SUSTAINABLE DEVELOPMENT STRATEGY FOR THE AGROINDUSTRY OF THE JAVA IJEN RAUNG SPECIALTY ARABICA COFFEE (*COFFEA ARABICA* L.)

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Abstract. Specialty Arabica coffee that meets the standards of the Specialty Coffee Association (SCA) is Java Ijen-Raung Arabica coffee. However, the superiority of arabica coffee production in Bondowoso Regency is not yet aligned with the development of its processing industry. The problems in the coffee agroindustry are multidimensional. This article aims to assess the sustainability of the Java Ijen-Raung Arabica coffee agroindustry. Sampling was conducted using a purposive sampling method. The respondents in this study included 307 coffee farmers and 32 respondents from coffe processing (Micro, Small, and Medium Enterprises) MSME entrepreneur and key informants. The data analysis used Multidimensional Scaling (MDS) and prospective analysis. The analysis results show that the development status of the Java Ijen Raung specialty Arabica smallholder coffee agroindustry is moderately sustainable. The Multidimensional Scaling (MDS) analysis identified 10 sensitive indicators as key factors in improving sustainability status, which is a crucial factor. Based on the prospective analysis, strategies fall into Quadrants I and II, indicating that the priority strategies for developing the Java Ijen-Raung specialty Arabica coffee agroindustry are determined by driving and leverage variables. The role of financial institutions and coffee farmer institutional associations serve as driving variables that stimulate the other eight key factors.
Keyword: *multidimensional scalling, quite sustainability, key factors, driving variabels, coffee processing*

Introduction

Coffee stands as one of the most traded commodities worldwide, deeply embedded in the daily routines of millions. This global industry engages both multinational corporations and small-scale farmers, with the latter comprising the majority of producers (Bager and Lambin, 2020). Ranked second among internationally traded goods (Murthy and Madhava Naidu, 2012) coffee production in Indonesia positions the country as a leading exporter, trailing only Vietnam, Brazil, Colombia, and India. For over ten years, Indonesia has maintained its place within the top ten coffee-exporting nations, accounting for roughly 3.69% to 8.34% of global exports (International Coffee Organization, 2022).

Sustainable agriculture remains a pivotal focus within broader sustainable development efforts, characterized by intricate dynamics between human activity and environmental stewardship. Key obstacles include financial constraints, insufficient awareness of sustainable farming practices, and the capacity of farmers to implement such systems effectively (Hajjar et al., 2019). Advancing sustainable agroindustry represents a critical strategy to address these challenges (Da Silva Medina and Pokorny, 2022). As emphasized by Reytar et al. (2020), the coffee agroindustry's growth must align with

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sustainability frameworks spanning five key dimensions: economic, social, ecological, technological, and institutional.

Recognized as a cornerstone of the 2030 sustainable development agenda (Global Coffee Platform, 2021), the coffee sector's future hinges on resource availability, product quality, and sustainable productivity. These factors are vital for the well-being of communities and stakeholders across the value chain, with economic, social, and environmental sustainability being paramount concerns for the International Coffee Organization (Pancsira, 2022).

In Indonesia, East Java emerges as a prominent hub for coffee cultivation, ranking fourth in national production. The region boasts 92,185 hectares of plantations and an annual output of 47,109 tons (East Java Plantation Office, 2023). Notably, East Java's Arabica coffee from the Ijen Raung area has earned international acclaim as a specialty product, often marketed under the distinguished "Java Coffee" label (Sari et al., 2013).

This Arabica coffee is grown on the slopes of Mount Ijen-Raung in Bondowoso Regency, hence the name Java Ijen Raung Arabica Coffee (Cristantoa et al., 2018). Arabica coffee that is cultivated in specific regions to produce coffee with a geographical indication label is known as specialty grade coffee (Qian, 2020). Specialty Arabica coffee is sold at a higher price compared to Robusta coffee. Bondowoso Regency holds significant potential in coffee plantation development but faces complex challenges. Efforts to increase the production of Java Ijen Raung specialty Arabica coffee are currently still hindered. In general, the development of smallholder coffee plantation agroindustry in Bondowoso faces issues such as traditional cultivation methods and unstandardized processing practices, resulting in coffee products that do not meet market demand standards. In addition to these issues, the income of smallholder coffee agroindustry actors in Bondowoso currently relies heavily on the sale of coffee beans (Wardhana et al., 2016).

The challenges confronting the coffee agroindustry are inherently multidimensional. Reytar et al. (2020) argue that the advancement of this sector must adhere to sustainable development principles encompassing five key dimensions: economic, social, environmental, technological, and institutional. Given the intricate nature of these interrelated factors, ensuring the sustainability of the Java Ijen Raung specialty Arabica coffee agroindustry becomes imperative.

A study conducted by Wardhana et al. (2023) in Bondowoso Regency revealed that institutional restructuring within the coffee agroindustry primarily focuses on enhancing product quality, productivity, market accessibility, and human resource capacity. Sustainable agricultural practices play a pivotal role in this sector, as emphasized by Wibowo et al. (2021) who highlight the significance of downstream agroindustrial development in boosting the value-added potential of Java Ijen Raung Arabica coffee. Their findings suggest that processed coffee products in Sumberwringin District hold substantial promise. Additionally, Mukhsin et al. (2023) identified that effective policy formulation, monitoring, and evaluation by local governments are critical drivers in fostering the long-term growth of Arabica coffee agribusiness. The purpose of this study is to analyze the sustainability of the development of smallholder Arabica coffee agroindustry in Bondowoso Regency and to formulate strategies for improving its sustainability. The novelty of this research lies in its comprehensive view of sustainability, from upstream to downstream aspects of coffee agroindustry development. Bondowoso Regency has great potential due to the uniqueness of its Java Ijen Raung specialty Arabica coffee production, but its management has not been optimized and

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requires solutions for further development. This research was conducted in Bondowoso Regency from September to November 2024.

Research method

Bondowoso Regency was chosen as the study site due to its unique status as the exclusive cultivation area for Java Ijen Raung specialty Arabica coffee, an endemic variety. Izzah et al. (2018) note that much of Bondowoso consists of highland terrain, with altitudes varying between 900 and 2,000 meters above sea level. The research encompassed four districts: Sumberwringin, Botolinggo, Ijen/Sempol, and Cerme (*Figure 1*). Participants included coffee farmers, micro and small-to-medium enterprise (MSME) operators, and other relevant stakeholders. A snowball random sampling technique was employed to select 307 Arabica coffee farmers, alongside 32 MSME representatives. Data were gathered through surveys, interviews, and observational methods from September to November 2024. Additionally, insights were obtained from key informants to assess the production dynamics of Java Ijen Raung Arabica coffee. These informants comprised representatives from Perhutani (State Forestry Company), PT Perkebunan Nusantara XII (a state-owned plantation enterprise), the Indonesian Coffee Association, leaders of farmer groups and coffee processing units, local agricultural officials, and academic specialists. Their contributions facilitated a comprehensive evaluation of critical factors in the agroindustrial development of Java Ijen Raung Arabica coffee through prospective analysis.

The study adopted a two-phase analytical approach: sustainability assessment and prospective analysis. The sustainability evaluation utilized the Multi-Dimensional Scaling (MDS) technique (Pitcher et al., 2013; Riptanti et al., 2021; Irianto et al., 2021) implemented via the Rapid Appraisal for the Development of the Agroindustry of Java Ijen Raung Coffee (RAP-DACOJARA). This method, adapted from RAP-FISH (Pitcher et al., 2013; Riptanti et al., 2021). incorporated sustainability indicators derived from prior studies on Arabica coffee agroindustry (Yudhari et al., 2020; Yusuf et al., 2022; Ulya et al., 2023; Sia et al., 2025a), alongside field observations and expert consensus. Each attribute was scored on a scale of 0 (worst) to 4 (best), with intermediate values (2 or 3) assigned based on predefined criteria (*Table 1*). These scores, tailored to reflect empirical and expert-derived benchmarks, were analyzed using MDS to determine sustainability positioning between optimal and suboptimal thresholds. Maximum score for a "good" category does not necessarily have to be 4, as the scoring scale is often adapted to reflect the specific characteristics of each attribute, the local context, and limitations in data availability. Certain attributes may only exhibit two or three meaningful levels, making it appropriate for the highest score—indicating a "good" condition—to be set at 2 or 3. This scoring adjustment also serves to ensure a balanced influence of each attribute in determining the overall MDS configuration.

The study examined 60 attributes across five dimensions: ecological (10 attributes), economic (14), technological (15), social (11), and institutional (10). The RAP-DACOJARA analysis followed a structured protocol: First, Attribute Selection: Indicators for each dimension were identified based on literature and expert consultation (Widiastuti et al., 2024). Second, Scoring: Attributes were scored using Excel, guided by established references (Rachmina et al., 2024). Third, Ordination Analysis: The RAP-DACOJARA ordination was computed to derive ordination and stress values. Fourth, Sustainability Indexing: Dimension-specific and aggregate sustainability indices were

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calculated on a 0–100 scale (0 = poor, 100 = excellent), categorized into four sustainability tiers (*Table 2*). Fifth, Leverage Analysis: Sensitivity of attributes was assessed via the Root Mean Square (RMS) method (Yudhari et al., 2020), informing strategy development based on pivotal factors (Rachmina et al., 2024).

Map of the Research Area
Bondowoso District, East Java Province, Indonesian

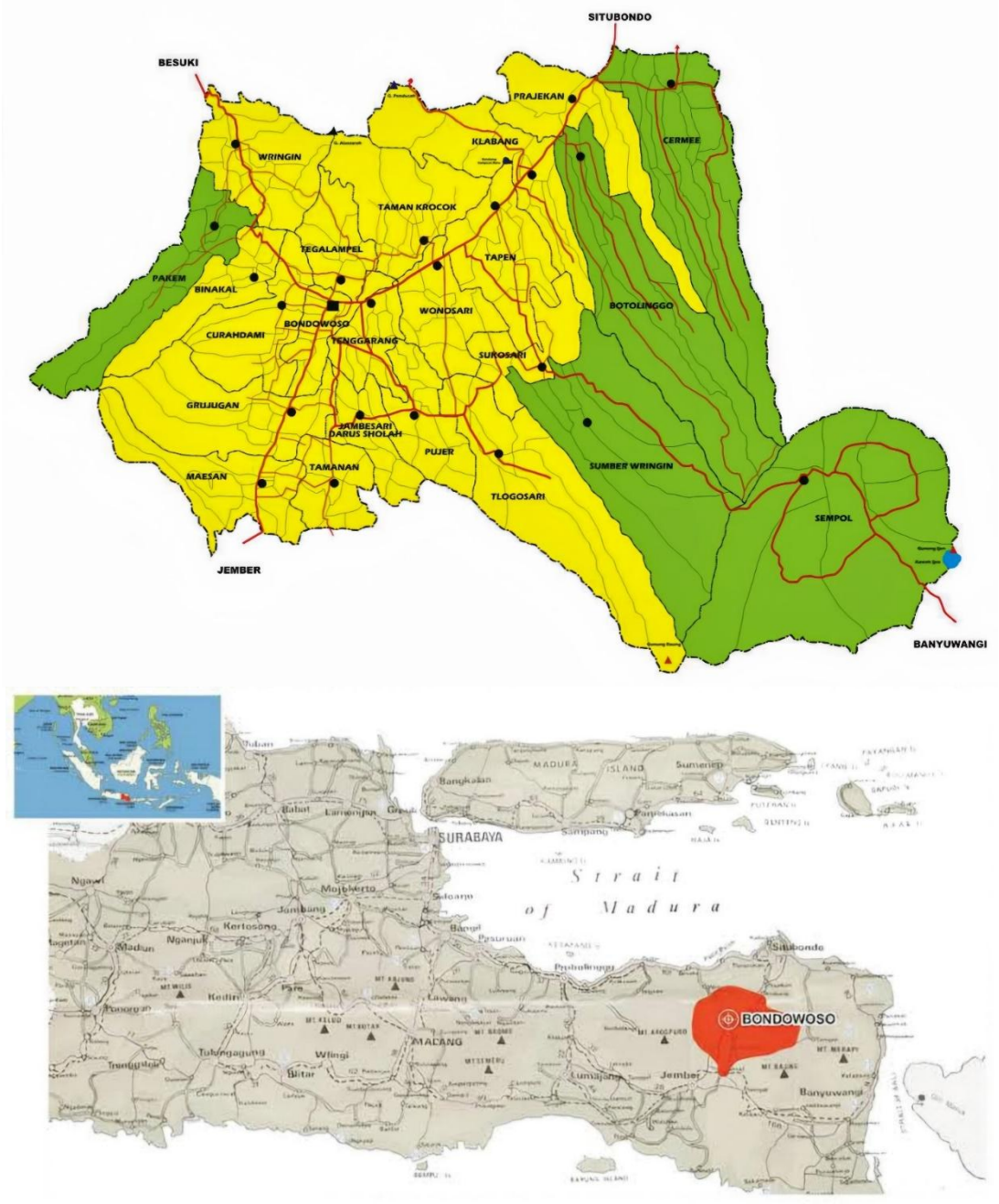

Figure 1. *Geographic indication area of Java Ijen Raung Specialty Arabica Coffee in Bondowoso Regency, East Java Provience, Indonesia*

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Table 1. *Assessment attributes for the development of Java Ijen Raung arabica coffee agroindustry*

Attribute	Classification	
	Good	**Bad**
Ecological Dimension		
Climate	2	0
Soil texture	2	0
Water conservation	3	0
Land conservation	4	0
Land suitability	3	0
Shade plants	3	0
Application of organic fertilizer	3	0
Utilization of coffee farm waste	3	0
Utilization of coffee husks	3	0
Coffee processing sanitation	4	0
Economic Dimension		
Land ownership status	4	0
Coffee productivity	3	0
Farmers' income level	3	0
Farmers' capital sources	4	0
Access to export markets	3	0
Profit-sharing system	3	0
Availability of raw materials	4	0
Product marketing	4	0
Quantity of processed coffee	4	0
Price of processed coffee	4	0
Capital sources for MSME actors	3	0
Ease of accessing agricultural inputs	4	0
Market coverage	4	0
Quality of processed coffee	4	0
Techonological Dimension		
Availability and use of superior seeds	3	0
Mastery of Good Agricultural Practices (GAP)	3	0
Mastery of post-harvest technology	3	0
Canopy pruning	3	0
Fertilization timing	3	0
Mastery of marketing techonology	4	0
Added Value	3	0
Harvest storage technology	2	0
Coffee processing methods	4	0
Coffee product packaging	4	0
Implementation of GMP (Good Manufacturing Practices) for coffee MSMEs	4	0
Completeness of processing equipment	4	0
Equipment damage	4	0
Processed product promotion media	4	0
Product quality standards	3	0
Social Dimension		
Community support	4	0
Participation in sustainable agriculture outreach	4	0
Farmers' education level	4	0

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Attribute	Classification	
	Good	Bad
Ecological Dimension		
Family member participation in managing sustainable coffee agroindustry	4	0
Role of farmer groups	4	0
Role of coffee associations/communities	3	0
Motivation in running a sustainable agroindustry	4	0
Conflict status	4	0
Experience in the coffee industry	4	0
Community empowerment	3	0
Role of processing units	2	0
Institutional Dimension		
Frequency of extension and training activities	3	0
Existence of farmer groups	4	0
Capacity development for farmers	4	0
Coffee farmers' institutional associations	4	0
Business organizational structure	4	0
Role of financial institutions	3	0
Role of private institutions	3	0
Role of marketing institutions	3	0
Role of agricultural cooperatives	4	0
Role of related government agencies	4	0

Sources: Wardhana et al. (2023), Pawiengla et al. (2020), Hosseini (2011), Yudhari et al. (2020), Sia et al. (2025a)

Table 2. *Sustainability status of the Java Ijen-Raung arabica coffee agroindustry development*

Index Value	Sustainability Status
$0 < \text{index} \leq 25$	Not sustainable
$25 < \text{index} \leq 50$	Less sustainable
$50 < \text{index} \leq 75$	Moderately sustainable
$75 < \text{index} \leq 100$	Sustainable

Source : (Irianto et al., 2021)

In the subsequent phase, sustainability-sensitive attributes were subjected to prospective analysis to point key factors. This process aimed to prioritize strategies for enhancing sustainability (Irianto et al., 2021).

The prospective analysis was employed to evaluate the relative influence and interdependence of critical factors affecting the sustainable development of Java Ijen-Raung specialty Arabica coffee agroindustry. This analysis incorporated all sustainability dimension scores, which collectively represent the key determinants of agroindustrial viability (Tarihoran et al., 2024). The study utilized Exsimpro software for data processing (Irianto et al., 2021).

The results of the prospective analysis are presented in *Figure 2*, which is divided into four quadrants: 1) Quadrant I: High influence but low dependency on other factors; 2) Quadrant II: High influence and high interdependence; 3) Quadrant III: Low influence but high reliance on external factors; 4) Quadrant IV: Limited influence and minimal dependency (Bourgeois and Jeaua, 2004).

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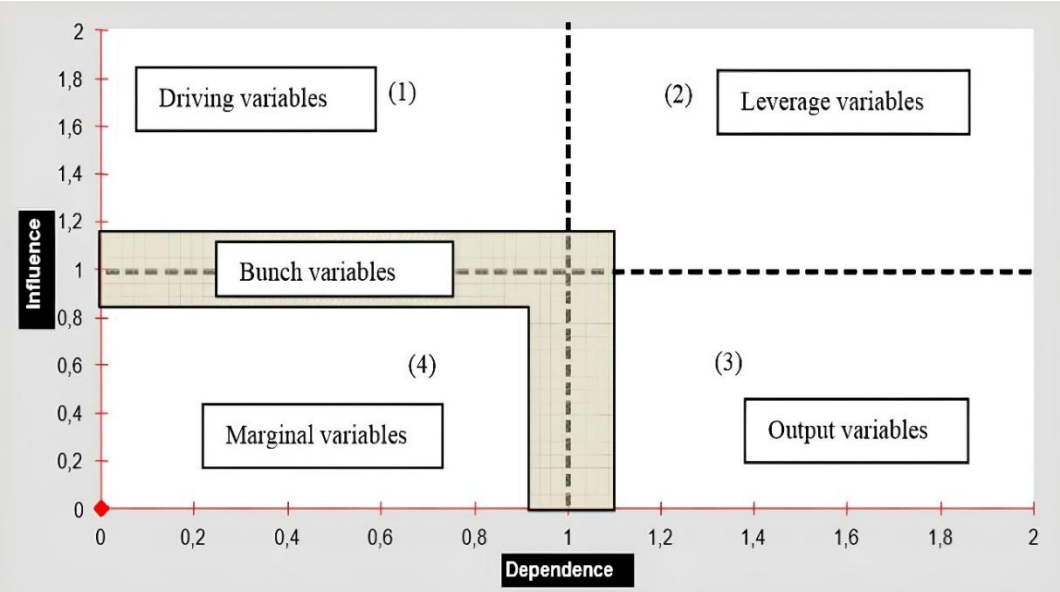

Figure 2. *Levels of influence and dependency among factors in the system. Source: Bourgeois and Jeaua (2004)*

Results and discussion

The RAP-DACOJARA multidimensional sustainability analysis yielded a composite index of 57.20, classifying the agroindustry as moderately sustainable. While this indicates a functional sustainability baseline, targeted interventions are necessary to enhance weaker dimensions.

Individually, the sustainability index for each dimension is as follows: Environmental: 60.92 (Moderate), Economic: 60.74 (Moderate), Technological: 73.58 (Moderate), Social: 49.05 (Less Sustainable), Institutional: 41.73 (Less Sustainable). These results align with prior research (Khasan et al., 2015; Pawiengla et al., 2020; Parmawati et al., 2022), confirming that smallholder coffee systems often exhibit moderate sustainability, with social and institutional dimensions lagging. Strategic improvements in these areas are critical for long-term viability. Visual representations of these indices are provided in *Figures 3, 4, 5, 6, and 7.*

Figure 3 shows that the environmental dimension is moderately sustainable. This indicates that the environmental aspect provides sufficient support for the development of the Java Ijen Raung specialty Arabica coffee agroindustry. The cultivation of this coffee is conducted on land that meets the growing requirements of Arabica coffee, at an altitude between 900–1,600 meters above sea level (Rokhmah et al., 2023). When compared to a similar study in Silo District, Jember, the environmental sustainability index was 33.38 (Pawiengla et al., 2020). The higher index found in this study suggests that the environmental conditions in the Ijen Raung area are more suitable. However, the value is slightly lower than the findings of Parmawati et al. (2022) which reached a sustainability index of 61.8. This difference is attributed to variations in conservation practices, shade tree density, and local environmental policies. A notable finding in this dimension is the use of local wisdom-based conservation practices, such as shade vegetation and the preservation of protected forests around coffee plantations. Research by Jazeer and Verweij (2015) shows that shaded agroforestry systems play a crucial role

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in biodiversity conservation and also provide economic benefits for farmers. In addition, several farmer groups have started implementing organic farming and have obtained international certifications, which indirect ly support environmental sustainability.

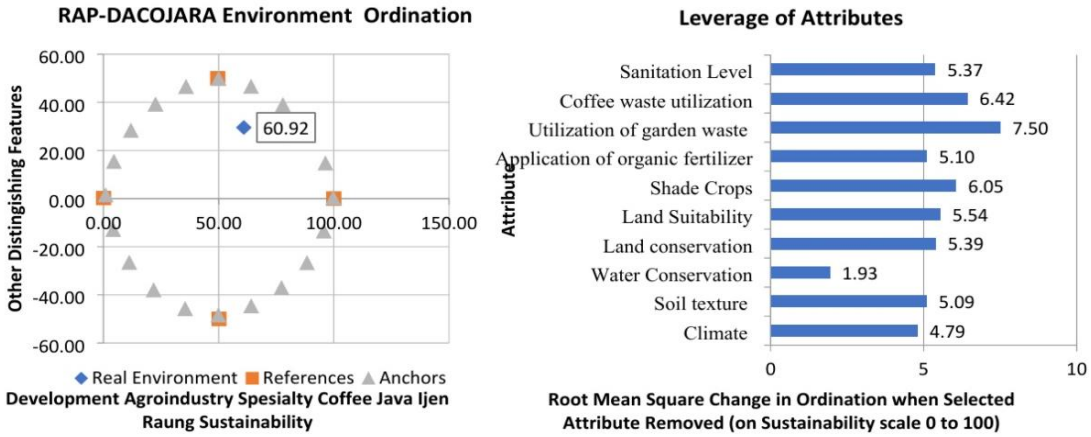

Figure 3. *Environmental dimension. Source: RAP-DACOJARA analysis results (2025)*

Based on leverage analysis, the RMS values show the following most sensitive attributes in the environmental dimension: Utilization of coffee plantation waste: 7.50, Utilization of coffee processing waste: 6.42, Shade trees: 6.05. These three attributes are the most sensitive in driving the environmental sustainability of the Java Ijen Raung specialty Arabica coffee agroindustry. A significant quantity of coffee processing waste remains unused by coffee processors, causing environmental pollution and potentially reducing the quality of life in surrounding communities. According to Fernandes et al. (2017), improperly disposed coffee waste can pose risks to human health and the environment due to compounds that may damage Deoxyribonucleic Acid (DNA) and cause toxicity to aquatic organisms.

On the other hand, Barham et al. (2011) found that using coffee waste as organic fertilizer can improve soil fertility and crop yields. This highlights a great potential to reduce waste and enhance productivity. Although the production of Java Ijen Raung specialty Arabica coffee is organically cultivated using leaf litter and other organic matter around the farms, its application is still suboptimal. This aligns with Laili et al. (2023) who stated that agricultural waste utilization in agroindustries is often hindered by a lack of knowledge and technology.

Furthermore, this specialty coffee farming is carried out on Perhutani land, requiring management through an agroforestry system. However, this system often limits optimal shade tree management. According to Puslitkoka (2016), pruning shade trees at the beginning of the rainy season is crucial for regulating sunlight, improving air circulation in coffee plantations, and reducing humidity during the wet season. Thus, this study highlights the urgent need to improve coffee waste utilization and shade tree management in agroindustry development, not only to increase productivity but also to maintain environmental sustainability.

Figure 4 shows that the economic dimension is moderately sustainable. This indicates that the economic aspect of developing the Java Ijen Raung specialty Arabica coffee agroindustry provides a reasonably good economic value. Several facts support this

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status, including the higher price of Java Ijen Raung Arabica coffee compared to other coffee varieties, stable pricing, and higher income received by farmers compared to cultivating other commodities. Coffee price stability has tended to improve since the establishment of the Program Management Office (PMO) in 2022. This program aims to enhance the quality and competitiveness of Indonesian coffee in the global market. The findings of Sia et al. (2025b) support this result, showing that managerial interventions and government support can increase coffee farmers' incomes and strengthen their bargaining position. Farmers who participate in training and capacity-building programs also experience a significant rise in income. This demonstrates that continuous support is crucial for the economic success of farmers (Ayesha et al., 2024).

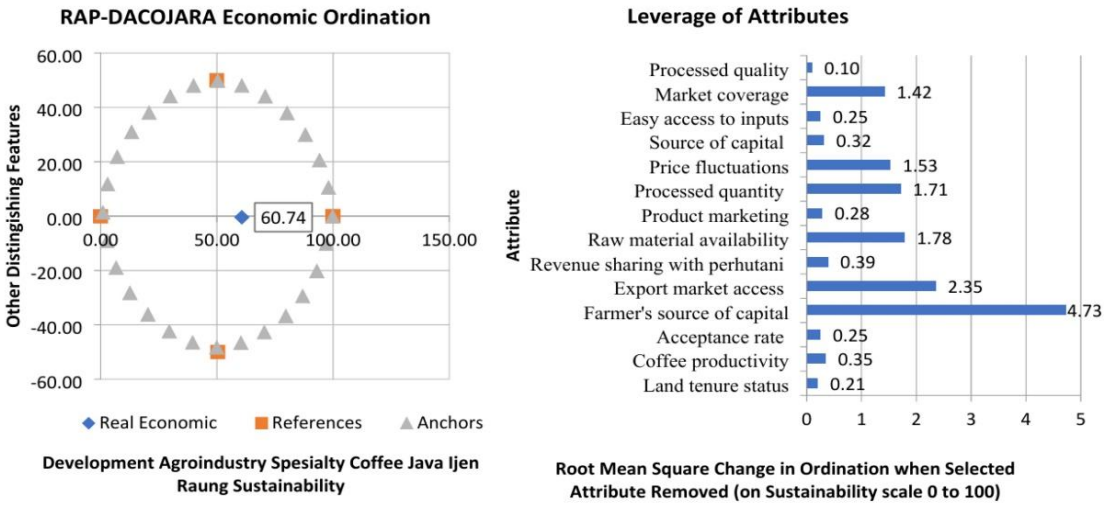

Figure 4. *Economic dimension. Source: RAP-DACOJARA analysis results (2025)*

Based on the leverage analysis results for the economic attributes, the source of capital (RMS value = 4.73) and access to export markets (RMS value = 2.35) are the most sensitive attributes in the economic dimension of sustainability for the development of the Java Ijen Raung specialty Arabica coffee agroindustry. The source of capital for coffee farmers in the research location is very limited. This lack of capital forces farmers to rely on the "ijon" system (advance payment for crops), which is highly disadvantageous because the prices offered by middlemen in this system are very low. Farmers must deliver their harvest to middlemen who then export it through private companies. As a result, farmers cannot determine how much of their harvest will be used as raw material for processing. Access to capital is crucial for agricultural development (Gomes et al., 2020).

The study by Sia et al. (2025a) shows that adequate access to capital can increase farmers' productivity and income while reducing dependence on middlemen. Additionally, Lushi et al. (2023) found that farmers with better access to financing tend to have stronger bargaining positions in price negotiations, which contributes to economic sustainability.

A study by Karyani et al. (2024) in other regions of Indonesia indicates that coffee farmers involved in cooperatives have better access to capital and markets**,** allowing them to obtain better prices. This demonstrates that organizing farmers into cooperatives or

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farmer groups can be a solution to overcome the problems of limited capital and market access.

Figure 5 shows that the social dimension is less sustainable. This indicates that the community's socio-economic conditions are not sufficiently supportive of the development of the Java Ijen Raung specialty Arabica coffee agroindustry. Motivation to run the coffee agroindustry is also low, which negatively affects the agroindustry's development. Although farmers and micro-small enterprise (MSE) actors have received community empowerment programs, these programs have not been continuous, so farmers have not yet felt significant benefits. As a result, their motivation to continue with the agroindustry is lacking.

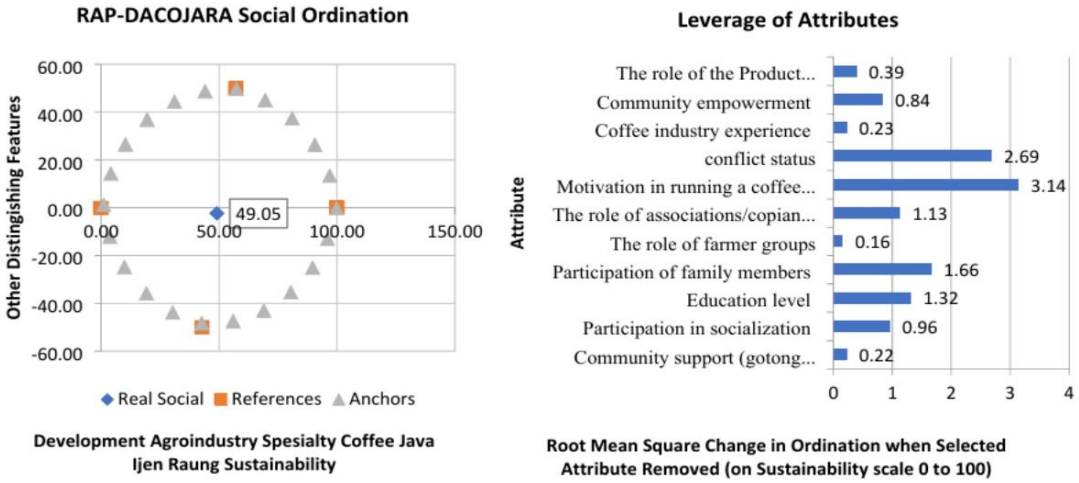

Figure 5. *Social dimension. Source: RAP-DACOJARA analysis results (2025)*

According to Stadnyk et al. (2021), motivation plays a role in building networks in business strategies to achieve sustainability**.** This study aligns with the findings of Maulidiah et al. (2021), which show that farmers' motivation to participate in agricultural development programs is highly influenced by continuous support from the government and relevant institutions**.** Moreover, conflicts among farmers**,** particularly conflicts with buyers, are factors that hinder sustainability in the social dimension. Research by Siebrecht (2020) shows that conflicts within farming communities can disrupt cooperation and collaboration**,** which are essential for increasing productivity and sustainability. Uncertainty in relationships between farmers, MSEs, and buyers reduces trust and motivation among farmers to invest in their enterprises.

The leverage analysis identified two critical factors significantly impacting Java Ijen Raung's specialty Arabica coffee sector: farmer motivation (RMS=3.14) and conflict status (RMS=2.69). These emerged as the most sensitive variables influencing agroindustry development. The results particularly highlight motivation's crucial role in sustaining coffee production, corroborating Pyk and Abu Hatab (2018) findings that psychological drivers often outweigh financial incentives in farming sustainability. Herasymenko (2023) research further supports this, demonstrating motivation's direct correlation with productivity levels.

Regarding conflict dynamics, our study reveals how disputes among stakeholders - including farmers, small businesses, and coffee institutions - create substantial development barriers. Fadli et al. (2024) note such internal conflicts compromise

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institutional efficiency and market connectivity. This aligns with Méndez et al. (2010) Central American case studies, where cooperative conflicts undermined economic viability despite premium market access.

Technological aspects, as illustrated in *Figure 6*, show moderate sustainability. While current technologies sufficiently support production, implementation gaps persist. Despite achieving Geographical Indication (GI) status requiring SCAA-standard SOPs, practical adoption remains suboptimal. Financial constraints limit most farmers to annual fertilization, contrasting with Soedirman (2024) recommendation of biannual application for optimal arabica coffee growth.

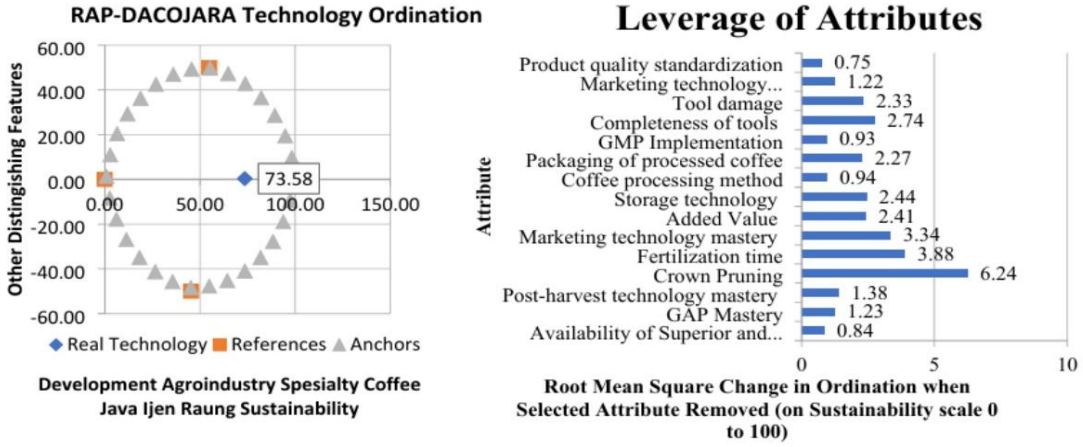

Figure 6. *Technological dimension. Source: RAP-DACOJARA analysis results (2025)*

Coffee processing technology at the research site is quite supportive in promoting the sustainability of the agroindustry. There are 32 micro and small enterprises that already have coffee processing equipment, although some still lack complete tools. Quality standardization has also been provided by the Coffee and Cocoa Research Center, but its implementation remains suboptimal. Quality tests on several coffee samples showed that the coffee products in this region averaged scores above 80 points (Puslikoka, 2024). The minimum score required for specialty coffee is 80 points based on cupping tests by certified Q-Graders (Spesialty Coffee Association, 2024). This indicates that Arabica coffee from the study area has high quality, making it competitive in both national and international specialty coffee markets.

Based on the leverage analysis results, the most sensitive attributes are: Canopy pruning (RMS = 6.24), Timing of fertilization (RMS = 3.88), and Mastery of marketing technology (RMS = 3.34). These findings are in line with the research of Gokavi et al. (2021), which states that coffee pruning is a key determinant of coffee plant productivity. Proper pruning leads to high, stable yields and easier maintenance**.** Additionally, Mota et al. (2023) emphasized that timely fertilization helps improve coffee yields.

The limited knowledge of marketing technology is a major barrier for both farmers and small business actors in marketing coffee and its processed products. Farmers often rely on middlemen, which leads to high dependency and often results in disadvantageous pricing and limited market access, as found in Ranjan (2017). Therefore, capacity building through marketing training, as recommended by Ayesha et al. (2024), is essential to empower farmers in maximizing the value-added from coffee products.

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Figure 7 shows that the sustainability index in the institutional dimension is categorized as less sustainable, indicating that this dimension does not adequately support the development of the coffee agroindustry. The intensity of extension services and training provided by relevant agencies is still insufficient, even though extension workers play a vital role in guiding and motivating farmers. The more frequently farmers attend extension activities, the higher their motivation tends to be in developing the coffee agroindustry. However, institutions such as the Indonesian Coffee Association and local coffee community groups have not functioned optimally as platforms for learning, collaboration, and provision of infrastructure and facilities.

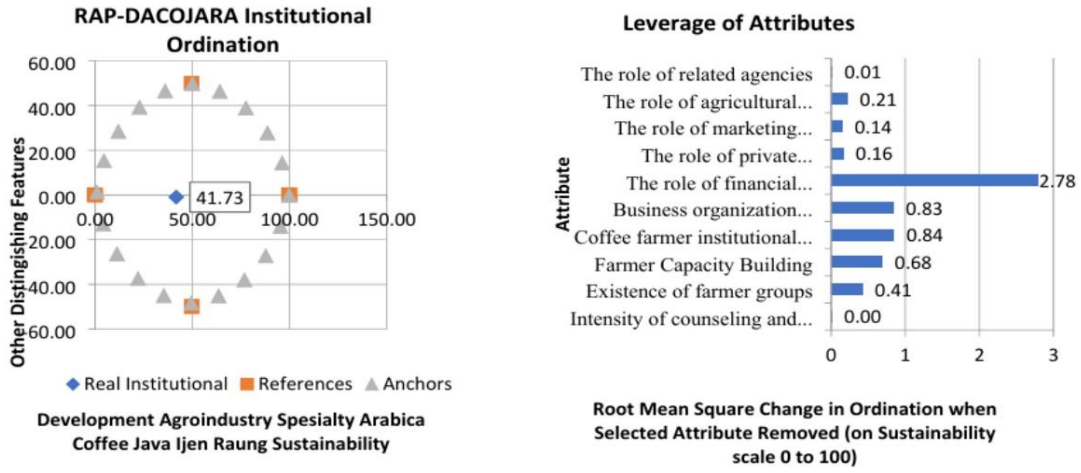

Figure 7. *Institutional dimension. Source: RAP-DACOJARA analysis results (2025)*

These findings are supported by the study of Ensor and De Bruin (2022) which highlights the role of institutions as media for farmer learning and capacity building. Similarly, Sharma and Sharma (2021) emphasize that the existence of strong institutions significantly influences farmers' knowledge, skills, and insight in managing agriculture. Research by Anggraeni et al. (2021) in Lampung showed that institutional and financial management training improved farmers' independence in digitally marketing their coffee harvests. This demonstrates the importance of strengthening institutional capacity at the farmer level.

Based on the leverage analysis results, the attributes of the role of financial institutions (RMS = 2.78) and coffee farmer institutional associations (RMS = 0.83) are the most sensitive factors in this dimension. Limited access to financial institutions causes farmers and micro and small enterprises to face capital constraints, which directly affects the suboptimal management of their coffee farming businesses. The Indonesian Coffee Association and local coffee community groups in the research area are not functioning optimally, so institutions that should serve as platforms for achieving specific goals are not fulfilling their intended roles. Farmers cannot be separated from institutions that influence their knowledge, insight, skills, and perspectives in managing agriculture (Prayoga et al., 2021).

The goodness-of-fit evaluation demonstrates excellent model performance, with S-Stress values below 0.25 and R^2 coefficients exceeding 0.94 (approaching the ideal value of 1). These metrics confirm that all five dimensions in the RAP-DACOJARA framework meet the criteria for proper model fit. To assess potential random errors in the

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multidimensional scaling (MDS) analysis, a Monte Carlo simulation was implemented with a 95% confidence interval. The simulation outcomes reveal no statistically significant discrepancies between the original RAP-DACOJARA findings and the Monte Carlo validation results (Chrispin et al., 2022) (*Table 3*).

Table 3. *Difference in values between RAP-DACOJARA analysis and Monte Carlo results*

Dimension	MDS	Monte Carlo	Difference
Environment	60.92	60.53	0.39
Economy	60.74	60.25	0.49
Social	49.05	48.74	0.31
Techonological	73.58	73.05	0.53
Institutional	41.73	41.25	0.48

Source: RAP-DACOJARA analysis results (2025)

Development of the Java Ijen Raung specialty arabica coffee agroindustry

The sensitivity analysis results from the RAP-DACOJARA analysis were used to determine the influence of sensitive attributes on the development of a sustainable Java Ijen Raung specialty Arabica coffee agroindustry. The higher the RMS value, the more sensitive the role of these attributes in the development of the specialty Arabica coffee agroindustry in Java Ijen Raung. The RMS values of the five dimensions are presented in *Table 4*. The attributes in *Table 4* represent the key factors in the development of the Java Ijen Raung specialty Arabica coffee agroindustry, and are used as the basis for prospective analysis.

Table 4. *Key factors or sensitive attributes in the development of the Java Ijen Raung specialty arabica coffee agroindustry*

Attribute Code	Attribute	RMS Value
A1	Utilization of plantation Waste	7.50
A2	Utilization of Coffee Waste	6.05
A3	Farmers' Capital Sources	4.73
A4	Access to Export Markets	2.73
A5	Motivation in Running Agroindustry	3.14
A6	Conflict Status	2.69
A7	Canopy Pruning	6.24
A8	Fertilization Timing	3.88
A9	Role of Financial Institutions	2.78
A10	Association of Coffee Farmer Institutions	0.84

Source: RAP-DACOJARA analysis results

Key factors are sensitive attributes with the highest RMS values within each sustainability dimension (Riptanti et al., 2022a). These key factors form the basis for policy strategies in the sustainable development of Java Ijen Raung specialty Arabica coffee agroindustry, comprising attributes A1 to A10. These sensitive attributes were then analyzed prospectively, as shown in *Figure 8*.

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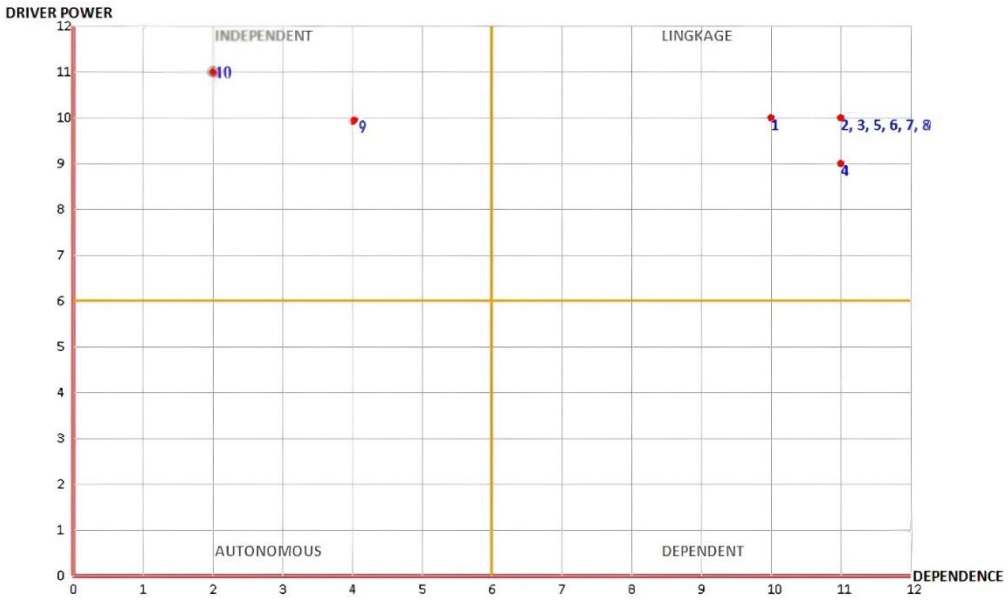

Figure 8. *Prospective analysis of the sustainable development of the Java Ijen Raung specialty arabica coffee agroindustry. Source: Prospective analysis results (2025)*

The prospective analysis, as illustrated in *Figure 8*, identifies pivotal elements located in quadrants I and II that are instrumental for advancing the Java Ijen Raung specialty Arabica coffee agroindustry. Quadrant I encompasses autonomous driving factors characterized by substantial systemic influence yet minimal interdependence. Within this category, two particularly impactful elements emerge: (1) financial institutional support systems and (2) collective farmer organizations. Empirical research by Kilelu et al. (2017) demonstrates that reinforcing these institutional frameworks substantially enhances adaptive capabilities and facilitates innovation diffusion within agricultural value chains in emerging economies. Such organizational structures serve as catalysts for productivity enhancement and commercial linkage development.

Quadrant two includes the key factors: utilization of plantation waste, utilization of coffee processing waste, farmers' capital sources, access to export markets, motivation in running agroindustry, conflict status, canopy pruning, and fertilization timing. These quadrant two key factors are leverage variables, which have strong influence and very high dependency (Bourgeois and Jesus, 2004). These eight factors are highly influential and interdependent in the development of the Java Ijen Raung Arabica coffee agroindustry. Leverage variables in agribusiness systems must be managed simultaneously and sustainably to support system growth and resilience. The implementation of these prospectively analyzed key factors then forms the basis for formulating development strategies for a sustainable Java Ijen Raung specialty arabica coffee agroindustry, as presented in *Table 5*.

The identification of key factors for advancing sustainable smallholder specialty Arabica coffee agroindustry is based on attributes demonstrating RMS values exceeding 50% of the threshold in each sustainability dimension. Following methodology by Irianto et al. (2021), these critical attributes are elevated by one sustainability level through targeted strategic interventions, as systematically outlined in *Table 5*.

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Table 5. *Strategies to enhance the sustainability of the Java Ijen Raung specialty arabica coffee agroindustry development*

Attribute	Strategies to Improve the Sustainability Attribute Scores
Utilization of Plantation Waste	Limited knowledge and skills in utilizing agricultural and livestock waste remain a challenge. Therefore, capacity building of human resources in the use of agricultural technology is essential. The role of farmer groups is crucial in the technology adoption process. Training to improve knowledge and skills in utilizing plantation waste as organic fertilizer is very important. Integration between agriculture and livestock is a key factor in supplying soil nutrients (Lemaire et al., 2014). Strategy implementation includes outreach, training, and assistance until the adoption process of using coffee plantation waste as fertilizer in the Java Ijen Raung specialty arabica coffee farming is achieved.
Utilization of Coffee Waste	Limited knowledge among micro and small business actors hinders the utilization of coffee waste, which includes coffee cherry skin and parchment from green beans. Thus, capacity building in agricultural technology is also required (Beintema and Stads, 2017). The roles of Puslitkoka and the Kampung Kopi community are essential to synergize in processing coffee waste. The strategy is for the relevant government agencies to conduct training and mentoring for micro and small business actors to convert coffee waste into organic fertilizer or planting media.
Sources of Farmers' Capital	Based on the People's Business Credit (KUR) program, banks and agricultural cooperatives play an important role in providing low-interest loans to coffee farmers and small processors (Wulandari et al., 2021). The implementation strategy is for financial institutions to disseminate information about low-interest credit schemes to farmers and coffee processors. This will increase their motivation to fund and scale up their businesses sustainably.
Access to Export Markets	Creasingly strict export requirements imposed by importing countries are a current challenge. Farmers must meet export-quality standards. In addition, export tariffs and growing competition from other Arabica-producing countries also hinder market access. Thus, farmers must enhance their coffee quality standards to compete globally. Exporters use export documentation to facilitate access to importing countries (Ginting, Lubis and Chalil, 2023). Strategy implementation involves the government assisting coffee exporters in accessing export markets and enacting export tariff policies that stimulate exporters to increase volumes.
Motivation in Running the Agroindustry	Motivation to run coffee agroindustry must be improved, as it encourages farmers to process coffee into marketable products. This strategy must be synergized with the expansion of funding sources for farmers and small businesses. Strategy implementation involves local authorities conducting intensive extension services on product downstreaming benefits and developing performance-based incentive programs (Barham et al., 2011).
Conflict status	Conflicts in the research area are highly complex — among farmers, between farmers and the Forest Village Community Institution (FVCI), and between farmers and buyers. Aligning perspectives among conflicting parties is crucial to prevent issues from escalating. The conflict resolution strategy involves awareness campaigns on the importance of protected forest areas, shared interests within protected forest zones, farmer capital access, and market expansion (Maring, 2022).
Canopy Pruning	Canopy pruning technology is essential. Pruning increases coffee plant productivity (Yuliasmara and Erdiansyah, 2016). Farmers should be introduced to pruning techniques throughout the production process, from basic pruning to umbrella-pruning methods to ensure the generation of optimal and continuous productive branches. Continuous support should be provided until farmers successfully increase yield per plant.

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Attribute	Strategies to Improve the Sustainability Attribute Scores
Fertilization Timing	Farmers rarely fertilize following standard operating procedures (SOPs)**.** Correct fertilizer dosage and timing improve production efficiency (Magalhães Júnior a et al., 2021). Using organic or manure-based fertilizers is essential for improving soil fertility, thereby boosting coffee production.
Role of Financial Institutions	Capital availability is one of the major constraints in agroindustry development (Da Silva Medina and Pokorny, 2022). Strengthening capital at both farmer and small processing business levels increases their production capacity and ability to pursue business opportunities. Financial institutions, from village-level to broader scales, are expected to provide or facilitate access to credit as additional capital for farmers and small businesses.
Institutional Associations of Coffee Farmers	The Indonesian Coffee Association**,** Kampung Kopi community**,** and the Association for the Protection of Geographical Indications (MPIG) play a vital role in agroindustry development in Bondowoso. Partnerships should be organized at the subdistrict level to improve collaboration and accessibility. Organizational structures and main functions must be adjusted to group dynamics and evolving member needs. Association selection should align with competency, main tasks, and functions (Riptanti et.al, 2022). Strengthening institutional frameworks through leadership development and formalizing inter-institutional partnerships is crucial to enhance sustainability (Ismail et al., 2025)

Effective implementation of these improvement strategies requires a coordinated, multi-stakeholder approach. Government agencies, agricultural extension services, farmer collectives, community representatives, individual growers, and relevant industry actors must each fulfill their distinct roles in executing these comprehensive measures. The prioritized sensitive attributes - when enhanced by one sustainability tier - are presented in *Table 6*.

Table 6. *Results of the sustainability value utilization in each dimension*

Dimensions	MDS	Leverage Value		
		MDS	Stress	RSQ
Environment	60.92	67.42	0.14	0.95
Economy	60.74	69.59	0.14	0.95
Social	49.05	54.51	0.15	0.95
Techonological	73.58	81.15	0.13	0.95
Institutional	41.73	52.16	0.14	0.95

Source: RAP-DACOJARA Analysis Results, (2025)

The implementation of the RAP-DACOJARA methodology to enhance performance indicators revealed an aggregate sustainability score of 64.9, which falls within the moderate sustainability classification. Building awareness and understanding among farmers about the importance of sustainable agriculture is essential before implementing the proposed strategies. If socialization regarding the importance of sustainable agriculture is conducted more frequently during farmer group meetings or community gatherings, farmers' comprehension will improve. This is because farmers face various limitations, making it difficult to implement strategies that can act as leverage factors for sustainability (*Figure 9*).

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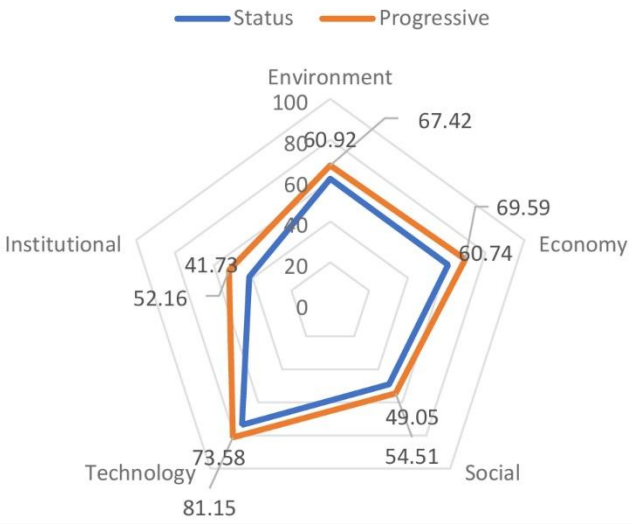

Figure 9. *Kite diagram of sustainability and progressive status. Source: RAP-DACOJARA analysis results (2025)*

Conclusion

The development of a sustainable specialty Arabica coffee agroindustry – Java Ijen Raung by farmers and MSME (Micro, Small, and Medium Enterprises) actors is challenged by complex internal and external issues. They rely on their knowledge gained from coffee farming experience and coffee processing to adapt and respond to environmental, social, economic, technological, and institutional conditions. Specialty Arabica coffee in Java Ijen Raung is cultivated by farmers on state forestry land (Perhutani), which limits optimal management due to existing regulations. Some micro and small business actors process harvested coffee into products to increase their income.

Based on the sustainability analysis using modified Multi-Dimensional Scaling (MDS) with RAP-DACOJARA, the development of the specialty Arabica coffee agroindustry in Java Ijen Raung is considered moderately sustainable. Following this finding, efforts to enhance sustainability should focus on implementing strategies targeting key attributes with RMS values exceeding half of each sustainability dimension. The success of these strategies requires synergy and shared commitment from all stakeholders in the plantation sector.

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