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Enhancing Sustainability of Coffee Farming: A Behavioral Approach and Multidimensional Analysis

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ABSTRACT

Coffee is a strategic agricultural commodity that significantly influences rural livelihoods and national economic stability in producing countries such as Indonesia, making the sustainability of its farming systems a critical concern. This study aims to evaluate the sustainability of coffee farming in Temanggung Regency by integrating the Theory of Planned Behavior. The analysis employs a quantitative approach using multidimensional scaling with the Rapcoffee method to assess sustainability status and identify leverage points. The results show that the sustainability index of coffee farming reaches 64.51%, indicating a moderate level of sustainability, with the economic dimension performing the strongest and the institutional dimension the weakest. Sensitivity analysis highlights several priority attributes whose improvement could elevate sustainability to a higher level. Intervention on sensitive attributes can increase sustainability to 78.77% to highly sustainable. The novelty of this study lies in operationalizing farmers' socio-psychological factors into measurable attributes that increase sustainability. The findings offer actionable strategies for policymakers, farmer organizations, and development agencies to optimize resource utilization, enhance institutional participation, and improve ecological resilience. This framework not only supports the sustainability of coffee farming but also contributes to achieving the Sustainable Development Goals (SDGs), particularly those related to poverty alleviation, responsible production, and climate action.

1. INTRODUCTION

Coffee is one of the world's most important agricultural commodities, with high economic value. It holds significant potential for development across the entire value chain, from upstream to downstream sectors. The advantages of coffee lie in its export competitiveness and agro-industrial value [1], as well as its role as a source of livelihood for farmers [2]. Data from The International Coffee Organization show that global coffee production in 2023/2024 reached 168.2 million sacks (60 kg per sack), an increase of 0.12% from the previous year. Similarly, global coffee consumption rose by 2.25% in 2023/2024, from 173.1 million sacks to 177 million sacks. This highlights the fact that global coffee demand relies on the number of farmers across various coffee-producing countries.

Indonesia is the second-largest coffee producer in Asia after Vietnam. In 2023, Indonesia's coffee production reached 758.73 thousand tons, indicating a decrease of 16.24 thousand tons (2.1%) compared to the previous year. Approximately 99.56% of Indonesia's coffee production comes from smallholder plantations [3]. Smallholder coffee farming in Temanggung has been practiced since the Dutch East Indies period; however, production remains a challenge. Data from the Central Java Provincial Agriculture and Plantation show that coffee production in Temanggung from 2021 to 2023 was recorded at 11,310.67 tons, 10,776.32 tons, and 10,775.83 tons, respectively.

The sustainability of coffee production currently faces complex challenges across various dimensions, including economic, environmental, social, technological, and institutional aspects. Climate change has led to a decline in both the quantity and quality of harvests, as well as an increased risk of pest and disease outbreaks in coffee crops [4]. Farmers' diverse levels of knowledge and skills significantly influence the cultivation practices they adopt [5]. Issues related to the availability and use of production inputs, as well as the lack of farmer regeneration, influence the sustainability of coffee farming [6]. Climate anomalies have also affected coffee prices in Brazil, the world's largest producer [7]. This has led to fluctuations in global coffee prices and contributed to income uncertainty for farmers. Consequently, the issues of sustainability and the well-being of coffee farmers are becoming increasingly critical. Furthermore, the international coffee market demands that coffee be produced responsibly, both environmentally and socially [8].

The sustainability of coffee farming has become an increasingly urgent issue both globally and nationally, in line with growing consumer demand for more environmentally friendly products. Sustainable agriculture seeks to optimize resources while taking into account social, economic, ecological, capital, institutional, and labor aspects in a balanced manner to support long-term viability. The sustainability of coffee farming plays a crucial role in ensuring long-term production and productivity, which directly impacts farmers' income and well-being. The core principles of sustainable agriculture include economic, ecological, social, technological and institutional dimensions [9].

Economic sustainability must ensure that farming activities can preserve resources and enhance product value, thereby providing long-term financial benefits for farmers [2]. Ecological balance highlights the importance of using appropriate production inputs, as well as efforts in land conservation and crop diversity [10] to improve yields. Social equity emphasizes that farming activities should serve as a solution to social issues, particularly poverty and essential needs, to improve the quality of life in rural communities [9]. Technological sustainability focuses on the application of good agricultural practices (GAP), including the use of quality seedlings, fertilization, and the management of shade trees through to harvest [11]. Institutional sustainability is reflected in the role of farmers and government institutions, supported by regulations, extension services, marketing institutions, and financial institutions [12] all of which contribute to sustainable coffee farming.

Farmers' attitudes influence the implementation of their farming practices, whether driven by internal or external motivations, perceived behavioral control, and the benefits they expect to gain [13]. Farmers' attitudes toward the adoption of sustainable agricultural practices are shaped by their knowledge, experience, and personal values [14]. Subjective norms, including land ownership and income, family expectations, as well as social and peer pressure, affect farmers' decisions to adopt the farming techniques [15]. Behavioral control refers to farmers' beliefs about their ability to adopt technologies based on the resources they possess [16]. Farmers' intentions influence every decision they make in applying technology to their farming practices [17], thereby affecting the outcomes they achieve and the sustainability of environmental, economic, social, technological and institutional dimensions [9]. Farmers' attitudes, perceptions, and beliefs are key components of the Theory of Planned Behavior [18], representing psychosocial factors that integrate individual cognitive evaluations with social influences, thus reflecting the dynamic interaction between personal attitudes and the social environment.

The sustainability of coffee farming is not merely a local concern but has broader implications for achieving the Sustainable Development Goals (SDGs) at the global level. Evaluating the sustainability of coffee farming is essential to support the achievement of SDG targets that prioritize food security, environmental management, and equitable development for farmers and the global agricultural sector [19].

Despite the growing research on sustainable coffee farming, most studies focus on biophysical, economic, or market-related factors [2, 10]. There is relatively limited attention to farmers' socio-psychological aspects. The Theory of Planned Behavior offers a robust framework for understanding how attitudes, subjective norms, and perceived behavioral control influence farmers' decision-making [18]. However, its integration into sustainability assessments remains underexplored. The Rapcoffee method, adapted from Rapfish analysis, applies multidimensional scaling techniques and offers significant advantages [20]. Combining these methods translates farmers' behavioral dimensions into measurable sustainability attributes. This approach helps bridge the gap between psychosocial perspectives and quantitative sustainability assessment.

This study aims to evaluate the sustainability status of coffee farming. A social-psychological approach is emphasized in determining the sustainability attributes of coffee farming, as it influences farmers' decision-making behavior. The findings of this study are expected to provide policy recommendations for priority strategies to realize sustainable coffee farming, thereby contributing to sustainable development, particularly in eradicating hunger and poverty.

2. MATERIAL AND METHODS

2.1 Research location

The study was conducted in Temanggung Regency (Figure 1), selected purposively based on their status as the largest producers of robusta and arabica coffee in Central Java [21]. Additionally, Temanggung Regency is predominantly an upland area, with elevations ranging from 650 to 1,684 meters above sea level. The region experiences high average annual rainfall and generally has a cool climate, with temperatures ranging between 20 ℃ and 30 ℃. These geographical conditions are highly favorable for coffee cultivation, where the area planted with robusta coffee is 11,189.96 hectares, and arabica coffee occupies 1,127.41 hectares. The sampling locations were determined using a cluster sampling technique, focusing on areas with significant potential for both robusta and arabica coffee production, specifically Candiroto, Tretep, and Wonoboyo Districts.

2.2 Data collection and sample

This study employed a quantitative research approach. Data were collected through structured interviews, guided by a questionnaire that had undergone prior validity and reliability testing to ensure data accuracy and consistency. Respondents were 380 farmers from a total of 9,879 coffee farmers, determined using the Isaac and Michael formula. Furthermore, respondents were selected using purposive random sampling, which combines purposive sampling criteria with random selection to ensure every eligible farmer has an equal opportunity to participate [21]. This sampling strategy was adopted to ensure that the findings accurately reflect field conditions while accounting for the specific characteristics of the coffee farmers targeted in this study.

2.3 Data analysis

The sustainability of coffee farming was analyzed using the Multidimensional Scaling (MDS) method with the Rapfish approach, which was modified for the coffee commodity (Rapcoffee) [22]. This analytical tool is a multidisciplinary technique that allows for comprehensive evaluation. Rapfish was selected due to its transparent process and the use of simple attributes, making it easy to assess and capable of producing visual outputs that are easy to interpret [23].

The first step involved determining the sustainability dimensions to be analyzed, which included economic, ecological, social, technological, and institutional dimensions.

The second step is to identify the attributes of each dimension, formulated by considering farmers' attitudes toward the benefits of farming practices, subjective norms from family and community, and perceived behavioral control related to farmers' beliefs and abilities. Therefore, the selected attributes not only represent the objective conditions of farming but also reflect the psychological and social factors that influence farmers' decisions to implement sustainable farming practices [24]. Based on a review of the scientific literature and field observations, 31 relevant attributes were identified to measure the sustainability of each dimension (Table 1).

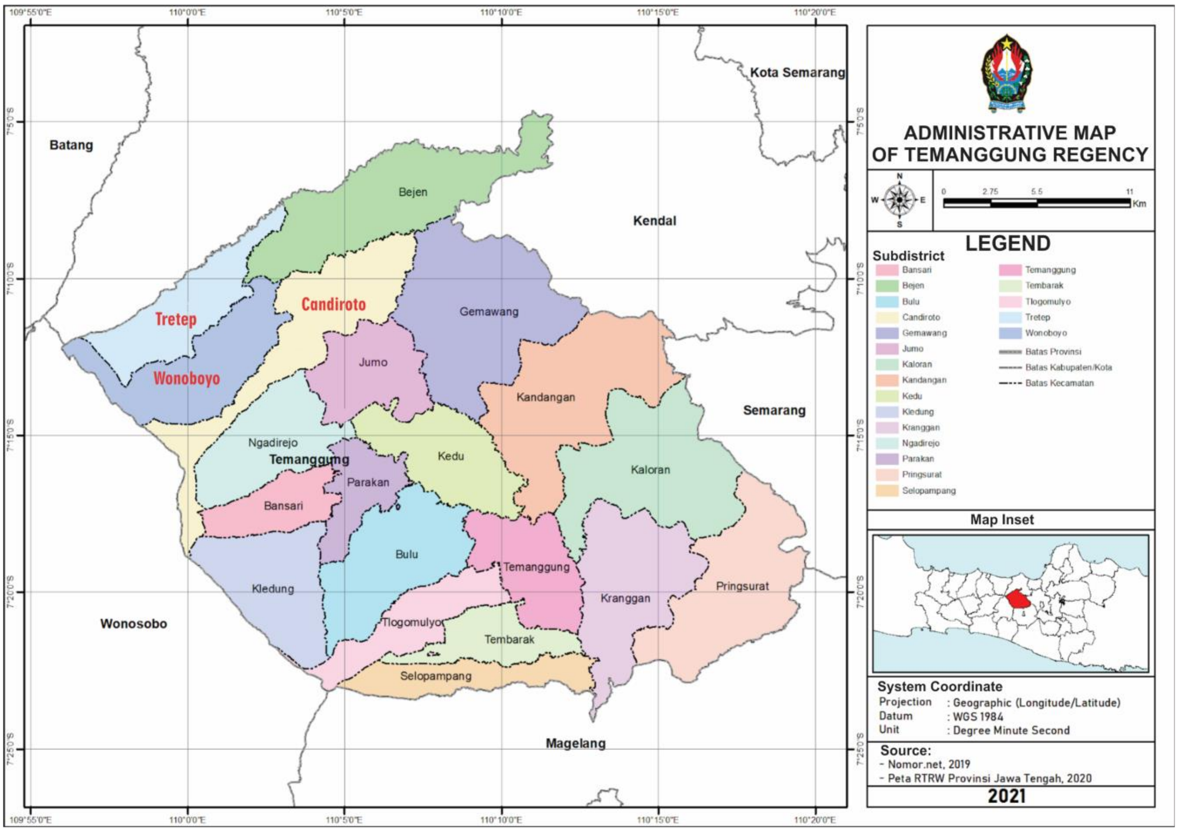

Figure 1. Research location
Source: https://neededthing.blogspot.com

Table 1. Dimensions and attributes for measuring sustainability status

Dimension	Attribute		
	Attitude	Subjective Norms	Perceived Behavioral Control
Economic	Farmers' perceptions of increased yields due to: ✓ Cost of coffee farming ✓ Farm-gate selling price of coffee ✓ Revenue from coffee farming ✓ Profit from coffee farming	Family support for: ✓ Family labor availability ✓ Farm business capital	Farmers' confidence and ability in: ✓ Access to non-family labor ✓ Access to external capital
Ecological	Farmers' perceptions of the importance of: ✓ Replanting frequency ✓ Pesticide application ✓ Use of organic fertilizer ✓ Use of inorganic fertilizer ✓ Crop diversity ✓ Conservation efforts	Family support in utilization: ✓ Land area	Confidence that existing resources support the sustainability of farming: ✓ Land area ✓ Land suitability for cultivation
Social	Farmers' perceptions of the importance of: ✓ Participation in farmer groups ✓ Frequency of extension services	External environmental support: ✓ Participation in farmer groups ✓ Frequency of extension	Farmers' confidence and ability to: ✓ Farming experience ✓ Farmers' motivation

		services ✓ Relations among group members	
Technological	Farmers' perceptions of the importance of: ✓ Type of seedlings used ✓ Fertilization technique for coffee plants ✓ Pest and disease control techniques ✓ Pruning techniques for coffee plants ✓ Shade tree management techniques ✓ Harvesting techniques	Family support in utilization: ✓ Type of seedlings used ✓ Fertilization technique for coffee plants ✓ Pest and disease control techniques ✓ Pruning techniques for coffee plants ✓ Shade tree management techniques ✓ Harvesting techniques	Farmers' access, capabilities, and skills in: ✓ Type of seedlings used ✓ Fertilization technique for coffee plants ✓ Pest and disease control techniques ✓ Pruning techniques for coffee plants ✓ Shade tree management techniques ✓ Harvesting techniques
Institutional	Farmers' perceptions of: ✓ Role of farmer institutions ✓ Role of agricultural extension agencies ✓ Regulations and policies ✓ Role of local government ✓ Role of associations ✓ Role of marketing institutions	External support: ✓ Role of farmer institutions ✓ Role of agricultural extension agencies ✓ Regulations and policies ✓ Role of local government ✓ Role of associations ✓ Role of marketing institutions	Ease of access for farmers to: ✓ Role of farmer institutions ✓ Role of agricultural extension agencies ✓ Regulations and policies ✓ Role of local government ✓ Role of associations ✓ Role of marketing institution

Table 2. Sustainability index categories

Index Value	Category	Sustainability Status
0 – 25	Bad	Not sustainable
25 –50	Less	Less sustainable
50 –75	Enough	Moderately sustainable
75–100	Good	Highly sustainable

Source: Study [25]

The third step involved data collection through respondent interviews, in which each attribute was assessed using a scale ranging from 0 (bad) to 4 (good). Subsequently, the sustainability index and status of coffee farming were determined and categorized based on the multidimensional scaling values (Table 2).

The fifth step was the leverage analysis, a type of sensitivity analysis used to identify attributes that can be targeted for intervention to improve the sustainability of coffee farming. Sensitive attributes were identified based on the highest root mean square (RMS) values. The sixth step was a Monte Carlo analysis to assess the margin of error for each attribute within each dimension at a 95% confidence level. The final step involved implementing interventions on leverage attributes to enhance the sustainability of coffee farming, followed by a reanalysis using the Rapcoffee approach.

3. RESULT

3.1 Respondent characteristics

Interview results revealed that the majority of coffee farmers are within the productive age group, with 22.11% classified as youth. Although the regeneration of young farmers is already underway, it still needs to be strengthened to support community empowerment and rural economic development [26]. On average, coffee farmers have completed basic education, with only a small proportion having pursued higher education. Education level influences farmers' mindsets, which in turn affects their attitudes toward farming [27]. The characteristics of coffee farmers are presented in Table 3.

Table 3. Characteristics of coffee farmers

Description	Number	Percentage (%)
Age		
16 – 35 years	84	22.11
36 – 64 years	290	76.32
> 64 years	6	1.58
Education		
Elementary Education	263	69.21
High School	109	28.68
Bachelor's Degree	6	1.58
Farming Experience		
2 - 10 years	96	25.26
11 - 25 years	212	55.79
>25 years	72	18.95
Farm Land Area		
< 0.5 ha	115	30.26
0.5 – 0.99 ha	154	40.53
> 1 ha	111	29.21

Source: Primary data analysis

The length of time farmers has been engaged in coffee farming varies, from 2 years to over 25 years. This contributes to farmers' experience in cultivation techniques, as well as facing challenges and developing adaptive capacities to improve their farm productivity [28]. Social factors, including age, educational level, experience, and membership in farmer groups, influence farmers' adoption of technology in their farming practices [29]. On average, coffee farmers are smallholders, cultivating less than 1 hectare of land, with an average coffee production of 3.23 tons per farmer. Land ownership is one of the key factors influencing farmers' technical efficiency in agricultural production [30]. The management of larger farming areas tends to be more efficient and supports higher productivity, thereby contributing to sustainability [31].

3.2 Analysis of coffee farming sustainability index and status

The multidimensional measurement using Rapcoffee indicated that the sustainability index of coffee farming in Temanggung Regency was 64.51%, which falls under the moderately sustainable category. Each dimension was then analyzed separately to determine the specific sustainability index reflecting the condition of each dimension (Figure 2).

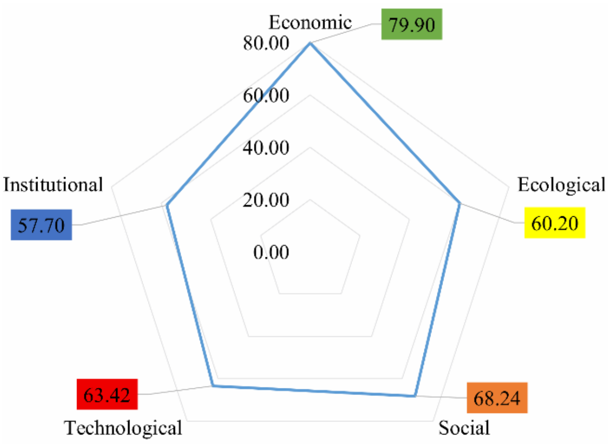

Figure 2. Sustainability dimension index of coffee farming

The analysis results indicate that the highest sustainability index was observed in the economic dimension (79.90%), positioning it as the most dominant factor influencing the sustainability of coffee farming compared to other dimensions. The social dimension ranked second, with an index of 68.24%, highlighting the crucial role of farmer motivation and experience, as well as the relationships between farmers and stakeholders, in maintaining sustainable farming practices. The technological and ecological dimensions recorded index values of 63.42% and 60.20%, respectively, suggesting that improvements are still needed in cultivation practices and environmental management. The institutional dimension exhibited the lowest index value at 57.70%, indicating that support from farmer organizations, local and central governments, and market-related institutions needs to be strengthened to enhance the overall sustainability of coffee farming. Overall, coffee farming in Temanggung Regency is categorized as moderately sustainable. However, there is still a gap from the maximum sustainability level, indicating the potential to improve key dimensions and attributes comprehensively to raise the overall multidimensional sustainability index [12].

Furthermore, the sustainability index values are supported by the results of the goodness-of-fit test (Table 4), which serve to ensure that the model used is valid and reliable in capturing the complexity of the interrelationships among the sustainability dimensions.

The goodness-of-fit results (Table 4) from the Rapcoffee analysis of coffee farming sustainability are demonstrated by the stress values (Standardized Residual Sum of Squares), all of which are below 0.25 [9]. This indicates that the model's accuracy closely reflects the actual conditions. Meanwhile, the average Squared Correlation (RSQ) value is 0.94, or close to 1, suggesting that the configuration produced by this model well explains the variability in the data. Subsequently, it is necessary to examine the results of the leverage analysis to evaluate sustainability further.

Table 4. Rapcoffee analysis results for sustainability dimensions

Sustainability Dimension	Stress Value	RSQ	MDS Score	Sustainability Status
Economic	0.15	0.94	79.90	Highly sustainable
Ecological	0.14	0.95	60.20	Moderately sustainable
Social	0.16	0.94	68.24	Moderately sustainable
Technological	0.16	0.94	63.42	Moderately sustainable
Institutional	0.16	0.94	57.70	Moderately sustainable

Source: Rapcoffee Output

3.3 Sensitive attributes in coffee farming sustainability

Leverage analysis indicates that attributes with the highest values are those that have the greatest influence on the sustainability index. Improvements in these attributes will have a significant impact on enhancing overall sustainability [32]. The most influential attributes affecting the sustainability index were identified through the results of the leverage analysis (Figure 3).

The leverage analysis (Figure 3) highlights the most influential attributes in each sustainability dimension. In the economic dimension, income, farming profit, and the farm-gate coffee price were the strongest contributors. Ecological sustainability was shaped by replanting frequency, pesticide use, and fertilizer application, while extension services, farmer group relationships, and farming motivation dominated the social dimension. In the technological dimension, pruning, pest and disease control, and shade tree management showed measurable influence, though less than other dimensions. The institutional dimension, the most responsive factors were regulations and policies, farmer groups, and marketing institutions.

These results provide a clear indication of the attributes that most strongly affect the sustainability index and form the basis for targeted interventions. However, several attributes, namely farming profit, coffee selling price, pesticide and organic fertilizer application, inter-farmer relationships, and the role of farmer groups, had already achieved maximum ordinal scores in the sustainability analysis. As a result, intervention efforts focused on other attributes that still showed high sensitivity and potential for improvement. This targeted approach aims to enhance the overall sustainability index and support progress toward achieving SDGs.

3.4 Strategies to enhance the sustainability of coffee farming

The strategy for improving the sustainability of coffee farming is implemented through progressive scenario simulations designed to raise its sustainability level. Recommendations for improvement refer to policy recommendations and improvement practices developed by the authors, based on the system's studied context, aimed at increasing sustainability through interventions on sensitive attributes. Based on the results of the leverage analysis, sensitive attributes were identified for strategic intervention to improve the sustainability index of coffee farming (Table 5).

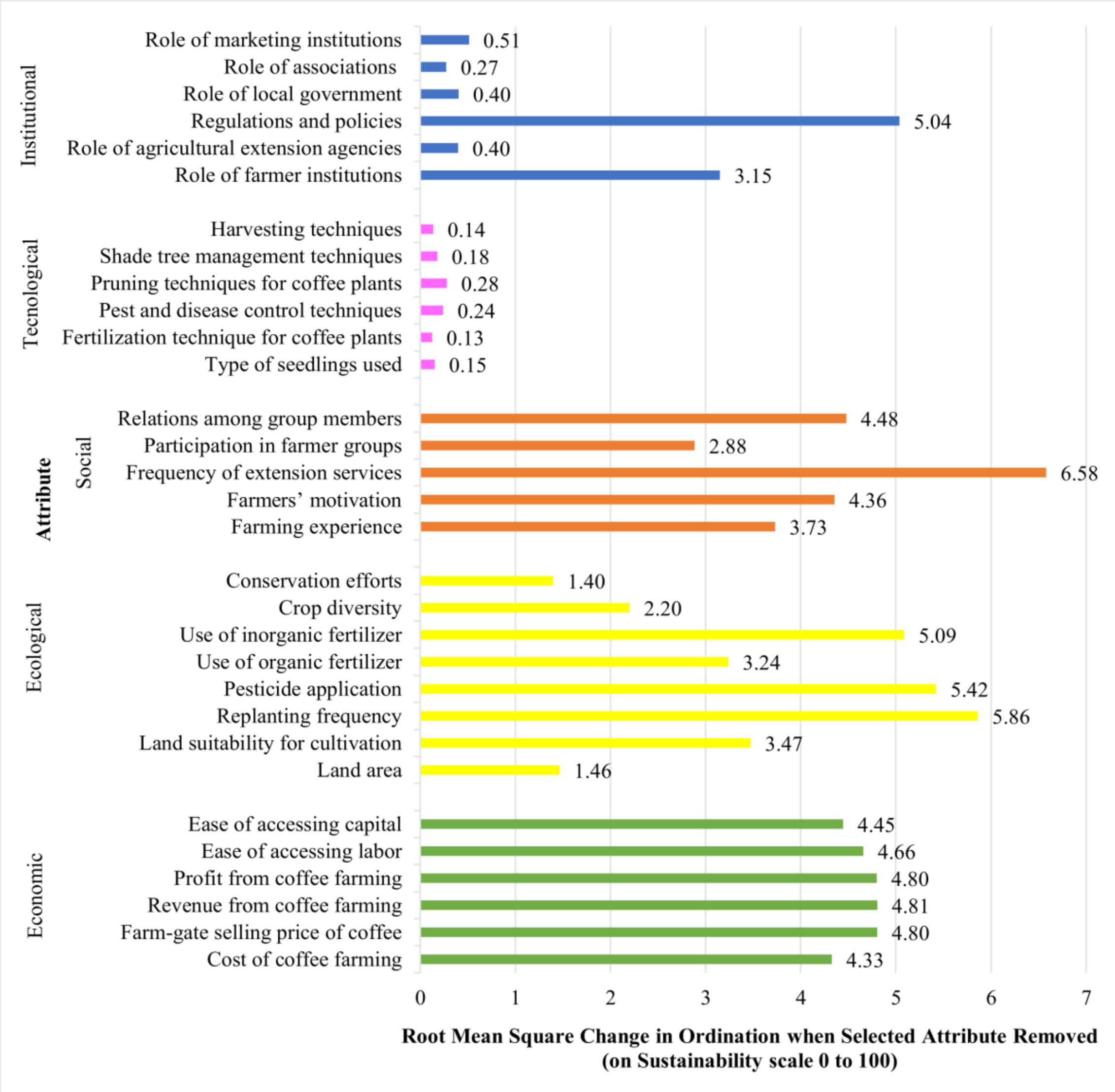

Figure 3. Leverage analysis attributes in Rapcoffee, based on standard error (%)

Table 5. Recommendations to support the improvement of coffee farming sustainability

No.	Dimension and Attributes	Initial Data	Post-Intervention Data	Recommendation for Improvement
1	Economic dimension			
	Farming profitability	3	4	Improve the efficiency of production input use and farming cost management.
	Labor availability	3	4	Enhance farmers' capacity and capability, especially young farmers', to increase youth interest in working in agriculture.
2	Ecological dimension			
	Replanting frequency	0	1	Promote replanting or topworking through extension services, incentives, or seed subsidies.
	Organic fertilizer application	2	3	Improve farmers' perception of organic farming and apply balanced fertilization (organic and inorganic).
	Crop diversification	2	3	Plant suitable shade trees to support coffee growth, improve soil quality, and enhance ecological functions.
	Conservation efforts	2	3	Create infiltration pits, improve terracing, plant shade trees, and expand arabica coffee cultivation to prevent erosion.
3	Social dimension			
	Farming experience	3	4	Encourage participation in farmer groups and the use of digital technology to access relevant information and innovations.
	Farming motivation	3	4	Strengthen harmonization among farmers, extension workers, local governments, and the private sector to support the development of coffee farming, thereby increasing farmers' motivation as the primary actors.

	Extension frequency	3	4	Enhance budgetary and regulatory support for extension activities from both central and local governments, and encourage private-sector support.
4	Technological dimension			
	Pest and disease management techniques	3	4	Strengthen preventive measures through field sanitation, pruning, and crop management; where necessary, prioritize the use of biological control agents.
	Pruning techniques	3	4	Improve farmers' skills and practices in the proper maintenance and pruning of unproductive branches.
	Shade management techniques	3	4	Enhance farmers' perception of the appropriate use of shade trees that are both agronomically suitable and economically valuable, along with their maintenance.
5	Institutional dimension			
	Role of regulations and policies	2	3	Formulate more specific and technical regulations to support the sustainability of coffee farming.
	Role of the coffee association	2	3	Evaluate and improve the management of coffee farmer associations to optimize their role.
	Role of marketing institutions	2	3	Develop and expand coffee marketing through technology and partnerships with individual enterprises or corporations.

Sources: A combination of several references developed by the author

Next, the intervention was modeled as a simulation of increasing the score level of one attribute toward a better condition (good category), which was designated as post-intervention data. The simulated data were then reanalyzed using the Rapcoffee method to obtain a progressive sustainability index for each dimension and a progressive multidimensional sustainability index. This approach aims to illustrate the direction and magnitude of potential sustainability improvements achievable if the recommended intervention is implemented effectively, while also strengthening prospective analysis in the formulation of policy strategies.

Sustainability strategies are a primary focus, not only for preserving natural resources but also for creating a balance across all sustainability dimensions. An approach that incorporates farmers' attitudes, perceived behavioral control, and beliefs toward coffee farming is essential for addressing both challenges and opportunities, thereby enabling the design of effective sustainability strategies. These findings demonstrate that targeted strategic actions can improve sustainability performance at the attribute level, significantly contributing to improvements in the sustainability index across various dimensions. Subsequently, a reanalysis was conducted using the Rapcoffee approach to assess the progressive sustainability status. The results of this analysis are presented in Figure 4.

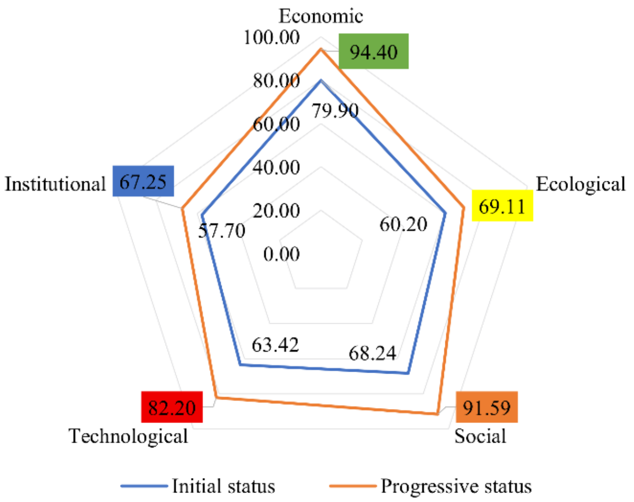

Figure 4. Progressive index of sustainability dimensions in coffee farming

After interventions were implemented in the farming system, the progressive index for the economic (94.40), social (91.59), and technological (82.20) dimensions reached the highly sustainable category. Meanwhile, the ecological (69.11) and institutional (67.25) dimensions remained in the moderately sustainable category. Efforts to enhance the sustainability index and status for each indicator cannot be separated from the implementation of other indicators. The recommended interventions successfully improved the overall multidimensional sustainability index of coffee farming from 64.51% to 78.77% (Figure 5).

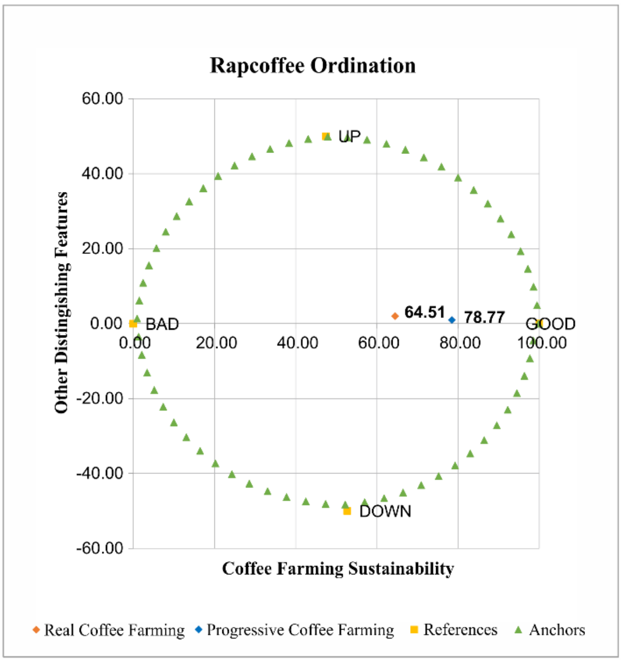

Figure 5. Initial and progressive sustainability index of coffee farming

4. DISCUSSION

The sustainability analysis of coffee farming was conducted using the Rapcoffee approach across five dimensions: economic, ecological, social, technological, and institutional. This method enables the mapping of relative sustainability positions based on predefined attribute values. The multidimensional assessment indicated that the sustainability index of coffee farming in Temanggung Regency fell within the moderately sustainable category.

In the economic dimension, high farm income during the 2023 harvest season was largely driven by elevated farm-gate prices for green beans. This represents a substantial increase compared to the 2021 – 2022 period. The rise in green bean prices enabled farmers to cover production costs and increase their net income [33]. Therefore, targeted interventions are required to improve farmers' attitudes toward optimizing production inputs and enhancing cost efficiency, especially labor cost. First, attitudes toward enhancing cost efficiency through the use of appropriate inputs and optimal farm management (e.g, balanced fertilization, planned pruning) can increase yields and, consequently, profits [34]. Second, to address constraints in productive resources, especially the lack of interest of young farmers in farming [35], capacity-building initiatives are essential to develop a skilled workforce capable of meeting the demands of modern agriculture [36]. Third, Improved farm income also positively influences farmers' perceptions of their farming capabilities, thereby strengthening their intention to continue farming [37]. This intervention strategy contributes to achieving Sustainable Development Goal, namely poverty eradication (SDGs 1).

In the ecological dimension, farmers' attitudes toward fertilizer and pesticide use, conservation practices, and shade plant selection are key determinants of sustainability [38]. Most farmers rely on urea fertilizer and chemical pesticides due to their perceived effectiveness and practicality [39] However, excessive use may harm long-term ecological balance [40, 41]. Some farmers adopt organic fertilization and environmentally friendly pest control, driven by beliefs in improving soil fertility and cultivation outcomes [42, 43]. Improving the sustainability index focuses on balanced fertilization, replanting, crop diversification, and conservation measures. Expanding Arabica cultivation in sloping areas could enhance biodiversity, prevent soil erosion, and strengthen overall ecological sustainability [10, 44]. Such strategies not only improve ecological resilience but also support the achievement of the SDGs (Climate Action – SDGs 13, and Life on Land – SDGs 15), ensuring that productivity is sustained without compromising environmental integrity.

In the social dimension, farmers' experiences, farming habits, and motivations play a crucial role in shaping their attitudes toward technology adoption, particularly from economic and social perspectives [45, 46]. Subjective norms, reinforced through farmer groups and peer interactions, facilitate knowledge sharing and establish social expectations that legitimize new practices while strengthening collective commitment to sustainability [10, 47]. Perceived behavioral control is enhanced by the support of agricultural extension services and related institutions, which increase farmers' confidence in addressing challenges and making informed decisions [5, 48]. These findings underscore that social sustainability is shaped not only by collective dynamics but also by the individual capacity of farmers to manage their farmland effectively. Strengthening the social dimension of sustainability contributes to achieving SDGs, particularly in alleviating poverty (SDGs 1), promoting quality education, and fostering decent work and economic growth (SDGs 12).

In the technological dimension, farmers' attitudes toward coffee cultivation techniques reveal both opportunities and challenges for enhancing sustainability. Pruning of unproductive branches, although often practiced as a tradition, has been shown to stabilize yields, strengthen plant vigor, and facilitate maintenance [38]. Shade tree management is another critical aspect; while economic considerations often lead farmers to use species that do not fully align with recommended practices, proper shade management is essential to prevent competition with coffee as the main crop [49]. Evidence indicates that integrating suitable shade trees can enhance yields, improve sensory quality, and support sustainable coffee production [50]. Consistent adoption of pruning, pest control, and shade management practices directly contributes to productivity, plant health, and ecological balance [11]. Strengthening perceptions and skills through extension and incentives is therefore critical to shifting behavioral intentions toward sustainable technologies [51]. Such interventions are vital to advancing technological innovation and achieving the Sustainable Development Goals [22], particularly those related to zero hunger (SDGs 2) and responsible consumption and production (SDGs 12).

In the institutional dimension, farmer groups remain crucial platforms for collaboration, learning, and access to resources [47], yet their benefits are unevenly distributed, particularly among less active members. Well-organized farmer groups can significantly enhance the implementation of good agricultural practices, facilitate the adoption of technology, and promote sustainability in farming systems [52]. However, the role of the Indonesian Coffee Farmers Association (APEKI) remains limited, with its benefits perceived as exclusive to certain groups [53]. Strengthening farmer institutions requires improvements in organizational governance [47], better coordination, member-centered service delivery [54], and strong, consistent government support [55]. Currently, coffee marketing is primarily conducted through local traders, with most farmers selling unprocessed beans, which limits market access and constrains cooperative partnerships [56]. Market expansion through traceability systems [57] and branding strategies [58] not only increases farmers' incomes but also contributes to achieving the Sustainable Development Goals, particularly economic growth and responsible consumption and production (SDGs 12). Ultimately, institutional sustainability requires integrated policies and consistent government support [59], that empower farmer groups as key agents of agricultural resilience and rural development.

Overall, this study demonstrates that strengthening the sustainability of coffee farming through targeted improvements in priority attributes contributes directly to SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land). Enhancing economic efficiency and productivity improves farmers' income stability and reduces livelihood vulnerability (SDG 1), while sustainable agronomic practices reinforce resilient agricultural systems and long-term production capacity (SDG 2). Improved input management and behavior-based adoption of Good Agricultural Practices promote resource efficiency and responsible production patterns (SDG 12). Simultaneously, soil conservation, climate-adaptive management, and ecological stewardship support mitigation and adaptation efforts (SDG 13) and safeguard terrestrial ecosystems (SDG 15). Policy actions should prioritize performance-based sustainability incentives, behavior-oriented extension services, institutional strengthening for market and financial access, and integration of climate adaptation into regional agricultural planning. This integrated approach ensures measurable contributions of coffee farming sustainability to global development goals.

5. CONCLUSION

This study evaluates the multidimensional sustainability of coffee farming in Temanggung Regency using the MDS-Rapcoffee approach integrated with the Theory of Planned Behavior. The findings indicate a moderate level of sustainability, with the economic dimension performing the strongest and the institutional dimension performing the weakest. Several attributes were identified as sensitive factors, such as fertilizer use, institutional participation, and ecological management, whose improvement could substantially enhance overall sustainability. The implications of these findings are twofold. For farmers, strengthening the adoption of Good Agricultural Practices requires optimizing input use, improving access to and participation in farmer institutions, and promoting ecological conservation. For policymakers, the results provide evidence-based guidance for program design and resource allocation, while for private sector stakeholders, they highlight strategic entry points to enhance supply chain sustainability. Although limited to Temanggung, the methodological approach provides a replicable framework for other regions and commodities and serves as a foundation for future comparative and longitudinal studies aligned with SDGs.

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