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Sustainability Index as a Basic for Policy Directions for Agroforestry Private Forest Management in Leuwiliang Subdistrict, Bogor Regency

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Abstract: Agroforestry-based private forests (HR) play an important role in supporting rural economies and providing ecosystem services. However, in Leuwiliang Subdistrict, Bogor Regency, HR management faces challenges such as land-use conversion, limited cultivation technology, and weak institutional support, which threaten its sustainability. This study aimed to assess the sustainability status of agroforestry-based private forests using a multidimensional approach covering ecological, economic, socio-cultural, institutional, and accessibility-technology dimensions. Data were collected through in-depth interviews with 49 purposively selected farmers and stakeholders and analyzed using the MDS-Rapfish method. The results show that the overall sustainability status is categorized as less sustainable (index 44.31). The ecological dimension has the highest score, while the economic dimension has the lowest. Sensitive attributes include felling intensity, community welfare level, and forestry extension programs. These findings indicate that improving economic performance, strengthening institutional support, and enhancing extension services are essential to achieve sustainable agroforestry management. The study provides policy directions for improving private forest sustainability in rural areas.

Keywords: Ecological Dimension; Economic Dimension; Leverage Analysis; MDS-Rapfish; Stakeholders

Introduction

Private forests (HR) are forests owned, established, and managed by local people. According to the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number 23 of 2021 on the Implementation of Forest and Land Rehabilitation, Article 1 paragraph (4), private forests are forests that grow on land with private ownership rights or other rights outside state forest areas with a minimum area of 0.25 ha (twenty-five per one hundred hectares) and canopy cover dominated by woody species. Private forests in Indonesia are highly important because they contribute to the wood supply for the timber industry and serve as one of the efforts to improve community welfare, especially for rural populations (Molo et al., 2021).

Over the period 2010–2019, the area of private forests in Bogor Regency increased from 11,896.72 ha to 84,432.88 ha, with an average annual increase of around 24%. However, the area of private forests declined sharply in 2020–2023 to around 39,108 ha, with an average decrease of around 16% per year (Open Data Jabar, 2023). If this declining trend continues, the ecological and economic functions of private forests in Bogor Regency will continually deteriorate (Hartoyo et al., 2025). Therefore, efforts are needed to improve the sustainable management of private forests by

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strengthening agroforestry practices (Fauziyah et al., 2024).

Through various policies, particularly the social forestry program, the Ministry of Environment and Forestry has encouraged communities to utilize land using an agroforestry approach. Regulation of the Minister of Environment and Forestry No. P.2/MENLHK/2020 defines agroforestry as the optimization of land use through combinations of woody species, fruit trees, and annual crops that interact ecologically and economically. Various studies show that agroforestry HR helps store more carbon in both trees and soils, increases soil organic matter, maintains water availability during dry seasons, and protects crops, grasslands, and livestock from extreme weather such as excessive heat and strong winds (Aertsens et al., 2019). Furthermore, according to Nurrochmat et al. (2021) agroforestry has the potential to reduce deforestation rates while improving community welfare.

In West Java, including Bogor Regency, most private forests are managed in agroforestry systems. A spatial analysis of private forest potential in Bogor Regency showed that the largest cover is from agroforestry HR, amounting to approximately 17,757.7 ha, out of a total private forest potential of ±28,351.4 ha, or 63% (Safe'i & P Sukmara, 2019). Several studies in Bogor Regency also indicate that agroforestry HR contribute significantly to farmers' income and livelihoods. Agroforestry HR in Argapura Village, Cigudeg Subdistrict, for example, clearly contributes to household income (Antriyandarti et al., 2023), while the agroforestry system in Cibatok Dua Village, Cibungbulang Subdistrict, reportedly provides substantial additional income to farm households through a combination of timber, fruit trees, and agricultural crops (Mardyantoro et al., 2015).

Leuwiliang Subdistrict is located in the western part of Bogor Regency and has the second largest area of community forest-based agroforestry after Sukajaya Subdistrict. A study conducted in Karyasari Village reported that community forests covering approximately 334 ha under an agroforestry system not only have the potential to produce timber but also generate employment opportunities of up to 1.93 workers per hectare. Meanwhile, research in Karacak Village described the stand structure and species composition as multilayered, which is characteristic of multistrata mixed gardens (Rozalina, 2020).

Private forest agroforestry in Leuwiliang Subdistrict plays an important ecological and economic role and therefore needs to be managed sustainably. However, several studies indicate that management constraints still exist, including relatively low farmer income, the tendency for land conversion to agricultural uses, dependence on middlemen in timber marketing, and suboptimal performance of farmer group institutions (Achmad et al., 2022). Similarly, Sukwika et al. (2018) noted that the challenges of community forest management in Bogor Regency are not solely biophysical in nature but are also influenced by institutional and marketing aspects, weak actor interactions, limited organizational capacity of farmer groups, and the involvement of intermediaries or middlemen.

Based on field surveys, three Forest Farmer Groups (KTH) remain active and apply agroforestry practices in Leuwiliang Subdistrict: KTH Taruna Tani (KTH 1), KTH Manggis (KTH 2), and KTH Sinar Makmur (KTH 3). Agroforestry HR in Leuwiliang plays an important ecological and economic role. However, previous studies, including (Achmad et al., 2022), indicate that the management of agroforestry HR still faces several challenges, such as relatively low farmer income, a tendency to convert land to short-term horticultural crops (Tropenbos Indonesia, 2023), dependence on intermediaries in timber marketing, and suboptimal performance of farmer group institutions (Rozaki et al., 2021). These conditions highlight a gap between the substantial potential of agroforestry HR and its management at the farmer level, which remains unsustainable. Therefore, this study was conducted to analyze the sustainability level of agroforestry HR management using the MDS–Rapfish approach and to formulate a basis for policy recommendations to support sustainable agroforestry HR management.

Method

Time and Location of the Research

This research was conducted in Karyasari, Karacak, and Pabangbon Villages, located in Leuwiliang Subdistrict, Bogor Regency, West Java. The study sites were selected purposively from three of the ten villages in Leuwiliang Subdistrict that have agroforestry-based HR. Data collection took place from March 2024 to November 2025. Figure 1 shows the research sites of agroforestry private forests (HR) in three villages in Leuwiliang Subdistrict: Karacak, Karyasari, and Pabangbon. HR cover (Hutan_Lokasi and Kebun) is concentrated in Karacak and Karyasari Villages, while in Pabangbon Village, it follows the landform and river network patterns. Sustainability of agroforestry HR management was evaluated using the MDS–Rapfish method.

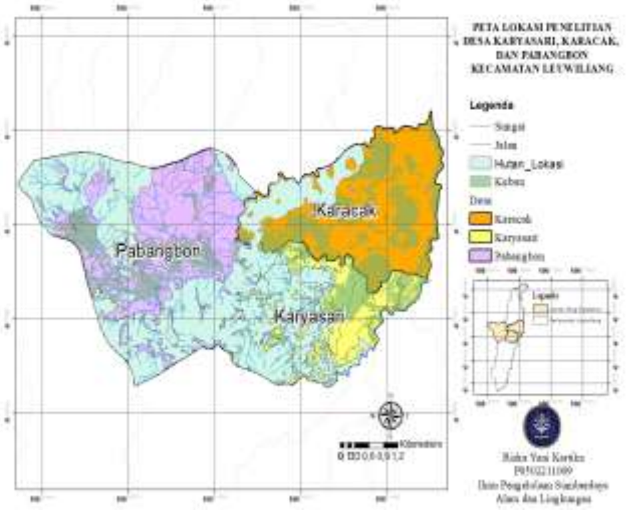

Figure 1. Study Area

Research Methods

The study used both primary and secondary data. Primary data were obtained through direct observation and in-depth interviews with stakeholders involved in agroforestry HR management, while secondary data were obtained from various relevant sources, including journals and related institutions that support this research.

Respondents, including KTH members and key actors, were selected using purposive sampling, and the sample size of KTH members was determined using Slovin's formula. With an error tolerance (e) of 10% or a 90% confidence level and a total KTH member population (N) of 95 people, Slovin's formula (Muntasib et al., 2018) is:

$$n = \frac{N}{1+Ne^2} \quad (1)$$

Description:

1 = Constant
n = Sample size
N = Population size
e = the allowable margin of error due to sampling error, which is set at 10% at a 90% confidence level.

$$n = \frac{95}{1+95(0.1)^2} = 48{,}72$$

Based on these calculations, the sample size used in this study was rounded to 49 KTH members distributed across the three study villages. Key actors involved in the sustainability analysis comprise three groups, as presented in Table 2: community, government, and company. These three actor groups represent field-level managers, extension and regulatory institutions, and forestry business actors. Their involvement is therefore important for understanding the roles and interests that influence the sustainability of agroforestry HR.

Table 2. Key actors in agroforestry HR management in Leuwiliang Subdistrict

Key Actors	Respondents
Community	Chairperson of KTH Taruna Tani
	Chairperson of KTH Manggis
	Chairperson of KTH Pabangbon
Government	Bogor Regency CDK (Forestry Branch Office)
	Bogor Regency BPP (Agricultural Extension Center)
	Ciliwung–Citarum Watershed Agency (Bapedas)
Company	Perum Perhutani

Research Stages

The sustainability analysis of agroforestry private forest management in Leuwiliang Subdistrict was carried out using the Multidimensional Scaling (MDS) method with the Rapfish tool to assess the sustainability index and status. The dimensions analyzed include ecological, economic, socio-cultural, institutional, accessibility, and technology. Each dimension was constructed from a set of attributes, and each attribute was evaluated using a 1–5 Likert scale, where higher scores (closer to 5) indicate better conditions and a higher level of sustainability. The resulting scores were then classified into sustainability status categories, as presented in Table 3. Table 4 shows the dimensions and attributes used in the MDS–Rapfish analysis. The selection of sustainability attributes for agroforestry-based private forests was based on the Forestry Law, relevant government regulations, scientific literature, and the views of key actors.

Table 3. Sustainability status categories based on MDS–Rapfish indices

Sustainability Index Value	Sustainability category
0-25	Bad (Unsustainable)
26-50	Less (Less sustainable)
51-75	Sufficient (sustainable enough)
76-100	Good (Very sustainable)

Source: (Fauzi, 2005)

Table 4. Scoring indicators for each dimension and attribute

Dimension	Code	Attribute	Score
Ecology	L1	Vegetated land cover	1-5
	L2	Felling intensity	
	L3	Agroforestry land-use efficiency	
	L4	Water source quality	
	L5	Selection of tree and crop species	

Dimension	Code	Attribute	Score
	L6	Type of soil conservation	
Economy	E1	Income from private forest farming	1-5
	E2	Farm operating costs	
	E3	Farm profit	
	E4	Landholding size	
	E5	Timber farm productivity	
	E6	Contribution of agroforestry income	
	E7	Contribution of forestry income	
	E8	Number of products from the land	
	E9	Number of household dependents	
Socio-Culture	S1	Health status	1-5
	S2	Community education level	
	S3	Welfare level	
	S4	Poverty level	
Institutions	I1	Community-based self-help extension organizations	1-5
	I2	Government extension organizations	
	I3	Agricultural and forestry extension programs	
	I4	Decision-making process in farmer groups	
	I5	Number of forestry and agricultural extension officers	
Accessibility and Technology	A1	Community access to cultivation activities	1-5
	A2	Agroforestry land management techniques	
	A3	Access to timber market information	
	A4	Distance from settlements to cultivation areas	
	A5	Road access to public service centers	
	A6	Land preparation	
	A7	Planting	
	A8	Type of harvesting system	
	A9	Post-harvest processing	

Data Analysis

Leverage analysis was used to identify the most sensitive indicators, as indicated by changes in Root Mean Square (RMS) values along the X-axis; the larger the RMS change, the greater the attribute's influence on sustainability status. Uncertainty analysis was then conducted using Monte Carlo simulations to evaluate the effect of random errors on index values at the 95% confidence level, comparing Monte Carlo indices with MDS indices. Goodness of fit in MDS is assessed using S-stress and the coefficient of determination (R^2); the model is considered acceptable if S-stress < 0.25 and R^2 approaches 1 (Fauzi, 2005).

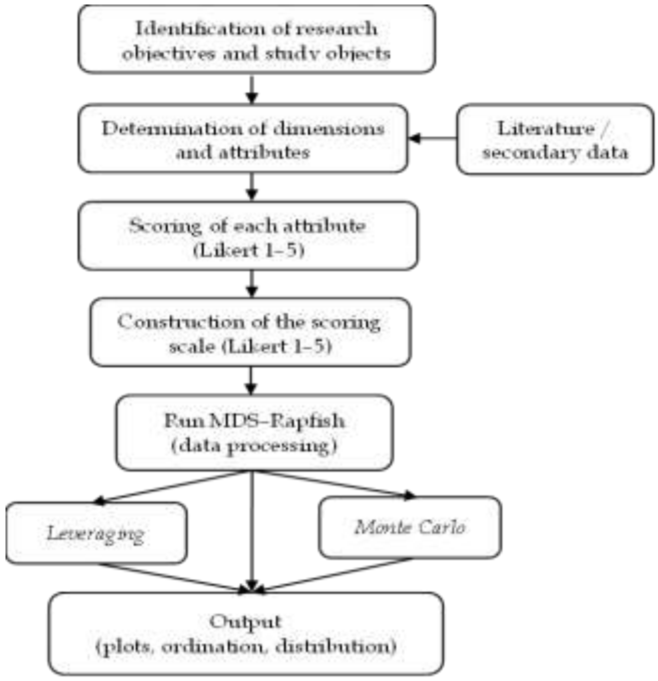

Figure 2. Stages of MDS-Rapfish (Fauzi, 2019).

The MDS–Rapfish analysis steps used in this study are briefly presented in Figure 2. The MDS–Rapfish results cover three main aspects: (1) sustainability index values for each dimension, (2) sustainability status categories, and (3) sensitive attributes (leverage analysis results). These were then combined with in-depth interview results from key actors. The combined quantitative and qualitative results were analyzed descriptively to derive implications and policy recommendations for sustainable agroforestry HR management in Leuwiliang Subdistrict.

Results and Discussion

MDS–Rapfish analysis shows that sustainability index values differ across dimensions. These differences are discussed in detail for each dimension, starting from the ecological dimension through to the accessibility and technology dimension.

Sustainability Index of the Ecological Dimension

The ecological dimension is a key factor in sustainable HR management. Figure 4 results indicate that the ecological dimension is in the Sufficient (sustainable enough). The sustainability index ranges from 0 to 100, with higher values indicating greater ecological sustainability. To see how this pattern differs between farmer groups, Figure 16 (kite radar chart) shows, ecological index of KTH 2 (57.45) is lower than that of KTH 1 (60.76) and KTH 3 (65.30), because some of the HR areas have been converted to horticultural crops, such as vegetables, which reduce canopy cover and stand stratification. The literature shows that tree cover in agroforestry systems maintains microclimate conditions, reduces runoff and erosion, maintains carbon and litter stocks, and supports biodiversity. In contrast, conversion to annual crops tends to reduce these indicators (Castle et al., 2022).

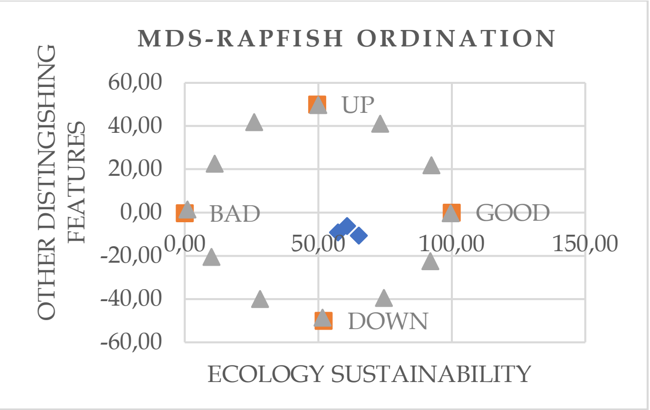

Figure 3. Sustainability Status Index of the Ecological Dimension

Leverage analysis identifies three attributes as the most sensitive in the ecological dimension: logging intensity, soil conservation type, and plant species selection.

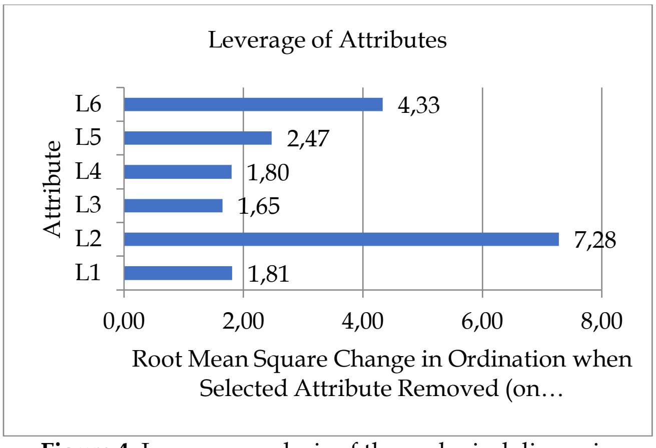

Figure 4. Leverage analysis of the ecological dimension

Due to Figure 4, the most sensitive attribute is logging intensity (L2). Low logging intensity due to low timber prices and limited access to timber markets encourages HR farmers to postpone harvesting, helping to maintain canopy cover (Budiaman & Hardjanto, 2023). Under preserved canopy conditions, HR farmers tend to choose species that provide short-term economic benefits, such as fruit trees and non-timber forest products (e.g., honey).

The second most sensitive attribute is soil conservation type (L6). All KTHs in Leuwiliang Subdistrict have implemented fairly good soil conservation practices. Huang et al. (2022) classify soil and water conservation techniques into four types: vegetative, land management, structural, and combinations of these. In the three KTHs, combinations of these techniques have been applied. On gently to moderately sloping agroforestry HR land, vegetative conservation through agroforestry is combined with intercropping.

Mechanically or structurally, some critical land (roadside or riverbanks) has been equipped with check dams or gabions. These structures reduce flow velocity, control erosion, trap upstream sediment, stabilize channel beds, and improve water quality (Ediş et al., 2023). The combination of conservation practices implemented in the three KTHs explains why the ecological dimension tends to be maintained and classified as Sufficient (sustainable enough).

Sustainability Index of the Economic Dimension

Figure 5 presents the MDS–Rapfish results for the nine attributes in the economic dimension. The indices for all KTHs are below 50, placing them in the less sustainable category. In MDS–Rapfish, values closer to 0 indicate lower economic sustainability, whereas values approaching 100 indicate better conditions. Leverage analysis identifies three sensitive attributes in the economic dimension (Figure 6): contribution of agroforestry income (E7), farm productivity (timber) (E5), and number of household dependents (E9). The most sensitive attribute is the contribution of agroforestry income. Products such as honey, mangosteen, durian, coffee, and vegetables are the main sources of HR farmer income, while income from timber is relatively low and corresponds to low timber productivity.

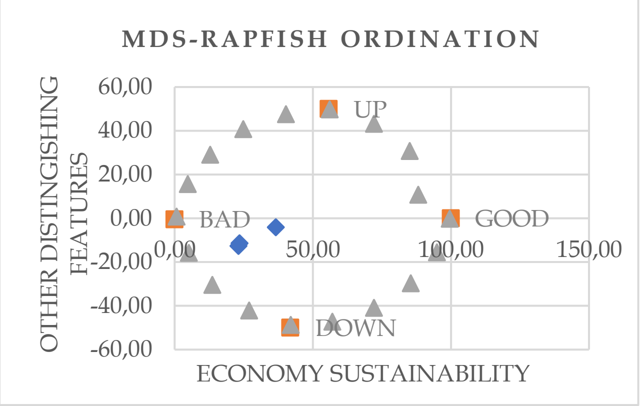

Figure 5. Sustainability Status Index of the Economic Dimension

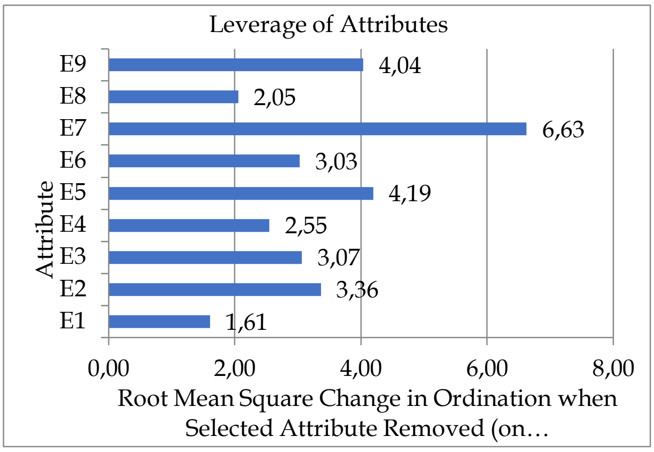

Figure 6. Leverage analysis of the economic dimension

Most agroforestry HR farmers in KTH 2 have shifted to vegetable cultivation, with timber trees maintained mainly as boundary plantings rather than as production commodities comparable to vegetables. This difference in cropping patterns is clearly shown in the land conditions of KTH 1 and KTH 2. In KTH 1 (Figure 7), the main commodities are mangosteen trees and trigona honey production.

Figure 7. Land Cover in KTH 1

Figure 8 shows that in KTH 2, land cover is dominated by annual vegetables. Although vegetable cultivation increases opportunities for short-term income, it simultaneously reduces the ecological functions of private forests.

Figure 8. Land Cover in KTH 2

For many farmers, the motivation to plant trees tends to be lower than for planting crops that provide short-term profits (Race et al., 2016). Limited market knowledge often leads smallholders to sell trees below market prices and at suboptimal felling times. Low motivation among HR farmers is exacerbated by low timber prices, poor access to timber markets, and the role of middlemen. Farmers often sell standing trees directly to middlemen because it is easier to access, but this practice suppresses timber prices.

The following sensitive attribute is the number of dependents. Ordinal scoring of attributes shows that household dependents significantly influence economic sustainability. On average, households have 3–4 dependents. Households with more dependents tend to be more food insecure (Ruslan, Prasetyo, et al., 2023). In the context of dryland farming, socio-demographic factors, including household size, correlate with food security; large consumption burdens without adequate income reduce household welfare.

Sustainability Index of The Socio-Cultural Dimension

Figure 9 presents the results of the analysis of the four attributes in the socio-cultural dimension, showing that the sustainability indices of all KTHs are below 50 and therefore fall into the “less sustainable” category. In this dimension, the lower the points' positions on the 0–100 social sustainability axis, the lower the socio-cultural sustainability level of HR management.

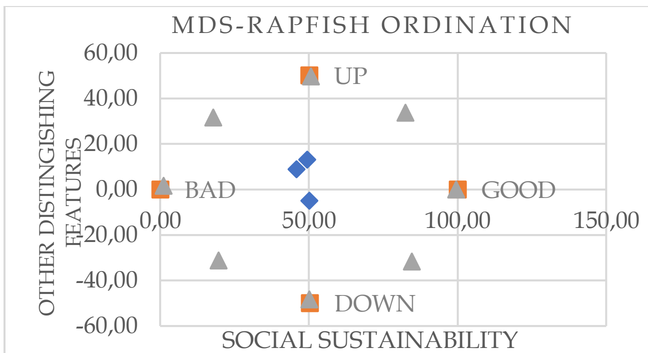

Figure 9. Sustainability Status Index of the Socio-Cultural Dimension

Leverage analysis identifies community welfare level (S3) as the most sensitive attribute (Figure 10), influenced by HR farmers' income and food expenditure. Interviews reveal that the monthly household incomes of HR farmers range from IDR 1,000,000 to 2,000,000, far below the decent living needs (KHL) in Bogor Regency. KHL is the standard of monthly expenditure for a single worker and is used as the basis for setting minimum wages. With this reference, households with per capita income ≥ KHL are categorized as more prosperous, while those with <

KHL are considered vulnerable. The KHL, based on the 2018 Bogor Regency minimum wage, is IDR 3,483,667.39.

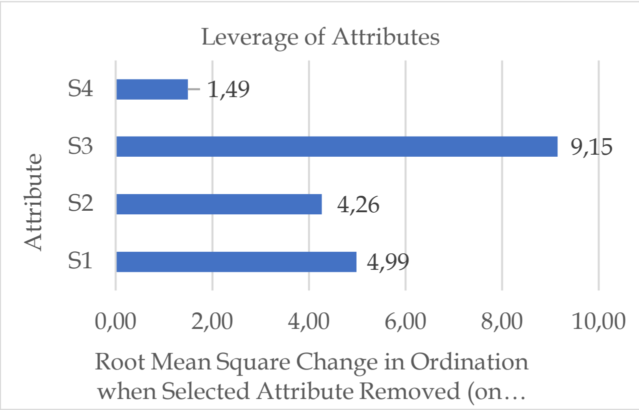

Figure 10. Leverage Analysis Chart of the Socio-Cultural Dimension

The second factor affecting community welfare is food expenditure. Household surveys indicate that farm households allocate 40% of income to food and 60% to non-food expenditure (Nadila & Mayangsari, 2025). A relatively high food share limits spending on education, health, and social activities, thereby reducing social welfare, especially since HR income alone is insufficient to cover monthly food costs. This pattern is consistent with Engel's Law: the larger the share of food expenditure, the more vulnerable household welfare becomes (Widarjono & Mumpuni Rucbha, 2016).

Sustainability Index of The Institutional Dimension

Figure 11 shows the results of the analysis of each attribute in the institutional dimension, indicating that the index values fall into the "less sustainable" category. On the MDS–Rapfish scale, points farther from 100 and approaching 0 reflect weak institutional support for the sustainability of agroforestry HR management.

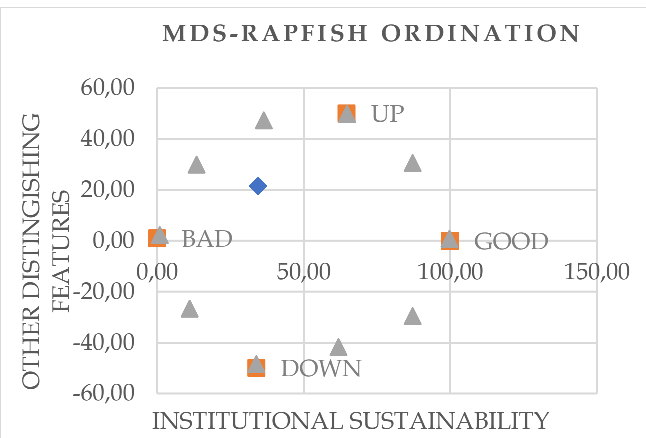

Figure 11. Sustainability Status Index of the Institutional Dimension

Leverage analysis (Figure 12) identifies three sensitive attributes in the institutional dimension: agricultural and forestry extension programs (I3), community-based self-help extension organizations (I1), and decision-making processes in farmer groups (I4). For extension programs, interviews with the Forestry Branch Office (CDK) indicate that CDK conducted up to 50 extension or facilitation sessions for KTH 1 and KTH 2 in 2023. However, KTH 3 has not yet been reached due to limited access, resulting in lower scores for this attribute. In contrast, the Agricultural Extension Center (BPP) has provided agricultural extension services to all three KTHs.

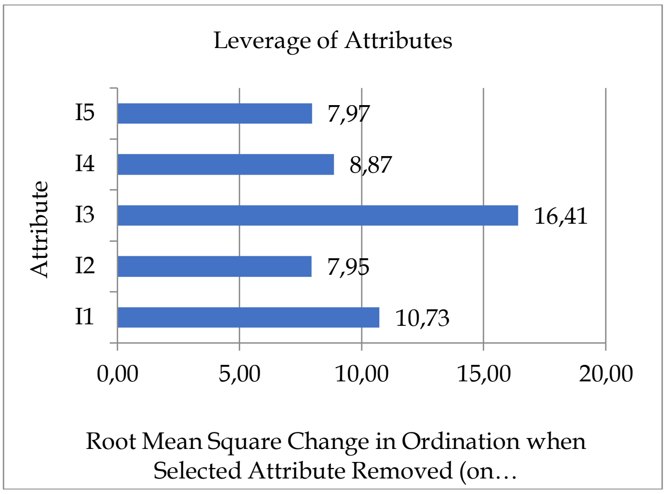

Figure 12. Leverage Analysis Chart of the Institutional Dimension

The second sensitive attribute is community-based extension organizations. The number of self-help extension workers (penyuluh swadaya) in Leuwiliang Subdistrict is adequate, as each KTH has at least one such worker. Most self-help extension workers are respected farmer leaders, such as chairs of farmer groups or women's farmer groups. This is consistent with previous findings that self-help extension workers are often farmer group leaders (Riana et al., 2015). Their roles mainly involve facilitating farmers' access to credit, connecting them with input suppliers, and collaborating with farmers to assess location-specific technologies (Amanah et al., 2025).

The third sensitive attribute is the decision-making process, which often centers on a single individual—the farmer group leader. Community or member participation is crucial for effective organizational performance (Hendriawan et al., 2023). However, KTH members' participation remains limited; many attend meetings formally but contribute few ideas to program formulation. Ideally, KTHs should grow from farmers' internal initiatives to cooperate in farming activities to achieve optimal results (Mardikanto & Soebiato, 2012).

Overall, these results suggest that improving institutional performance can be achieved by expanding extension services to all KTHs, clarifying the roles of self-help extension workers to avoid role overlap, and strengthening inclusive and accountable deliberation mechanisms. Such measures are expected to increase institutional scores and strengthen HR management sustainability in Leuwiliang Subdistrict.

Sustainability Index of The Accessibility and Technology Dimension

The results of the analysis of the nine attributes in the accessibility and technology dimension, as shown in Figure 13, fall into the "less sustainable" category. Overall, the index values remain within the less sustainable range, as the sustainability scores of the KTHs have not exceeded the threshold index value of 50.

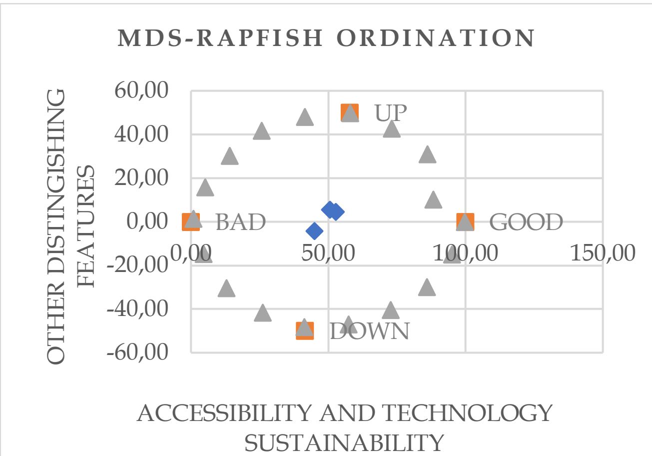

Figure 13. Sustainability Status Index of the Accessibility and Technology Dimension

Based on the leverage analysis, three attributes were identified as sensitive to the sustainability level of the accessibility and technology dimension (Figure 14), namely: access to timber market information (A3), land preparation (A6), and planting (A7). The most sensitive attribute is access to timber market information. Access of agroforestry HR farmers to timber markets is highly dependent on middlemen. Farmers sell their timber through middlemen for reasons of convenience and practicality. As a result, their bargaining position remains weak because middlemen can set buying prices unilaterally (Sudrajat et al., 2016). The second sensitive attribute is land preparation. Conversion of agroforestry HR to vegetable fields requires more intensive land preparation than fruit-based gardens. Vegetable cultivation demands more standardized and intensive management, including soil tillage, raised bed construction, mulching, basal fertilization, and irrigation arrangement before planting.

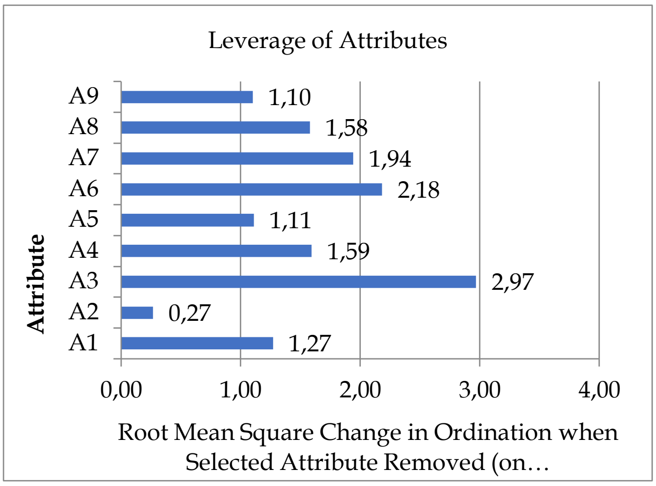

Figure 14. Leverage Analysis Chart of the Accessibility and Technology Dimension

The third sensitive attribute is planting systems. In all three KTHs, agroforestry HR generally adopts mixed/multistrata gardens combining various timber trees, fruit trees, and annual crops (Pranoto & Yuni, 2025). These are arranged through spacing, intercropping, and planting patterns consistent with land suitability. However, the accessibility and technology dimension indices remain in the less sustainable category. Strengthening access to market information and marketing institutions via partnership schemes, along with improving standardized land preparation (standard operating procedure), are key to improving sustainability in this dimension.

Multidimensional Sustainability of Agroforestry HR Management.

Table 5 shows that only the ecological dimension is in the Sufficient (sustainable enough), whereas the other four dimensions remain less sustainable. This pattern is visualized more clearly in the radar (kite) diagram.

Table 5. Multidimensional Analysis Values

Dimension	Sustainability Index (%)	Sustainability Category
Ecology	61.17	Sufficient (sustainable enough)
Economy	27.86	Less (less sustainable)
Socio-Cultural	48.50	Less (less sustainable)
Institutional	34.48	Less (less sustainable)
Accessibility and Technology	49.53	Less (less sustainable)
Multidimensional	44.31	Less (less sustainable)

Source: Data analysis result, 2025

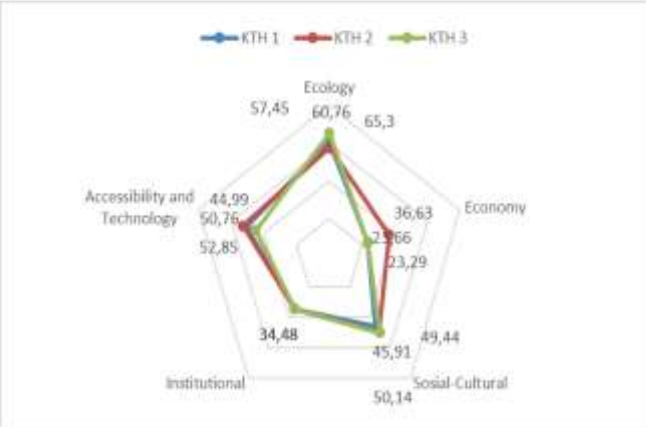

Figure 15. kite Radar Chart

Figure 15 shows the sustainability indices for the five dimensions on a 0–100 scale, where values closer to 100 indicate higher sustainability, while values approaching 0 indicate lower sustainability. The radar (kite) pattern illustrates that the ecological dimension has the highest index, so the ecological aspect of agroforestry HR can be categorized as fairly sustainable. Conversely, the economic dimension has the lowest index and is approaching 0, indicating that the economic aspect remains less sustainable. The institutional dimension has the second-lowest value, with an index that remains below 50. In contrast, the socio-cultural, accessibility, and technology dimensions have indices slightly above 50 but are still classified as less sustainable.

Monte Carlo analysis results (Table 6) for all five dimensions compared with MDS analysis show that the differences between Monte Carlo and MDS indices are all below 5%, indicating that attribute selection and scoring are sufficiently accurate (Brown et al., 2025).

Table 6. Differences in Sustainability Index Values from MDS and Monte Carlo Analyses

Dimension	Sustainability Index Value MDS	Sustainability Index Value Monte Carlo	Difference (%)
Ecology	61.17	60.22	0.91
Economy	27.86	29.12	1.26
Socio-Cultural	48.50	48.12	0.37
Institutional	34.48	35.69	1.21
Accessibility and Technology	49.53	49.43	0.24

Source: Data analysis result, 2025

Table 7 shows that MDS–Rapfish results have S-stress values <0.2 and R^2 values close to 1. The combination of low stress and high R^2 indicates a good goodness of fit, meaning that the MDS ordination configuration represents the data reasonably well and that more than 90% of data variation is explained by the model. Although the socio-cultural dimension has the highest stress and lowest R^2 among the five dimensions, its values remain within acceptable limits. Overall, MDS–Rapfish results across all dimensions can serve as a basis for assessing agroforestry HR sustainability indices and status in Leuwiliang Subdistrict.

Table 7. Stress values and R^2 values

Dimension	Stress Value (%)	R^2
Ecology	0.1497	0.9385
Economy	0.1404	0.9474
Socio-Cultural	0.1953	0.9047
Institutional	0.1538	0.9281
Accessibility and Technology	0.1625	0.9385

Source: Data analysis result, 2025

Policy Directions Based on the Sustainability Index

Leverage analysis indicates that three attributes are the most sensitive to changes in sustainability status (Table 8). These three attributes are key to prioritizing efforts to improve agroforestry HR sustainability in Leuwiliang Subdistrict.

Table 8. Most Sensitive Attributes Based on MDS–Rapfish Results

Dimension	Attribute	RMS
Institutional	Agricultural and forestry extension programs	16.41
Socio-Cultural	Welfare level	9.15
Ecology	Felling intensity	7.28

Source: Data analysis result, 2025

The role of extension programs has a considerable influence on the sustainability of agroforestry HR. When the content and direction of these programs run counter to sustainability principles, the sustainability status of the institutional dimension tends to decline. At present, agricultural extension officers are relatively more active in promoting the cultivation of short-cycle vegetables to pursue short-term income. In contrast, the role of CDK as a forestry extension institution is less prominent in guiding farmers towards more sustainable agroforestry practices. This situation creates a lack of synergy in extension activities: agricultural extension tends to emphasize short-term horticultural enterprises without fully considering the ecological functions of timber and fruit stands, whereas forestry extension has not yet been able to offer sufficiently attractive short-term income schemes for farmers. As a result, pressure to convert HR into horticultural land continues.

The second most sensitive attribute is the level of community welfare. A decline in farm household income directly reduces welfare levels, which in turn lowers the sustainability index of agroforestry HR management. When income from HR decreases, farmers tend to open or convert forest land into short-term horticultural crops to meet daily income needs. This pattern negatively affects the ecological dimension, as canopy cover is reduced and the stands' ecological functions weaken.

The third most sensitive attribute is logging intensity. Logging intensity is closely related to ecological sustainability because the frequency and number of trees harvested will affect stand continuity and canopy cover. Repeated logging without replanting or strengthening of appropriate planting patterns can reduce the ecological functions of agroforestry HR. Therefore, regulating logging intensity more carefully, along with efforts to maintain productive stands and to replant harvested plots, is essential to maintain ecological stability and improve the ecological dimension's sustainability index.

Table 9. Interviews with Key Actors

Questions	Key Persons	Yes/No
Need for synergy in agroforestry management	Community	Yes
Increasing income from agroforestry	Goverment	Yes
Agroforestry programs that promote vegetation cover	Company	Yes

Based on Table 9, the views of key actors are consistent with the sensitive attributes identified by the MDS–Rapfish analysis. This implies that policy directions for agroforestry HR management should prioritize collaboration between agricultural and forestry extension programs that explicitly encourage farmers to adopt productive and sustainable agroforestry practices. Extension materials should be integrated so that extension officers from CDK and BPP deliver aligned messages, namely to maintain economically valuable timber and fruit trees (such as mangosteen, durian, and coffee) in combination with annual crops and to utilize non-timber forest products, such as honey, as sources of short-term income. Such a pattern is expected to maintain canopy cover and ecological functions (related to the logging intensity attribute), while also broadening farm households' income sources and contributing to improved welfare levels. Thus, simultaneous intervention in the attributes of extension programs, logging intensity, and community welfare can serve as a policy basis for strengthening the sustainability of agroforestry HR in Leuwiliang Subdistrict.

Conclusion

The MDS–Rapfish analysis across five dimensions shows that, overall, agroforestry HR management in Leuwiliang Subdistrict is still in the less sustainable category. If weaknesses in the other dimensions are not addressed, there is a concern that, in the long term, they may reduce the ecological dimension's sustainability index by increasing the conversion of agroforestry HR into short-term horticultural land.

The leverage analysis identified three attributes as the most sensitive to changes in sustainability status. Strengthening synergy between agricultural and forestry extension programs is needed to fully optimize agroforestry programs, rather than merely promoting short-term enterprises. Improving farm household welfare through the development of more productive and economically valuable agroforestry systems is expected to reduce the tendency to convert HR into short-term horticultural crops. In addition, regulating logging intensity, accompanied by replanting and maintaining productive stands, is essential to maintaining canopy cover stability and ecological functions. Targeted strengthening of these three key attributes is expected to improve the sustainability index across dimensions.

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There are no conflicts of interest to declare.

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