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# Multidimensional Sustainability Analysis of Forest and Land Rehabilitation Program in Bombana Regency, Southeast Sulawesi, Indonesia

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**ABSTRACT**

*Forest and land degradation remains a significant environmental challenge in Bombana Regency, Southeast Sulawesi, Indonesia, requiring rehabilitation strategies that ensure long-term sustainability. This study evaluated the sustainability status of the Forest and Land Rehabilitation (RHL) program and identified the key factors influencing its performance. Sustainability was assessed using the Rapid Appraisal for Sustainability (RAPSUS) approach based on Multidimensional Scaling (MDS) across the ecological, economic, and social dimensions using 21 attributes. Data were collected through field observations, structured interviews, and expert judgment involving relevant stakeholders. Model performance was evaluated using stress values, coefficients of determination ($R^2$), leverage analysis, and Monte Carlo simulations. The results indicated that the RHL program was moderately sustainable, with the ecological dimension showing the highest sustainability index (62.82), followed by the economic (58.61) and social (52.09) dimensions. Leverage analysis identified flora species diversity, planting success rate, and clarity of area boundaries as the most influential attributes affecting sustainability. The MDS model demonstrated good reliability, with stress values ranging from 0.1477 to 0.1529 and $R^2$ values ranging from 0.9408 to 0.9432. These findings highlight the importance of improving vegetation diversity, increasing planting success, and strengthening stakeholder participation to enhance the long-term sustainability of RHL programs and support adaptive rehabilitation policies.*

## 1. INTRODUCTION

Bombana Regency, located in Southeast Sulawesi Province, Indonesia, possesses extensive forest resources that provide essential ecological functions, including biodiversity conservation, watershed protection, and the provision of environmental services. However, increasing anthropogenic pressures, such as agricultural expansion, land conversion, mining activities, and unsustainable resource utilization, have accelerated forest and land degradation in the region (Mansourian & Vallauri, 2014; Chazdon, 2018). These pressures have reduced ecosystem quality, disrupted ecological balance, and negatively affected the livelihoods of communities that depend on forest resources. As a result, widespread land degradation and declining environmental quality have further disrupted ecosystem functions (KLHK, 2021; Reed *et al*., 2009). Land degradation not only affects ecological integrity but also reduces land productivity and undermines the welfare of communities that depend on forest resources. To address these challenges, the Indonesian government has implemented the Forest and Land Rehabilitation (*Rehabilitasi Hutan dan Lahan*, RHL) program as part of its national strategy to restore degraded ecosystems and improve environmental quality (KLHK, 2020; BPPN, 2020). The RHL program aims to restore ecological functions, enhance vegetation cover, increase ecosystem resilience, and support sustainable development objectives (Stanturf *et al*., 2015; Meli *et al*., 2017). Despite substantial investments in rehabilitation activities, several studies have reported limitations in program effectiveness, particularly

with respect to post-planting maintenance, seedling survival rates, monitoring systems, and long-term sustainability outcomes. In Indonesia, rehabilitation programs are further challenged by the extensive area of degraded land, which requires appropriate site assessment and prioritization before restoration interventions can be effectively implemented (Wahyuningrum & Putra, 2019). Furthermore, numerous studies have shown that the long-term success of forest and land rehabilitation is often constrained by inadequate post-planting maintenance, low seedling survival rates, insufficient monitoring, and limited adaptive management, particularly during the early stages of restoration (Castro *et al*., 2021; Ota *et al*., 2021).

Beyond technical considerations, the sustainability of RHL programs is strongly influenced by social and institutional factors. Stakeholder participation plays a critical role in ensuring successful rehabilitation outcomes (Erbaugh *et al*., 2020; Mansourian, 2016) as local communities, government agencies, and other stakeholders have different interests, responsibilities, and levels of influence in natural resource management (Reed *et al*., 2009; Ansell & Gash, 2008). In Bombana Regency, community participation in rehabilitation activities remains relatively limited, particularly during the maintenance and monitoring stages. Consequently, rehabilitation efforts continue to rely heavily on government interventions, thereby reducing opportunities for collaborative and adaptive management.

Most previous evaluations of Forest and Land Rehabilitation programs in Indonesia have primarily focused on output indicators, such as the number of seedlings planted and the area rehabilitated. Although these indicators are important, they provide limited information on the long-term sustainability of rehabilitation programs. Furthermore, studies applying multidimensional sustainability assessments that simultaneously integrate ecological, economic, and social dimensions remain limited, particularly in Bombana Regency (Crouzeilles *et al*., 2016; Wortley *et al*., 2013). Recent studies have emphasized that forest landscape restoration should be evaluated using integrated sustainability frameworks that consider ecological effectiveness, socioeconomic benefits, governance performance, and long-term resilience. Such multidimensional assessments provide a more comprehensive basis for developing adaptive restoration policies and management strategies (Mansourian *et al*., 2020; Di Sacco *et al*., 2021).

Therefore, this study addresses this research gap by applying the Rapid Appraisal for Sustainability (RAPS) approach based on Multidimensional Scaling (MDS) to evaluate the sustainability status of the RHL program. The novelty of this study lies in its multidimensional assessment framework, which identifies sensitive sustainability attributes and provides practical recommendations for improving the long-term effectiveness of rehabilitation programs.

Based on the issues described above, this study aims to (1) assess the sustainability status of the Forest and Land Rehabilitation program in Bombana Regency across the ecological, economic, and social dimensions, and (2) identify the most sensitive attributes influencing sustainability performance. The findings are expected to support evidence-based policy formulation and adaptive rehabilitation management strategies.

## 2. MATERIALS AND METHODS

### 2.1. Study Area

This study was conducted in Bombana Regency, Southeast Sulawesi Province, Indonesia, from July to September 2025. The research focused on the Forest and Land Rehabilitation (RHL) program implemented within and around Rawa Aopa Watumohai National Park (RANP). The study area was selected because it represents one of the priority rehabilitation areas experiencing land degradation and ecological pressures resulting from land-use changes, agricultural expansion, and anthropogenic disturbances.

### 2.2. Informants and Data Collection

The study involved five key informants who were purposively selected based on their expertise, authority, and direct involvement in the implementation of the RHL program. The informants consisted of one representative from the Forestry Service, one representative from the Regional Development Planning Agency (BAPPEDA), one representative from the Environmental Agency, one representative from the local community surrounding Rawa Aopa Watumohai National Park, and one representative from a community organization. Primary data were collected

through structured interviews, field observations, and expert judgment. Secondary data were obtained from government reports, policy documents, and relevant scientific publications related to rehabilitation activities and sustainability assessment.

### 2.3. Data Analysis

The sustainability status of the Forest and Land Rehabilitation (RHL) program was assessed using the Rapid Appraisal for Sustainability (RAPS) approach, which was adapted from the Rapid Appraisal for Fisheries (RAPFISH) method based on Multidimensional Scaling (MDS). RAPFISH is a well-established approach for rapidly evaluating sustainability across multiple dimensions and identifying sensitive attributes that influence overall sustainability performance (Pitcher & Preikshot, 2001; Kavanagh & Pitcher, 2004). Recent studies have further emphasized that multidimensional sustainability assessment provides an effective framework for integrating ecological, social, economic, and institutional dimensions in forest and landscape restoration, thereby supporting adaptive management and long-term restoration outcomes (César et al., 2021; Thapa et al., 2025).

### 2.4. Sustainability Attributes

The RAPS analysis was performed using the Multidimensional Scaling (MDS) technique. The sustainability assessment comprised three dimensions: ecological, economic, and social. A total of 21 sustainability attributes were evaluated, consisting of seven attributes for each dimension. Data for each attribute were collected through structured interviews, questionnaires, and direct field observations at the study site.

Table 1. Sustainability attributes used in the RAPS analysis

| Ecology Dimension | Economy Dimension | Social Dimension |
|---|---|---|
| 1. Diversity of flora species | 1. Community income level | 1. Public awareness |
| 2. Diversity of fauna species | 2. Product price stability | 2. Stakeholder coordination |
| 3. Planting success rate | 3. Market access | 3. Community participation |
| 4. Intensity of plant maintenance | 4. Government budget support | 4. Local wisdom implementation |
| 5. Protection level of flora and fauna | Business development | 5. Formal regulations |
| 6. Suitability of land use | Employment opportunities | 6. Community organizations |
| 7. Clarity of area boundaries | Contribution to state revenue | 7. Conflict resolution |

### 2.5. RAPS-MDS Analysis

Each sustainability attribute was evaluated using an ordinal scoring system ranging from 1 to 5, where higher scores represented better sustainability performance. The scoring categories were defined as follows: 5 (very good), 4 (good), 3 (moderate), 2 (poor), and 1 (very poor). Scores were assigned based on expert judgment, field observations, and stakeholder interviews using predefined criteria developed for each attribute. The resulting scores were subsequently used as input variables for the RAPS-MDS analysis to determine sustainability indices and identify the sensitive attributes influencing the sustainability status of the rehabilitation program.

The attribute scores were transformed into ordination values using the RAPS software to generate sustainability indices ranging from 0 to 100 for each dimension and for the overall assessment. Higher index values indicate better sustainability performance. The MDS results were visualized using ordination diagrams that illustrate the sustainability position of the system on a scale from 0 to 100. Sustainability status was classified into four categories: unsustainable (0–25), less sustainable (25.1–50), moderately sustainable (50.1–75), and highly sustainable (75.1–100) (Pitcher & Preikshot, 2001).

### 2.6. Leverage Analysis

Leverage analysis was conducted to identify sensitive attributes that exerted the greatest influence on sustainability status. The sensitivity of each attribute was measured using Root Mean Square (RMS) values. Attributes with higher RMS values were considered more influential in determining sustainability performance and were therefore identified as priority targets for management interventions.

### 2.7. Monte Carlo Analysis

Monte Carlo analysis was conducted to evaluate the stability and robustness of the sustainability assessment. This procedure was used to detect potential errors arising from scoring variations, data entry errors, missing information, and uncertainty in expert judgment. Differences of less than 5% between the MDS and Monte Carlo results indicate that the model is stable and produces reliable sustainability estimates.

### 2.8. Model Validation

The goodness-of-fit of the RAPS-MDS model was assessed using stress values and coefficients of determination ($R^2$). Stress values below 0.25 indicate acceptable ordination accuracy, whereas higher $R^2$ values indicate stronger explanatory power. The stress values obtained were 0.1477 for the economic dimension, 0.1529 for the social dimension, and 0.1502 for the ecological dimension. The corresponding coefficients of determination ($R^2$) were 0.9420, 0.9408, and 0.9432, respectively. These values indicate that the sustainability model adequately represents the observed system and provides reliable results for sustainability assessment.

## 3. RESULTS AND DISCUSSION

### 3.1. Sustainability Status of the RHL Program

The sustainability status of the Forest and Land Rehabilitation (RHL) program in Rawa Aopa Watumohai National Park (RANP), Bombana Regency, was evaluated using the Rapid Appraisal for Sustainability (RAPS) approach based on the modified Multidimensional Scaling (MDS) method. This approach enables a rapid, comprehensive, and systematic assessment of program sustainability based on a set of attributes representing the current management conditions of forest and land rehabilitation in the study area. The sustainability framework comprised three dimensions: economic, social, and ecological. These dimensions are interrelated and collectively determine the sustainability of the RHL program.

Table 2. Sustainability index of RHL program in RANP Watumohai, Bombana Regencey

| Dimension | Sustainability Index | Category |
|---|---|---|
| Economic | 58.61 | Moderately Sustainable |
| Social | 52.09 | Moderately Sustainable |
| Ecological | 62.82 | Moderately Sustainable |

Table 2 presents the sustainability indices of the RHL program across the three assessed dimensions. All dimensions were classified as moderately sustainable, with sustainability index values ranging from 52.09 to 62.82. Among the three dimensions, the ecological dimension achieved the highest sustainability index (62.82), indicating better ecological performance than the economic and social dimensions. In contrast, the social dimension obtained the lowest sustainability index (52.09), suggesting that social factors remain the primary challenge affecting the long-term sustainability of the program.

The sustainability index for each dimension reflects the overall performance of the RHL program based on the indicators evaluated within the economic, social, and ecological dimensions. These indices were visualized using the RAPS sustainability diagram, which illustrates the relative position of each dimension along the sustainability continuum. This visualization provides a comprehensive overview of the strengths and weaknesses of RHL management in RANP Watumohai.

Figure 1 illustrates the multidimensional sustainability profile of the RHL program in Bombana Regency. The kite diagram reveals clear differences among the three sustainability dimensions, with the ecological dimension showing the strongest performance and the social dimension representing the weakest. Although the relatively balanced shape of the diagram indicates that rehabilitation activities have contributed positively across multiple dimensions, further improvements are required to achieve a more balanced and integrated level of sustainability. While the sustainability indices provide an overall assessment of the RHL program, the contribution of individual sustainability attributes

varies across dimensions. To better understand the factors underlying these results, the average scores of the ecological, economic, and social attributes used in the RAPS-MDS analysis are presented in Table 3. These attribute scores were derived from stakeholder assessments and field observations and served as the basis for calculating sustainability indices and identifying the sensitive attributes affecting program sustainability.

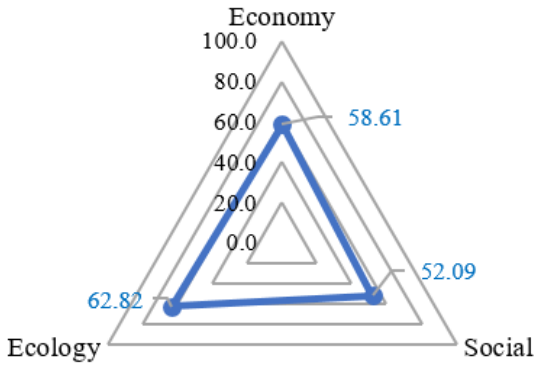


Figure 1. Sustainability indices of the ecological, economic, and social dimensions of the RHL program in RANP Watumohai, Bombana Regency, Southeast Sulawesi.

Table 3 shows that sustainability performance varies considerably among attributes and dimensions. Several attributes received relatively high scores, particularly government budget support, employment opportunities, formal regulations, local practices, and the protection of flora and fauna. In contrast, attributes such as market access, conflict resolution mechanisms, clarity of area boundaries, and flora species diversity received comparatively low scores, indicating priority areas for management improvement. These findings suggest that the sustainability of the RHL program is influenced by ecological, economic, and social factors with different levels of contribution. Therefore, a more detailed discussion of each sustainability dimension is necessary to identify critical attributes and formulate appropriate management strategies.

Table 3. Average scores of sustainability attributes used in the sustainability assessment

| Economy | Score | Social | Score | Ecology | Score |
|---|---|---|---|---|---|
| Government revenue contribution | 5.00 | Conflict resolution mechanism | 1.57 | Clarity of area boundaries | 1.00 |
| Employment and business opportunities | 4.95 | Community organizations availability | 4.24 | Land-use suitability | 4.24 |
| Government budg*et al*location | 5.00 | Formal agreements and regulations | 4.95 | Flora and fauna diversity | 1.43 |
| Market access for products | 1.00 | Local cultivation practices | 4.95 | Biodiversity management | 3.10 |
| Disaster management support | 1.14 | Community participation and contribution | 4.90 | Planting and maintenance activities | 1.24 |
| Production improvement | 4.90 | Stakeholder coordination | 3.10 | Protection of flora and fauna | 4.86 |
| Community income level | 3.10 | Conservation awareness | 4.86 | Rehabilitation success rate | 4.19 |

### 3.1.1. Sustainability Status of the Economic Dimension

Based on the evaluation of seven economic attributes, the economic dimension of the RHL program in RANP Watumohai, Bombana Regency, obtained a sustainability index of 58.61, indicating a moderately sustainable status. The RAPS ordination results for the economic dimension are presented in Figure 2.

The leverage analysis (Figure 3) identified government budget support for RHL activities as the most sensitive attribute influencing the sustainability of the economic dimension, with the highest Root Mean Square (RMS) value of 6.73. This value is substantially higher than those of the other attributes, indicating that financial support plays a dominant role in determining the success of the RHL program. Adequate funding directly influences the

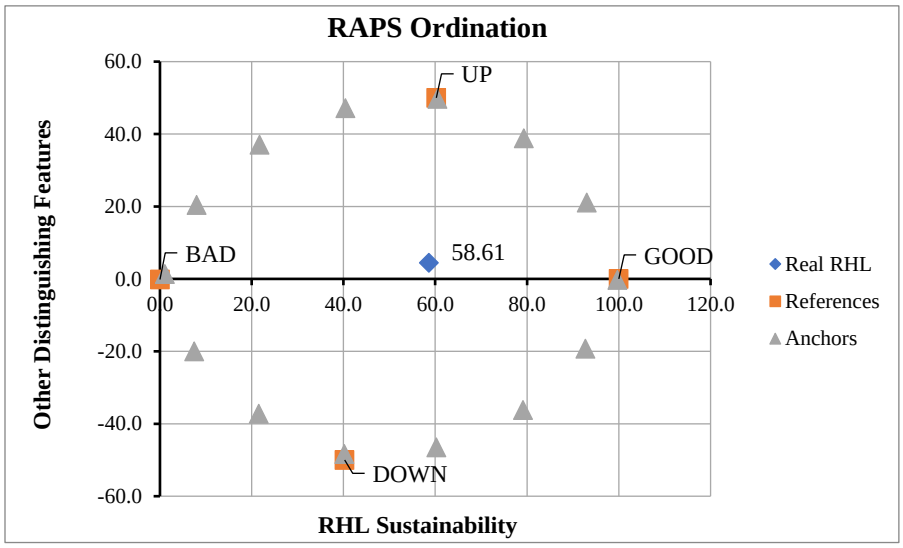


Figure 2. RAPS ordination for economy dimension.

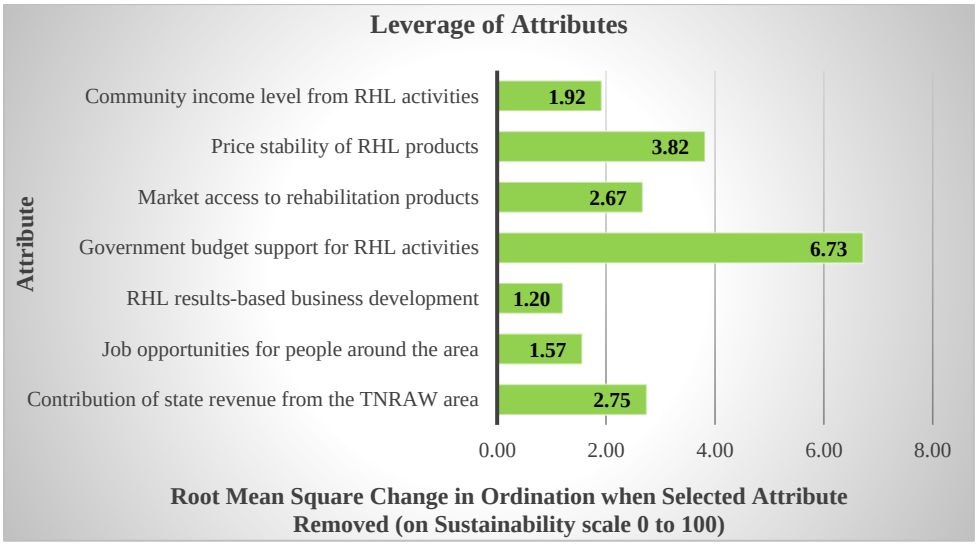


Figure 3. Leverage analysis for economy dimension.

implementation of rehabilitation activities, including planting, maintenance, monitoring, and supervision. Therefore, increasing budget allocation and ensuring its effective utilization are essential for improving the long-term sustainability of the RHL program in RANP Watumohai. Recent studies have shown that the long-term success of forest and landscape restoration depends not only on financial resources but also on institutional capacity, community participation, technical support, and governance arrangements that integrate ecological and socioeconomic objectives (Thapa et al., 2025). Likewise, effective forest landscape restoration requires governance systems that integrate multiple administrative levels, strengthen cross-scale collaboration, and promote adaptive learning among stakeholders (Wiegant *et al*., 2022). The second most influential attribute was product price stability, with an RMS value of 3.82. This finding indicates that market conditions, particularly stable product prices, have a substantial influence on the economic sustainability of the RHL program. Price instability may reduce community interest in participating in rehabilitation activities because it creates uncertainty regarding future income. Conversely, stable and profitable market prices provide stronger economic incentives, encouraging communities to participate actively in rehabilitation activities and the sustainable utilization of rehabilitation products.

Another sensitive attribute was the contribution of the RANP Watumohai area to state revenue, which obtained an RMS value of 2.75. This result indicates that the economic contribution generated by the rehabilitation area is an important indicator of sustainability. Greater economic contributions increase the strategic value of the area in supporting sustainable development. Therefore, optimizing the economic potential of the rehabilitation area while maintaining its ecological functions should become a management priority, enabling the program to generate economic benefits without compromising environmental sustainability.

### 3.1.2. Sustainability Status of the Social Dimension

Based on the assessment of seven social attributes, the social dimension of the RHL program obtained a sustainability index of 52.09, indicating a moderately sustainable status (Figure 4). This result suggests that the social dimension has been maintained at a moderate level; however, several social attributes still require improvement to strengthen the long-term sustainability of the program.

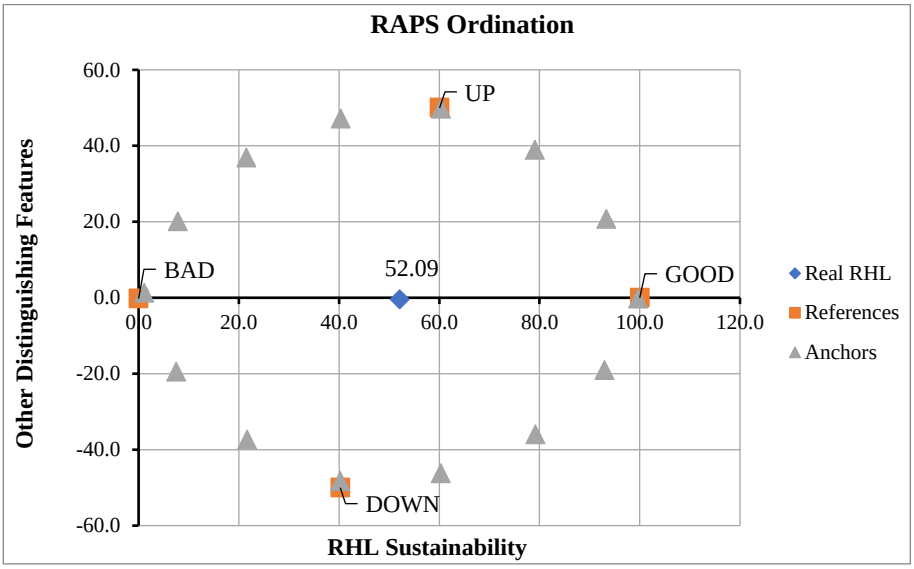


Figure 4. RAPS ordination for the social dimension.

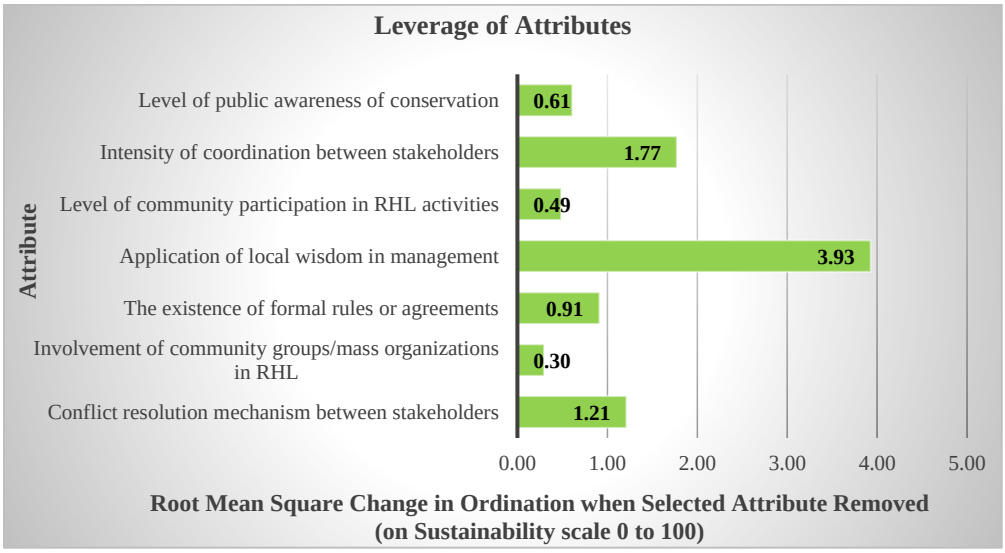


Figure 5. Leverage analysis for the social dimension.

The leverage analysis (Figure 5) identified the implementation of local wisdom as the most sensitive attribute influencing the social dimension, with the highest Root Mean Square (RMS) value of 3.93. This finding indicates that local wisdom plays a dominant role in determining the social sustainability of the RHL program. Local values, customary rules, and traditional management practices strengthen social legitimacy and enhance community acceptance of rehabilitation activities. Therefore, integrating local wisdom into RHL management represents an important strategy for sustaining the program's long-term social impacts. Incorporating local knowledge while promoting meaningful community participation can strengthen social cohesion, improve rural livelihoods, and enhance the overall effectiveness and sustainability of forest landscape restoration initiatives (Ullah, 2024).

The second most influential attribute was stakeholder coordination, with an RMS value of 1.77. This result indicates that communication and collaboration among stakeholders have a significant influence on the social sustainability of the RHL program. Effective coordination improves program implementation, minimizes conflicts, and strengthens collaboration among government agencies, local communities, and other stakeholders. Conversely, weak coordination may result in overlapping responsibilities, policy inconsistencies, and implementation inefficiencies.

Another sensitive attribute was the conflict resolution mechanism among stakeholders, which obtained an RMS value of 1.21. This finding demonstrates that the ability to manage and resolve conflicts is an important factor in maintaining social stability. Unresolved conflicts may hinder the implementation of rehabilitation activities and reduce community participation. Therefore, effective, inclusive, and sustainable conflict resolution mechanisms are essential to support the long-term success of the RHL program in Rawa Aopa Watumohai National Park.

Community participation remains one of the most important determinants of restoration success. Restoration initiatives that actively involve local stakeholders in planning, implementation, and monitoring processes tend to achieve higher levels of social acceptance, institutional support, and long-term sustainability (Di Sacco et al., 2021; Erbaugh et al., 2020). Likewise, community-based forest governance can simultaneously enhance biodiversity conservation, carbon sequestration, and local livelihoods when supported by inclusive institutional arrangements (Fischer et al., 2023). Institutional change and stakeholder compliance also play important roles in improving the effectiveness of forest landscape restoration governance (Owusu et al., 2024). Furthermore, restoration outcomes are strongly influenced by interactions among institutions, stakeholder interests, and governance arrangements operating across multiple administrative scales (Kleinschmit *et al*., 2024).

### 3.1.3. Sustainability Status of the Ecological Dimension

Based on the assessment of seven ecological attributes, the ecological dimension of the RHL program obtained a sustainability index of 62.82, indicating a moderately sustainable status (Figure 6). Among the three sustainability dimensions, the ecological dimension achieved the highest index value, reflecting relatively favorable ecological conditions within the rehabilitation area.

Figure 6 presents the RAPS ordination of the ecological dimension, illustrating the sustainability position of the RHL program on a scale ranging from 0 to 100. The "Real RHL" point is located at an index value of 62.82, indicating that the ecological sustainability of the program falls within the moderately sustainable category. According to the sustainability classification, index values between 50.1 and 75 represent a moderately sustainable condition, suggesting that the program is progressing in a positive direction but still requires improvements in several key ecological aspects.

Visually, the "Real RHL" point is positioned closer to the "GOOD" reference point than to the "BAD" reference point, indicating that the RHL program has contributed positively to ecosystem recovery. Nevertheless, the program has not yet reached the highly sustainable category, indicating that several ecological factors still require improvement. These factors are mainly associated with biophysical land conditions, planting success, vegetation establishment, and environmental disturbances such as fires and anthropogenic activities. Furthermore, the distribution of the reference points in the ordination diagram illustrates the structural variation in sustainability conditions. The "BAD" (0), "GOOD" (100), "UP", and "DOWN" reference points serve as benchmarks in the MDS ordination process. The position of the "Real RHL" point between these references indicates that the ecological system remains sensitive to changes in several key attributes, particularly those with high leverage values.

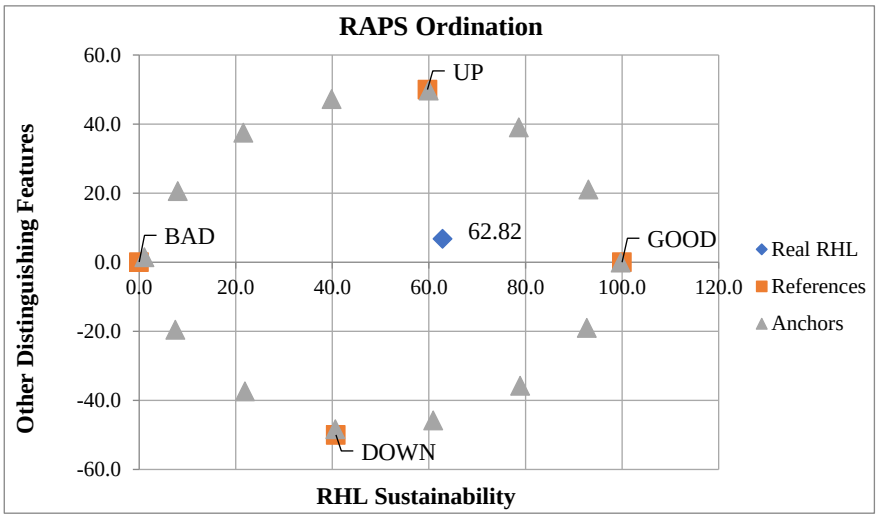


Figure 6. RAPS ordination for the ecological dimension.

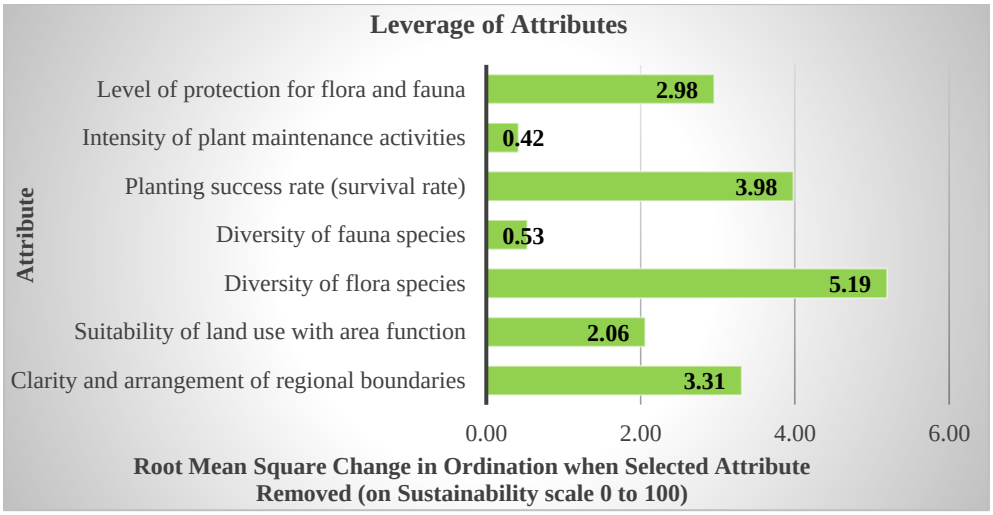


Figure 7. Leverage analysis for the ecological dimension.

The ordination results indicate that the ecological sustainability of the RHL program has reached a moderately sustainable level; however, further improvements are required, particularly in sensitive attributes such as flora species diversity, planting success, and the management of environmental disturbances. Strengthening these attributes is expected to improve the sustainability index and move the program toward a highly sustainable condition.

The leverage analysis (Figure 7) identified flora species diversity as the most sensitive ecological attribute, with the highest RMS value of 5.19. This finding indicates that vegetation diversity is the most influential factor determining the ecological sustainability of the RHL program in Rawa Aopa Watumohai National Park. Greater plant species diversity contributes to healthier ecosystem structure and function, demonstrating that successful rehabilitation should be evaluated not only by the number of surviving trees but also by the establishment of diverse and resilient vegetation communities that support long-term ecosystem functioning.

The second most influential attribute was the planting success rate (survival rate), with an RMS value of 3.98. This result confirms that seedling survival remains a key indicator of rehabilitation effectiveness. High survival rates indicate that species selection, planting techniques, and site conditions are appropriate, whereas low survival rates reduce the effectiveness of ecosystem recovery and negatively affect ecological sustainability.

Another sensitive attribute was the clarity of rehabilitation area boundaries, which obtained an RMS value of 3.31. This finding suggests that governance aspects also play an important role in ecological sustainability. Clearly defined boundaries help minimize land-use conflicts, prevent encroachment, and strengthen the protection of rehabilitated areas. Therefore, the long-term success of the RHL program depends not only on ecological restoration activities but also on effective land governance and protected area management.

### 3.2. Monte Carlo Analysis

Monte Carlo analysis was conducted to evaluate the robustness and reliability of the sustainability assessment by detecting potential sources of error in the RAPS-MDS analysis. According to Fauzi (2019), potential sources of error in RAP-based analyses include: (1) errors in attribute scoring resulting from insufficient information, misinterpretation of attributes, or inappropriate scoring procedures; (2) variations in scoring caused by differences in expert judgments; (3) instability in the repeated MDS ordination process (unstable anchor positions); (4) data entry errors or missing data; and (5) high stress values in the MDS analysis. Potential errors were evaluated by comparing the sustainability indices obtained from the MDS analysis with those generated through Monte Carlo simulation.

Table 4. Comparison of sustainability indices between the MDS and Monte Carlo analyses

| Dimensions | Analysis Results | | |
|---|---|---|---|
| | Value (%) | Monte Carlo (%) | Difference (%) |
| Economy | 58.61 | 57.84 | 0.77 |
| Social | 52.09 | 51.74 | 0.35 |
| Ecology | 62.82 | 61.90 | 0.92 |

Table 4 shows that the differences between the sustainability indices obtained from the MDS analysis and the Monte Carlo simulation were relatively small for all three sustainability dimensions, ranging from 0.35% to 0.92%, which is well below the 5% threshold. These results indicate that the sustainability assessment has a low level of uncertainty and that variations in attribute scoring have only a minor influence on the final sustainability indices. The close agreement between the MDS and Monte Carlo results also demonstrates that the RAPS-MDS model is stable, consistent, and robust against potential errors arising from data entry, missing information, or differences in expert judgment. Consequently, the sustainability assessment provides a reliable representation of the current status of the RHL program in Rawa Aopa Watumohai National Park. Overall, the Monte Carlo analysis confirms the validity and reliability of the sustainability assessment and supports the use of the results as a scientific basis for developing sustainable management strategies. These strategies should prioritize strengthening local economic development, increasing stakeholder participation and institutional collaboration, and maintaining ecological functions through effective biodiversity conservation and sustainable rehabilitation management.

## 4. CONCLUSION

The Forest and Land Rehabilitation (RHL) program in Bombana Regency was classified as moderately sustainable, with sustainability index values of 58.61, 52.09, and 62.82 for the economic, social, and ecological dimensions, respectively. Among these dimensions, the ecological dimension demonstrated the highest level of sustainability, whereas the social dimension remained the primary constraint affecting the long-term sustainability of the program. Leverage analysis identified government budget support, the implementation of local wisdom, flora species diversity, planting success rate, and the clarity of rehabilitation area boundaries as the most influential attributes affecting sustainability performance. These findings indicate that improving financial support, strengthening community participation and stakeholder collaboration, enhancing biodiversity conservation, increasing planting success, and ensuring clear boundary management are essential for improving the long-term sustainability of the RHL program in Bombana Regency.

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## DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE MANUSCRIPT PREPARATION

Not applicable. The authors did not use any generative AI tools or services in the preparation of this manuscript. All content is entirely the intellectual work of the authors.

## AUTHOR CONTRIBUTION

| Author | C | M | So | Va | Fo | I | R | D | O | E | Vi | Su | P | Fu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Har | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | |
| SR | | ✓ | | | | ✓ | | ✓ | ✓ | ✓ | ✓ | | | |
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|---|---|---|---|
| C: Conceptualization | Fo: Formal Analysis | O: Writing - Original Draft | Fu: Funding Acquisition |
| M: Methodology | I: Investigation | E: Writing - Review & Editing | P: Project Administration |
| So: Software | D: Data Curation | Vi: Visualization | |
| Va: Validation | R: Resources | Su: Supervision | |

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