

Assessing agricultural sustainability through economic, social, and ecology indicators: a case study in Luwu Regency, Indonesia

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Abstract. Sustainable agriculture is not just a technological endeavour, but a social and ecological obligation to ensure food security, maintain environmental integrity, and foster inclusive rural development. This study evaluates agricultural sustainability in Luwu District, South Sulawesi, using a Multidimensional Scaling (MDS) approach across economic, social and environmental dimensions. The results revealed that the sustainability index values were relatively balanced: 53.74 (ecological), 51.86 (economic), and 49.04 (social), with an overall multidimensional index of 49.42. These findings indicate that while environmental and economic aspects have approached 'moderate sustainability' status, social sustainability is still slightly below the threshold, reflecting vulnerabilities in human capacity, social equity, and institutional strength. The leverage analysis identified limited access to credit, low productivity, poor market connectivity, gender disparities, and weak farmer group organizations as key constraints. The study recommends three strategic directions: (1) strengthening access to finance and innovation for farmers; (2) institutionalizing participatory agricultural extension with gender-sensitive approaches; and (3) promoting agroecological practices and diversified livelihoods to enhance resilience. These interventions are essential to transform agricultural development in Luwu from a productivity-driven model to an inclusive and sustainable system that empowers rural communities and safeguards natural resources.

1 Introduction

Agriculture remains a key foundation in sustaining rural livelihoods and national food security in Indonesia, especially in agrarian regions such as Luwu District, South Sulawesi. However, the sector faces significant multidimensional challenges. Climate change, commodity price fluctuations, natural resource degradation, land conversion, and weaknesses in local institutions have exacerbated the vulnerability of agricultural systems at the local level [1]. In this context, sustainable agriculture not only demands efficiency and

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productivity, but also emphasizes the importance of balance between ecological sustainability, economic viability, and social justice [2].

The Government of Indonesia through the RPJMN 2025-2030 places sustainable agriculture as a top priority to ensure national food availability, strengthen self-sufficiency in strategic commodities, and protect production buffer ecosystems. In the latest national policy direction document, agricultural development strategies are directed to encourage agroecology-based intensification, land efficiency, and capacity building of smallholders [3]. This shows the transformation of policy direction from merely increasing production to developing ecologically, socially and economically resilient agriculture.

Globally, the sustainable agriculture approach is also an important part of the framework for achieving the Sustainable Development Goals (SDGs), especially SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). Therefore, it is important for Indonesia to have an instrument that is able to precisely measure the extent to which agricultural systems in various regions support this sustainable development agenda [4,5].

On the other hand, the inequality of rural development and the institutional crisis of farmers are still serious challenges. Many agricultural areas do not have adequate institutional capacity, production infrastructure and market access. Evaluation of agricultural development so far is still partial and does not consider the interconnectedness between dimensions-ecological, economic, and social-which is precisely the core of sustainability [6].

Luwu District in South Sulawesi is one example of a region with a high dependency on the agricultural sector, especially cocoa and rice. However, the sustainability of this sector is threatened by local climate change, land degradation, weak access to finance, and low value-added products. On the other hand, the potential of land and water resources in Luwu is still large enough to be developed with a more adaptive and sustainable approach.

In this context, the intervention of the Food Systems, Land Use and Restoration (FOLUR) project is relevant. The project aims to build a sustainable landscape-based integrated food system that combines conservation, restoration and strengthening the value of commodities such as cocoa and rice. FOLUR also emphasizes the importance of multi-stakeholder collaboration in designing evidence-based strategies for the transition to more sustainable agriculture [7].

However, an evaluative approach that captures the real conditions at the local level is needed. Multidimensional Scaling (MDS) is one of the quantitative methods that has been widely used in assessing the sustainability of agrarian, agricultural and fisheries systems in Indonesia because it is able to integrate various indicators and present visualizations of sustainability status systematically [8,9,10]. MDS also allows the identification of attributes that are most sensitive to sustainability so that they can be the basis for local policy formulation or evaluation of existing policy formulations [9].

This research aims to assess the sustainability status of agriculture in Luwu Regency based on three main dimensions: ecological, economic, and social. These three dimensions are measured with indicators relevant to the local context and organized based on the FOLUR and SDGs frameworks. The results of the measurement are then examined to identify the factors inhibiting and driving sustainability and formulate strategic recommendations for rural and agricultural development policies.

By examining the dynamics of sustainable agriculture in Luwu, this study is expected to provide an empirical contribution to the implementation of RPJMN 2025-2030 and become a reference for the development of agricultural sustainability assessment methodologies in other regions in Indonesia.

2 Methods

This research applies the Multidimensional Scaling (MDS) method with the Rapfish approach adapted for agricultural systems. MDS is a nonparametric ordination technique that reduces complex multivariate data into a simplified spatial representation. This method enables the calculation of a sustainability index (0-100 scale) and the identification of leverage indicators that most influence sustainability outcomes [11].

The research was conducted in five selected villages in Luwu district, which were chosen based on their agroecological diversity and relevance to the FOLUR program. Primary data were collected through structured interviews, field observations, and expert judgment assessments, while secondary data were obtained from local planning documents, statistical reports, and academic references [12].

Sustainability was assessed through three dimensions: Ecological (e.g., soil erosion, pesticide use, CBA protection, water availability), Economic (e.g., productivity, credit access, input-output ratio, market access), and Social (e.g., farmer education, gender roles, participation, institutional capacity). Each indicator was scored and normalized for MDS analysis.

This study used a quantitative approach with a modified Rapid Appraisal for Fisheries (Rapfish)-based Multidimensional Scaling (MDS) method to evaluate the sustainability of agricultural systems. MDS is used to reduce multivariate data into a two-dimensional spatial representation, enabling visualization and classification of sustainability levels.

The study was conducted in five villages in Luwu District, South Sulawesi Province. Primary data were obtained through structured interviews, field observations, and focus group discussions. Secondary data were collected from local planning documents, official statistical publications, and scientific literature.

The sustainability assessment covered three dimensions: ecological (erosion, water quality, chemical inputs, CBA), economic (income, access to credit, business efficiency, markets), and social (participation, education, gender, institutions). Each indicator was scored using an ordinal scale and compiled in a data matrix for analysis using Rapfish software.

The results of the analysis include:

- Sustainability index score (0-100),
- Model validity through stress value, R^2 , and Monte Carlo simulation,
- Leverage analysis to determine priority indicators, and
- Classification of sustainability in four categories: not, less, moderately, and highly sustainable.

These findings form the basis for developing evidence-based policy intervention recommendations for sustainable agricultural development.

3. Results and discussion

3.1. Sustainability status of agricultural activities in luwu regency

Agricultural activities in Luwu District play a strategic role in sustaining the economic life of rural communities, providing food, and maintaining the environmental balance of the region. However, with increasing pressure on natural resources, dependence on external inputs, and changing socio-economic dynamics, new challenges arise to the sustainability of local agricultural systems [13].

To address these challenges, a comprehensive evaluation of the sustainability status of agricultural activities is needed, covering three main dimensions: environmental (ecological),

economic, and social. These three dimensions are interrelated and are key indicators in determining the extent to which agricultural systems in Luwu can survive, adapt, and develop sustainably amid global and local pressures.

Based on the results of the MDS analysis, the index and status of the sustainability of agricultural activities in Luwu Regency, MDS value for the ecological dimension: 53.74, economic dimension: 51.86, and social dimension: 49,04.

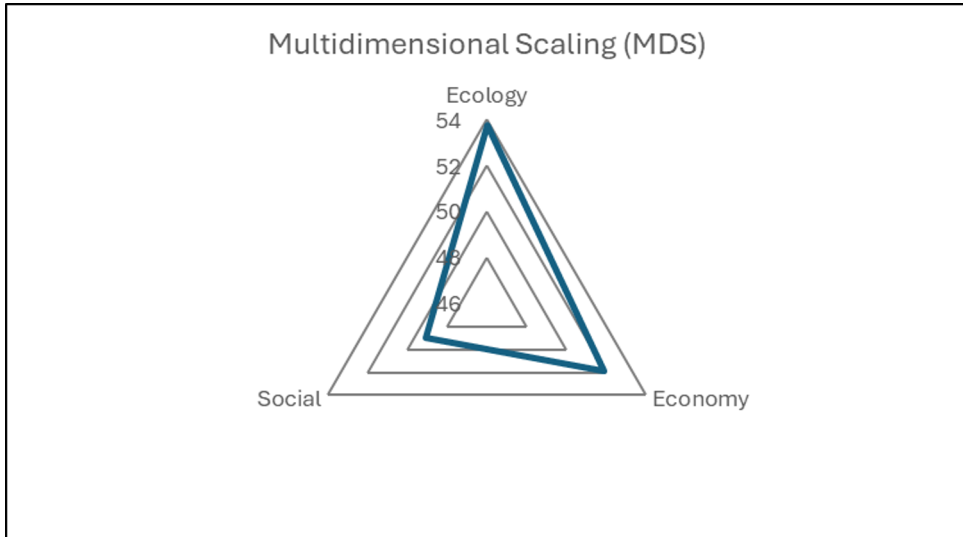


Fig. 1. Layout diagram of Agriculture sustainability index analysis in Luwu District.

The R^2 value of 0.95 in the Multidimensional Scaling (MDS) analysis results in Table 6.1 shows that the MDS model is able to explain 95% of the variation or relationship between sustainability indicators accurately, so that only 5% of the information is not represented in the visual mapping. This indicates that the model has very high statistical validity and can be relied upon to represent the state of agricultural sustainability. Thus, the patterns and scores generated from this analysis can be used as a scientific basis in the formulation of public policies, the formulation of sustainable agricultural development strategies, and to compare the level of sustainability among regions as well as between dimensions such as ecological, economic, and social [14].

The Monte Carlo value of 49.42 in the multidimensional dimension indicates that the sustainability index score obtained is not the result of chance or data noise but represents a consistent and reliable sustainability structure. This strengthens the validity of the analysis and the basis for policy recommendations for sustainable agricultural development in Luwu District.

Table 1. Stress and Difference values of MDS and Monte Carlo analysis results in Luwu District.

Dimension	MDS	Stress	R^2	Monte Carlo
Ecology	53,74	0,14	0,95	53,8
Economy	51,86	0,16	0,94	51,68
Social	49,04	0,16	0,94	48,44
Multidimensional	49,42	0,13	0,95	49,64

3.1.1 Sustainability status of agricultural activities based on environmental dimensions in luwu district

Based on the Multidimensional Scaling (MDS) approach, the value of the agricultural sustainability index in the environmental (ecological) dimension in Luwu District was recorded at 53.74. This score is included in the “moderately sustainable” category, which indicates that the agricultural system in this region has several supporting elements for environmental sustainability but still faces various structural and technical challenges.

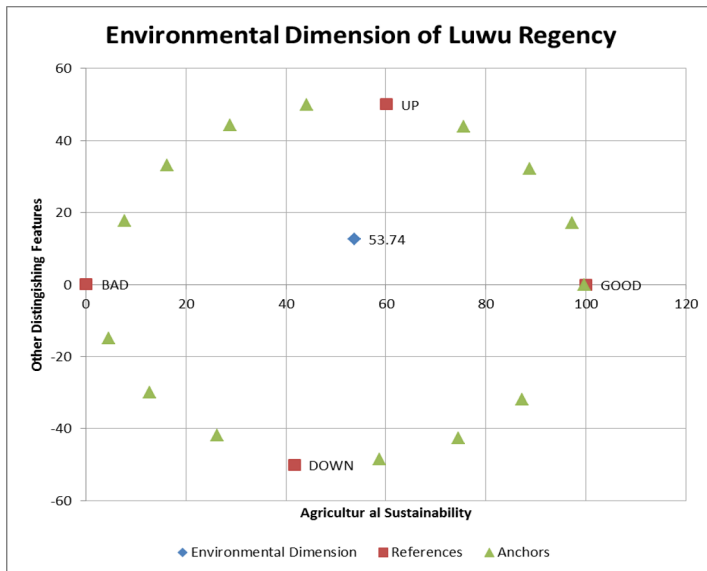


Fig. 2. Index values and sustainability status of the environmental dimension of sustainable agricultural activities in Luwu District.

Although the sustainability index on the environmental dimension in Luwu District shows a moderately sustainable category (53.74), this achievement is still faced with significant structural and technical challenges. These challenges hinder the transformation towards a truly sustainable and ecologically resilient agricultural system.

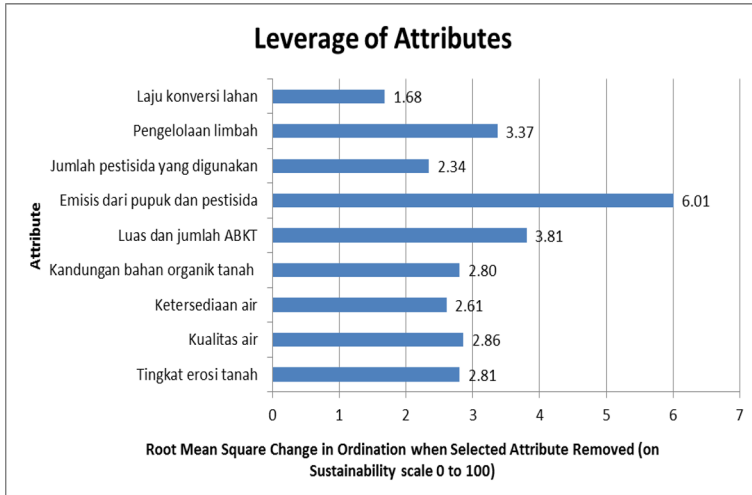


Fig. 3. Leverage value of environmental dimension attributes of sustainable agriculture activities in Luwu District.

Indicators that have the highest leverage on the ecological dimension in Luwu District include as follows: Intensive Use of Chemical Fertilizers and Pesticides; Critical Land Conditions and Erosion Rates; Irrigation Systems and Water Availability; and Agricultural to Non-Agricultural Land Conversion Rates. These findings provide a clear direction that efforts to improve ecological sustainability should focus on reducing chemical inputs, rehabilitating critical land, improving irrigation systems, and strengthening the role of social forestry [15].

3.1.2 Sustainability status of agricultural activities based on economic dimension in luwu district

Based on the MDS results, the agricultural sustainability index in the economic dimension in Luwu Regency was recorded at 51.86. With this value, the economic status of agriculture is in the “moderately sustainable” category, which means that the agricultural sector in this region already has a supportive economic base, but it is not yet strong enough to sustain long-term sustainability.

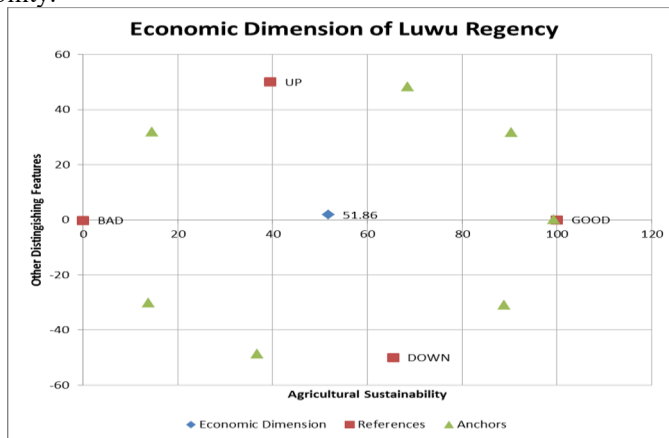


Fig. 4. Index value and sustainability status of the economic dimension of sustainable agricultural activities in Luwu District.

Based on the results of the Multidimensional Scaling (MDS) analysis, the agricultural sustainability index in the economic dimension in Luwu District was recorded at 51.86, which places it in the “moderately sustainable” category. This achievement indicates that the agricultural sector has a supportive economic base but is not yet solid enough to sustain long-term sustainability. This result is reinforced by the statistical validity of the MDS visualization, with a stress value of 0.16 and RSQ of 0.94, indicating a low level of distortion and an excellent representation of the relationship between economic indicators.

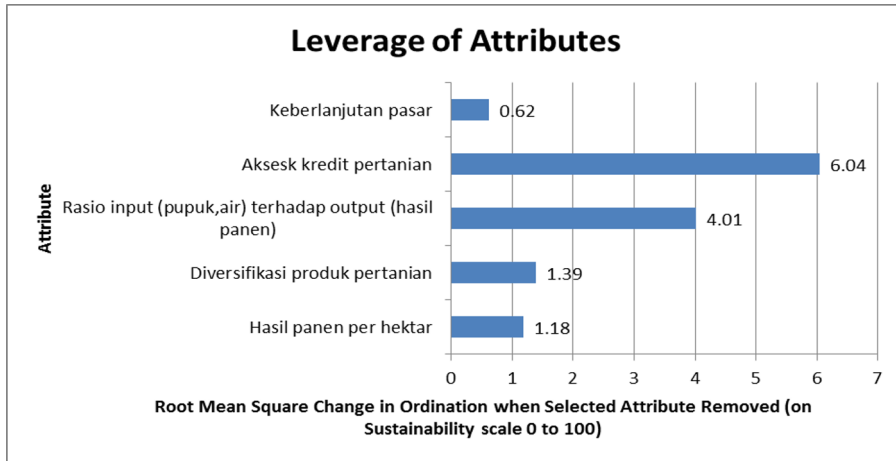


Fig. 5. Leverage value of economic dimension attributes of sustainable agriculture activities in Luwu District.

Based on the results of the leverage analysis, it was found that there are five economic attributes that most influence changes in sustainability scores, namely: access to credit, input-output efficiency, product diversification, yield per hectare, and market sustainability. The high leverage in the access to finance and production efficiency indicators signals that the vulnerability of farmers' economic systems is not only caused by the agricultural products themselves, but also by immature economic support structures.

The five indicators above are critical points that determine the direction of improvement or decline in the sustainability of the agricultural economy in Luwu District. Policy interventions and agricultural development programs need to be directed on a priority basis to improve the structural and operational weaknesses reflected in these indicators, in order to realize a more equitable, resilient, and productive agricultural economic system.

3.1.3 Status of agricultural activities based on social dimensions in luwu district

The results of the Multidimensional Scaling (MDS) analysis on the social dimension show that the social sustainability index in Luwu District is at 49.04, with a fairly strong validity of the results (RSQ = 0.94 and stress = 0.16). This value places the social aspect in the “less sustainable” category, indicating that social development in the agricultural sector still faces various limitations, both in terms of participation, institutional capacity, and farmer empowerment.

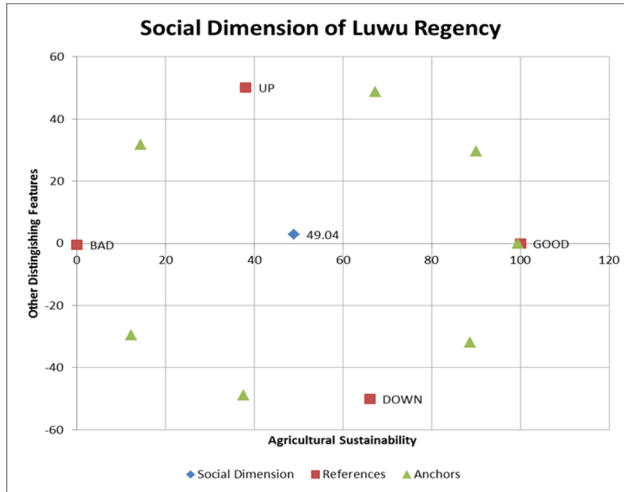


Fig. 6. Index values and sustainability status of the social dimension of sustainable agricultural activities in Luwu District.

Furthermore, the leverage attributes analysis shows that indicators such as access to education and training, involvement in decision-making, gender roles, farmers' income, and farmer group capacity are the factors that most influence changes in social sustainability scores. This suggests that the social resilience of farming communities in Luwu is highly dependent on the quality of human resources and local institutions.

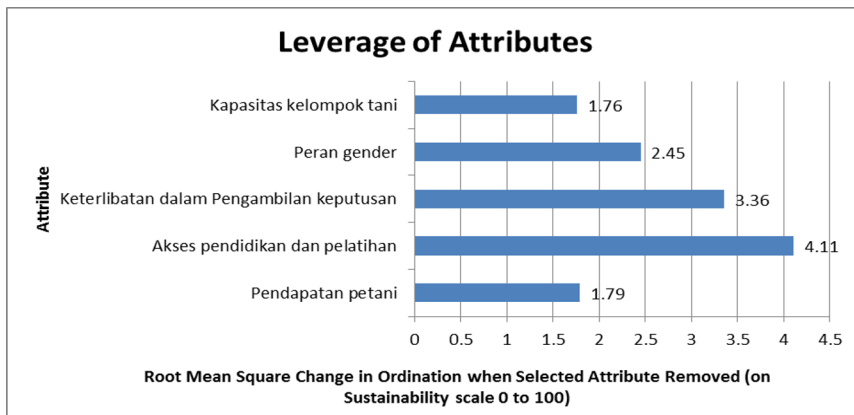


Fig. 7. Leverage value of social dimension attributes of sustainable agricultural activities in Luwu District.

4. Conclusion

Agricultural activities in Luwu District play a strategic role in rural economic development, food security, and environmental conservation. However, the sustainability of the agricultural system is faced with serious challenges due to natural resource pressures, dependence on external inputs, and local socio-economic dynamics.

Based on the Multidimensional Scaling (MDS) analysis, the sustainability status of the agricultural sector in Luwu District can be classified as follows. The ecological dimension obtained an index value of 53.74, including in the moderately sustainable category. The

biggest challenges come from the intensive use of agrochemicals, critical land degradation, inefficient irrigation systems, and land conversion. Leverage analysis identified this indicator as a crucial point for improving environmental sustainability.

The economic dimension, with a score of 51.86, is also in the moderately sustainable category, but is still overshadowed by limited access to credit, low farm business efficiency, dependence on one commodity, and not optimal farm economic institutions. Indicators such as access to financing and input-output ratios show a dominant influence on the dynamics of economic sustainability.

The social dimension is the most vulnerable with an index of 49.04, which is categorized as less sustainable. This reflects weak farmer empowerment, low participation in village planning, and the suboptimal role of women and farmer groups in social agricultural development.

Overall, the high R^2 value (≥ 0.94) and low stress value (< 0.16) indicate that the MDS model used has strong validity and reliability to map the sustainability structure. Meanwhile, the Monte Carlo value of 49.42 indicates that the results of the analysis are not mere coincidence, but a consistent representation of the sustainability structure.

By considering the results of the leverage analysis on each dimension, it is concluded that agricultural sustainability in Luwu District can be strengthened through (1) strengthening access to finance and innovation for farmers; (2) institutionalizing participatory agricultural extension with gender-sensitive approaches; and (3) promoting agroecological practices and diversified livelihoods to enhance resilience. These interventions are essential to transform agricultural development in Luwu from a productivity-driven model to an inclusive and sustainable system that empowers rural communities and safeguards natural resources.

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