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# The Sustainability Status of Lahumoko Watershed Management, North Buton Regency, Southeast Sulawesi, Indonesia


## ABSTRACT

*The current management of Lahumoko Watershed is still conventional. Mainly, in agricultural land management, the practices do not use the principles of soil and water conservation. This is not sufficient in supporting people's lives so that the biological, physical, social, economic and institutional dimensions do not support the sustainability of the Lahumoko Watershed. This study aimed to analyze the sustainability and the factors that have multidimensional influence on the sustainability of the Lahumoko Watershed, North Buton Regency, Southeast Sulawesi, Indonesia. The method used was Rapid Appraisal for Watersheds, adopted from Rapid Appraisal for Fisheries using the Multi-Dimensional Scaling technique. The sustainability status of the Lahumoko Watershed management for the physical, economic and institutional dimensions were still less sustainable, while the biological and social dimensions were fairly sustainable. Some leverage attributes contributing to improving the sustainability of watershed management were patterns of agricultural crop cultivation, plant diversity in forest, management of protected organisms, river biota, management of forest cover, soil and water conservation technologies, agricultural infrastructure, runoff, sedimentation, water quality, education level, relationship pattern of the community, conflict status, land dependency, agricultural productivity, access to resources, access to markets, resource management planning and rule comprehensiveness for watershed management.*


**Keywords**: *watershed management, sustainability, multidimensional, leverage attributes*


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## INTRODUCTION

The Lahumoko watershed is a small watershed located in North Buton Regency, Southeast Sulawesi, Indonesia, with an area of 5,190.35 ha and has the potential for environmental resources, such as use of forest land, which is still dominant at 3,531.85 ha (68.05%) of the watershed area. There are indications of land conversion or changes in land use such as forest areas to cultivation areas in the form of mixed gardens, dry fields and rural settlement areas. The management of the Lahumoko Watershed can still be considered as conventional, thus causing destruction to natural resources, which can lead to land criticality (*Peraturan Daerah Propinsi Sulawesi Tenggara 2015*). Land criticality affects environmental quality such as soil, water and the ability to produce economically (*Fiquepron et al. 2013*), water quantity or discharge, erosion and sedimentation (*Yang et al. 2015*), decreasing diversity of forest vegetation types (*Zanella et al. 2012*), diversity of aquatic organisms (*Carro-Borrero et al. 2015*). Thus, efforts to reduce land vulnerability by reducing the susceptibility of the land, it is necessary to do sustainable land management in the Lahumoko River Basin.

Sustainability management of the Lahumoko watershed is very important to be implemented. Considering its main function and role to provide economic and social benefits to communities in the watershed, this area needs to be protected and preserved. Sustainability can be interpreted as an effort to maintain program sustainability in all dimensions of watershed characteristics, such as: biological, physical, social, economic and institutional (*Brooks et al. 2013, Sridhar et al. 2012*). Sustainable development is a concept of development that is environmentally sound by integrating various factors in multidimensional manner (*Solomon et al. 2013*). Watershed is an area that describes environmental conditions that can be used as a unit of sustainable development. This is because the watershed is an easily measured area because it has clear boundaries and the determining factors are very

complex and multidimensional (*Hester and Little 2013*).

Watershed management activities can affect changes in the biological, physical, social and economic dimensions of the community around the watershed (*Edwards 2015*). Biological impacts include the decrease of plant diversity in a forest and aquatic biota (*Sukwika et al. 2016*). Whereas, the physical impacts are the increase in erosion, sedimentation and surface runoff that will have an impact on decreasing agricultural production and reducing water quality (*Juniansyah et al. 2016*). In general, these factors can cause changes in environmental conditions and can affect the sustainability of the watershed (*Jordan and Benson 2015*).

Every development activity carried out throughout the watershed in the form of agricultural activities, settlement and forest management must refer to the concept of sustainable development (*Cortés et al. 2012*). Sustainable watershed development requires multidimensional management efforts, namely biophysical, economic, social and institutional dimensions so that each dimension creates a sustainable value for certain indicators in the long term (*Castro et al. 2017*). Thus, this study aimed to analyze the sustainability and the factors that have multidimensional effect on the sustainability of the Lahumoko Watershed.

## MATERIALS AND METHODS

This study was conducted at the Lahumoko Watershed, in North Buton Regency of Buton Island, South East Sulawesi Indonesia (**Figure 1**). It is a small watershed in an island that is vulnerable to land use change (*Kahirun et al. 2019*). Lahumoko Watershed is located at 04°57'57"- 04° 59'05" S and 122° 52' 40"-122° 56'47" E with an altitude of 0-800 masl (*Martin et al. 2017*). Climatic conditions are characterized by rainfall of about 1,751 mm $yr^{-1}$, and an average air temperature of about 27.5°C. The rainy season occurs from November to June, the dry season occurs from July to September, and the high rainfall occurs between April to June (*Whitten et al. 2002; Patterson et al. 2017*).

The study used a quantitative approach, with descriptive analysis methods (*Creswell 2014*). The population in this study was people selected from three villages in the Lahumoko Watershed as areas that have forest,

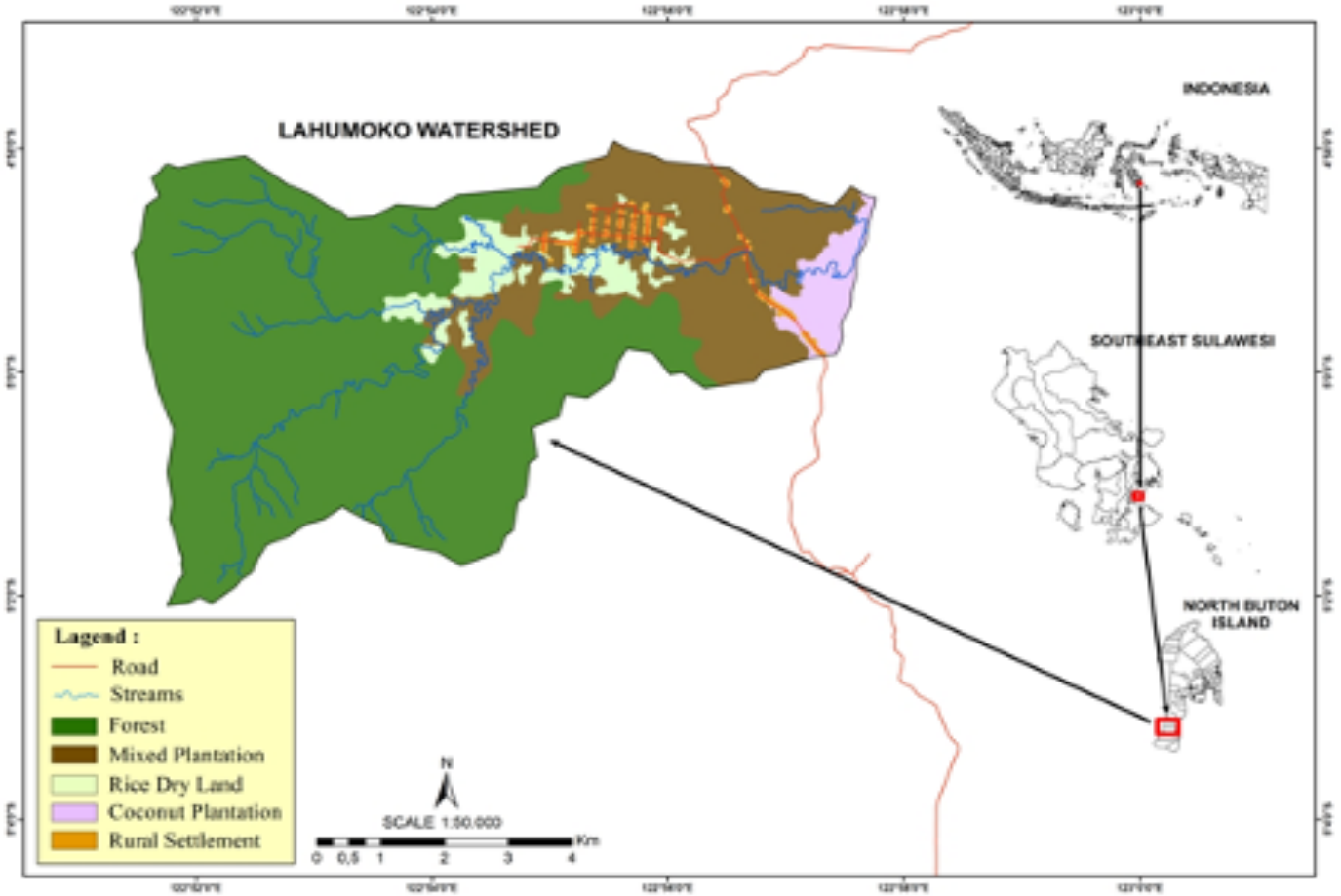


Figure 1. The study sites in Lahumoko Watershed, North Buton Island, South East Sulawesi Indonesia.

agricultural and rural settlement areas.

The method used is Rapid Apraisal for Watersheds (RAPDAS) which was adopted from Rapid Apraisal for Fisheries (RAPFISH) using the Multi-Dimensional Scaling (MDS) approach (*Pitcher and Preikshot 2001; Kavanagh and Pitcher 2004*). The software used was RAPFISH, which was developed by the Rapfish Group Fisheries Centre University of British Columbia, Canada. MDS analysis on the Lahumoko Watershed used the Rapfish and was called Lahumoko RAPDAS, which was developed based on the biological, physical, social, economic and institutional dimension with each indicator used to assess the sustainability status of Lahumoko Watershed management. The attributes determination in each dimension was done through a literature review, interview sources and field observations. Each attribute scoring in the dimensions of biological, physical, social, economic and institutional (*Peraturan Pemerintah Republik Indonesia 2012*) was done based on field observations and expert opinions (scientific judgments) in accordance with the stipulation of a predetermined numbers. In the study, the range of scores was from 1-3, which was interpreted from bad to good or vice versa based on the set attributes. Primary data were sourced from respondents and selected experts, as well as on-site observations. Data collection methods were done through interviews, discussions, questionnaires and field surveys.

Biological dimension described the biological conditions of watersheds such as plant diversity in a forest, diversity/patterns of agricultural cultivation (*Morin 2011; Pullin et al. 2013*), area of forest cover, extensive use of agricultural land, protected organisms and forest area management, diversity of river biota (*Zanella et al. 2012; Riutta et al. 2014*).

The physical dimension was based on the physical characteristics of watershed such as river water quality, rate of surface runoff, erosion, sedimentation, drainage density, river shape, riverbank erosion and riparian area conditions (*Kowsalya and Babu 2013; Singh et al. 2012; Banarjee et al. 2017*), soil type and infiltration rate (*Pingale et al. 2012; Gebre et al. 2015*), land slope, soil and water conservation technology, and availability of agricultural/irrigation infrastructure (*Safarina 2011; Singh et al. 2014*).

The social dimension was developed based on social parameters according to local regulations, such as population density, population pressure on land, land dependency (*Adhiambo et al. 2017*), education level, conflict status, relationship patterns of community/social structure, knowledge to the environment and the level of community participation (*Kareiva et al. 2011*).

The economic dimension was based on principles that refer to the economic value of natural resource use in watersheds (*Brooks et al. 2013*), such as community income, dryland productivity, wetland productivity, income from forest products, access to resources and access to markets (*Ekawati et al. 2005, Paimin et al. 2012*).

The institutional dimension was based on the existence of both formal and informal institutions, values and ethics in natural resource management in watersheds, such as access to information/counseling, rule comprehensiveness, local wisdom and knowledge (*Mesheshe and Tripathi 2015*), willingness to make efforts to conduct soil and water conservation, resource management planning (*Mhawish and Saba 2016*), comprehensiveness of the management institutions, the existence of community institutions/NGOs and the existence of research and community service programs from the University.

Data were analyzed using MDS method. Attribute assessment was on an ordinal scale based on sustainability criteria of each dimension and ranking was from 0 (lowest) to 3 (highest). The sustainability index was categorized into four groups (*Kavanagh and Pitcher 2004*) namely: unsustainable (0-25%), less sustainable (> 25-50%), moderate sustainable (> 50-75%) and sustained well (> 75-100%). Level sustainability dimension was displayed simultaneously using a kite diagram.

Determination of leverage attributes that represent the factors was based on the order of percentage changes in Root Mean Square (RMS) ordination. The greater the value of the changes in RMS, the greater the role of the attributes that represent the factors (*Kavanagh and Pitcher 2004*) on the sustainability of the Lahumoko Watershed.

## RESULTS AND DISCUSSIONS

### Sustainable Status of Biology Dimension

The sustainability status of biological dimension in Lahumoko Watershed was in moderate sustainability with the average sustainability index of dimensions of 55.06% (**Figure 2**). It means that the management of land use and land cover in the Lahumoko Watershed is satisfactory.

The results of the MDS analysis of the RAPDAS for biological aspects determined the sustainability of

the Lahumoko watershed management and the leverage attributes that were of concern in the biological/landuse sustainability in the Lahumoko Watershed (**Figure 3**).

The role of each attribute in the biological dimension as leverage factors of the biological sustainability that required attention in the Lahumoko Watershed management were protected organisms, diversity/patterns of agricultural crop cultivation and forest plant diversity. Also, it was also necessary to manage the protected organisms in the forest area. The pattern of agriculture with agroforestry systems is a choice of agricultural patterns that can increase farmers' income economically and also determine the level of sustainability of the watershed ecologically (*Ben Hamman Lech-hab et al. 2015*). The pattern of agroforestry was a combination of agricultural crops and forestry plants so that the diversity of forestry plants could also be increased so that biological sustainability could increase. In the forest area, if the management is good, the forest diversity can be maintained which can support and protect watersheds from damage (*Rahardjanto et al. 2017*).

## Sustainable Status of Physical Dimension

The sustainability status of physical dimension in Lahumoko Watershed was in less sustainability with the average sustainability index of dimensions of 47.29% (**Figure 4**). This means that the management of soil physics such as erossion, flooding, and soil and water conservation in watershed Lahumoko is still insufficient.

The results of the MDS analysis on the Lahumoko RAPDAS for physical aspects determined the sustainability of the Lahumoko Watershed management and the factors or leverage attributes that were of concern in the physical sustainability of the Lahumoko Watershed (**Figure 5**).

The role of each attribute in the physical dimension as leverage factors of the physical sustainability that required attention in the Lahumoko Watershed management were soil and water conservation technology, agricultural infrastructure availability, surface runoff rate/ flood discharge and sedimentation rate. Soil and water conservation technology is an effort made on ground with the aim of reducing surface flow (*Merten et al. 2016*), sedimentation and improving water quality (*Stang et al. 2016*). Conservation technique is a treatment for manipulating the ground so that it can control surface runoff rate and soil erosion so that ecological sustainability occurs (*He et al. 2017*). The good treatment techniques

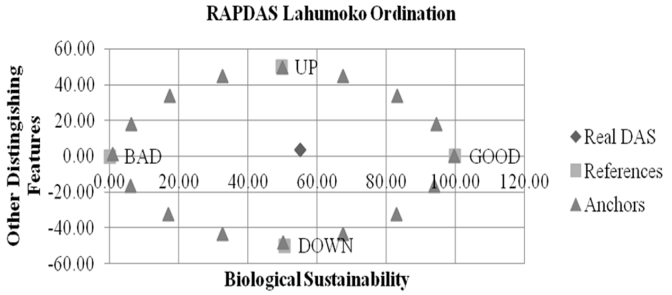


Figure 2. Biological rapdas ordination.

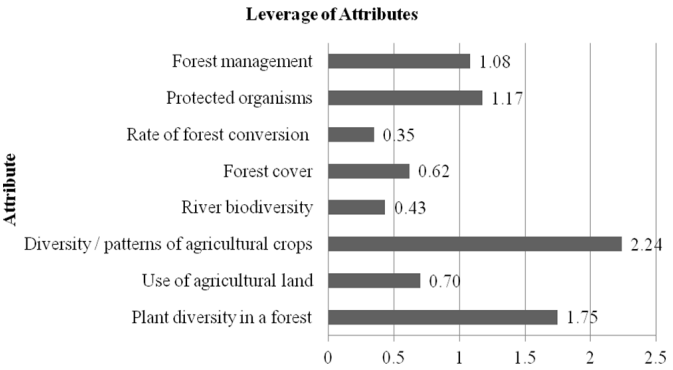


Figure 3. Leverage analysis of biological dimension.

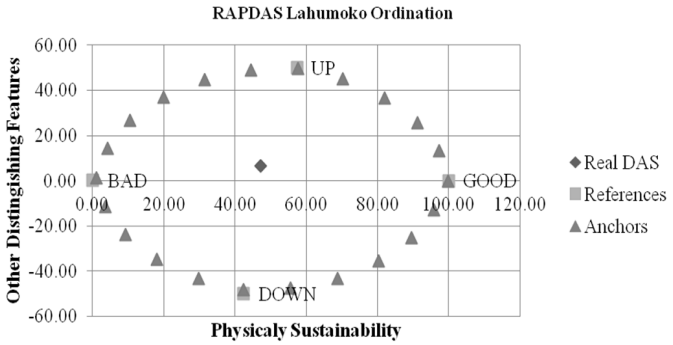


Figure 4. Physically rapdas ordination.

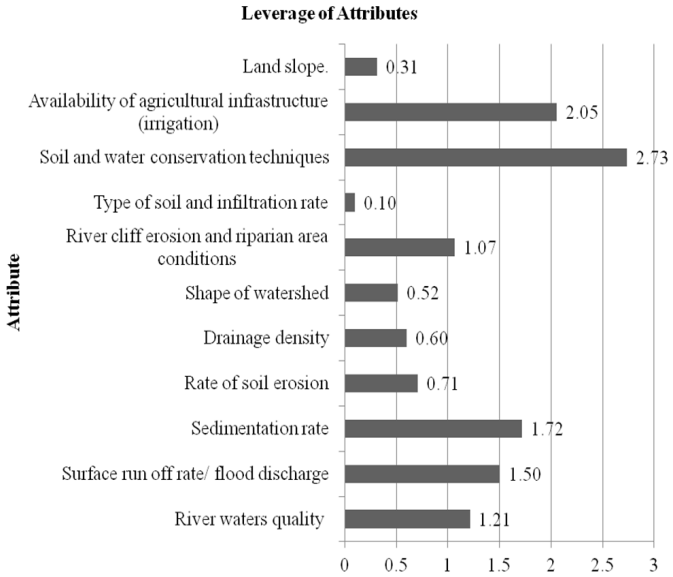


Figure 5. Leverage analysis of physical dimension.

for conservation is by a model of strip and contour cropping (*Phomchaa et al. 2012*) with a mixture of plant of cover crop types, especially on high sloped lands, which is very helpful in reducing surface runoff rates and improving land quality as an indicator of ecological sustainability (*Panagopoulos et al. 2014*). Agricultural infrastructure facilities such as irrigation, retention basin and small dam are facilities and infrastructure that are very helpful in providing water supply and at the same time regulate and reduce river flow/flood and sedimentation for more precise development and management of groundwater and selection of artificial groundwater filling structures (*Paul and Bayode 2012*).

**Sustainable Status of Social Dimension**

The sustainability status of social dimension in Lahumoko watershed was in moderate sustainability with the average sustainability index of dimensions of 60.16% (**Figure 6**). It means that the management of social dimension in the Lahumoko Watershed was relatively sustainable.

The role of each attribute in social dimension as leverage factors of the social sustainability that required attention in the Lahumoko Watershed management were the level of education, conflict status, relationship patterns of the community and land dependency (**Figure 7**). Proper education will facilitate the formation of an understanding of watershed management issues (*Salminah et al. 2014*). Education has an impact on the community activity in following the watershed management planning and influences the adoption and application of new innovations (*Burroughs 2009*).

The relationship pattern among communities was crucial in the development and management of watersheds. Harmonious relations can increase community participation in managing natural resources at the planning, implementation and maintenance stages to create high and sustainable productivity (*Bagdi and Kurothe 2014*).

The Lahumoko Watershed is still dominated by forests where the status and function are state-owned forests and production forests. The management is still under the authority of the central government, namely the Ministry of Forestry. Communities sometimes conduct activities in the watershed, thus conflicts arise between the government and the community. Land bank for agriculture has a status as state-owned forests or production forests and with the increasing population throughout the watershed, there is a land dependency (*Paimin et al. 2010*).

**Sustainable Status of Economics Dimension**

The economic sustainability of the Lahumoko Watershed had a value of 34.79 (**Figure 8**). Based on the sustainability index criteria, it was less sustainable.

The role of each attribute in economics dimension as leverage factors of the economics sustainability

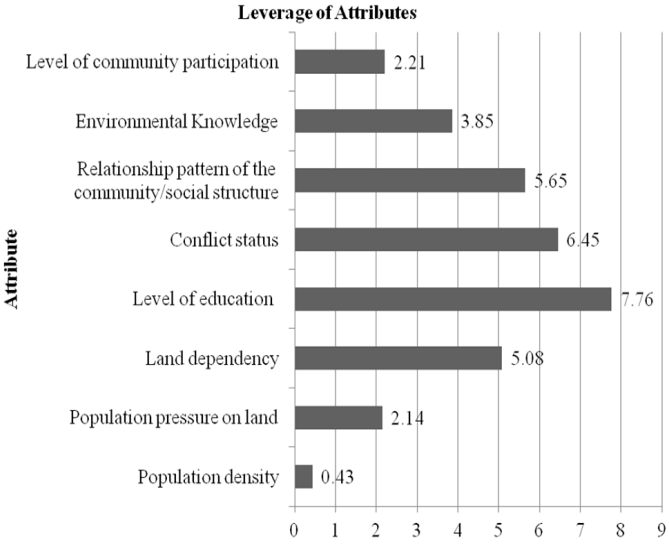


Figure 7. Leverage analysis of social dimension.

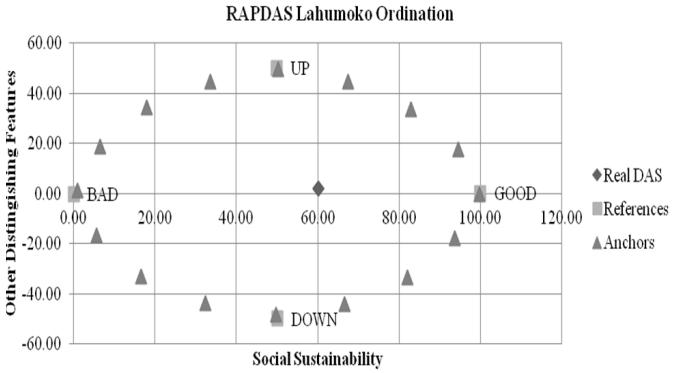


Figure 6. Rapdas ordination of social dimension.

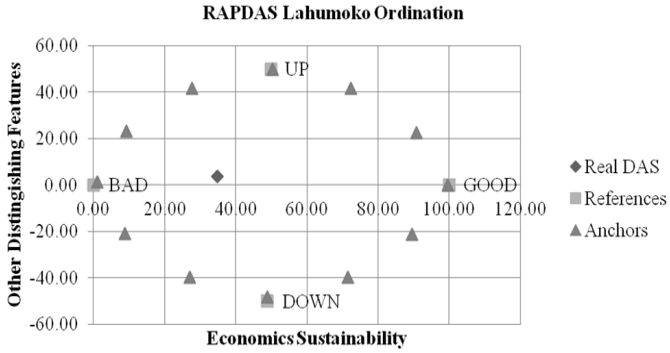


Figure 8. Rapdas ordination of economic dimension.

that required attention in the Lahumoko watershed management were dryland agricultural productivity, productivity of paddy fields, access to resources, and access to markets (**Figure 9**).

If integrated watershed management is carried out, the farm household income from agricultural land will increase due to the increased yields from agricultural land such as rice and corn (*Yaebiyo et al. 2015*). Moreover, the economic aspects that have a significant influence on land degradation due to the use of technology that is not in accordance with the environmental rules are the access to forest and land resource management (*Juniansyah et al. 2016*). The access to the market is a form to answer the improving welfare of the community to produce more sustainable patterns of consumption and production (*Platje 2013*).

**Sustainable Status of Institutional Dimension**

The sustainability from the institutional aspect of the Lahumoko watershed had a value of 42,73 (**Figure 10**). Based on the sustainability index criteria, it was less sustainable.

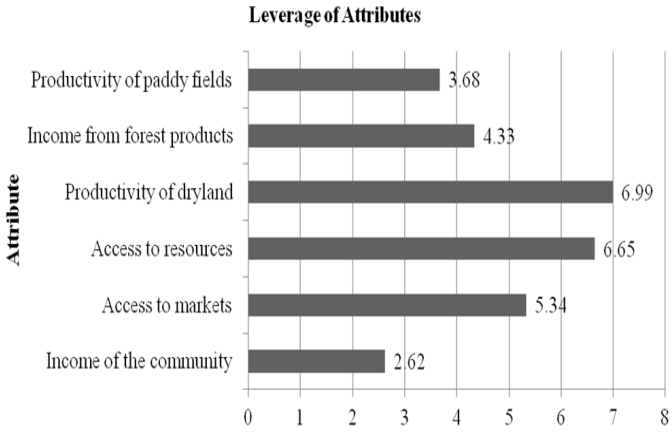


Figure 9. Leverage analysis of economic dimension.

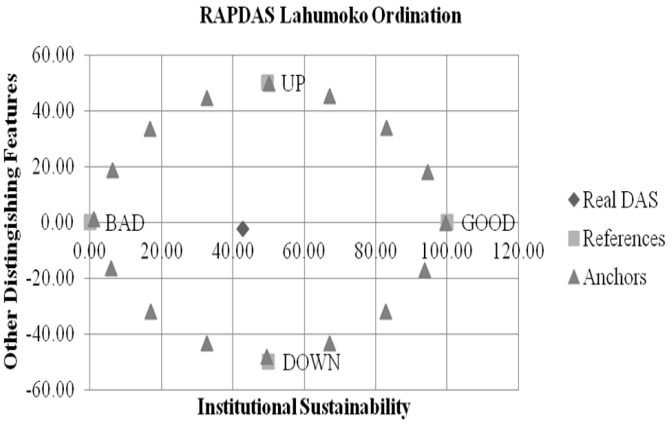


Figure 10. Rapdas ordination of institutional dimension.

The results of the MDS analysis of the Lahumoko RAPDAS for institutional aspects determined the sustainability of the Lahumoko watershed management and the factors or leverage attributes that were of concern in the institutional sustainability in the Lahumoko watershed.

The role of each attribute in the institutional dimension as leverage factors of the institutional sustainability that required attention in the Lahumoko watershed management were the resource management planning and rule comprehensiveness in Lahumoko watershed management (**Figure 11**). Watershed management planning is a process that integrates the objectives, constraints and techniques available to improve the effectiveness and efficiency of the implementation of integrated watershed management. The art of integrating biological, physical and social sciences is emphasized because planning is an art in science. Planning is a continuous process with information about the results of management actions taken and problems that emerge continuously were put back into the process (*Brooks et al. 2013*).

The comprehensiveness of a rule is in a norm or rules that govern the community in relation to watershed management. Physically, the norms about soil and water conservation actually exists in peoples' lives, for example, planting with agroforestry systems in the central part of the subwatershed, making contour farming and planting animal feeds on sloping land. These norms are still alive and maintained until now, but in its implementation, there has been no sanctions if someone violates them (*Ekawati et al. 2005*).

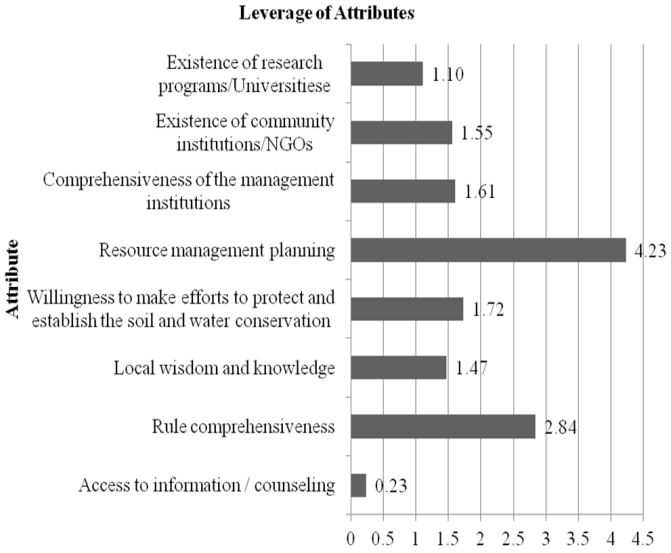


Figure 11. Leverage analysis of institutional dimension.

**The Validity of Lahumoko Watershed Sustainable Status**

Montecarlo analysis was used at 95% confidence intervals to find out the error rate in MDS analysis and RAP-PF sensitivity.

The difference between the mean values of the two analyzes, MDS and Monte Carlo, is very small between 0.02% to 0.24% (<5%) in all dimensions (**Table 1**). The analysis shows that the sustainability index produced by RAPDAS is valid and does not need to be improved because the difference is not more than 5% in each dimension (*Adiga et al. 2016;Narendra et al. 2019*). Thus, the ongoing analysis of the Lahumoko watershed management can be explained as follows: the assessment of each indicator has a relatively small error, the variation of the assessment of the opinions of experts and the evaluation conducted by researchers is relatively small, repeated analysis of data is relatively stable, and Errors in entering data and data loss can be avoided (*Berhitu et al. 2016*).

The analysis that showed the accuracy of MDS values was obtained automatically through RAP-Watershed, namely the value of Stress and Squared Correlation (RSQ). The results of the analysis are stated to be accurate and can be accounted for if the stress value is smaller than 0.25 or 25% (*Santosa et al. 2016*). If the value of stress become smaller, the quality of the results of the analysis applied is getting better. A good measure of the quality of analysis was determined by the value of Squared Correlation (RSQ), which was when the RSQ value was greater or close to the value of 1 or 100%.

The stress values ranged from 0.14 -0.15 which was smaller than 0.25 or 25% and the RSQ values ranged from 0.94-0.95 where the value was close to 1 or 100% (*Berhitu et al. 2016*) (**Table 2**). Therefore, the Stress and RSQ parameters could justify the assumption that all indicators used in the analysis of the sustainability of Lahumoko watershed management from the aspects of biological, physical, social, economic and institutional were relatively positive. Based on the results of the analysis above, it could be concluded that the stress value of the MDS analysis model obtained had a higher accuracy (goodness of fit) to assess the sustainability of the Lahumoko watershed management in North Buton Regency.

Table 1. Differences of analysis values MDS (Multi-Dimensional Scale) and Montecarlo.

| Sustainability Aspects | Lahumoko Watershed | | |
|---|---|---|---|
| | MDS | Montecarlo | Different |
| Biological/Land Use | 55.06 | 55.23 | 0.17 |
| Physical | 47.29 | 47.05 | 0.24 |
| Social | 60.16 | 60.11 | 0.15 |
| Economical | 34.79 | 34.56 | 0.23 |
| Institutional | 42.73 | 42.75 | 0.02 |

The kite diagram shows that the five dimensions of the Lahumoko watershed management are different each where the smallest sustainability value is the economic dimension with a value of 34.79% which is no different from the dimensions of the physical and institutional management of the watershed with values of 47.29% and 42.73%, respectively, where all three dimensions were categorized as less sustainable (**Figure 12**). Whereas the management of biological and social dimensions have value of 55.06% and 60.16% respectively, where both dimensions were categorized as quite sustainable.

Thus, the sustainability of the management of the Lahumoko Watershed is at the level of less

Table 2. Stress values and determinant co-efficient (R^2). Squared Correlation = determinant co-effiiec (R^2).

| Sustainability Aspects | Lahumoko Watershed | |
|---|---|---|
| | S-Stress | Squared Correlation (RSQ) |
| Biological/Land Use | 0.15 | 0.94 |
| Physical | 0.14 | 0.95 |
| Social | 0.14 | 0.94 |
| Economical | 0.15 | 0.94 |
| Institutional | 0.15 | 0.94 |

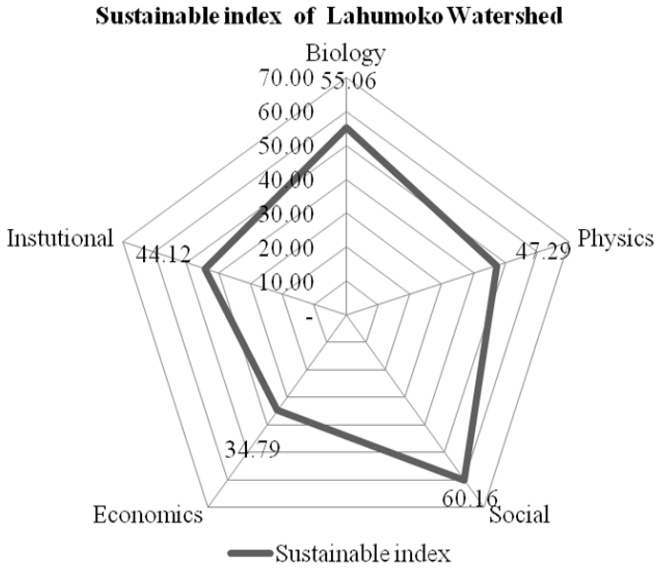


Figure 12. The kite diagram sustainability index value of the Lahumoko Watershed Management.

sustainability with an average sustainability index dimension of 48.21%. It means that in general, the performance of the Lahumoko watershed management is poor, the activities carried out in managing the forest and land in the watershed is insufficient. Among all dimensions, economic, physical and institutional were classified at a less sustainable level. Thus, the economic, physical and institutional dimensions must be a priority for further improvement to raise the level of sustainability in the Lahumoko watershed management. Furthermore, the social and biological dimensions obtain a high sustainability index which is classified at a fairly sustainable level.

## CONCLUSIONS AND RECOMMENDATIONS

The sustainability status of the Lahumoko Watershed was less sustainable. The sustainability status of the physical, economic and institutional dimensions were less sustainable, while the biological and social dimensions were fairly sustainable. The attention from the government and all relevant stakeholders is needed to improve the sustainability status in the Lahumoko Watershed management, especially in some indicators that became the leverage in all dimensions of sustainability of the Lahumoko Watershed characteristics. Leverage indicators on the biological dimension were the diversity/ patterns of agricultural crop cultivation and forest plant diversity, management of protected organisms and river biota, and management of forest cover in forest areas. The physical dimensions were the soil and water conservation technology, agricultural infrastructure availability, surface runoff rate/flood, sedimentation rate and river water quality. The social dimensions were the level of education, relationship pattern of the community, conflict status and land dependency. The economic dimensions were dryland agricultural productivity, access to resources and access to markets while the institutional dimensions were resource management planning and comprehensiveness of the rules in Lahumoko Watershed management. This study can be conducted in another watershed as a comparison to add empirical data from various locations were similar. In addition, this research can be modified using wider scale variables to analyze the effect and the correlation between dimensions or variables.

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