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Analysis of Clove Agroforestry Productivity and Sustainability Using a Systemic Approach (MDS RAP-AFS) in Wolo District, Kolaka Regency

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ABSTRACT

Kolaka Regency makes a significant contribution to clove production in Southeast Sulawesi. Wolo District, as one of the centers of clove production in Kolaka, faces complex challenges, including declining productivity. Agroforestry systems are expected to be a solution to increase productivity and the sustainability of clove farming in Wolo District. The purpose of this study is to analyze the productivity and sustainability of agroforestry-based clove farming. The method used to address the problem is productivity analysis and MDS analysis, utilizing the RAP-AFS approach (encompassing ecological, economic, social, and institutional dimensions). The results of the study show that clove productivity before the introduction of agroforestry in 2020 was 0.27 ton/ha. After the introduction of clove agroforestry in 2023, clove productivity began to increase, reaching 0.54 ton/ha in 2025. The level of sustainability of agroforestry-based clove farming in Wolo District, Kolaka Regency, is entirely in the fairly sustainable category in each dimension. The respective index values are ecological (67.01), economic (56.73), social (57.63) and institutional (51.90). The study's conclusion reveals that productivity has increased following the introduction of agroforestry, and the sustainability status of clove agroforestry in Wolo District, Kolaka Regency, is categorized as fairly sustainable, with the institutional dimension attribute being the most influential factor.

1. INTRODUCTION

Agriculture is often associated with a significant source of anthropogenic greenhouse gas emissions, contributing to climate change that is felt not only by human populations. Monoculture agricultural systems are indicated to be one of the causes because they require annual replanting, substantial resource inputs, and weed management (Zhang *et al*., 2023). This repetitive pattern of planting, fertilising, and spraying primarily benefits considerable agribusinesses that provide the necessary inputs, rather than effectively contributing to global food security (Gerhardt *et al*., 2022), whose productivity needs to be maintained (Paul *et al*., 2023). Agroforestry can maintain productivity while simultaneously providing many ecosystem services through systems that mimic activities observed in nature, such as agroforestry of clove plants with food crops or horticultural crops.

Cloves are a plantation commodity with promising development prospects and significant export opportunities. Indonesia is the world's largest clove exporter, with an average export volume of 24.45 thousand tons from 2017 to 2021, contributing 32.18% of the world's total clove export volume (Pusdatin, 2023). Cloves play a crucial role in the plantation configuration of Southeast Sulawesi Province. Kolaka Regency is the regency with the most significant contribution to clove development in Southeast Sulawesi.

In 2020, Kolaka Regency contributed 47.77% to clove production in Southeast Sulawesi Province. Clove production in Kolaka Regency continues to increase, reaching 5,947 tons in 2017, then increasing by 10.78% to 6,588 tons in 2020. In 2022, clove production in Wolo District, Kolaka Regency was 1,073.75 tons and decreased to 1,017.35 tons in 2023 (BPS Kolaka, 2024). Furthermore, climate change, fluctuating market prices, and suboptimal environmental conservation practices also contribute to the decline in clove productivity in this region. Poorly managed land loses fertility due to excessive use of pesticides or fertilisers and neglect of sustainable agricultural practices. This contributes to declining yields and the inability of farmers to maintain ecosystem balance.

To address these challenges, agroforestry systems are expected to be a solution that can increase the productivity and sustainability of clove farming in Wolo District. Agroforestry is a system of integrating perennial crops, such as cloves, with intercrops or shade trees that improve soil conditions, reduce erosion, and enhance environmental balance.

Agroforestry practices have numerous benefits for human life and the environment. These practices play a crucial role in providing for people's daily needs (Duffy *et al*., 2021), increasing flora and fauna biodiversity (Murniati *et al*., 2022; Raihan, 2023; Santos *et al*., 2022; Xiao & Xiong, 2022), moderating microclimates, mitigating and adapting to climate change (van Noordwijk *et al*., 2018), promoting soil and water conservation and soil health (Kaushal *et al*., 2021), and restoring landscapes (Murniati *et al*., 2022; Sahoo *et al*., 2020). However, clove farmers have not yet entirely accepted and adopted agroforestry systems. Farmers still employ conventional practices that focus only on short-term results and ignore environmental sustainability. Sustainability analysis of agroforestry-based clove farming integrated with a systemic approach will provide holistic information integrating all aspects of the ecological, economic and social systems, so that it will help in developing a holistic and sustainable agroforestry-based clove farming strategy. Despite the growing promotion of agroforestry, empirical sustainability assessments of clove-based agroforestry systems using a multidimensional systemic approach remain limited, particularly in Eastern Indonesia. The integration of crops with agroforestry systems not only optimizes land use but also improves soil and water quality, providing other ecological benefits, such as creating habitat for wildlife. However, agroforestry systems have not yet been entirely accepted and adopted by clove farmers. Farmers generally still employ conventional practices that focus solely on short-term results, often at the expense of environmental sustainability. An analysis of the sustainability of agroforestry-based clove farming, integrated with a systemic approach, will provide holistic information that integrates all aspects of the ecological, economic, and social systems, thereby assisting in the development of a comprehensive and sustainable agroforestry-based clove farming strategy.

The objectives of this research are to analyzing the level of clove productivity in agroforestry-based farming in Wolo District, and to analyzing sustainable is agroforestry in Wolo District, Kolaka Regency.

2. MATERIALS AND METHODS

2.1. Time and Place

The research was conducted in Wolo District, Kolaka Regency in June 2025, an agroforestry-based clove farming development centre. The stages to be implemented are:

1. Location survey to get a general overview of the research area and respondents who will be involved in the data collection process
2. Data was collected through structured interviews, in-depth interviews, FGDs to identify data related to ecological, economic, social and institutional dimensions that influence clove agroforestry activities.

2.2. Population and Sample

The population in this study is the community involved in agroforestry activities, namely the community of Lalonaha Village and Lambopini Village, Wolo District, Kolaka Regency. These are members of farmer groups that carry out clove cultivation activities using the agroforestry system and parties involved in agroforestry-based clove farming activities in Wolo District.

Farmer samples were selected from Lalonaha Village and Lambopini Village that implement clove agroforestry activities. Each village has one farmer group, namely the Lahopu Jaya farmer group and the Pelangi Harapan farmer group, with 15 members per farmer group selected as a whole (census). Stakeholder samples were selected intentionally (purposive) with the consideration that these parties have knowledge related to agroforestry in Wolo District, consisting of community leaders of Lalonaha and Lambopini Villages, Village Heads, representatives of farmer groups (contact farmers), Agricultural/Forestry Extension Workers, the Agriculture Service and the Forestry Service of Kolaka Regency. The total sample numbered 39 people.

2.3. Indicators and variables

Indicators are based on respondents' perceptions, measured using a Likert scale ranging from 1 to 4. Answers strongly agree (score 4), agree (score 3), disagree (score 2) and strongly disagree (score 1). The indicators and variables used in this study are described in Table 1.

Table 1. Research variables and indicators

Variables	Indicator
Productivity	The ratio between production output and land area input
Ecology	1. Soil productivity
	2. Use of organic fertiliser
	3. Soil fertility level
	4. Soil and water conservation measures
	5. Availability of fertiliser manufacturing technology
	6. expansion for agroforestry systems
	7. Water conservation activities
	8. Use of inorganic fertilisers
	9. suitability of the application of agroforestry systems
Economy	1. Stability of selling prices for harvested crops
	2. Sources of capital for farming businesses
	3. Effectiveness of farming business value
	4. Subsidies from the government
	5. price of agroforestry products
	6. Agroforestry product sales system
	7. Systems can increase income
Social	1. The occurrence of conflict
	2. Participation in farmer group activities
	3. Land owned by the community
	4. Amount of socialisation given
Institutional	1. Institutions available for marketing
	2. Frequency of providing counselling
	3. Support from the Government
	4. The innovation technology provided

2.4. Data Analysis

Data analysis to answer the research objectives as follows:

2.4.1. Productivity Analysis

The productivity of clove farming is analysed using the formula:

$$Productivity = \frac{Output\ (clove\ production)}{Input\ (Land\ Area)} \quad (1)$$

2.4.2. Sustainability Analysis

Sustainability of clove agroforestry using MDS (Multidimensional Scaling) sustainability analysis. Multidimensional Scaling (MDS) analysis is a multiple variable technique that can be used to determine the position of an object relative to another based on its similarity assessment. MDS visually maps respondents' perceptions and preferences on a geometric map (*spatial map/perceptual map*). Sustainability analysis of agroforestry systems using the (Rapid

Appraisal for Agroforestry (RAP-AFS) RAP-AFS is a sustainability evaluation method for agroforestry systems that combines techniques such as Multidimensional Scaling (MDS), leverage analysis, and Monte Carlo analysis to identify the sustainability status (ecological, economic, social) method based on ecological, economic, social and institutional dimensions. The stages are as follows: 1) determining attributes/criteria for each sustainability dimension through literature review, discussions and field observations, 2) conducting attribute/criteria assessments for each sustainability dimension. The assessment is carried out using a questionnaire. 3) Assessment of the index and sustainability status through ordination analysis using MDS, sensitivity analysis (Leverage analysis) and anomaly analysis (Monte Carlo analysis). The clove agroforestry sustainability index values in the data analysis are grouped into four levels of sustainability status, namely:

1) 0–25.00 (not continuous)
2) 25.01–50.00 (less sustainable)
3) 50.01–75.00 (quite sustainable)
4) 75.01–100.00 (continuous)

To test whether the sustainability aspect indicators studied in the MDS analysis are accurate enough (close to the actual conditions) and there is no need to add indicators, this can be done by looking at the magnitude of the stress value and the coefficient of determination (R^2) value on software RAP-fish (Ariandi, 2022; Pawiengla *et al*., 2020; Subhan *et al*., 2020). Suppose the stress value is smaller than 0.25 or 25% and the coefficient of determination (R^2) value is close to 1.0 or 100%. In that case, the level of accuracy of the analysis results can be accounted for (Kavanagh & Pitcher, 2004).

3. RESULTS AND DISCUSSION

3.1. Productivity of agroforestry-based clove farming

Based on interview data, clove production in 2025 averaged 763.08 kg with an average land area of 1.42 ha. Calculated productivity is 536.22 kg/ha or 0.54 tons/ha. Compared to clove productivity before the introduction of agroforestry, in 2020, clove productivity was 0.27 tons/ha. This indicates that productivity changes may also be influenced by climatic variability and plant age, after the introduction of clove agroforestry in 2023, clove productivity began to increase, reaching 0.54 tons/ha in 2025.

3.2. Sustainability of Clove Agroforestry

The results of the RAP-AFS analysis using the MDS (Multidimensional Scaling) ordination technique and Monte Carlo Analysis (Table 2) show that:

a. The level of sustainability of agroforestry-based clove farming in Wolo District, Kolaka Regency, in each dimension is entirely in the fairly sustainable category, with the respective index values being ecology (67.01), economy (56.73), social (57.63) and institutional (51.90). The implication that, the current system is resilient, but it is highly vulnerable and could quickly fall into the "unsustainable" category. Therefore, the policies adopted must be holistic and integrated.
b. The stress value based on the analysis results for all dimensions has a value of S <0.25, which means that the influence of errors on the assessment of an attribute in the social dimension is so small that it can be ignored or in other words, the level of accuracy of the analysis results can be accounted for (close to the actual conditions).

Table 2. Results of the analysis of the sustainability of agroforestry-based clove farming using RAP-AFS

Dimensions	Sustainability Index	Coefficient of Determination	Stress Value	Mark Monte Carlo	Difference between Monte Carlo and MDS
Ecology	67.01	0 9 5	0.15	66.33	-0.68
Economy	56.73	0.94	0.16	56.57	-0.16
Social	57.63	0.93	0.18	57.15	-0.48
Institutional	51.90	0.92	0.17	51.94	0.04

Source: Research results, 2025

c. The resulting coefficient of determination (R^2) has a value for each dimension ranging from 0.92 to 0.95. This indicates that the attributes used in the MDS analysis with RAP-AFS already explain ±90% of the currently implemented agroforestry system.

The difference between the Monte Carlo and MDS values reflects the sustainability status. If the difference is <1, it indicates that the sustainability index status value within the confidence interval corresponds to the RSQ value, resulting in a relatively small difference. The analysis revealed that each dimension has a Monte Carlo and MDS difference value < 1, indicating that:

a. The error in scoring each attribute is relatively small.
b. The range of scoring for each attribute is relatively small.
c. The analysis process carried out repeatedly is relatively stable.
d. Errors in entering missing data can be avoided.

3.2.1. Sustainability Analysis based on Ecological Dimensions

The results of the MDS ordination analysis for the ecological dimension fall into the fairly sustainable category with an index value of 67.01.

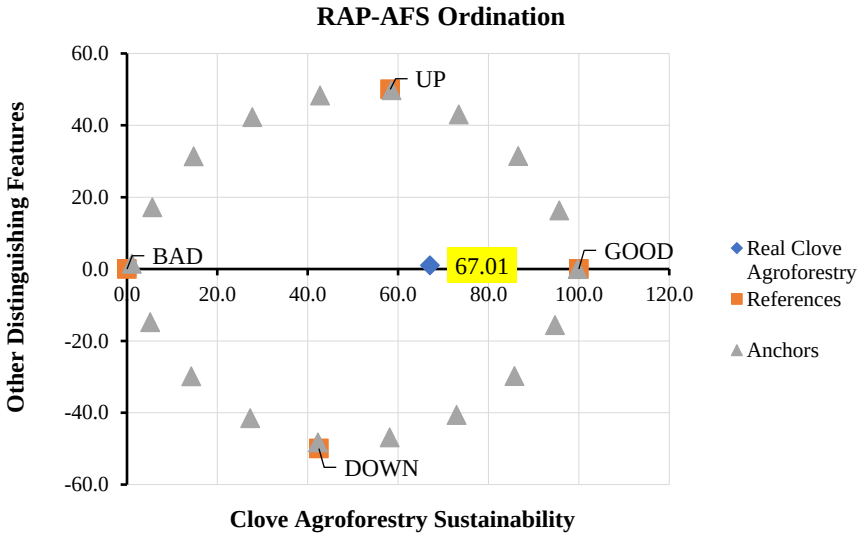

Figure 1. Sustainability index in the ecological dimension

In the ecological dimension, researchers examined all ecological aspects related to the sustainability of clove agroforestry. The attributes studied in the ecological dimension consist of nine attributes suspected of influencing the level of sustainability of clove agroforestry in Wolo District, Kolaka Regency. These nine attributes are presented in Figure 2.

From an ecological perspective, the sustainability of clove agroforestry in Wolo District is heavily influenced by a single variable: soil and water conservation practices. Although the mountainous geographic characteristics of the region support a favourable climate for clove farming, several fundamental factors related to local characteristics, the nature of the agroforestry system itself, and the vulnerability of the local ecosystem influence the sustainability of the clove agroforestry system in Wolo District. Wolo District, Kolaka District, generally has hilly to mountainous topography. Land for clove plantations is located in areas with a particular slope. In such areas, the threat of soil erosion is very high, especially during the rainy season. Without conservation measures, fertile topsoil will easily be washed away by water. If fertile soil is lost due to erosion, less fertile base soil remains. This will directly reduce clove productivity in the long term, threatening the economic aspects of sustainability.

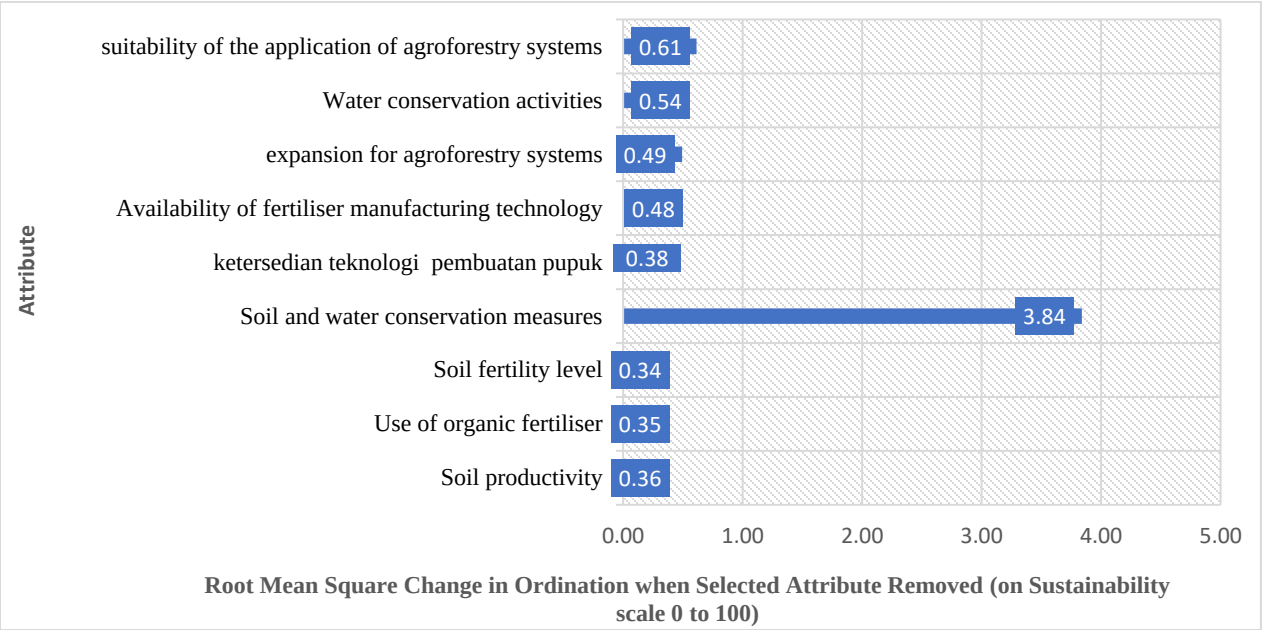

Figure 2. Results of leverage analysis for ecological dimension

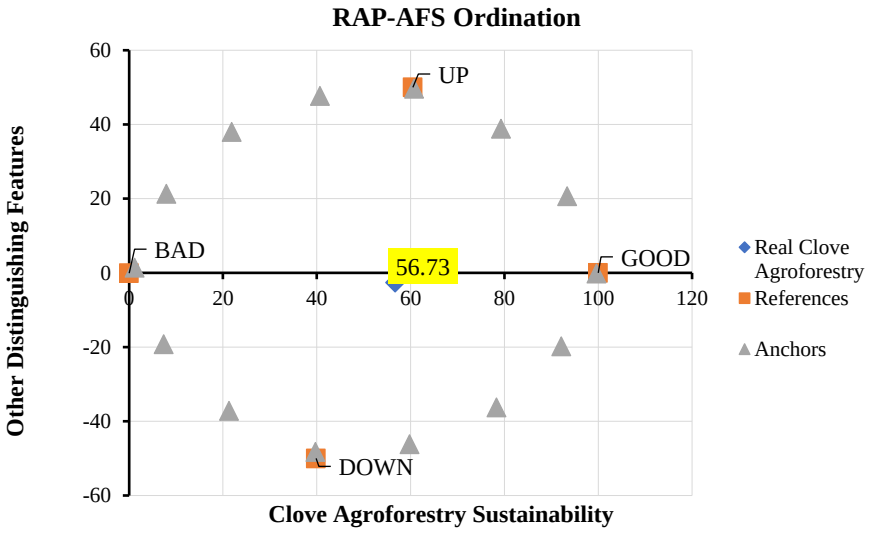

Figure 3. Sustainability index in the economic dimension

3.2.2. Sustainability Analysis based on Economic Dimension

In the economic dimension, the sustainability index value indicates that the sustainability of clove agroforestry is moderately sustainable (56.73). The Rapfish analysis results (Figure 3) illustrate this. The economic sustainability of the clove agroforestry system in Wolo District, Kolaka Regency, is influenced by the variables of sources of farming capital, clove selling prices, and government subsidies.

The first variable that most significantly impacts the sustainability of agroforestry from an economic perspective is the limited capital available to farmers. Clove farmers in Wolo District rely solely on their limited capital due to limited access to capital assistance institutions. Complex administration, lack of collateral, and low financial literacy often hamper access. Government subsidies, particularly those related to production inputs, are also not entirely

supportive, as quotas are often limited and uneven. Clove agroforestry farmers whose land is not registered as "rice fields" or "gardens" face difficulty accessing these funds, especially as subsidies are sometimes prioritised for food crop farmers over plantation crops.

Furthermore, fluctuating clove selling prices, due to independent marketing by farmers, also impact economic sustainability. Uncertain market security and a lack of market information result in clove farming products being marketed independently within a simple marketing chain involving only local actors such as collectors and retailers, thus reducing the income of clove farmers. To support the sustainability of clove agroforestry in Wolo District, a partnership or collaboration pattern is needed with related agencies or the government regarding capital subsidies to help ease the burden on farmers in managing their farming businesses.

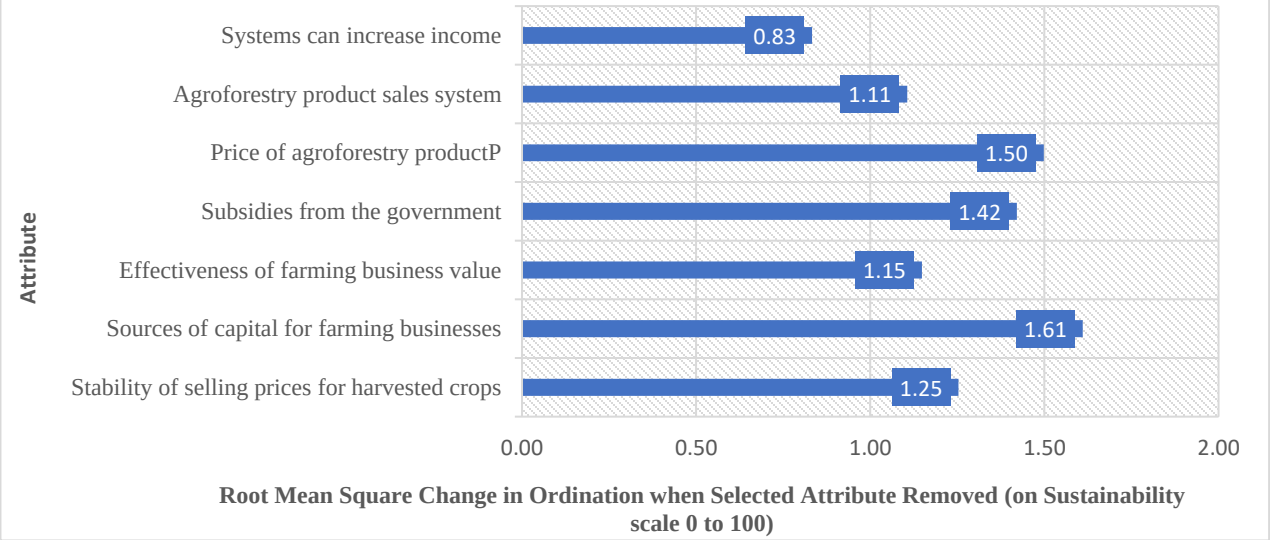

Figure 4. Economic dimension leverage analysis

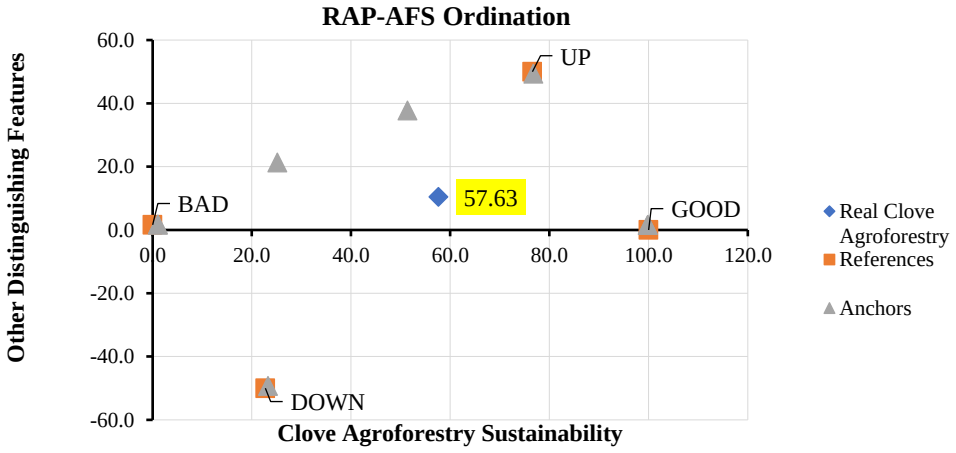

Figure 5. Sustainability index in the social dimension

3.2.3. Sustainability Analysis based on Social Dimension

The clove agroforestry sustainability index in the social dimension, based on the results of the RAP-AFS analysis using the MDS (Multidimensional Scaling) ordination technique, shows a value of 57.63 (Figure 5), which means that the clove agroforestry system in Wolo District, Kolaka Regency, is in the fairly sustainable category.

As shown in Figure 6, the most influential attributes based on sensitivity analysis (leverage) include the occurrence of conflict and the amount of socialisation provided. Conflict can be a balancing *force* in achieving desired goals. Its impact extends beyond a single dimension and can permeate all aspects of sustainability. Agroforestry is a system involving forest areas and generally relies on the cooperation of farmer groups and adherence to shared rules. Conflict can lead to distrust, division, and reduced participation in collective activities (such as conservation). Common conflicts include overlapping claims, lack of certificates, illegal expansion of land into forest areas, or inheritance of unclear boundaries. Therefore, clarity of regulations applicable to agroforestry areas remains a priority to ensure sustainability.

The sustainability of agroforestry systems requires intensive outreach through increased knowledge and skills by relevant parties. Outreach provided by officers from relevant agencies can develop community skills. Outreach can enhance farmers' capacity in managing their farms, both in terms of managerial and social skills and technical skills through the learning process (Suprayitno, 2011).

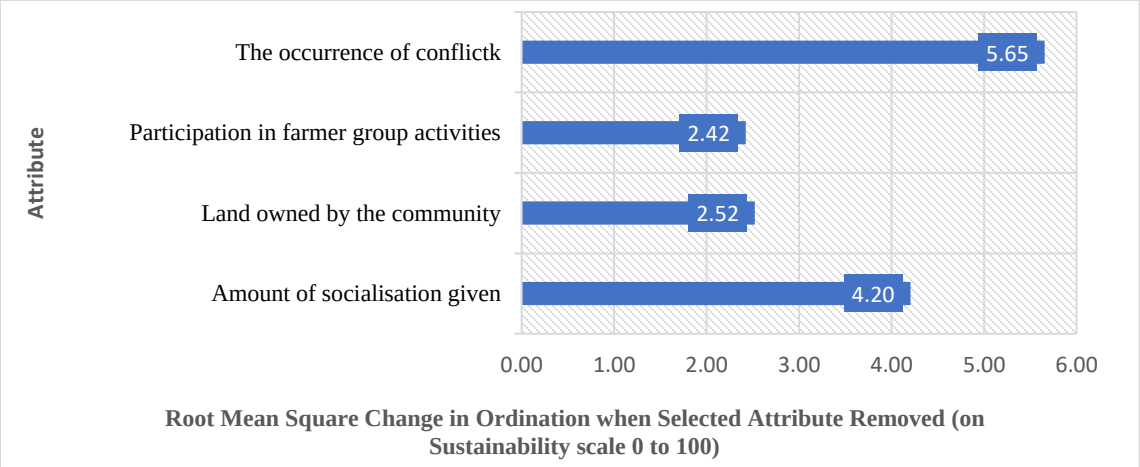

Figure 6. Social dimension leverage analysis

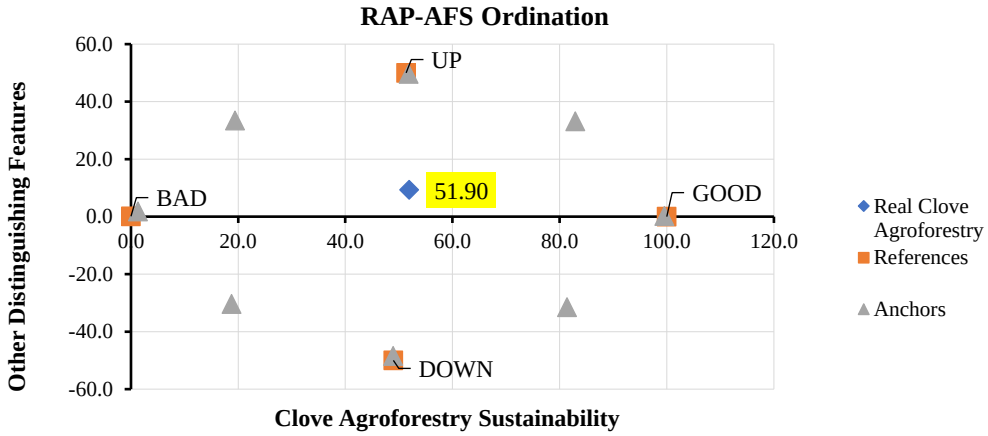

Figure 7. Sustainability index in the institutional dimension

3.2.4. Sustainability Analysis based on Institutional Dimensions

The institutional dimension consists of four attributes: the availability of marketing institutions, the frequency of extension, government support, and the technology/innovation provided**.** The results of the RAP-AFS analysis (Figure 7) show the sustainability index of clove agroforestry in the institutional dimension in Wolo District, Kolaka Regency.

The sustainability status of clove agroforestry based on the RAP-AFS analysis using the MDS method is quite sustainable (51.90). The sensitivity values in the leverage analysis are examined to determine the most influential attributes. The sensitivity analysis results in the institutional dimension are shown in the attributes with the highest values.

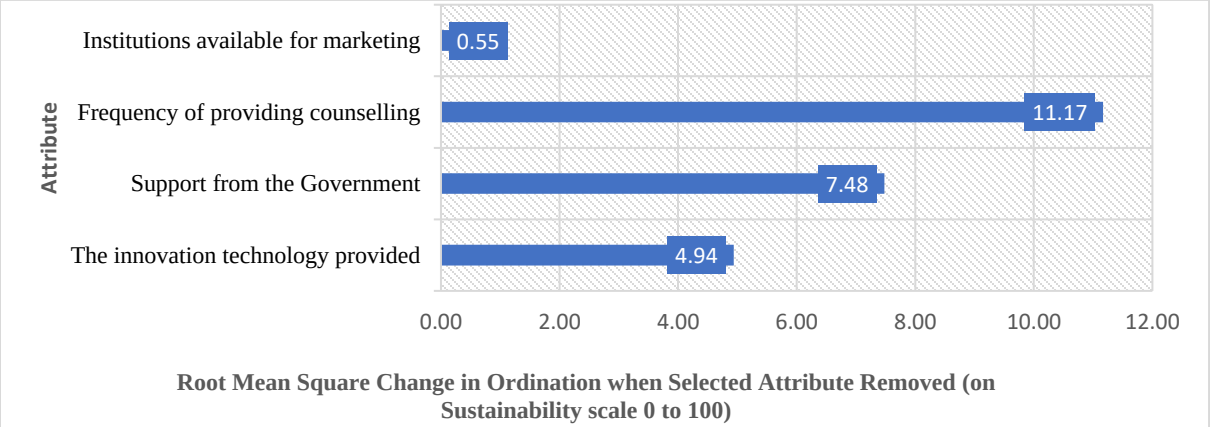

Figure 8. Institutional dimension leverage analysis

The frequency of extension services, government support, and the technology/innovation provided influence sustainability in the institutional dimension. Optimal extension service intensity will expand farmers' opportunities to improve their capacity (social, ecological, and economic aspects) through an effective and dynamic learning process. Increasing farmer capacity supported by innovation/technology packages and government policy/program support will significantly impact the sustainability of clove agroforestry in Wolo District, Kolaka Regency, optimising the system's benefits (economic, ecological, and social).

3.3. Sustainability Status of Clove Agroforestry in Wolo District, Kolaka Regency

Figure 9 below shows the results of the multidimensional ordination analysis of clove agroforestry in Wolo District, Kolaka Regency. The multidimensional scaling (MDS) analysis shows that the sustainability status of clove agroforestry in Wolo District, Kolaka Regency, is in the fairly sustainable category with an index value of 58.03. The sustainability index value from the sustainability analysis of clove agroforestry in Wolo District is obtained from the accumulation of mode values in each dimension. The sustainability status of clove agroforestry for the four dimensions can be depicted in the kite diagram in Figure 10.

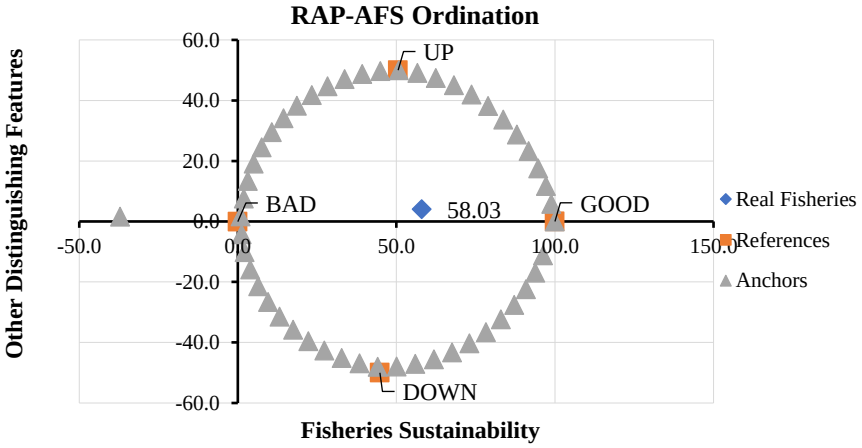

Figure 9. Results of multidimensional ordinance analysis of clove agroforestry in Wolo District, Kolaka Regency

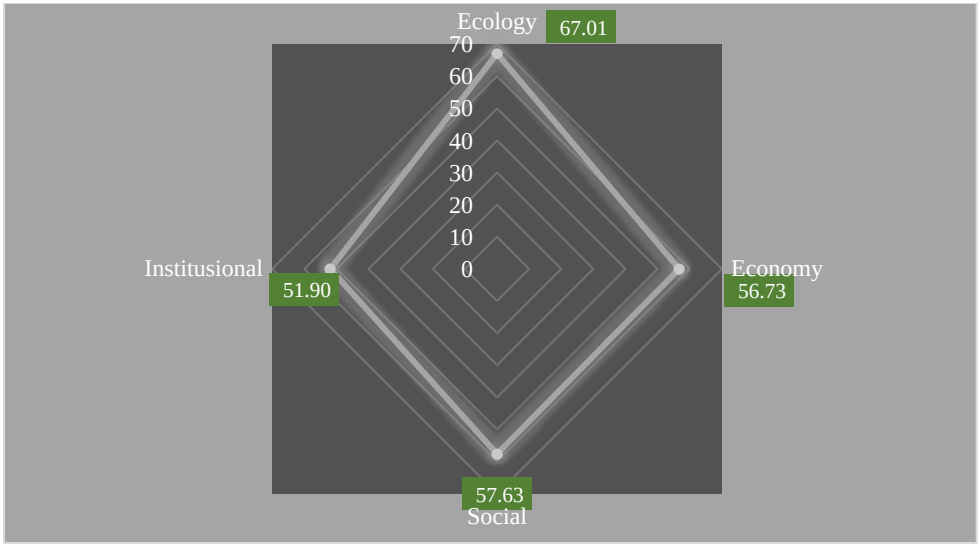

Figure 10. Kite diagram of clove agroforestry in Wolo District

One aspect influencing the sustainability of clove agroforestry in Wolo District is the institutional aspect. Although all related aspects are categorised as fairly sustainable, efforts are needed to improve these aspects further to ensure sustainability. The institutional aspect is considered the most sensitive and influences all aspects because it has the lowest ordination value. Intensive assistance is needed through extension/mentoring institutions to assist farmers in managing their farming businesses using appropriate extension methods based on the problems and needs faced by farmers. The active role of extension workers can be beneficial for farmers so that they are willing and able to organise themselves in implementing the latest technology (Lamatungga *et al*., 2024; Rosmalah, 2022; Rosmalah *et al*., 2023a; Rosmalah *et al*., 2023b). "Sufficient" sustainability across all dimensions demonstrates that the partial approach has reached its maximum limit. The Kolaka Regency Government (Pemkab) needs to establish an Integrated Clove Agroforestry Task Force involving the Departments of Agriculture, Environment, Cooperatives-SMEs, and Community Empowerment, and use the Systems Dynamics framework as a policy planning tool to assess the holistic impact of each intervention.

4. CONCLUSION

The conclusions of this study are as follows:

1. The productivity of agroforestry-based clove farming in Wolo District, Kolaka Regency, is 536.22 kg/ha, or 0.54 tons/ha. Compared to the 0.27 tons/ha before the introduction of agroforestry in 2020, clove productivity increased by 0.54 tons/ha after introducing the agroforestry system in 2023.
2. The analysis results show that the sustainability status of clove agroforestry in Wolo District, Kolaka Regency, is "quite sustainable". The overall sustainability status index value is 58.03, while for each dimension are ecological (67.01), economic (56.73), social (57.63), and institutional (51.90). The factor that most influences the sustainability of clove agroforestry in Wolo District, Kolaka Regency, is the institutional dimension, so that this dimension requires special attention, especially related to the intensity of mentoring/extension, policy support and introduction of innovation/technology to farmers.

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AUTHOR CONTRIBUTION STATEMENT

Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
AAS	✓	✓		✓	✓	✓	✓	✓		✓	✓		✓	
SR	✓	✓		✓	✓					✓			✓	
Har	✓	✓		✓		✓				✓			✓	
AHP			✓			✓		✓				✓	✓	

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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