada[2]. This MDS method was chosen to provide comprehensive, fast, and objective results related to aspects affecting watershed sustainability.

This MDS method has been widely used to identify the level of sustainability of natural resource management. Sustainability status is stated in the Sustainability index values developed by Columbia University, Canada[3] are shown in table 1.

| Index Category | Category       |
|----------------|---------------|
| 0,00-25.00     | Not sustainable|
| 25.01-50.00    | Less sustainable|
| 50.01-75.00    | Reasonably sustainable|
| 75.01-100.00   | Sustainable    |

Procedures carried out in the MDS method as shown in Figure 2, namely the determination of dimensions and attributes through expert discussion, ordinal scoring in the range of 0 (bad) to 3 (good) under the characteristics of attributes by selected respondents or based on data obtained (both primary and secondary).

The next step is to carry out the MDS ordinance on the leverage factor dimension of the attribute based on the Root Mean Square (RMS) on the X-axis. The final stage is to conduct a Monte Carlo analysis to determine the effect of the error in scoring.

Collecting of research data was carried out on selected respondents from Belawan Watershed stakeholders.
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Figure 2. Flow chart of Belawan Watershed sustainability evaluation with MDS Method

3. Result and Discussion

Based on the results of attribute assessment by selected respondents from Belawan watershed stakeholders and analysis of secondary data collected, MDS analysis results with modified Rapfish are illustrated in table 2., table 3, and table 4.

The kite diagram of the sustainability index of the Belawan watershed is illustrated in figure 3. The sustainability status Belawan watershed, for ecological, economic, social-cultural, and institutional and legal dimensions is less sustainable, while the technology dimension is not sustainable.

By paying attention to the conditions and attributes sensitive to existing sustainability, there can be an improvement scenario to the sustainability status of watershed management, both program and policy. With the scenario of moderate improvement, obtained the status of sustainability dimension of ecology, economy, social culture and institutions and legal is reasonably sustainable, while the technology dimension is less sustainable.

For optimistic improvement scenarios, sustainability status for all dimensions is relatively sustainable. For sustainable management of the Belawan watershed, it is necessary to plan the management of the watershed in an integrated manner, involving cross-institutions and related stakeholders.

Varies improvement Scenarios for Belawan Watershed sustainability status are shown in figure 4.

| Dimension           | Sustainability Index | Remark          |
|---------------------|----------------------|-----------------|
| Ecology             | 41.56                | Less Sustainable|
| Economy             | 38.57                | Less Sustainable|
| Social & Culture    | 44.02                | Less Sustainable|
| Technology          | 23.19                | Unsustainable   |
| Institution & Legal | 39.15                | Less Sustainable|

Table 2. The result of sustainability index
Table 3. MDS analysis result and Monte Carlo analysis

| Dimension       | MDS  | Monte Carlo | Difference | RMS  | Stress |
|-----------------|------|-------------|------------|------|--------|
| Ecology         | 41.56| 40.76       | 0.80       | 0.949| 0.147  |
| Economy         | 38.57| 38.80       | 0.23       | 0.944| 0.157  |
| Social & Culture| 44.02| 43.06       | 0.96       | 0.944| 0.156  |
| Technology      | 23.19| 23.86       | 0.67       | 0.954| 0.135  |
| Institution & Legal | 39.15| 38.84       | 0.31       | 0.948| 0.147  |

Table 4. Leverage sensitive attributes to sustainability

| Dimension       | Attributes                                      |
|-----------------|------------------------------------------------|
| Ecology         | -Sedimentation rate                             |
|                 | -Land Cover Condition                          |
| Economy         | -Status of regional development                |
|                 | -Product domestic gross value                  |
| Social & Culture| -Health services                                |
|                 | -The role of community in environment management|
|                 | -Conflict of land use                           |
| Technology      | -Educational Infrastructure                     |
|                 | -Road Infrastructure                            |
| Institution & Legal | -Community participation in watershed environment management |
|                 | -Coordination and institution synergy in watershed management |

Figure 3. The Kite Diagram of Sustainability of Belawan Watershed (Existing)
### Table 5. Index Sustainability with several scenarios

| Dimension          | Existing | Moderate | Optimistic |
|--------------------|----------|----------|------------|
| Ecology            | 41.56    | 53.58    | 60.39      |
| Economy            | 38.57    | 56.20    | 60.83      |
| Social & Culture   | 44.02    | 58.84    | 73.67      |
| Technology         | 23.19    | 46.59    | 66.04      |
| Institution & Legal| 39.15    | 56.88    | 74.41      |

**Figure 4.** The Kite Diagram of Sustainability Index of Belawan Watershed (varies scenario)

### 4. Conclusion

The results of evaluating the existing sustainability status index of the Belawan watershed, the sustainability index of ecological, economic, social-cultural, institutional and legal dimensions are less sustainable. In contrast, the technological dimension is not sustainable.

Improvement scenarios can be done by program interventions as well as policies on attributes that are sensitive to sustainability indexes. For moderate scenarios, obtained index status is reasonably sustainable for the ecological, economic, Socio-Cultural, and Institutional & Legal, while the technology dimension is less sustainable. For optimistic scenarios, obtained a reasonably sustainable status for all dimensions.

The results illustrate the arisen complexity of several issues regarding the sustainability parameter of Belawan Watershed.

For sustainable management of the Belawan watershed, it is necessary to plan and manage the watershed in an integrated manner, involving cross-institutions and related stakeholders.

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