Research Article

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Sustainability of Arabica coffee business in West Java, Indonesia: A multidimensional scaling approach

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Abstract: Arabica coffee plantation area is limited, and production is still low while demand increases. The development of Arabica coffee in Indonesia faces many obstacles that threaten its sustainability. The objective of this study is to determine the sustainability status of the Arabica coffee business in West Java and formulate a sustainability strategy. Primary data were obtained through interviews with respondents and key persons from relevant stakeholders from upstream to downstream using a structured questionnaire. The study was conducted in August–October 2021 in Garut District, West Java. Multidimensional Scaling (MDS) was used to assess the sustainability status of the Arabica coffee business in five dimensions, i.e., ecological, economic, social, marketing, and institutional. The results show that the Arabica coffee business in West Java is fairly sustainable, with an average score of 55.65%. The MDS analysis for each dimension reveals that the social dimension has the highest score (62.45%), followed by the ecological dimension (59.01%), the economic dimension (53.00%), the institutional dimension (51.92%), and the marketing dimension (51.87%). This study emphasizes five actions as parts of the sustainability strategy, i.e., adaptation and mitigation of climate change, creative efforts to increase farmers' income, human resource capacity building, strengthening business partnerships, and strengthening farmer organizations.

Keywords: leverage attribute, sustainability index, sustainability strategy, sustainable coffee farming

1 Introduction

Indonesia is the world's fourth largest coffee producer after Brazil, Vietnam, and Columbia [1,2]. In 2018, Indonesian coffee contributed approximately 7% of the world's coffee needs. However, Indonesian coffee production and exports are still dominated by Robusta coffee, which is considered second-class coffee in the international market [1]. While the demand for Arabica coffee continues to increase, the Arabica coffee plantation area is still limited, and production is still low. In Indonesia, approximately 98% of the coffee plantation area is managed by smallholder farmers [3]. The Arabica coffee smallholder plantation area was 360,703 ha in 2019, producing 202,296 tons of coffee beans, or approximately 27% of the total smallholder coffee bean production. West Java is the fourth largest Arabica coffee-producing center after North Sumatra, Aceh, and South Sulawesi. Arabica coffee is a little bit more dominant in this province, amounting to 59% of the total area and 54% of the total production of smallholder coffee plantations in West Java.

Several studies have shown that Arabica coffee farming is technically efficient [4] and financially feasible [5,6]. Previous studies in various regions in Indonesia also reported that Arabica coffee has both comparative advantage and competitive advantage [7–11]. However, these facts are insufficient to ensure the sustainability of coffee agribusiness due to the influence of many factors, such as climate

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change, that negatively impact Arabica coffee production [12,13].

The concept of sustainability has undergone various stages of development since its introduction [14]. This concept basically contains two dimensions: time, because sustainability concerns what will happen in the future, and the interaction between economic systems and natural resources and the environment [15]. However, sustainability in agriculture is a complex concept, so its meaning is multidimensional and can be multi-interpreted. Researchers have no common view about how many dimensions need to be involved. The sustainability dimension is sometimes seen as locally specific, depending on the purpose of the study.

Some previous studies [16,17] stated that sustainability integrates three fields: economic, social, and environmental. The meaning of sustainability in agricultural production systems is closely related to the aggregate value of these three aspects [18]. Somehow, it is necessary to develop technologies and practices that are environmentally friendly, accessible, and practical for farmers and increase productivity [19]. Therefore, they add a technological aspect to the three mentioned fields earlier [20]. Furthermore, several sustainability studies use the Multidimensional Scaling (MDS) approach by integrating five fields, by adding an institutional field [21–23], six fields with an additional ethical field [24], or even seven fields by further adding legal and infrastructure fields [25]. In contrast, Dahliani and Maharani's study [26] only focused on one dimension, namely the social dimension.

The many farmers involved in coffee cultivation make sustainability an essential issue. The ecological, economic, and social dimensions are directly related to farmers. The long-term sustainability of Arabica coffee production depends on the ecological dimension [27], while farmers' participation in sustainable coffee production is motivated mainly by economic incentives [28]. Meanwhile, farmers' intentions to embrace sustainable farming techniques are impacted by their sense of societal pressure [29]. The limited knowledge capacity of farmers can cause less than the optimal achievement of these three dimensions, in terms of cultivation, post-harvest, land resources, and supporting facilities and infrastructure. Therefore, it is necessary to support the institutional and marketing dimensions to increase the effectiveness of the three dimensions. These five dimensions will become strong pillars in supporting the sustainability of Arabica coffee farming.

Studies on the sustainability of Arabica coffee farming using MDS are still very limited and in specific locations [9,24,30–32]. None of these studies assessed the Arabica coffee sustainability in West Java Province, one of the coffee-producing centers in Indonesia. Given the wide distribution of coffee plantations in Indonesia, information regarding the sustainability of the Arabica coffee business in its producing areas, including West Java, is needed. This will help provide a clearer picture of the sustainability of Arabica coffee production in Indonesia. The objective of this article is to assess the sustainability status of the Arabica coffee business in West Java and formulate its sustainability strategy. With the various dimensions used by researchers, as discussed previously, the study focuses on five main dimensions of sustainability, i.e., ecological, economic, social, marketing, and institutional.

2 Methods

2.1 Study location

This study location was focused on Garut District (Figure 1), one of the Arabica coffee-producing areas in West Java, Indonesia. In 2019, Arabica coffee production in Garut was approximately 19% of West Java's total Arabica coffee production. Three sub-districts, i.e., Pakenjeng, Cikajang, and Cisurupan, were purposively selected as sample locations.

2.2 Data and data collection

Primary and secondary data were used in this study. Primary data were gathered through interviews with respondents purposively selected along the Arabica coffee value chain (15 farmer groups, 15 traders, and 11 coffee shop/cafe owners). Primary data were also obtained through in-depth interviews with key persons from relevant government agencies, at central and regional (provincial and district) levels, and coffee associations (Association of Indonesian Coffee Exporters and Industries [AICE], Specialty Coffee Association of Indonesia [SCAI], Association of Indonesian Coffee Farmers [APEKI]). Secondary data were collected from related institutions, scientific journals, and various previous studies related to this research.

Respondents selected were the business actors/stakeholders directly involved in the coffee business, from producers to consumers. The selected key persons are considered to know and understand coffee cultivation, processing, and marketing. The proportion of respondents in each group was determined proportionally. The respondents were selected in each group by considering their representativeness. The study was carried out from August to October 2021.

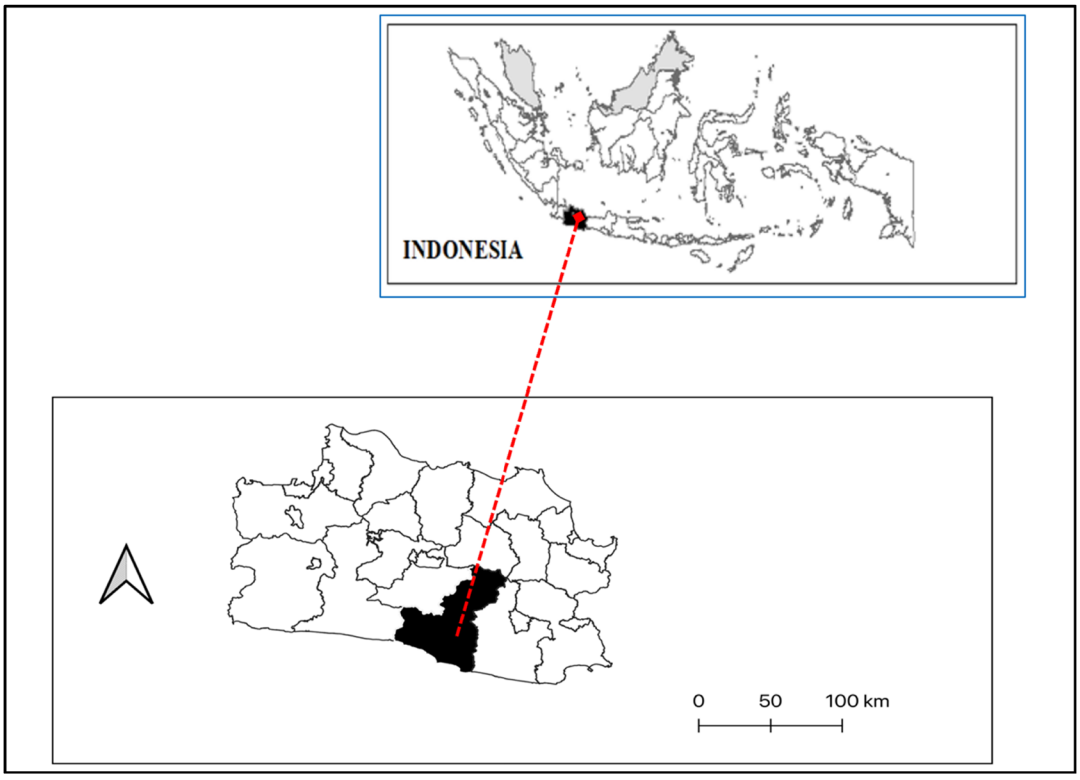

Figure 1: Map of the study location.

2.3 Data analysis

This study employed the Rapcoffee approach to analyze the sustainability of the coffee business in West Java, Indonesia. This technique is a modification of the Rapfish technique (Rapid Assessment Techniques for Fisheries) [33,34], a multidisciplinary approach based on the ordination technique using MDS. MDS is a statistical analytic technique that transforms each dimension and is multidimensional in the sustainability dimension [35]. The MDS method was utilized in this study since it has been proven to produce stable parameter approximations [34]. It can also provide comprehensive, timely, and objective results on elements that affect the sustainability of the coffee business in West Java, making it easier to implement policies in making appropriate business models.

The MDS approach is commonly used to determine the sustainability of natural resource management. In particular, this technique is also commonly used to assess the sustainability of agricultural commodities, such as coffee [22,24,25,31], rice [36–38], corn [23], shallot [39], seaweed [40], and oil palm [16]. In addition, MDS is also used to assess the sustainability of regional development programs such as Agropolitan Villages [41] and forest communities [42].

In this study, the sustainability of coffee business is ordinated in five critical areas, namely (1) **ecological dimension** which consist of five attributes (land area, land suitability, land expansion, climatic conditions, climate change adaptation and mitigation, and pest and disease attack potential); (2) **economic dimension** which consists of 10 attributes (production, productivity, labor costs, farm income, coffee price, price of production facilities, added value of coffee processing, land tenure area, capital, and price and distribution of quality seeds); (3) **social dimension** which consists of six attributes (number of farm laborers, number of coffee farmers, number of farmers receiving counseling/guidance/assistance, communication accessibility, transportation accessibility, and coffee plantation area); (4) **marketing dimension** which consists of eight attributes (cooperation relationship with key partners, relationships with customers, customer benefits, marketing channels, reinvestment in the community, promotion and branding activities, value propositions, and market segmentation); (5) **institutional dimension** which consists of eight attributes (policy programs and government roles, program activities and the role of APEKI, farmer organization, capital institution, innovation and technology institution, marketing institution, production and pest control facility institution, and seeds/nursery institution).

The sustainability determination of the coffee business in West Java was carried out in the following stages. First, determine the attributes of each dimension according to field observations and literature review. These attributes were compiled together with experts, referring to previous research, and adapted to the situation and conditions at the study site. Second, scoring each attribute of each dimension based on the scientific judgment of respondents/key persons. The score ranges between 0 and 3, depending on the state of each attribute, which was interpreted from bad (0) to good (3). Third, the scores for each attribute were analyzed multidimensionally using the Rapcoffee technique to obtain sustainability indexes. The sustainability status for each dimension was determined into four categories according to score interval as follows: 0.00–25.00% (bad/not sustainable); 25.01–50.00% (poor/less sustainable); 50.01–75.00% (moderate/fairly sustainable); and 75.01–100.00% (good/sustainable) [43]. Fourth, conducting Monte Carlo simulation and determining the stress value and the coefficient of determination (R^2). Fifth, conducting leverage analysis to determine sensitive attributes that can influence sustainability.

Through MDS, the position of the sustainability point can be visualized in two dimensions, namely the horizontal axis and the vertical axis. The horizontal axis shows the differences in the studied systems in the ordination of "poor" (0%) to "good" (100%) for each analyzed dimension. Meanwhile, the vertical axis shows the differences in the mix of attribute scores among the studied systems. Leverage analysis is employed to determine the sensitive attributes or interventions performed on these attributes. Monte Carlo analysis was used to evaluate the effect of the error on the estimation of the ordination value as well as in the analysis process, which was carried out at a 95% confidence interval. A goodness of fit test must be performed to measure how accurately the original data can be reflected in the configuration of a point. This goodness of fit in the MDS is reflected in the magnitude of the stress value. A low-stress value denotes a well-fit model, whereas a high-stress value denotes the inverse. A stress value of less than 0.25 ($S < 0.25$) indicates a fit model [44].

3 Results and discussion

3.1 Sustainability status of Arabica coffee business

The results of the Rapcoffee technique using the MDS ordination show that the sustainability status of the Arabica coffee business in the Garut District is multidimensionally moderate, with an average score of 55.65% (Table 1). This relatively low score indicates the presence of many factors that hinder the sustainability of Arabica coffee agribusiness in the Garut District. These factors should be appropriately addressed so that they will not threaten its sustainability. This score is lower than those of the Arabica coffee farming in Temanggung District (66.88%) [24] and Liberica coffee farming in Tanjung Jabung Barat District (63.83%) [22], even though they are still in the same category.

Among the five dimensions analyzed, social sustainability has the highest score (62.45%), followed by ecological (59.01%), economic (53.00%), institutional (51.92%), and marketing (51.87%). These results mean that the marketing dimension is the least sustainable and should be emphasized more in developing Arabica coffee in West Java. The kite diagram of the sustainability status of the Arabica coffee business in Garut District, West Java, based on the five dimensions analyzed, is presented in Figure 2. A detailed discussion is presented in the following subsections (3.2–3.6).

This analysis was performed at a 95% confidence interval [34]. The difference between the Monte Carlo and MDS results was <5%, which means that the MDS

Table 1: Statistic parameters and sustainability status of Arabica coffee business in Garut District, West Java, 2021

No.	Dimension	MDS	Monte Carlo	Difference	Stress	RSQ	Status
1.	Ecological	59.01	58.52	0.49	0.18	0.91	Moderate
2.	Economic	53.00	52.73	0.27	0.15	0.91	Moderate
3.	Social	62.45	61.54	0.91	0.16	0.92	Moderate
4.	Institutional	51.92	51.67	0.25	0.17	0.89	Moderate
5.	Marketing	51.87	51.57	0.30	0.18	0.82	Moderate
6.	Multidimensional	55.65	55.21	0.44	0.17	0.89	Moderate

At 95% significance interval.

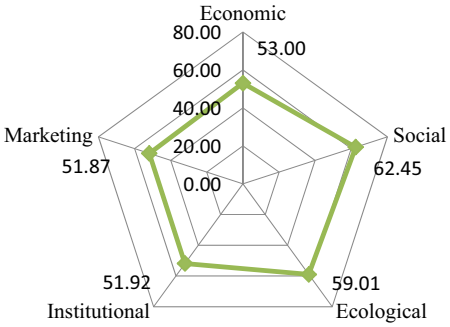

Figure 2: Kite diagram of the sustainability status of Arabica coffee business in Garut District, West Java, 2021.

results were adequate and valid [45–47]. The results of the Monte Carlo simulation with 25 repetitions of the scatter plot method for each dimension are shown in Table 1. Overall, the resulting difference between the two analyses is valid and adequate because it has a very small difference value (<5%). The slight difference between the two methods demonstrates that (1) errors in scoring each attribute are relatively small, (2) scoring variation because of differences in opinion is slight, (3) the repeated analysis process indicates relatively stable results, and (4) data entry errors and missing data can be avoided [48].

The accuracy (goodness of fit) assessment in the MDS analysis is determined by the resulting stress value [49]. A good model is indicated by a stress value <0.25 and an *R*-square or RSQ value close to 1 [45,47,50]. Overall, the stress values in this study are <0.25, indicating that the model is sound and can be employed to accurately assess the sustainability of the Arabica coffee business in Garut District.

3.2 Ecological dimension

The Rapcoffee ordination in the ecological dimension of the Arabica coffee business in the study area shows an average score of 59.01% and is categorized as fairly sustainable (Figure 3). This result shows that the sustainability of Arabica agribusiness faces challenging conditions that should be appropriately addressed, such as climate change, which has become the most significant limiting factor of coffee farming [51]. On the other hand, the farmers have tried to adapt and mitigate the climate change impacts on their coffee farming. This result is in line with some similar previous studies in some other areas of Indonesia, namely, Temanggung District, Central Java [24], and Tanjung Jabung Barat District, Jambi [22]. Nevertheless, the result is better than those in Jember District, East Java [25], and Bangli District, Bali [31], where coffee farming is considered less sustainable.

Intergovernmental Panel on Climate Change (IPCC) reported that climate change is widespread rapidly and intensifying [52]. Climate change significantly impacts the agricultural sector [53], including coffee cultivation, which is susceptible to climate change [54], specifically

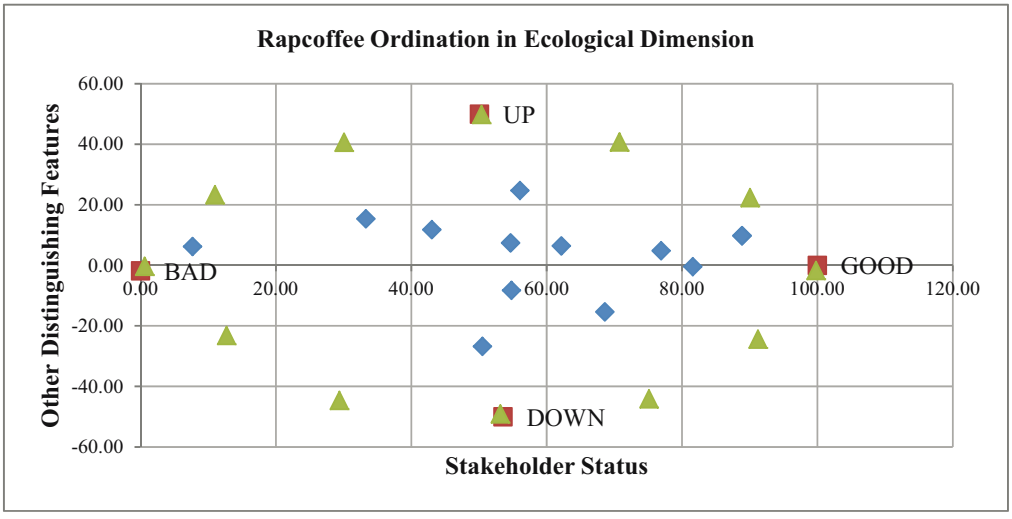

Figure 3: Two-dimensional ecological ordination of the Arabica coffee business in Garut District, 2021. Green triangles represent stakeholders/respondents; blue diamonds represent attributes of the economic dimension.

high air temperature variations [55]. Plantation crops such as coffee are sensitive to climate change due to their lengthy economic life cycle, non-irrigated cropping pattern, and inability to readily switch crops due to significant capital expenses [56,57]. Because most Indonesian coffee is cultivated on marginal land, which is susceptible to abiotic changes such as climate changes, the climate has an increasing influence on the Indonesian coffee production system [58]. Nevertheless, drought severity will worsen in the coming years, resulting in higher payouts from the weather index structure [59]. In particular, the climatic regionalization in West Java Province shows that the northern and southern regions of the province have distinct climate types, while the central areas of the region have fairly complicated spatial variations [60].

Some previous studies reported negative impacts of climate change on coffee cultivation to varying extents, i.e., declines in coffee yield (harvest loss) [12,13,57,61–64], lower coffee quality [62,64,65], loss of coffee-suitable areas, including in Indonesia [55,65–68], and increases in pest and disease outbreak which indirectly reduce yield [61,64,69–71]. Climate conditions significantly impact coffee yield, specifically in the vegetative and reproductive phases [55]. The temperature rises and precipitation deficits harm flowering, fruiting, and bean quality [72]. In addition, climate variables influence the occurrence of severe pests and diseases, causing significant yield losses (up to 70%) [69] and quality reduction while increasing production costs [54]. Such an attack reduced coffee farming income [71].

Based on the leverage analysis results, out of the five ecological attributes analyzed, three attributes are considered the most sensitive, namely climate change adaptation and mitigation (8.12), land expansion (6.84), and land suitability (6.41) (Figure 4). Hence, these attributes should be prioritized in improving the sustainability of the Arabica coffee business in Garut District. This result is in line [51] with the previous study mentioning that land and agro climate suitability is one leverage factor of the sustainability of coffee farming [25].

Given the negative impact caused by climate change on coffee plantations, suitably developed adaptation alternatives to deal with ongoing climate change are critical for lowering exposure and susceptibility [73]. Previous studies have reported some adaptation and management practices. The most common and potential adaptation and management practices identified for coffee production systems was agroforestry, through either intercropping or shading [12,63,72,74–79]. Agroforestry systems are an economically viable and potentially adaptive strategy for farmers in areas prone to climate extremes [72]. This system has been applied by some coffee farmers in the research location in collaboration with Perum Perhutani, a state-owned forestry company. Some studies also reported the implementation of a coffee-based agroforestry system in some regions of Indonesia [80–88]. In addition to adaptation, agroforestry has a mitigation aspect, i.e., increased carbon absorption and improved soil fertility due to increased organic matter content from fallen leaves [89–93]. Aji et al. [89] reported that agroforestry soil quality is similar to that of natural forests.

Other adaptation and mitigation measures practiced by coffee farmers include irrigation and water-efficient use and management [12,13,54], the creation of new cultivars that are drought and heat-tolerant or pest and disease-tolerant, and land conservation [92]. Meanwhile, Sarvina et al. [94] promoted climate-smart agriculture in the coffee production system to adapt to climate change. Related to those measures, coffee farmers in the research location have applied various technologies such as adaptive

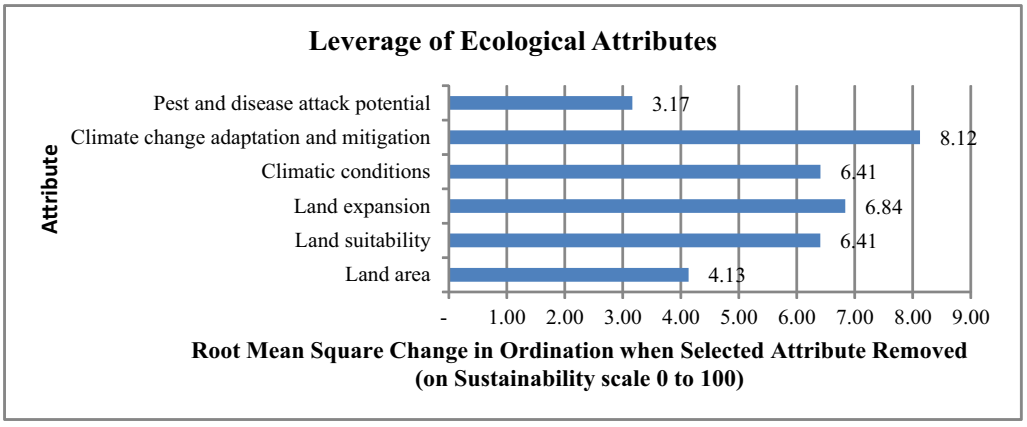

Figure 4: Leverage of individual attributes for the ecological dimension of Arabica coffee business in Garut District, 2021.

clones and soil conservation technology. However, only a small number of farmers use mulch and cover crops.

Land expansion and suitability are the other sensitive attributes in the ecological dimension. This result is supported by the study by Mucharam et al. [21] on the case of rice sustainability in Indonesia. Cooperation with Perum Perhutani is one solution to expand the coffee plantation area besides serving as adaptation and mitigation measures. To increase coffee production and productivity, appropriate technology must support land expansion, especially land-related technology. As mentioned earlier, climate change also affects land suitability, and relocating Arabica coffee plantations to more climatically favorable regions becomes one alternative solution [65,66].

Syakir and Surmaini [53] reported that, although various adaptation technologies have been produced, the level of adaptation of coffee farmers is generally still low. Most farmers have limited access to climate knowledge, markets, technology, farm credit, and climate risk management information, which exacerbates the situation. This is because most coffee farmers in Indonesia are smallholders with limited capacity to deal with climate change effects [94].

3.3 Economic dimension

The results of the economic ordination analysis consisting of ten attributes are presented in Figure 5. The economic sustainability status of the Arabica coffee business is fairly sustainable, with a sustainability index of 53.00%. This score is also relatively low because the coffee business in the area still has not generated decent income for the farmers and processors. The coffee prices received by farmers still tend to fluctuate. Furthermore, farmers lack processing skills and still treat Arabica coffee using a wet process that prevents producing top-quality coffee beans. The score is lower than Ardana's study result (67.37%) [24] but higher than that of Pawiengla et al. [25] (51.52%), although still in the same category. Different conditions are obtained from Gayo Arabica coffee farming [30] and Arabica coffee farming in Sinjai District [32], which have lower scores and fall into the less sustainable category.

The results of the leverage analysis, as shown in Figure 6, reveal that out of ten attributes, three attributes are the most sensitive in the economic dimension, namely, farm income (5.79), coffee processing added value (4.74), and coffee price (4.60). The previous study shows that profitable farming (reflected in business feasibility) is a decisive factor in the sustainability of coffee farming in the Ciamis District [95]. Related to price attributes, the stability of coffee prices was among the most sensitive attributes in the economic dimension [24]. Likewise, the post-harvest selling price of coffee is a sensitive attribute [22]. Thus, price assurance is a crucial factor in supporting the sustainability of Arabica coffee farming.

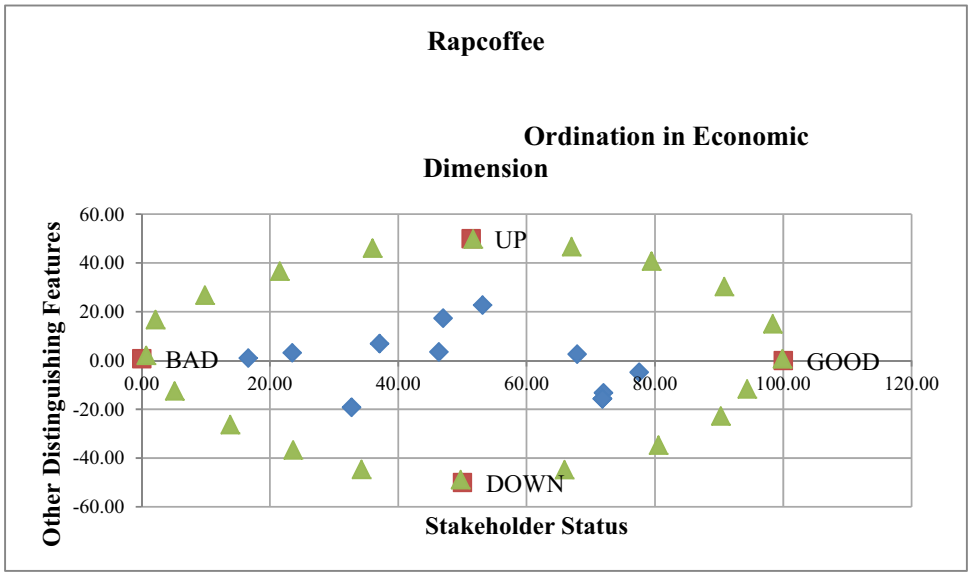

Figure 5: Two-dimensional economic ordination of the Arabica coffee business in Garut District, 2021. Green triangles represent stakeholders/respondents; blue diamonds represent attributes of the economic dimension.

Since farm income is the most sensitive economic attribute, serious and creative efforts are needed to increase coffee farm income to improve economic sustainability. The increase in farm income can be obtained by reducing production costs (labor wages, purchase of seeds, medicines, and fertilizers) through efficient farming or by improving selling prices through improved quality. Farmers can also earn additional income from timber if they perform shaded coffee plantations [78].

Added value is another sensitive attribute to changes in sustainability. Hence, agro-industry development is directed to increase added value, create jobs, and make coffee products more diverse. Hasibuan et al. [96] showed that processing cherry into green beans, roast beans, and even coffee drinks has increased coffee farmers' and entrepreneurs' income. Optimizing the main partners in providing guidance and assistance to farmers is necessary to increase the farmers' capacity in processing (hard skin and green beans) to comply with the standard. This will ultimately impact the stability of coffee prices and, even further, can be a price determinant. For farmers, the lack of price fluctuations is critical in determining the long-term viability of the coffee business [40].

3.4 Social dimension

The results of the social ordination analysis consisting of six attributes are presented in Figure 7. The average sustainability score of the Arabica coffee business in the social dimension is 62.45%. It means that the Arabica coffee farming in Garut District is in the fairly sustainable category. The social dimension has the highest score compared to other dimensions. In the social aspects of the Arabica coffee business in Garut, there is an effort to increase the farmer's resource capacity in coffee cultivation and post-harvest activities through education and training, especially for green beans processing (upstream). In addition, the construction of road infrastructure has provided ease of economic access and social interaction between farmers and other coffee agribusiness actors. According to Laapo et al. [40], good cooperation between farmers, the government, and other stakeholders determines the sustainability of the coffee business.

The result indicates that the social sustainability index of Arabica coffee farming in Garut District is higher than that in Temanggung (59.22%) [24] and in Jember and Malang (56.3%) [25]. However, the value is still lower than that in Tanjung Jabung Barat District (79.86% [sustainable]) [22].

The two most sensitive social attributes in supporting the sustainability of the Arabica coffee business in Garut District are the number of farmers receiving counseling/guidance/assistance (6.74) and transportation accessibility (6.34) (Figure 8). This result is different from other studies, which show that conflict frequency [22], community solidarity [24], and land status [32] are the most sensitive social attributes.

Farmers are at the forefront of increasing production. Therefore, capacity building is very crucial. Extension/technical guidance and assistance from extension workers will significantly determine the success of Arabica coffee development because extension workers can act as intermediaries and information liaisons for farmers and from farmers [39]. Extension workers convey information from the research centers and researchers to farmers and bring

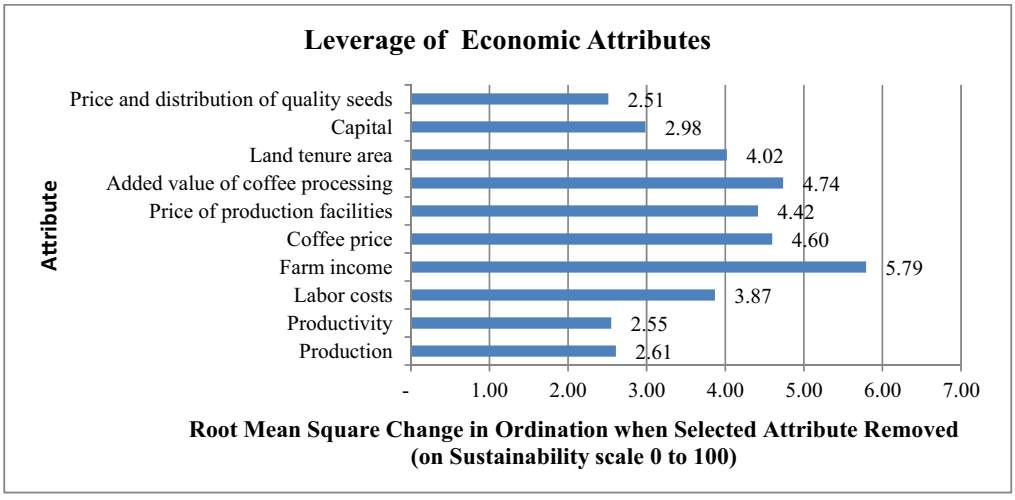

Figure 6: Leverage of individual attributes for the economic dimension of Arabica coffee business in Garut District, 2021.

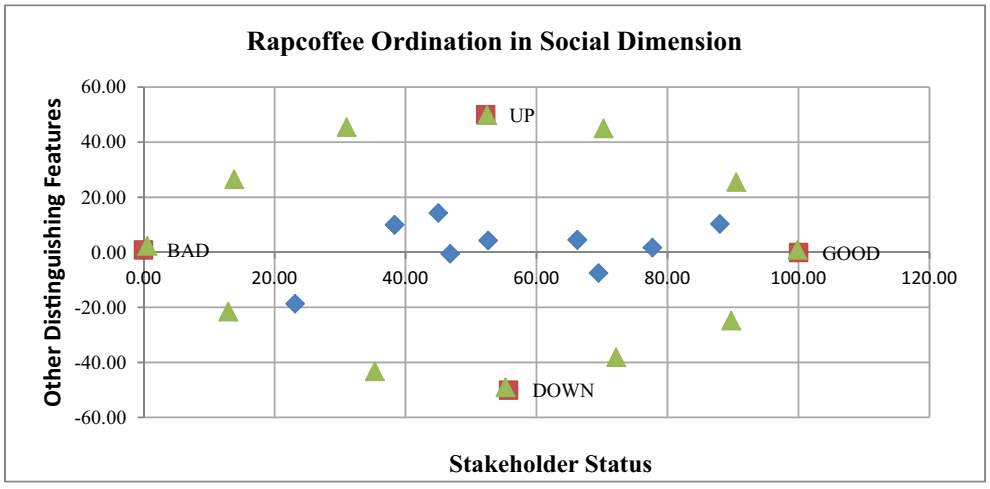

Figure 7: Two-dimensional social ordination of the Arabica coffee business in Garut District, 2021. Green triangles represent stakeholders/respondents; blue diamonds represent attributes of the economic dimension.

the aspirations of farmers to policymakers. Piñeiro et al. [97] showed that technical guidance and extension are the main factors determining the success of sustainable agriculture programs. Technical assistance has also proven to be very effective in helping clients in rural areas to gain access to micro finance instrument credit [98]. In addition, there is a strong correlation between the technical guidance provided to farmers and the level of adoption of high-yielding varieties [99]. Thus, the mentoring/guidance attribute is proven to be sensitive and needs special attention.

Another most sensitive attribute is transportation accessibility. Good infrastructure will increase farmers' access to meet the needs of goods and services, expand marketing areas, improve farmers' capabilities and economy, and provide unlimited mobility for farmers in distribution so that they can freely sell their products. The study by Chacon-Hurtado et al. [100] shows that transportation accessibility can create a strong regional economy. In addition, the study by Nurhaeny et al. [101] reveals that good access to transportation indirectly impacts the growth of regencies/cities in Maluku Province. Meanwhile, the existence of high-speed rail as a mode of transportation in China has proven to encourage the export growth of agriculture-related companies [102]. Likewise, road infrastructure in China can drive aggregate productivity growth due to the entry of new companies and reallocation among existing companies [103]. On the other hand, inefficient transportation can result in losses for farmers, such as depressed harvest prices at the farm level [104]. This can harm the sustainability of agricultural businesses, in this case, the Arabica coffee business.

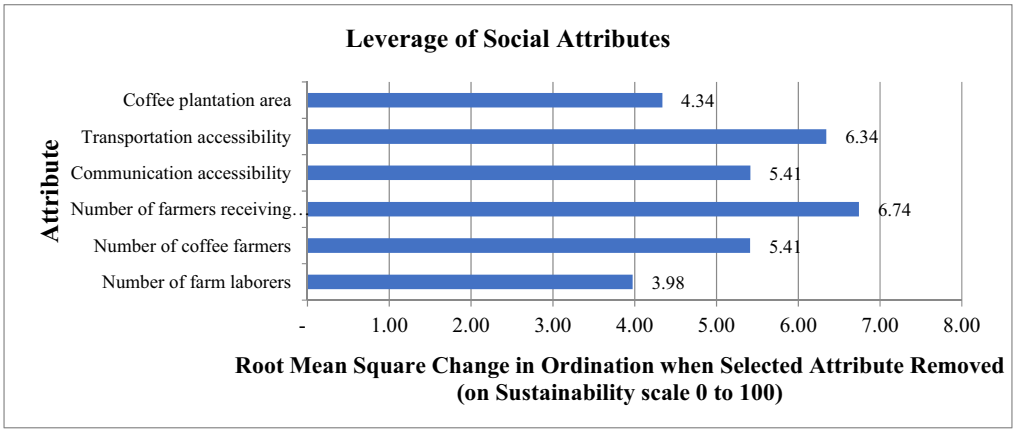

Figure 8: Leverage of individual attributes for the social dimension of Arabica coffee business in Garut District, 2021.

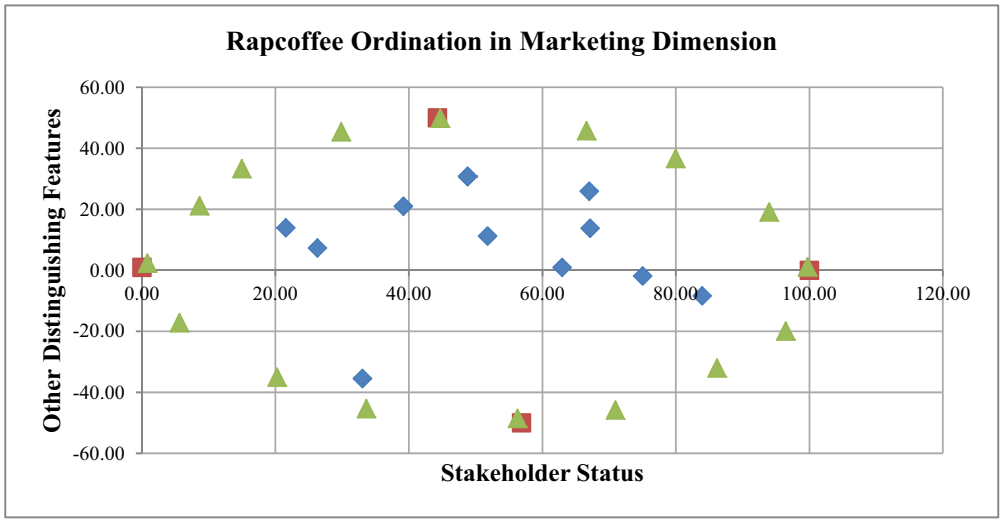

Figure 9: Two-dimensional marketing ordination of the Arabica coffee business in Garut District, 2021. Green triangles represent stakeholders/respondents; blue diamonds represent attributes of the economic dimension.

3.5 Marketing dimension

Figure 9 presents two-dimensional marketing ordination consisting of eight attributes. This figure shows an average score of 51.87%, which falls into the moderate category. The marketing dimension has the lowest sustainability score compared to other dimensions, which is likely caused by the marketing channels that have not been established well.

The results of leverage analysis show that there are two most sensitive attributes in the marketing dimension, namely customer benefits (19.11) and profit surplus/reinvestment (14.71; Figure 10). The high leverage indices show that the two attributes are essential to making the Arabica coffee business in Garut District sustainable. The customers who gain the benefit can establish good relationships and create customer loyalty so that customers are willing to pay according to the set price. Loyal customers will emotionally love the products and establish long-term partnerships because there is a significant relationship between customer satisfaction and loyalty to the company/product [105]. Meanwhile, the profit reinvestment attribute refers to the activity of reinvesting the returns (profits) obtained from an investment. This can be done by investing the profits in the same instrument or investing them in other instruments. Adesehinwa et al. [106] found that business sustainability depends on farmers' ability to earn sufficient profits to reinvest in their businesses.

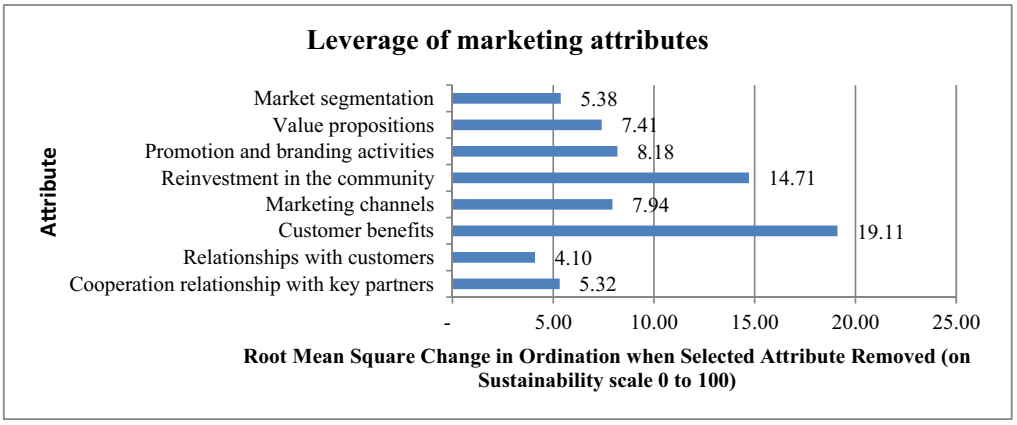

Figure 10: Leverage of individual attributes for the marketing dimension of Arabica coffee business in Garut District, 2021.

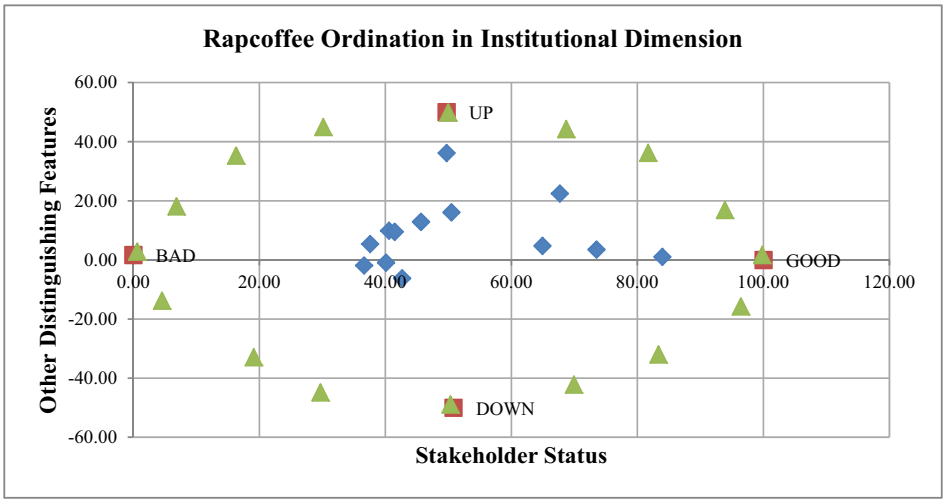

Figure 11: Two-dimensional institutional ordination of the Arabica coffee business in Garut District, 2021. Green triangles represent stakeholders/respondents; blue diamonds represent attributes of the economic dimension.

Since reinvestment is one of the ways to raise the value of the company's shares to obtain optimal profits [107], the company makes reinvestments that provide future profit prospects [108].

3.6 Institutional dimension

The two-dimensional institutional ordination consisting of eight attributes is presented in Figure 11. The institutional sustainability status of the Arabica coffee business in the Garut District is fairly sustainable, with an average score of 51.92%. This score is relatively low and almost falls into the poor category, showing that the institutional aspect related to Arabica coffee in West Java has not been developed well. This institutional sustainability score is smaller than that in Jambi (60.93%) [22] and Temanggung (74.40%) [24]. However, the three studies fall into the same category, i.e., the fairly sustainable category, with varying scores. However, the sustainability score of coffee farming in this study is much greater than that in Sinjai District, which only has a score of 32.09 (less sustainable) [32].

Figure 12 shows that there are four most sensitive attributes out of the six institutional attributes analyzed, namely farmer organization (5.67), marketing institution (5.52), innovation and technology institution (5.30), and capital institution (5.11). Among these attributes, two are in agreement with the previous study [32], which

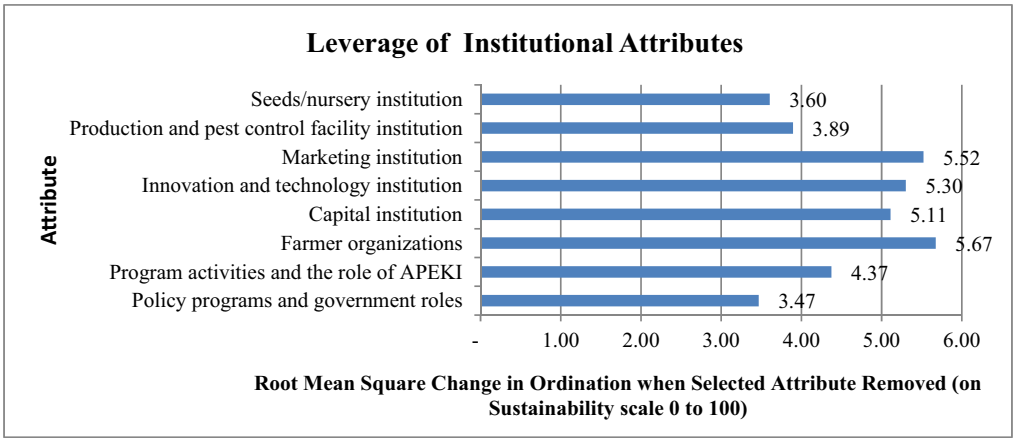

Figure 12: Leverage of individual attributes for the institutional dimension of Arabica coffee business in Garut District, 2021.

revealed that farmer group institutions and financial institutions were the most sensitive attributes. Meanwhile, Zuhra et al. [22] mentioned that knowledge about farming (including innovation and technology) is an essential attribute in the institutional dimension.

Farmer organizations serve as a forum for learning, a vehicle for cooperation, a unit that provides production facilities and infrastructure, a production unit, a processing and marketing unit, and a supporting service unit. In short, in addition to increasing production, it can also carry out agribusiness activities, including marketing and capital. Therefore, the role of central and local governments in policymaking, facilitation, program support, and monitoring and evaluation in optimizing the function of farmer organizations is crucial. The government's role in facilitating the quality control of Arabica coffee from production until being received by consumers [2] is one way to ensure the sustainability of the coffee business.

Innovation and technology institution is another sensitive attribute. Innovation and technology can encourage changes in institutional arrangements and impact the structure of labor and income. The selection of appropriate agricultural innovations can increase farmers' interest in using the introduced technology so that technology adoption will achieve its goals through the optimal empowerment of agricultural extension workers.

3.7 Sustainability strategy of Arabica coffee business

The analysis results show that all five dimensions fall into the fairly sustainable category and mostly have relatively low sustainability scores. This means that there is a strong need for continuous efforts by all coffee business actors along the value chain. One of the efforts to be made is the integration and synergy between agriculture (cultivation) and the industrial, trade, and service sectors to increase Arabica coffee's added value and competitiveness. This is supported by Lazuardi et al. [109], who emphasize the importance of synergy between farmers and various related stakeholders to ensure the long-term viability of coffee farming.

Based on the results of the leverage analysis, it can be concluded that the most sensitive attribute of each dimension, among others, is (a) the ecological dimension: adaptation and mitigation of climate change, (b) the economic dimension: increasing farmers' income, (c) the social dimension: increasing the capacity of farmers' human resources, through technical guidance, counseling, and assistance, (d) the marketing dimension: maintaining relationships with key partners and customers, and (e) the institutional dimension: farmer institutions. To maintain and develop the sustainability of Arabica coffee farming, the most sensitive attributes of each dimension must be a major concern for business actors, including the government, in improving the performance of the most sensitive attributes.

One of the efforts to adapt and mitigate climate change in the ecological dimension is collaborating with Perhutani through agroforestry patterns. Perhutani is a state-owned enterprise with the task and authority to manage state forest resources on the islands of Java and Madura. The effort can be made by applying various technologies to increase production and productivity. Furthermore, raising awareness, building capacity, promoting knowledge and experience exchange, and providing technical and financial support should be prioritized to facilitate adaptation implementation and strengthen farmer resilience to climate variability and change [54].

In the economic dimension, efforts to increase farmers' income can be made by reducing production costs (labor wages, purchasing seeds, medicines, and fertilizers) or improving the selling price of coffee. Thus, efficient farming and improved coffee quality are the keywords to reduce production costs and obtain higher prices. Participation in the specialty coffee market can also increase coffee farmers' income due to the higher unit price for coffee [110].

In the social dimension, one effort is to build the capacity of farmers' human resources through technical guidance, counseling, and assistance. Farmers and land are the main resources needed in producing Arabica coffee. Coffee cultivation must be handled by farmers with good skills, from selecting quality seeds to planting and maintenance. Therefore, efforts to increase the capacity of farmers' human resources must be a major concern. However, it should be supported by the availability of land, both area and land suitability. According to Ortega et al. [111], a cooperative is an essential institution for farmer capacity building. Aside from capacity building in crop production, increasing entrepreneurial capacity is also critical to increasing farmers' income through optimizing added value [112,113].

In the marketing dimension, how much benefit the customer gets should be of concern. Customers' satisfaction due to their benefits will establish good relationships and create customer loyalty so that they are willing to pay according to the price. In terms of maintaining relationships with key partners and customers, one of the efforts is economic partnership development [114]. Smallholder coffee producers benefit from company partnerships

through smooth coffee marketing [115]. Furthermore, the quality and intensity of collaboration in the cluster would boost the cluster community's engagement [116]. One example of partnership has been shown by the Community Partnership Program (PKM), which has supported Pilozz coffee partners to become productive MSMEs [117].

Meanwhile, for the institutional dimension, the central and local government has an essential role in optimizing the function of farmer organizations. Farmer organizations significantly positively affect members' farm performance [118]. Several studies revealed there are some strategies to strengthen the organization. The collective empowerment of farmers could be realized through new collaborations and experiments [119]. Optimizing innovation, education, and training, credit facilities increased community empowerment and business partnerships for poor and women farmers [120,121]. In addition, grouping in small-scale cooperatives offers female farmers to become economically emancipated [122]. Candelo et al. [123] stated that increasing value co-creation empowers low-power and vulnerable global players. Therefore, the government should provide support through policies, facilitation, mentoring, and monitoring and evaluation.

4 Conclusions

Multidimensionally, the Arabica coffee business in Garut District, West Java, is fairly sustainable. Likewise, the five dimensions analyzed also fall into the fairly sustainable category. This means that there need to be continuous efforts along the value chain, one of which is through integration and synergy between agriculture (aspects of cultivation), industry, trade, and services to increase Arabica coffee's added value and competitiveness. The most sensitive attributes of each dimension must be highly considered in maintaining the sustainability of the Arabica coffee business in Garut District, West Java. Therefore, efforts to improve the performance and maintain the sustainability of the Arabica coffee business need to be focused on (1) adaptation and mitigation to climate change, (2) seeking breakthroughs to increase farmers' income, (3) capacity building of farmers through technical guidance, counseling, and assistance, (4) maintaining relationships with key partners and customers to obtain customer loyalty, and (5) strengthening farmer organizations.

This study is limited in scale; i.e., it was only conducted in Garut District, West Java Province, so the result cannot be extrapolated nationally. Therefore, extending the study area to other Arabica coffee-producing regions in Indonesia or even outside Indonesia to provide a global-scale conclusion is an excellent opportunity for future research. In addition, future studies need to look at coffee sustainability in the context of a circular economy. Arabica coffee farming should be designed without waste and provides added value to the economy and the environment. The role of the corporate social responsibility program in supporting this effort can also be a notable study to accommodate.

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References

[1] Maulani RD, Wahyuningsih D. Analisis ekspor kopi Indonesia pada pasar internasional. Pamator J. 2021;14:27–33. doi: 10.21107/pamator.v14i1.8692.

[2] Pratiwi LPK, Budiasa M, Yudiarini N. The role of the geographic indication certification of Arabic coffee as an effort of local farmers. Int J Res. 2021;9:330–8. doi: 10.29121/granthaalayah.v9.i2.2021.3102.

[3] Directorate General of Estate Crops. Statistical of national leading estate crops commodity 2019-2021. Jakarta: Directorate General of Estate Crops; 2020.

[4] Sudjarmoko B, Randriani E. Technical efficiency of Arabica Garut Kuning (AGK) coffee farming. J Tanam Ind Penyegar. 2019;6:13–20. doi: 10.21082/jtidp.v6n1.2019.p13-20.

[5] Puspita C, Rifin A, Daryanto HK. Revenue and farming management analysis of Arabica and Robusta coffee in Jember Regency, East Java, Indonesia. J Sci Res Publ. 2015;5:139–43.

[6] Zakaria A. Analisis kelayakan finansial usaha tani kopi arabika (Coffea arabica) di Desa Suntenjaya, Kecamatan Lembang Kabupaten Bandung Barat. Agroscience. 2019;9:34–40. doi: 10.35194/agsci.v9i1.633.

[7] Boto AB, Khairati R, Ifdal I. Analisis daya saing dan dampak kebijakan pemerintah pada komoditas kopi arabika Kabupaten Solok. J Pembang Nagari. 2021;6:1–12. doi: 10.30559/jpn.v%vi%i.216.
[8] Muttoharoh V, Nurjanah R, Mustika C. Daya saing dan faktor-faktor yang mempengaruhi ekspor kopi Arabika Indonesia di pasar internasional. E-J Perspekt Ekon Pembang Drh. 2018;7:127–36. doi: 10.22437/pdpd.v7i3.6904.
[9] Pratiwi A, Sebayang T, Hasyim H. Analisis daya saing komoditas kopi Arabika di Kabupaten Tapanuli Utara. J Agric Agribus Socioecon. 2013;2:1–15.
[10] Amaliyah DR, Dwiastuti R, Setiawan B. Analisis daya saing kopi arabika PT Perkebunan Nusantara XII Kebun Kalisampit-Jampit. Habitat. 2013;24:173–83.
[11] Yusiska S, Kasimin S, Sugianto S. Analysis of factors affecting the production and price of coffee Arabica to competitiveness in Central Aceh District. Int J Multicult Multireligious Underst. 2019;6:408–13. doi: 10.18415/ijmmu.v6i4.1006.
[12] Chengappa PG, Devika CM, Rudragouda CS. Climate variability and mitigation: perceptions and strategies adopted by traditional coffee growers in India. Clim Dev. 2017;9:593–604. doi: 10.1080/17565529.2017.1318740.
[13] Jayakumar M, Rajavel M, Surendran U, Gopinath G, Ramamoorthy K. Impact of climate variability on coffee yield in India–with a micro-level case study using long-term coffee yield data of humid tropical Kerala. Clim Change. 2017;145:335–49. doi: 10.1007/s10584-017-2101-2.
[14] Klarin T. The concept of sustainable development: From its beginning to the contemporary issues. Zagreb Int Rev Econ Bus. 2018;21:67–94. doi: 10.2478/zireb-2018-0005.
[15] Heal G. Valuing the future: economic theory and sustainability. New York: Columbia University Press; 1998.
[16] Papilo P, Marimin, Hambali E, Sitanggang IS. Sustainability index assessment of palm oil-based bioenergy in Indonesia. J Clean Prod. 2018;196:808–20. doi: 10.1016/j.jclepro.2018.06.072.
[17] Munasinghe M. Sustainable development in practice: Sustainomics methodology and applications. Cambridge University Press; 2009. doi: 10.1017/CBO9780511626777.
[18] Sydorovych O, Wossink A. The meaning of agricultural sustainability: Evidence from a conjoint choice survey. Agric Syst. 2008;98:10–20. doi: 10.1016/j.agsy.2008.03.001.
[19] Pretty J. Agricultural sustainability: Concepts, principles and evidence. Philos Trans R Soc Lond B Biol Sci. 2008;363:447–65. doi: 10.1098/rstb.2007.2163.
[20] Jaya R, Ferizal M, Ardiansyah R, Mirza I, Ismail M, Rahmah FF. Sustainability design for development of Gayo's Science Park's. IOP Conf Ser: Earth Environ Sci. 418, 2020. p. 012087. doi: 10.1088/1755-1315/418/1/012087.
[21] Mucharam I, Rustiadi E, Fauzi A, Harianto. Assessment of rice farming sustainability: Evidence from Indonesia provincial data. Int J Sustain Dev Plan. 2020;15:1323–32. doi: 10.18280/ijsdp.150819.
[22] Zuhra Z, Syarifuddin H, Maryani AT. Pengembangan usahatani kopi liberika berbasis indeks keberlanjutan di Kecamatan Betara Kabupaten Tanjung Jabung Barat. J Pembang Berkelanj. 2019;2:89–101. doi: 10.22437/jpb.v21i1.5101.
[23] Ariningsih E, Rachman B, Sudaryanto T, Ariani M, Septanti KS, Adawiyah CR. Strategies for sustainable corn production: A case of South Lampung District, Lampung Province, Indonesia. IOP Conf Ser: Earth Environ Sci. 2021;892:012075. doi: 10.1088/1755-1315/892/1/012075.
[24] Ardana IK. Sustainability of Temanggung coffee farming system in the perspective of geographical indications. J Penelit Tanam Ind. 2019;25:69–80. doi: 10.21082/littri.v25n2.2019.69-80.
[25] Pawiengla AA, Yunitasari D, Adenan M. Analisis keberlanjutan usahatani kopi rakyat di Kecamatan Silo Kabupaten Jember. J Ekon Pertan Agribis. 2020;4:701–14. doi: 10.21776/ub.jepa.2020.004.04.01.
[26] Dahliani L, Maharani MDD. Palm oil sustainable management using MDS model from social dimension. Adv Soc Sci Educ Hum Res: Proc 5th Int Conf Com Dev; 2018. p. 50–3. doi: 10.2991/amca-18.2018.15.
[27] Saragih JR. Aspek ekologis dan determinan produksi kopi Arabika spesialti di wilayah dataran tinggi Sumatera Utara. J Wil Lingkung. 2018;6:74–87. doi: 10.14710/jwl.6.2.74-87.
[28] Anh NH, Bokelmann W, Nga DT, Van Minh N. Toward sustainability or efficiency: The case of smallholder coffee farmers in Vietnam. Economies. 2019;7:66. doi: 10.3390/economies7030066.
[29] Nguyen N, Drakou EG. Farmers intention to adopt sustainable agriculture hinges on climate awareness: The case of Vietnamese coffee. J Clean Prod. 2021;303:126828. doi: 10.1016/j.jclepro.2021.126828.
[30] Jaya R, Machfud, Raharja S, Marimin M. Sustainability analysis for Gayo coffee supply chain. Int J Adv Sci Eng Inf Technol. 2013;3:24–8.
[31] IDAS Yudhari, Darwanto DH, Waluyati LR, Mulyo JH. Multidimensional scaling: Sustainability of Arabika coffee agro-tourism in Kabupaten Bangli Bali. J Env Manag Tour. 2020;11:1455–65. doi: 10.14505/jemt.v11.6(46).16.
[32] Awaluddin A, Nuraeni N, Ilsan M. Analisis keberlanjutan usahatani kopi arabika Bawakaraeng Kecamatan Sinjai Barat Kabupaten Sinjai. J Agrotek. 2018;2:73–84.
[33] Pitcher TJ, Preikshot DB. Rapfish: A rapid appraisal technique to evaluate the sustainability status of fisheries. Fish Res. 2001;49:255–70.
[34] Pitcher TJ, Lam ME, Ainsworth C, Martindale A, Nakamura K, Perry RI, et al. Improvements to Rapfish: A rapid evaluation technique for fisheries integrating ecological and human dimensionsa. J Fish Biol. 2013;83:865–89. doi: 10.1111/jfb.12122.
[35] Rao NH, Rogers P. Assessment of agricultural sustainability. Curr Sci. 2006;91:439–48.
[36] Yusuf R, Tang UM, Karnila R, Pato U. Index and sustainability status of economic dimension for wetland rice business in Siak Regency, Riau, Indonesia. J Env Sci Technol. 2019;12:177–85. doi: 10.3923/jest.2019.177.185.
[37] Yusuf R, Tang UM, Karnila R, Fuadi I, Pato U. Ecological sustainability of rice farms in Siak District, Riau, Indonesia. Biodiversitas. 2020;21:3797–804. doi: 10.13057/biodiv/d210847.
[38] Barchia MF, Ishak A, Utama SP, Novanda RR. Sustainability status of paddy cultivation on marginal peat soils in Indonesia. Bulg J Agric Sci. 2021;27:259–70.

[39] Parmawati R, Hardyansah R, Rahmawati A. Sustainability of corporate based shallot farming business: Evidence from Malang Regency, Indonesia. J Socioecon Dev. 2021;4:46–56. doi: 10.31328/jsed.v4i1.1644.
[40] Laapo A, Howara D, Kassa S, Sultan H, Rahim A. A multidimensional approach to assessing the leverage factors of the sustainability of seaweed farming in coastal area of Parigi Moutong District, Indonesia. J Aquac Fish Health. 2021;10:271–81. doi: 10.20473/jafh.v10i3.24281.
[41] Parmawati R. Sustainable managemen and rural agropolitan development in Sendang Village of Tulungnagung East Java a multidimensional analysis of sustainability. J Kawistara. 2019;9:239–53. doi: 10.22146/kawistara.40437.
[42] Nandini R, Kusumandari A, Gunawan T, Sadono R. Multidimensional scaling approach to evaluate the level of community forestry sustainability in Babak watershed, Lombok Island, West Nusa Tenggara. Forum Geogr. 2017;31:28–42. doi: 10.23917/forgeo.v31i1.3371.
[43] Fauzi A, Anna S. Pemodelan sumber daya perikanan dan kelautan untuk analisis kebijakan. Jakarta: Gramedia Pustaka Utama; 2005.
[44] Kavanagh P. Rapid appraisal of fisheries (Rapfish) project. Vancouver: Fisheries Centre, University of British Columbia; 2001.
[45] Alder J, Pitcher TJ, Preikshot D, Kascher K, Feriss B. How good is good? A rapid appraisal technique for evaluation of the sustainability status of fisheries of the North Atlantic. In: Pauly D, Pitcher TJ, editors. Methods for evaluation the impacts of fisheries on the North Atlantic ecosystem. 8, 2nd edn. Vancouver: Fisheries Centre, University of British Columbia; 2000. p. 136–82.
[46] Mastuti R, Alham F, Gustiana C, Hanisah H, Jamil M, Muslimah M, et al. Sustainability of technological dimension in dairy agribusiness. J Phys: Conf Ser. 2019;1375:012043. doi: 10.1088/1742-6596/1375/1/012043.
[47] Mulyatna L, Yustiani YM, Andisa RR, Ramadhan RF, Hidayanti D. Sustainability analysis of the application of waste bank in elementary school with a multidimensional scaling approach. J Commun Based Env Eng Manag. 2021;5:103–10. doi: 10.23969/jcbeem.v5i2.4535.
[48] Arsyad AH, Fanani Z, Nugroho BA. Nasich Moch. Sustainability status of multidimensions of beef-cattle development in integrated agricultural areas in Bone Bolango Regency, Gorontalo Province. Int J Adv Res. 2019;7:666–79. doi: 10.21474/IJAR01/9547.
[49] Barroso PA, Medeiros AM, Santos NPS, Silva DC, Silva SD, Gomes RLF. Phenotypic Dispersion of Landrace Lima Bean Varieties Using Multidimensional Scaling. J Agric Sci. 2019;11:178. doi: 10.5539/jas.v11n13p178.
[50] Kavanagh P, Pitcher TJ. Implementing Microsoft Excel software for rapfish: a technique for the rapid appraisal of fisheries status. Vancouver: Fisheries Centre, University of British Columbia; 2004.
[51] Wijaya MI. Usahatani kopi robusta di Kecamatan Candiroto Kabupaten Temanggung (Studi Kasus Desa Gunungpayung dan Desa Sidoharjo). E-J UNY. 2017;2(7):1–15.
[52] Climate IPCC change 2021: The physical science basis. Summary for Policymakers. In: Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger S, et al. editors. Climate change 2021: The physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. New York: Cambridge University Press; 2021. p. 3–32. doi: 10.1017/9781009157896.001.
[53] Syakir M, Surmaini E. Perubahan iklim dalam konteks sistem produksi dan pengembangan kopi di Indonesia. J Penelit Pengemb Pertan. 2017;36:77–90. doi: 10.21082/jp3.v36n2.2017.p77-90.
[54] Pham Y, Reardon-Smith K, Mushtaq S, Cockfield G. The impact of climate change and variability on coffee production: a systematic review. Clim Change. 2019;156:609–30. doi: 10.1007/s10584-019-02538-y.
[55] Tavares PD, Giarolla A, Chou SC, Silva AJ, Lyra AD. Climate change impact on the potential yield of Arabica coffee in southeast Brazil. Reg Env Change. 2018;18:873–83. doi: 10.1007/s10113-017-1236-z.
[56] Gunathilaka RPD, Smart JCR, Fleming CM. Adaptation to climate change in perennial cropping systems: Options, barriers and policy implications. Env Sci Policy. 2018;82:108–16. doi: 10.1016/j.envsci.2018.01.011.
[57] Bacon CM, Sundstrom WA, Stewart IT, Beezer D. Vulnerability to cumulative hazards: Coping with the coffee leaf rust outbreak, drought, and food insecurity in Nicaragua. World Dev. 2017;93:136–52. doi: 10.1016/j.worlddev.2016.12.025.
[58] Sarvina Y, June T, Sutjahjo SH, Nurmalina R, Surmaini E. The impacts of climate variability on coffee yield in five Indonesian coffee production centers. Coffee Sci. 2021;16:1–9. doi: 10.25186/.v16i.1917.
[59] Hohl R, Jiang Z, Tue Vu M, Vijayaraghavan S, Liong SY. Using a regional climate model to develop index-based drought insurance for sovereign disaster risk transfer. Agric Fin Rev. 2021;81:151–68. doi: 10.1108/AFR-02-2020-0020.
[60] Adi RF, Sugiarto Y, Arifah A, Arini EY, Atmaja T. Climate regionalization for main production areas of Indonesia: Case study of West Java. IOP Conf Ser: Earth Env Sci. 2017;54:012031. doi: 10.1088/1755-1315/54/1/012031.
[61] Harvey CA, Saborio-Rodríguez M, Martinez-Rodríguez MR, Viguera B, Chain-Guadarrama A, Vignola R, et al. Climate change impacts and adaptation among smallholder farmers in Central America. Agric Food Secur. 2018;7:1–20. doi: 10.1186/s40066-018-0209-x.
[62] Guido Z, Finan T, Rhiney K, Madajewicz M, Rountree V, Johnson E, et al. The stresses and dynamics of smallholder coffee systems in Jamaica's Blue Mountains: a case for the potential role of climate services. Clim Change. 2018;147:253–66. doi: 10.1007/s10584-017-2125-7.
[63] Rahn E, Vaast P, Läderach P, van Asten P, Jassogne L, Ghazoul J. Exploring adaptation strategies of coffee production to climate change using a process-based model. Ecol Model. 2018;371:76–89. doi: 10.1016/j.ecolmodel.2018.01.009.
[64] Boer R, Jadmiko SD, Hidayat P, Wachjar A, Ardiansyah M, Sulistyowati D, et al. Managing climate risk in a major-growing region in Indonesia. In: Venkatramanan V, Shah S, Prasad R, editors. Global Climate Change and Environmental Policy: Agriculture Perspectives. Singapore: Springer Singapore; 2019. p. 147–205. doi: 10.1007/978-981-13-9570-3.
[65] Läderach P, Ramirez–Villegas J, Navarro-Racines C, Zelaya C, Martinez–Valle A, Jarvis A. Climate change adaptation of

coffee production in space and time. Climatic Change. 2017;141:47–62. doi: 10.1007/s10584-016-1788-9.
[66] Schroth G, Läderach P, Blackburn Cuero DS, Neilson J, Bunn C. Winner or loser of climate change? A modeling study of current and future climatic suitability of Arabica coffee in Indonesia. Reg Env Change. 2015;15:1473–82. doi: 10.1007/s10113-014-0713-x.
[67] Chemura A, Kutywayo D, Chidoko P, Mahoya C. Bioclimatic modelling of current and projected climatic suitability of coffee (Coffea arabica) production in Zimbabwe. Reg Env Change. 2016;16:473–85. doi: 10.1007/s10113-015-0762-9.
[68] Imbach P, Fung E, Hannah L, Navaroo-Racines CE, Roubik DW, Ricketts TH, et al. Coupling of pollination services and coffee suitability under climate change. PNAS. 2017;114:10438–42. doi: 10.7910/DVN/9DY3GE.
[69] Djuikem C, Grognard F, Wafo RT, Touzeau S, Bowong S. Modelling coffee leaf rust dynamics to control its spread. Math Model Nat Phenom. 2021;16:1–25. doi: 10.1051/mmnp/2021018.
[70] Lemma DT, Abewoy D. Review on integrated pest management of coffee berry disease and coffee berry borer. Int J Plant Breed Crop Sci. 2021;8:1001–8.
[71] Triana EF, Hasanuddin T, Nurmayasari I. Persepsi petani kopi terhadap program sertifikasi Rainforest Alliance Coffe (RFA) di Kecamatan Pulau Panggung Kabupaten Tanggamus. J Ilmu Ilmu Agribisnis. 2019;7:397–404.
[72] Lin BB. Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture. Agric Meteorol. 2007;144:85–94. doi: 10.1016/j.agrformet.2006.12.009.
[73] Climate IPCC change 2022: Impacts, adaptation and vulnerability. Summary for Policymakers. In: Pörtner HO, Roberts DC, Tignor M, Poloczanska ES, Mintenbeck K, Alegría A, et al. editors. Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press; 2022.
[74] Nesper M, Kueffer C, Krishnan S, Kushalappa CG, Ghazoul J. Shade tree diversity enhances coffee production and quality in agroforestry systems in the Western Ghats. Agric Ecosyst Env. 2017;247:172–81. doi: 10.1016/j.agee.2017.06.024.
[75] Cerda R, Allinne C, Gary C, Tixier P, Harvey CA, Krolczyk L, et al. Effects of shade, altitude and management on multiple ecosystem services in coffee agroecosystems. Eur J Agron. 2017;82:308–19. doi: 10.1016/j.eja.2016.09.019.
[76] Meylan L, Gary C, Allinne C, Ortiz J, Jackson L, Rapidel B. Evaluating the effect of shade trees on provision of ecosystem services in intensively managed coffee plantations. Agric Ecosyst Env. 2017;245:32–42. doi: 10.1016/j.agee.2017.05.005.
[77] Ehrenbergerová L, Šenfeldr M, Habrová H. Impact of tree shading on the microclimate of a coffee plantation: a case study from the Peruvian Amazon. Bois Forets Des Trop. 2017;334:13–22. doi: 10.19182/bft2017.334.a31488.
[78] Jezeer RE, Santos MJ, Boot RGA, Junginger M, Verweij PA. Effects of shade and input management on economic performance of small-scale Peruvian coffee systems. Agric Syst. 2018;162:179–90. doi: 10.1016/j.agsy.2018.01.014.
[79] Moreira SLS, Pires CV, Marcatti GE, Santos RHS, Imbuzeiro HMA, Fernandes RBA. Intercropping of coffee with the palm tree, macauba, can mitigate climate change effects. Agric Meteorol. 2018;256–257:379–90. doi: 10.1016/j.agrformet.2018.03.026.
[80] Premono BT, Lestari S. Financial analysis on agroforestry system of coffee with Marrango tree (Azadirachta excelsa Jack.) in Rejang Lebong Regency, Bengkulu Province, Indonesia. Indones J Res. 2018;5:45–56. doi: 10.20886/ijfr.2018.5.1.43-54.
[81] Withaningsih S, Rabbany M. Correlation between some landscape metrics and insect species richness in coffee agroforests in Pangalengan Subdistrict, Bandung district, West Java, Indonesia. Biodiversitas. 2019;20:3075–85. doi: 10.13057/biodiv/d201042.
[82] Lisnawati A, Lahjie AM, Simarangkir BDAS, Yusuf S, Ruslim Y. Agroforestry system biodiversity of Arabica coffee cultivation in North Toraja district, South Sulawesi, Indonesia. Biodiversitas. 2017;18:741–51. doi: 10.13057/biodiv/d180243.
[83] Iskandar BS, Iskandar J, Irawan B, Suroso, Partasasmita R. The development of coffee cultivation in the traditional agroforestry of mixed-garden (dukuh lembur) to provide social-economic benefit for the outer Baduy community, South Banten, Indonesia. Biodiversitas. 2019;20:2958–69. doi: 10.13057/biodiv/d201026.
[84] Yuliasmara F. El Nino effect on coffee growth and productivity on several agroforestry systems in Gumitir Mountain coffee farms, East Java, Indonesia. Pelita Perkeb. 2017;33:168–79. doi: 10.22302/iccri.jur.pelitaperkebunan.v33i3.291.
[85] Withaningsih S, Parikesit, Alham RF. Diversity of bird species in the coffee agroforestry landscape: Case study in the Pangalengan Sub-District, Bandung District, West Java, Indonesia. Biodiversitas. 2020;21:2467–80. doi: 10.13057/biodiv/d210619.
[86] Hairiah K, Widianto W, Suprayogo D, van Noordwijk M. Tree roots anchoring and binding soil: Reducing landslide risk in Indonesian agroforestry. Land. 2020;9:1–19. doi: 10.3390/LAND9080256.
[87] Kusnendi FS, Supijatno S, Wachjar A, Hidayat Y, Suseno SH. Study of intercropping system and in situ organic matter application on coffee agroforestry at Citarum Watershed, West Java, Indonesia. J Trop Crop Sci. 2020;7:51–8. doi: 10.29244/jtcs.7.02.51-58.
[88] Duffy C, Toth GG, Hagan RPO, McKeown PC, Rahman SA, Widyaningsih Y, et al. Agroforestry contributions to smallholder farmer food security in Indonesia. Agrofor Syst. 2021;95:1109–24. doi: 10.1007/s10457-021-00632-8.
[89] Aji BDS, Wijayanto N, Wasis B. Visual evaluation of soil structure (VESS) method to assess soil properties of agroforestry system in Pangalengan, West Java. J Manaj Hutan Tropika. 2021;27:80–8. doi: 10.7226/jtfm.27.2.80.
[90] Mulyono A, Suriadikusumah A, Harriyanto R, Djuwansah MR. Soil quality under agroforestry trees pattern in upper Citarum watershed, Indonesia. J Ecol Eng. 2019;20:203–13. doi: 10.12911/22998993/93942.
[91] Hanisch S, Dara Z, Brinkmann K, Buerkert A. Soil fertility and nutrient status of traditional Gayo coffee agroforestry systems in the Takengon region, Aceh province, Indonesia. J Agric Rur Dev Trop Subtrop. 2011;112:87–100.

[92] Yuliasmara F. Strategi mitigasi perkebunan kopi menghadapi perubahan iklim. War Pus Penelit Kopi Kakao. 2016;28(3):1–7.
[93] Gomes LC, Bianchi FJJA, Cardoso IM, Fernandes RBA, Filho EIF, Schulte RPO. Agroforestry systems can mitigate the impacts of climate change on coffee production: A spatially explicit assessment in Brazil. Agric Ecosyst Env. 2020;294:106858. doi: 10.1016/j.agee.2020.106858.
[94] Sarvina Y, June T, Sutjahjo SH, Nurmalina R, Surmaini E. Why should climate smart agriculture be promoted in the Indonesian coffee production system? J Sustain Sci Manag. 2021;16:347–63. doi: 10.46754/jssm.2021.10.024.
[95] Syachruloh A, Setiawan I, Yusuf MN. Analisis keberlanjutan usahatani kopi di Kecamatan Panjalu Kabupaten Ciamis. J Ilm Mhs Agroinfo Galuh. 2021;8:40–50.
[96] Hasibuan SAF, Harahap RH, Purwoko A. Peran pemuda dalam pengembangan usaha kopi di kawasan wisata Simarjarunjung. Perspektif. 2021;10:644–55. doi: 10.31289/perspektif.v10i2.4970.
[97] Piñeiro V, Arias J, Dürr J, Elverdin P, Ibáñez AM, Kinengyere A, et al. A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. Nat Sustain. 2020;3:809–20. doi: 10.1038/s41893-020-00617-y.
[98] Garcia A, Cecchi F, Eriksen S, Lensink R. The plus in credit-plus-technical assistance: Evidence from a rural microcredit programme in Bolivia. J Dev Stud. 2021;58:275–91. doi: 10.1080/00220388.2021.1928639.
[99] Sinare B, Miningou A, Nebié B, Eleblu J, Kwadwo O, Traoré A, et al. Participatory analysis of groundnut (Arachis hypogaea L.) cropping system and production constraints in Burkina Faso. J Ethnobiol Ethnomedicine. 2021;17:1–15. doi: 10.1186/s13002-020-00429-6.
[100] Chacon-Hurtado D, Kumar I, Gkritza K, Fricker JD, Beaulieu LJ. The role of transportation accessibility in regional economic resilience. J Transp Geogr. 2020;84:1–18. doi: 10.1016/j.jtrangeo.2020.102695.
[101] Nurhaeny A, Miharja M, Pradono, Dirgahayani P. Measuring accessibility and island development in ambon city. Isl Stud J. 2021;16:373–87. doi: 10.24043/isj.157.
[102] Zhou J, Fan X, Yu A. The impact of high-speed railway accession on agricultural exports: Evidence from Chinese agriculture-related enterprises. Complexity. 2021;2021:1–19. doi: 10.1155/2021/4225671.
[103] Yang Y. Transport infrastructure, city productivity growth and sectoral reallocation: Evidence from China. IMF Working Papers No. 276. Washington, DC: IMF; 2016.
[104] Fliehr O, Zimmer Y, Smith LH. Impacts of transportation and logistics on Brazilian soybean prices and exports. Transp J. 2019;58:65–77. doi: 10.5325/transportationj.58.1.0065.
[105] Bambang B, Wahyudi TA. Analisis pengaruh citra perusahaan dan kualitas layanan terhadap loyalitas pelanggan melalui kepuasan pelanggan. J Manaj Strategi Aplikasi Bisnis. 2019;2:61–70.
[106] Adesehinwa AOK, Saka JO, Makanjuola BAM, Sorunke AO, Boladuro BA, Omodele T, et al. Economics of smallholder chicken egg production among KAFACI project farmers in Southwest Nigeria. Niger J Anim Prod. 2019;2019:144–52.
[107] Siagian S. Model optimalisasi kebijakan pembayaran dividen. Perspektif. 2020;18:54–9. doi: 10.31294/jp.v17i2.
[108] Faluthy A. Pengaruh struktur modal terhadap harga saham dengan ukuran perusahaan sebagai variabel moderating pada perusahaan property dan real estate yang terdaftar di bursa efek Indonesia. J Inst Politeknik Ganesha Medan. 2021;4:160–5. doi: 10.33395/juripol.v4i1.11013.
[109] Lazuardi P, Jati A, Pratama R. Sustainability of Wonosobo's coffee agriculture and industry from community-based conservation perspective. E3S Web Conf. 2021;317:01097. doi: 10.1051/e3sconf/202131701097.
[110] Schuit P, Moat J, Gole TW, Challa ZK, Torz J, MacAtonia S, et al. The potential for income improvement and biodiversity conservation via specialty coffee in Ethiopia. PeerJ. 2021;9:1–29. doi: 10.7717/peerj.10621.
[111] Ortega DL, Bro AS, Clay DC, Lopez MC, Tuyisenge E, Church RA, et al. Cooperative membership and coffee productivity in Rwanda's specialty coffee sector. Food Secur. 2019;11:967–79. doi: 10.1007/s12571-019-00952-9.
[112] Fatchiya A, Tjitropranoto P. Factors affecting entrepreneurial capacity building of smallholder coffee farmers in East Java Province. Pelita Perkeb. 2020;36:84–95.
[113] Sudarko S, Fatchiya A, Tjitropranoto P. Factors affecting farmer' autonomy and sustainability of smallholder coffee farming sing SEM Lisrel. Int J Innov Technol Explor Eng. 2020;9:1839–45. doi: 10.35940/ijitee.E2985.039520.
[114] Soetriono S, Soejono D, Zahrosa DB, Maharani AD, Hanafie SR. Strategy and policy for strengthening the agricultural cooperative business in East Java, Indonesia. J Socioecon Dev. 2019;2:12–22. doi: 10.31328/jsed.v2i1.886.
[115] Cahyanto GD, Wibowo A, Permatasari P. Kemitraan antara petani kopi dengan perusahaan (Studi Kasus Kintamani). Salam. 2021;8:173–90. doi: 10.15408/sjsbs.v8i1.19426.
[116] Bembenek B, Kowalska K. Inclusive business model - strategic challenge for agribusiness cluster management. Hum Soc Sci. 2017;22:9–27.
[117] Marhaeniyanto E, Rusmiwari S, Susanti S. Prospek kopi pilazz di Desa Bocek Kecamatan Karangploso Kabupaten Malang. J Akses Pengab Indones. 2019;4:18–27.
[118] Minah M. What is the influence of government programs on farmer organizations and their impacts? Evidence from Zambia. Ann Public Cooperative Econ. 2022;93:29–53. doi: 10.1111/apce.12316.
[119] Forney J. Farmers' empowerment and learning processes in accountability practices: An assemblage perspective. J Rural Stud. 2021;86:673–83. doi: 10.1016/j.jrurstud.2021.05.021.
[120] Irwansyah D. Empowerment and innovation of peasants in Nisam District, Aceh Utara. Konfrontasi J. 2021;8:205–17. doi: 10.33258/konfrontasi2.v8i3.158.
[121] Rathnachandra SDD. Empowermwnt of rural women farmers and food production in Rathnapura District in Sri Lanka: A household level analysis. Appl Stud Agribus Commer. 2020;14:105–12. doi: 10.19041/APSTRACT/2020/3-4/12.
[122] Theeuwen A, Duplat V, Wickert C, Tjemkes B. How do women overcome gender inequality by forming small-scale cooperatives? The case of the agricultural sector in Uganda. Sustain. 2021;13:1–25. doi: 10.3390/su13041797.
[123] Candelo E, Casalegno C, Civera C, Mosca F. Turning farmers into business partners through value co-creation projects. Insights from the coffee supply chain. Sustain. 2018;10:1–21. doi: 10.3390/su10041018.