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# ASSESSMENT OF INTEGRATED WATER RESOURCE MANAGEMENT SUSTAINABILITY OF ACEH MEUREUDU RIVER BASIN

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ABSTRACT: Integrated water resource management contributes significantly in addressing the upsurge in water demands and challenges. The Global Water Partnership (GWP) defined the overall concept based on economic growth, accurate coordination, food security, health improvement, and social equity without compromising the sustainability system. Therefore, a need for consensus development and stakeholder involvement at every level becomes very paramount. However, the integration of sectoral organization within a particular river basin and effective management information appears imperative but complex to achieve due to political differences, individual interests, institutional influence, and objectives. The purpose of this study was to evaluate the sustainability of water resource management in Aceh Meureudu River Basin in a multi-dimensional and integrated approach by considering the social, economic, environmental, engineering, legal, and institutional frameworks. Furthermore, multi-dimensional scaling by a modified Rapfish software known as Rap-river basin was employed to calculate the percentage sustainability of several dimensions and reviewed attributes. The results of the MDS analysis on the Aceh Meureudu River Basin show the value of the sustainability of the technical (43.15), legal (43.07), and institutional (43.87) dimensions that fall into the less sustainable category. Some attributes do not indicate the direction of sustainable integrated water resources management. Value of sustainability the social (54.35), economic (53.40), and environmental (53.13) dimensions can be said to lead to the sustainability of the system even though the value is still low. Great efforts are needed to overcome this inequality so that the IWRM of the Aceh Meureudu River Basin is sustainable.

*Keyword: Integrated Water Resource Management, Sustainable, Multi-Dimensional Scaling*

## 1. INTRODUCTION

Indonesia is generally confronted with several challenges relating to water resource management, and the changing river basin conditions tend to greatly influence the water quality and quantity [1]. The water basin territories define one or more watershed and/or minor islands with a breadth less than or equals to 2,000 m2, as specified in the state regulation: No. 17 of 2019.

River basin occurs in one or several administrative regions. Sustainability awareness is necessary to effectively manage the water body and also serves as a water basis in supporting performance and policy development [2]. In addition, sustainable development will be more effective if supported by a good policy, as water forms a fundamental element of human existence [3]. However, the adverse impact due to the resource exploitation has resulted in various close watersheds, as the currents no longer extend into the oceans [4].

Apart from the above phenomenon, other problems of river basin control include agricultural land conversion into settlements, erosion and sedimentation, destructive conditions, unbalanced supply, and demand. New challenges emerge in achieving food and energy securities, including conflicts between water users related to the increasing demand for food and energy production (WEF nexus). Consequently, a coordinated security guarantee is required in addition to water resource allocation [5]. Therefore, proper research in every management aspect is the best necessity to confront these challenges [6]. The primary problem is related to the integration of water resources management by multi-actor collaboration. This effort appears complex and involves the particular public-owned institutions as pressing issues, including funding, expertise, mission, operational scale, and corrupt government agencies persist [7]. Also, the association results in sufficient trust among various stakeholders [8].

Aceh Meureudu River Basin appears inseparable from the Indonesian national strategic target, including increasing support for water protection, food sovereignty, and energy security in the area. This circumstance consists of conservation activities, utilization, and countermeasures for the destructive power of water. Moreover, the efforts

employed an integrated water resource management (IWRM) approach to meet the necessity of integrating planning and implementation. IWRM ensures more efficient and sustainable water resource management. However, management function, urgency, and water control are possibly delegated to other institutions. [9]. Stakeholder involvement in various roles ranging from decision making to implementation is believed to minimize poor management. Consequently, various attempts are involved in structuring regulations and policies as well as sustainable water resource management institutions. There is a need to consider the present and future importance of water existence. Eco-friendly management systems tend to achieve the change in demands without possible degradation [10].

Moreover, social and economic value is decreased due to unsustainable governance, affecting the quality and availability of water resources. Meanwhile, the water resources availability and sustainability naturally terminated caused by unbalanced supply and accessibility.

The present study is expected to explore the sustainability of Aceh Meureudu River Basin based on social, economic, environmental, technical, legal, and institutional dimensions. Next, identifying attributes for each component believed to significantly impact the sustainability conditions.

## 2. MATERIALS AND METHODS

This research was based on a particular national strategic river basin in Indonesia called Aceh Meureudu, and is known to extend to certain administrative regions, including Kota Banda Aceh, District Aceh Besar, Pidie, Pidie Jaya, Bireuen, and Kota Sabang. The sample basin consists of 30 watersheds with an area of 5,568.00 km², equating to 9.60 % of the total Aceh Province covering approximately 57,956.00 km² (Fig.1).

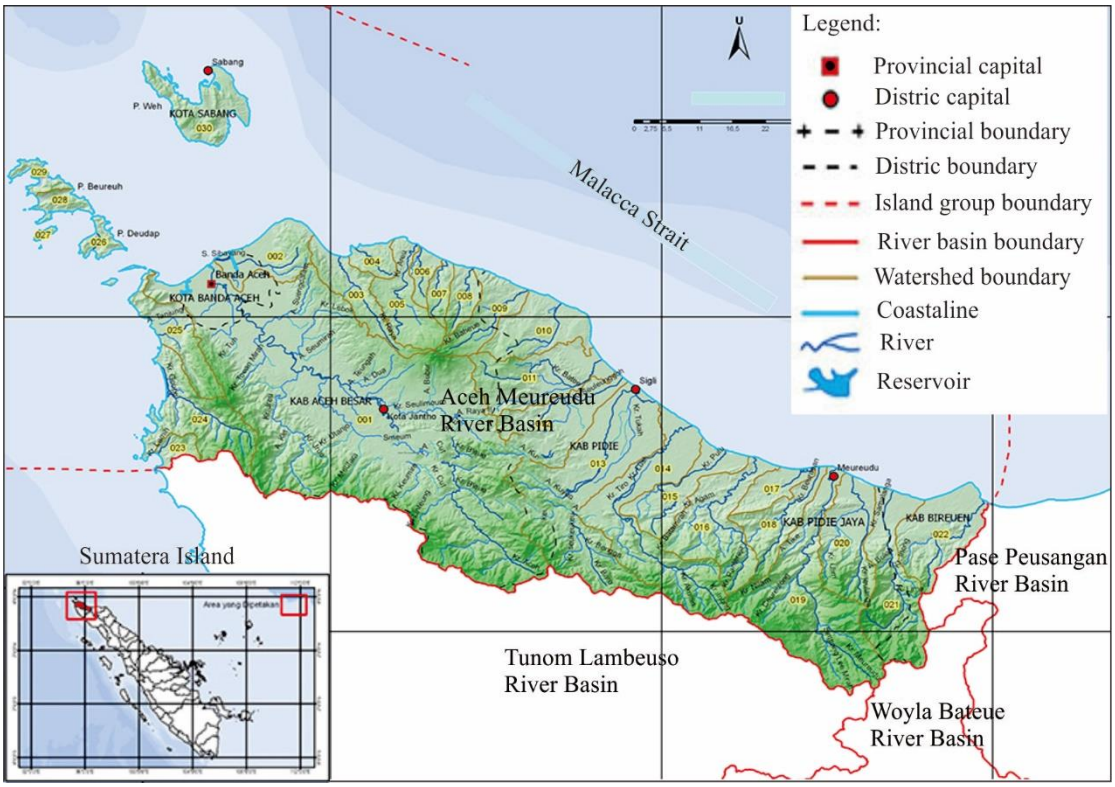


Fig.1 Map of Aceh Meureudu River Basin

The rapid growth of the population also causes significant demand for clean water, hopefully with sufficient supply, thus can avoid conflict among communities. Unfortunately, floods and overrun tend to fill the residential area during the rainy season, while water deficiency happens in the reservoir during the dry season. Furthermore, damages to irrigation and inadequate water services are also observed.

Primary and secondary data were collected in this investigation. The primary sources included in-depth interview/discussion, in a bid to acquire attributes for each dimension of the subject matter, followed by the distribution of questionnaires to stakeholders, NGOs, and academic/scholars. Meanwhile, the secondary data were derived from literature and other institutional materials, using direct means or digital information systems owned by state bodies.

Dimensions and attributes of water resources management in Aceh Meureudu River Basin that are collected, consist of 6 dimensions, i.e., social, economic, environmental, technical, legal, and institution dimensions. Each dimension has attributes such as public participation, social conflict, community awareness, comprehension of IWRM for a social dimension. In the attributes of the Economic dimension increase in community income, economic impact disaster of water resources, available financial planning, satisfactory operation, and maintenance fund. The government's fund for IWRM, tariff suitability for water services, customers' contribution to the service payment, the problem of government's budget, IWRM work opportunities, dependence on people's livelihoods in the river basin, and business prospects for economic productivity. The environmental dimension includes the erosion level, river pollution, upstream damage, catchment area ability for water conservation, conservation rate of productive agriculture. While on the technical dimension includes water availability, infrastructure availability, synchronization of implementation activities between various sectors, and strategic management plan availability framework. Attributes such as laws and regulations availability, legal harmonization, drafting regulations by considering community interests, implementation of law enforcement are contained in the legal dimension. The dimensions of the institution have attributes including coordination and synergy between agencies, division of authority and responsibility of institutions, the existence of cross-regional institutions, community-based water supply, and management bodies, socialization of institutions.

This method is referred to as multi-dimensional scaling (MDS), using Rap-river basin application, a modification of the rapid appraisal of the status of fisheries (Rapfish) software, also used to determine sustainability status in fishing, with continuous improvement (rapfish.org). The recent evaluation occurred in the form of an institutional dimension. Also, the MDS method provides a computer-based statistical analysis to transform each dimension attribute [11].

### 2.1 IWRM Approach

The integrated water resource management (IWRM) is a subject with continuous development. Also, it involves several parties, including state and federal governments, non-governmental organizations, academics, as well as international and intergovernmental bodies [12]. This tool was employed to overcome increasing water demands and considered every aspect of the water system while addressing gaps between technical and unified attempts [13]. Despite the absence of fully integrated management, the solution was acquired from natural and social sciences [14]. Furthermore, IWRM intends to increase water resources management and effectiveness, address the catchment area degradation, inadequate law enforcement, institutional limitations, and other risk factors of water resource sustainability [15].

However, decision-making in IWRM was based on consensus and communication among river basin stakeholders as a single hydrological unit. Also, water resource management and inherent transformation appeared relatively political, involving the mediation of social powers. Community actions probably depended on authority, interest, and preferential workplace circumstances [16]. In decision making, policy actors and advisors formulate strategic conclusions on the linkage of policies and institutions to water management and contribute to achieving food security, sustainable environment, economic growth, and poverty alleviation. This description referred to a process of transforming perceptions, interests, and objectives into effective strategies. Personal positions influenced actors' perceptions in the social system and interests. Furthermore, actor networks, rules, functions, complex organizations, overlaps, and competitions already existed in communities [16]. Also, governance, management, and water consumption were characterized by three diversities, termed (i) several actors and organizations involved in every decision-making process (ii) numerous regulations and procedures related to a specific problem, e.g., legal pluralism, and (iii) multi-functional water resource system within distinct values. Therefore, water resource management in the river basin based on real-time data requires an integrated management mechanism amongst stakeholders. The improvement of data access helps reduce the work gap between investors, to achieve sustainability goals [17].

The spiral IWRM model explains the management stages based on the socio-economic and environmental development of the river basin. Individual turn in this spiral assists users to comprehend the current situation and the direction of IWRM goals initially from the recognition stages to identifying needs and realizing the structural problem, as well as conceptualization to determining realistic alternative actions towards balancing supply and demand aspects, including the entire stakeholders. Furthermore, effective coordination and detail planning ascertains the comprehensive strategy and finalizes the concept with every stakeholder in the previous phase to establish an agreement. The implementation, monitoring, and evaluation stages are needed in the agreed scheme or framework, followed by the impact assessment of the activities, with adequate

funding. Also, the spiral IWRM model is adapted to the necessities and dynamic conditions related to the changes in social, economic, environmental, technical, legal, and existing institutions. This provides a framework for prospects and improvement in management quality by planning subsequent 'spiral loops' [18].

### 2.2 Sustainable Development

Brundtland Commission 1983 report revealed, "Sustainable development is the development that can meet the needs of the present without compromising the ability of future generations to meet their own needs". This concept utilizes resources efficiently in economic and social advancement as well as equally preserves environmental sustainability. In addition, there is a need for an integrated approach with a holistic perspective by calculating every related dimension, including environment, economy, social, institutional sub-systems [19], and engineering [20, 21]. Furthermore, the combination of various sustainable features tends to provide more comprehensive prosperity [22]. Sustainability assessment is required to ensure convincing decision-making. Sustainable IWRM tends to adapt and control conditions due to socio-economic and environmental developments.

### 2.3 Multidimensional Scaling (MDS)

Multidimensional scaling (MDS) is one dimensionality reduction technique that converts multidimensional data into lower dimension space while keeping the intrinsic information [23]. This approach was relatively reliable to analyze the functional IWRM status, including the Aceh Meureudu river basin. Therefore, a modified Rap-river basin appears suitable for this circumstance.

In Rap-river basin, objects strived as close as possible to the initial origin mapped into two or three-dimensional spaces. The ordination technique (distance determination) in MDS is based on Euclidean distance, but is written in n dimension space (eq.1) as:

$$\mathbf{d} = \sqrt{(|\mathbf{x_1} - \mathbf{x_2}|^2 + |\mathbf{y_1} - \mathbf{y_2}|^2 + |\mathbf{z_1} - \mathbf{z_2}|^2 + ..)} \quad (1)$$

Configuration or ordination from an object or dot in MDS is then approximated by regressing Euclidian distance (dij) from points i to j with the origin (δijd), using the eq.2 as :

$$\mathbf{d_{ij}} = \boldsymbol{\alpha} + \boldsymbol{\beta}\boldsymbol{\delta_{ij}} + \boldsymbol{\varepsilon} \quad (2)$$

The technique used to regress the equation above is referred to as the least square method based on Euclidean distance (squared) roots, also known as ALSCAL. It is optimized to the quadratic data (origin = oijk) in three dimensions (i, j, k). The formula for the S-Stress value is calculated by eq.3 as:

$$\mathbf{S} = \sqrt{\frac{1}{\mathbf{m}}\sum_{\mathbf{k=1}}^{\mathbf{m}}\left[\frac{\sum_i\sum_j\left(\mathbf{d_{ijk}^2} - \mathbf{o_{ijk}^2}\right)^2}{\sum_i\sum_j \mathbf{o_{ijk}^4}}\right]} \quad (3)$$

The squared distance used in the calculation of S stress (eq. 3) is a weighted Euclidian distance as shown in eq. 4. The calculation results are shown in Table 3.

$$\boldsymbol{d_{ijk}^2} = \sum_{a=1}^{r} \boldsymbol{w_{ka}}\ \left(\boldsymbol{x_{ia}} - \boldsymbol{x_{ja}}\right)^2 \quad (4)$$

The goodness of fit in MDS measures the point configuration accuracy representing the original data and is reflected in the S-Stress and $R^2$ values. Low S-stress indicates high precision, while a larger outcome generates minimal accuracy. In the Rapfish approach, an effective model is represented with an S-stress below 0.25 or S <0.25 [24,25]. Therefore, a reliable $R^2$ value possibly occurs closer to 1.

Leverage (influence) calculation is based on the standard error of the difference between the scores with and without the attribute (Root Mean Square Change in Ordination when Selected Attribute Removed). However, each property's participation was evaluated from the change in the coordinates on removal. Typically, the attributes from similar fields tend to contribute more and less equally, indicating an accurate multivariate estimation. Conversely, with barely a single feature showing the dominant percentage, the variable is considered essential.

In Rapfish, close attention is relevant to uncertainty caused by scoring error, scoring diversity, and data entry oversight. Monte Carlo analysis is required to evaluate the impact due to the miscalculations [11, 24].

The MDS was employed to describe sustainability position visually in both horizontal and vertical axes indicating "bad" (0%) to "good" (100%) conditions for every analyzed dimension, as shown in Table 1 [11, 24].

Table 1 Sustainability Status Assessment Category

| Dimension Index Value | Category | Description |
|---|---|---|
| 0.00 - 25.00 | Bad | Unsustainable |
| 25.01 - 50.00 | Less | Less sustainable |
| 50.01 - 75.00 | Fair | Fairly sustainable |
| 75.01-100.00 | Good | Sustainable |

Monte Carlo analysis was performed at a 95% confidence interval. The results were subsequently compared with MDS assessment outcomes. As a consequence, a minor difference indicated relatively less impact in scoring error and multiple scoring variations on the attributes, as well as the occurrence of stable repeated MDS analysis and minimal data mistakes or losses. By comparing the results of Monte Carlo (MC) and MDS at 95% confidence level or 5% error rate, the difference in the values of the two analyzes was more significant (MC-MDS> 5%) or smaller (MC-MDS <5%). For values > 5%, the MDS results proved inadequate to estimate the sustainability index of water resources management in Aceh Meureudu River Basin, but sufficient for <5%.

## 3 RESULTS AND DISCUSSION

### 3.1 The Sustainability Status of the Social Dimension

The analysis results of the social dimension sustainability index using 10 attributes were valued at 54.35%. In addition, the index score ranged between 0 (bad) to 100% (good), as a reasonably sustainable status was achieved. Figure 2 shows the value of the social dimension sustainability index.

This index is increased by the impact of sensitive attributes. Leverage analysis was used to observe these delicate influencing properties.

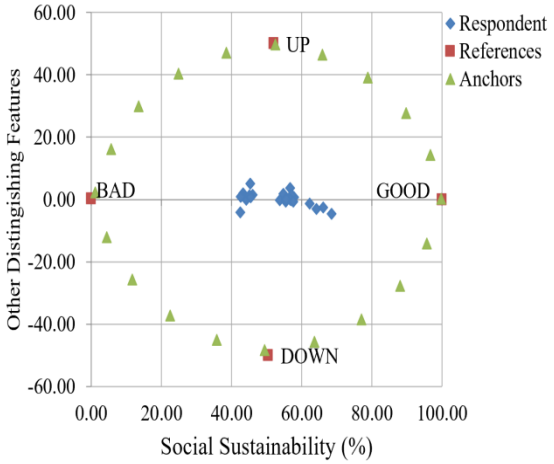


Fig.2 Social dimension sustainability index

Based on leverage analysis, three sensitive attributes were obtained, including public participation in IWRM, people culture in river preservation, and social conflict related to water utilization. Figure 3 represents the leverage analysis results.

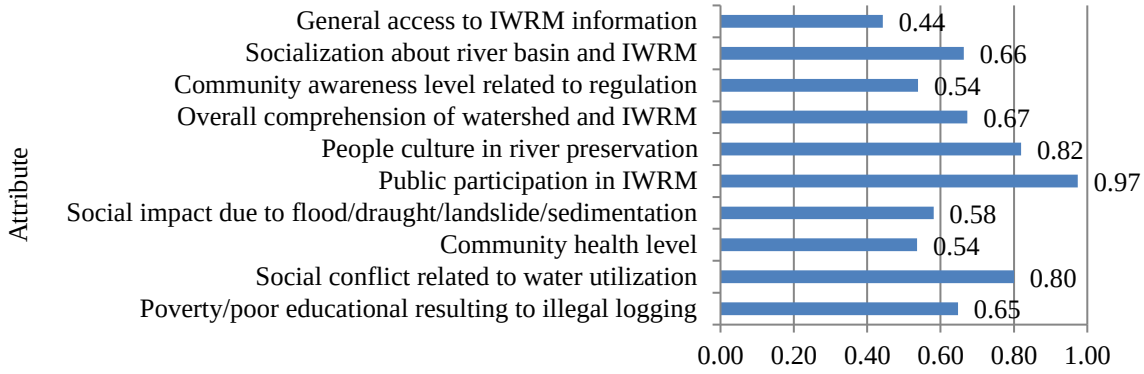


Fig.3 Leverage analysis value of social attributes

The IWRM community participation served as a significant factor due to the direct impact. Moreover, community participation in the IWRM of the sample basin remained drastically low. Local culture in water resource preservation in customary rules was activated after Aceh experienced various internal problems. Social conflicts that occur in the community regarding water utilization are frequently happening due to water decreasing during the dry season.

### 3.2 The Sustainability Status of the Economic Dimension

There are 12 attributes to assess the sustainability status of the economic dimension. The MDS analysis generated a sustainable index of 53.40%, indicating fairly sustainable, as represented in Figure 4.

Sensitive attributes with an influence on the sustainability index of economic dimension were evaluated using Leverage analysis. The results are represented in Figure 5.

Based on the above analysis, three sensitive attributes of the economic dimension sustainability index occurred, including the dependence on people's livelihoods in the river basin, sufficient operation and maintenance (O&M) fund, and

national/provincial/ district/city funds for IWRM. These sensitive factors depended on people's revenue sources from the river basin, where the riverbank was greatly utilized for farming and served as trading centers. In addition, the community also explores the forest as a potential income source. However, to overcome this circumstance, the government is expected to conduct public outreach to develop other revenue opportunities.

Adequate operation and maintenance (OM) costs are one of the critical indicators in water infrastructural sustainability. Limitations in this indicator are observed in OM activity budgeting regarding the figures for OM costs. In low O&M, the maintenance costs tend to increase, and in the end, the next O&M becomes higher [26]. Therefore, it is crucial to ensure the existence of an agreement on sharing funds between national and regional (provincial/district/city) in certain activities, including irrigation network rehabilitation and river basin improvement.

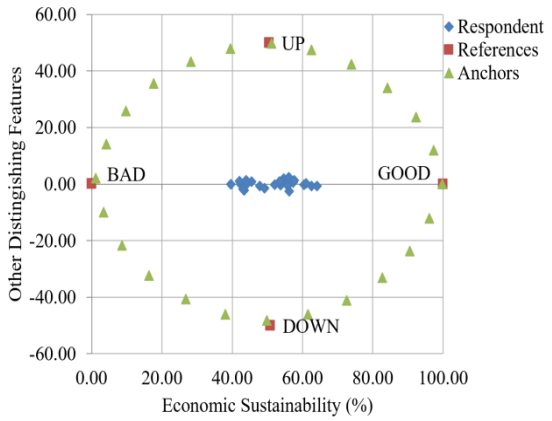


Fig.4 Economic dimension sustainability index

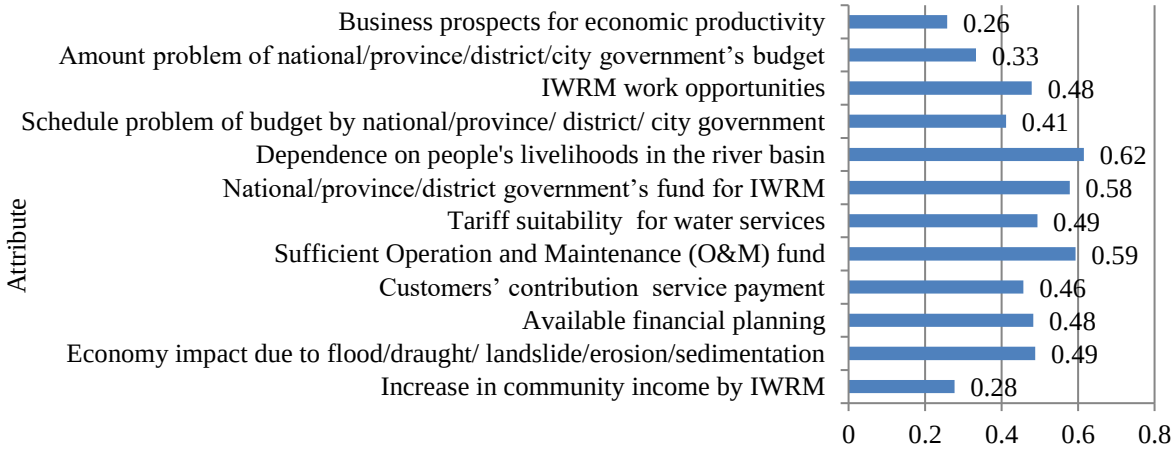


Fig.5 Leverage analysis value of economic attributes

### 3.3 The Sustainability Status of Environmental Dimension

The sustainability index of environmental dimension based on MDS analysis on 25 respondents was estimated at 53.13%. Figure 6 represents this index value as fairly sustainable.

Seven attributes were used in assessing the sustainability status. In addition, three were sensitive and demonstrated significant influence based on leverage analysis, and were termed upstream damage due to illegal logging, catchment area ability for water conservation, and conversion rate of productive agricultural land into settlements. Figure 7 shows the results of leverage analysis.

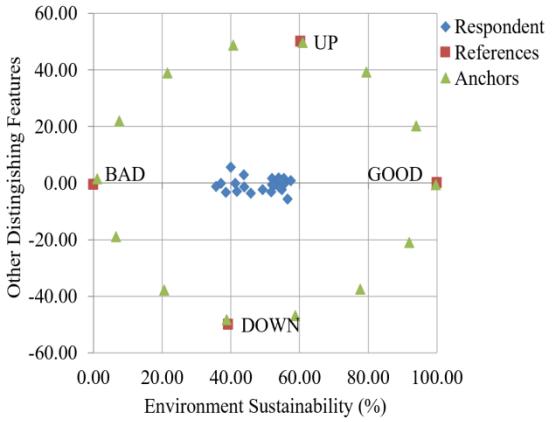


Fig. 6 The sustainability index of the environmental dimension

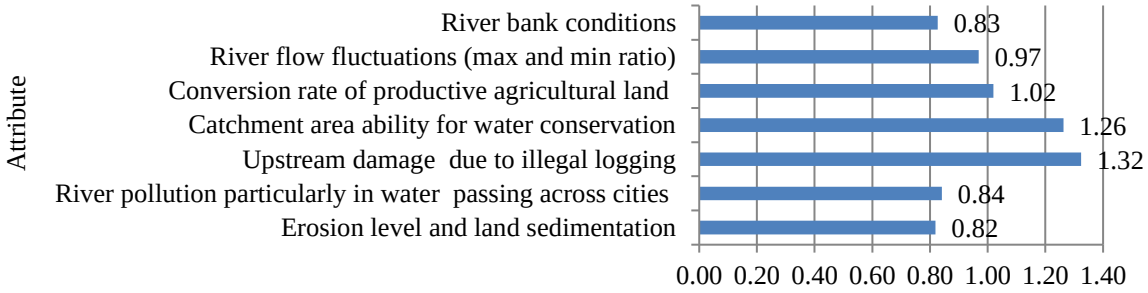


Fig.7 Leverage analysis value of environmental attributes

Krueng Aceh Watershed ecosystem is threatening by illegal logging, plantation, and mining, which is damaging upstream, and they are related to the key factors aforementioned. This loss resulted in further sedimentation, and in turn, decreased the ability of the rain catchment to store water. However, several activities are needed to replant diminished forests and efforts to dredge/flush sediment.

Moreover, the increasing population in a site, higher conversion rate of agricultural land into the settlement, and other built-up areas are recorded. This factor significantly impacted the existing hydrological system related to water availability. However, to limit the conversion rates, a viable government policy intervention is expected, using related institutions, including zoning residential and agricultural areas.

### 3.4 The Sustainability Status of the Technical Dimension

The sustainability index value of technical dimension with MD analysis was evaluated at 43.15% with a fairly sustainable status, as represented in Figure 8.

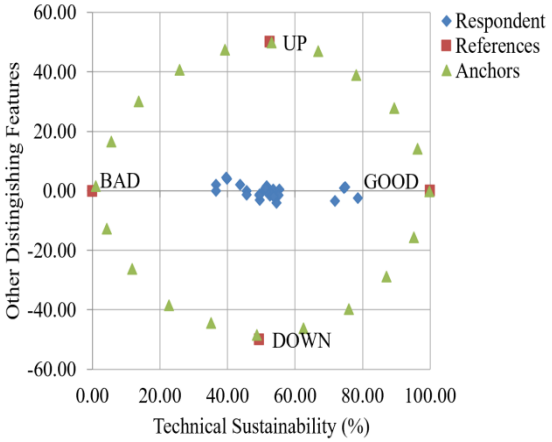


Fig. 8. The sustainability index of the technical dimension

Ten attributes were used in assessing this sustainability status. In addition, leverage analysis was employed to observe the effects. The results obtained three sensitive attributes; termed infrastructure convenience, available framework for strategic management plans, and synchronization of implementation activities between various sectors. Figure 9 shows the results of the leverage analysis.

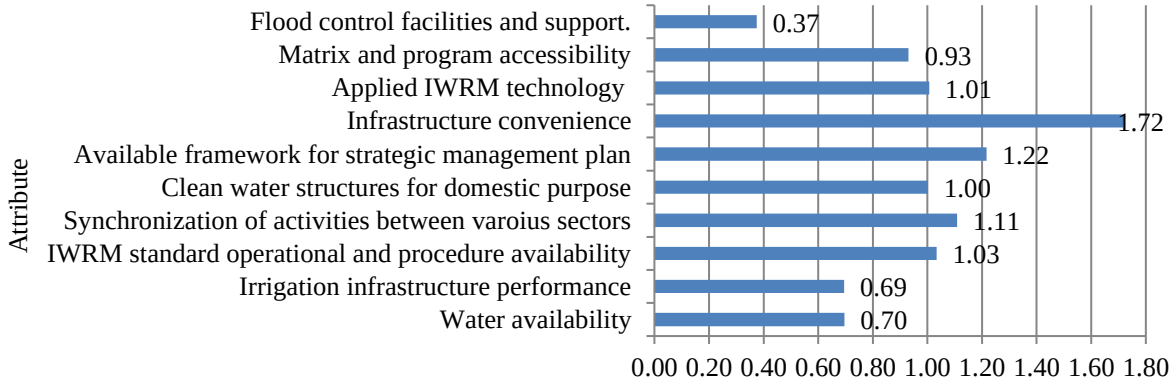


Fig. 9 Leverage analysis value of technical attributes

In the technical dimension, infrastructural availability appeared as a significant concern but has not been fully maximized. Meanwhile, several existing infrastructures were already in damaged conditions due to the age factor of the building or poor maintenance. There is a need to initiate infrastructure development and rehabilitation for effective water resource management. Available framework for strategic management plans is an essential consideration in conducting water resource management activities for various sectors and administrative areas. This structure was determined by the Minister of Public Work (PUPR) in 2020 and purposely used to synchronize data, information, and activities between sectors. Nevertheless, the irrigation management implementation of central, provincial, and district/city governments has not been significantly encouraging.

### 3.5 The Sustainability Status of the Legal Dimension

The result of the analysis of the legal dimension sustainability index was achieved at 43.07%, with a less sustainable status. Figure 10 represents the overall values.

Nine attributes were involved in assessing the sustainability status of the legal dimension. The values are possibly increased by adjusting the sensitive properties. Leverage analysis was employed to observe these features. The results showed the three attributes, including laws and regulations related to IWRM availability, legal harmonization as well as the implementation of law enforcement. Figure 11 represents the leverage analysis results.

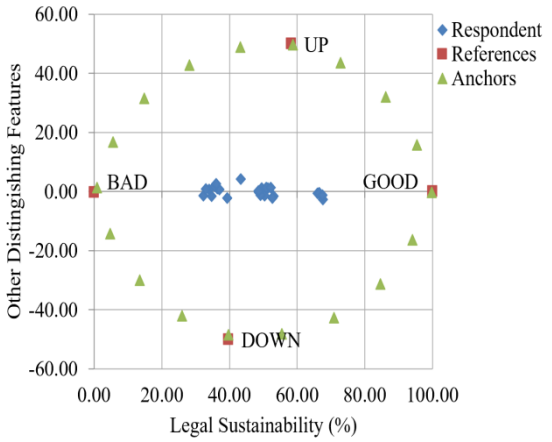


Fig.10 The sustainability index of the legal dimension

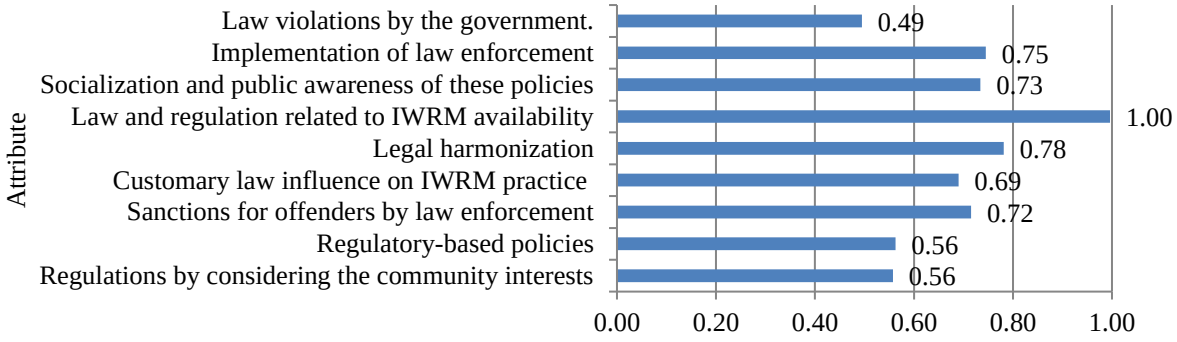


Fig.11 Leverage analysis value of legal attributes

The availability of WRM related laws and regulations served as an important factor in the legal dimension, as stated at the national level or Aceh regional regulations. However, with the issuance of Law No. 17 of 2019 and other associated rules on water resources and several provincial/district/city provisions, the practice of natural resource management embraced legal protection as a guideline in providing community services. In addition, regulations were developed to assign water resource management authorities to suitable management agencies for each sector and administrative area. Therefore, to improve the overall performance, specific existing laws and regulations require absolute harmonization to prevent horizontal conflicts as clearly defined roles and authorities were outlined. This is very necessary to overcome the current overlaps. In addition, effective law enforcement by competent institutions served as a supporting factor in ensuring appropriate regulations.

### 3.6 The Sustainability Status of the Institutional Dimension

The sustainability index of the institutional dimension based on MDS analysis was 43.87% with a less sustainable status, as demonstrated in Figure 12. Eight attributes were used in assessing the sustainability status.

Leverage analysis was performed on these variables to reveal the most influential. Three attributes were observed, including coordination and synergy between agencies, division of authority and responsibilities of institutions in the river basin, and the existence of the cross-regional institution. Figure 13 displays the leverage analysis results.

In the institutional dimension, coordination and synergy between sectors and regions are essential keys. The problem of WRM was prevalent in Aceh Meureudu River Basin, where coordination between agencies, governments (national, provincial, district/city), and among stakeholders was not optimal due to sectoral approaches and overlapped division of functions/responsibilities. The absence of cross-regional and sectoral institutions required to manage water resources from planning, development, operation, maintenance, and water services, tends to increase the efficiency and effectiveness of an IWRM system. However, to enhance the sustainability index, there is a need to strengthen the existing coordinating institutions or formulate a new structure to perform both regulator and operator functions.

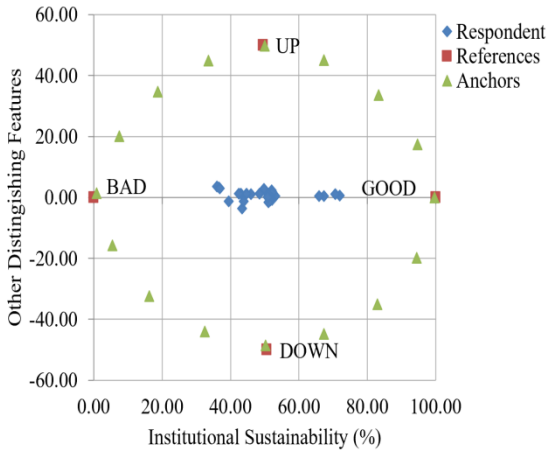


Fig.12 The value of the sustainability index for the institutional dimension

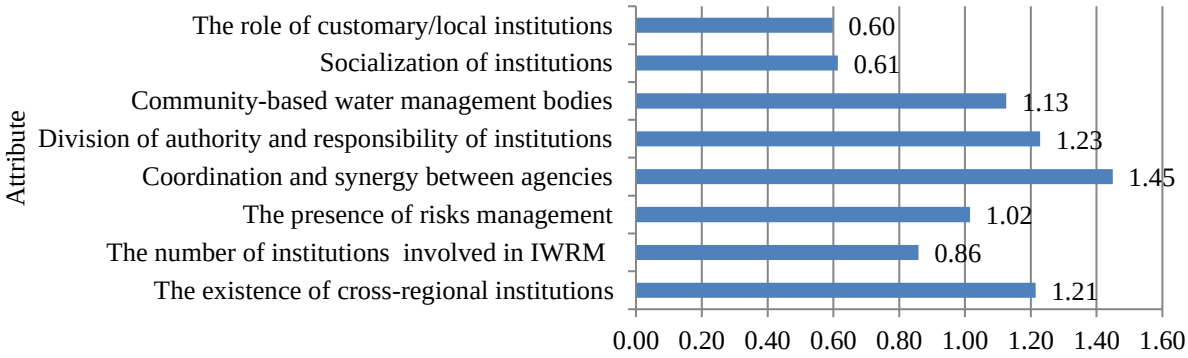


Fig.13 Leverage value of the institutional attributes

The Aceh Meureudu River Basin analysis provided a sustainability index, and the attributes employed were composed of six dimensions, including social, economic, environmental, technical, legal, and institutional. Also, the results achieved a sustainable status of 54.35, 53.40, and 53.13% for social, economic, and environmental dimensions, respectively. Meanwhile, technical, legal and institutional parameters were estimated at the less sustainable status of 43.15, 43.07, and 43.87%, correspondingly. Furthermore, the sustainability analysis for dimensions of the sample basin was also less sustainable, with the index value at 48.49%. Figure 14 illustrates the multidimensional sustainability index.

Based on the calculated value of Monte Carlo analysis at 95% confidence level for each dimension and the combined six elements, a relatively minimal difference was observed compared to the MDS results. This situation showed the accurate value of the MDS evaluation [7].

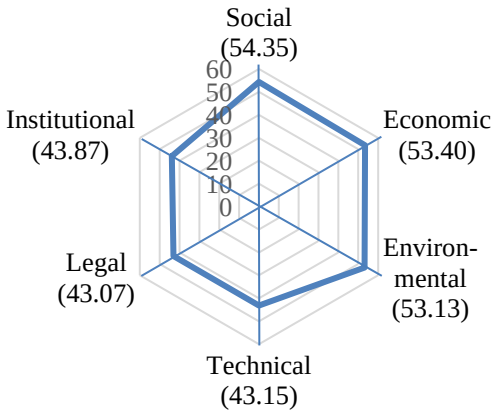


Fig.14 The multidimensional sustainability index value of Aceh Meureudu River Basin

The results of MDS analysis on the sustainability index of the Aceh Meureudu River Basin also indicated minor procedural errors in determining attribute scores due to insufficient information. There was also the occurrence of relatively low oversights in score differences, caused by varying opinions, a high level of MDS stability, neglecting errors in the entry or missing data, and high S-stress values. Table 2 represents the results of the Monte Carlo analysis for the multi-dimensional sustainability index.

Table 2 Monte Carlo analysis results for multidimensional sustainability index and each dimension at a confidence level of 95%

| The sustainability status Index | MDS Result (%) | Monte Carlo Result (%) | Difference (%) |
|---|---|---|---|
| Multi-dimensional | 48.49 | 47.21 | 1.28 |
| Social | 54.35 | 52.10 | 2.25 |
| Economic | 53.40 | 51.04 | 2.36 |
| Environmental | 53.13 | 51.46 | 1.67 |
| Technical | 43.15 | 43.00 | 0.15 |
| Legal | 43.07 | 42.87 | 0.20 |
| Institutional | 43.87 | 42.81 | 1.06 |

The determination coefficient ($R^2$) was relatively high and occurred within the range of 0.73-0.91. This showed the attributes in this analysis represented 93-95% of the existing diversity of the sample basin and described the accuracy of the built model. Also, the variables developed in each dimension appeared very representative.

Table 3 indicates a low estimate for individual S-stress value, ranging between 0.09-0.21 or below 0.25. This demonstrated an excellent configuration accuracy of MDS points representing the sustainability index of the Aceh Meureudu River Basin.

Table 3 The results of the analysis for the value of S-stress and the coefficient of determination ($R^2$)

| Dimensions | S-stress value | $R^2$ value |
|---|---|---|
| Social | 0.17 | 0.79 |
| Economic | 0.21 | 0.73 |
| Environmental | 0.09 | 0.93 |
| Technical | 0.18 | 0.74 |
| Legal | 0.19 | 0.75 |
| Institutional | 0.12 | 0.91 |

In terms of leverage values, the social, economic, and environmental dimensions are above 50%; however, these values remain close to being less sustainable. The three dimensions' leverage is definitely bound to increase in cases where the leverage of the next three dimensions, the currently less sustainable technical, legal, and institutional aspects, are improvable. Figure 9 shows the technical dimension, where infrastructure availability, strategic management plan availability, and synchronization of implementation activities between various sectors are highly sensitive attributes. These attributes are also strongly influenced by legal and institutional aspects, as stated in [9], [10], [12]. According to Figures 11 and 13, the three highly sensitive attributes in the legal dimension, as well as in the institution's dimension, are the laws and regulations related to IWRM availability, harmonization in laws and regulation, implementation of law enforcement, coordination, and synergy between agencies, division of roles, authority as well as responsibilities, between institutions in the river basin, and the existence of cross-regional institutions.

The IWRM approach offers solutions to problems related to water resources. IWRM requires a compromise of multisectoral stakeholders. In its implementation, IWRM solves existing issues in a win-win solution. The IWRM process is carried out in stages to improve water management in a country. This process requires good Institutions with capable multidisciplinary staff and a supportive environment. Integrated planning and management are made possible by the availability of comprehensive and coherent legislation and the political will to enforce these laws. At the planning stage, it takes the participation of all stakeholders in the long term so that decision making when implemented, can run smoothly, efficiently, and effectively [27].

The solution offered is spiral IWRM which consists of several stages. The information obtained at the recognizing and the identifying stages indicated the damage to the upstream watershed due to logging and forest encroachment, the high rate of conversion on productive agricultural land into settlements, the low ability of the rain catchment area to store water, the high dependence of people's livelihoods on the river basin, and social conflicts in community-related to water use. The conceptualizing stages aimed at increasing institutional power by classifying the roles, the authorities, and the responsibilities in the river basin, and the concept of sharing central/provincial/ district funds in the water resources management. Coordination and synergy between institutions, community participation in water resources management, synchronization of the implementation of activities between sectors, and harmonization in-laws and regulations are carried out at the coordinating and planning stages. At the implementing, monitoring and evaluating stage the

availability of adequate infrastructure, availability of water resources management patterns and plans, availability of laws and regulations related to water resources management, implementation of enforcement of regulations, and the existence of cross-regional institutions as well as the availability of adequate costs.

## 4 CONCLUSION

The results of the MDS analysis on the Aceh Meureudu River Basin show the value of the sustainability of the technical (43.15), legal (43.07), and institutional (43.87) dimensions that fall into the less sustainable category. Some attributes do not indicate the direction of sustainable integrated water resources management. Value of sustainability the social (54.35), economic (53.40), and environmental (53.13) dimensions can be said to lead to the sustainability of the system even though the value is still low. Great efforts are needed to overcome this inequality so that the IWRM of the Aceh Meureudu River Basin in Aceh province is sustainable. Socio-economic and environmental changes in the Aceh Meureudu River Basin require alternative management approaches. An evaluation of the existing challenges, improvements, and restructuring is needed. Improvements are made by identifying the attributes that affect the IWRM spiral. Problem information obtained at the introduction and identification stage is followed by making a clear concept so that it is realistic to implement. For this concept to work well, proper planning and coordination, and synergy between stakeholders are needed to run smoothly during the monitoring and evaluation implementation. It is also essential to evaluate the impact of an issue that requires further attention in the future on an ongoing basis. This is done on an ongoing basis to lead to the next round of the IWRM spiral that begins again in recognizing and identifying phase. It is also important to evaluate the impact of an issue that requires further attention in the future on an ongoing basis. This leads to the next round of the IWRM spiral, starting back in the recognizing and identifying phase.

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