Sustainability factors for agroforestry coffee plantations in Pangalengan based on the coffee farmer's perspective

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Abstract. Coffee as one of the most traded agricultural commodities in the world increases its need over time, including the supply of coffee from Indonesia. Indonesia, as the seventh largest country in the world in terms of coffee exporters, demands its coffee plantations to improve their quality and productivity even with limited land. One coffee-producing area in Indonesia with the highest productivity in West Java is Pangalengan District in Bandung Regency. Coffee in Pangalengan is grown with an agroforestry system that benefits not only its economic value but also the land conservation in that area. By facing various challenges, agroforestry coffee in Pangalengan must be maintained to remain sustainable. This research aims to find out what factors influence the sustainability of agroforestry coffee in Pangalengan from the perspective of coffee farmers as the main actors in the upstream coffee supply chain. Data was collected through semi-structured interviews by sampling 70 coffee farmers in Pangalengan and analyzed using qualitative descriptive analysis. From the results of the study, it was found that 24 factors influence the sustainability of agroforestry coffee plantations in Pangalengan which are divided into five sustainability dimensions: Environment (3 factors), Social (4 factors), Economy (5 factors), Technology (6 factors) and Institutional Governance (6 factors).

1 Introduction

Coffee is one of the most traded agricultural commodities in the world [1-3]. Until now, coffee has become a drink that is very popular throughout the world. Innovations resulting from coffee products are increasingly developed over time and this certainly presents challenges for coffee-producing countries, one of which is Indonesia. Indonesia is the fourth largest country in coffee production in the world, producing up to 774,689 tons of coffee in 2021 [4-5]. Meanwhile, for exports, Indonesia is the 7th coffee exporting country, spreading its local coffee products to various countries. The products that can be exported are limited because domestic consumption itself has increased rapidly [5-6].

Even though coffee plantations need to increase their productivity to continue to meet coffee needs abroad and domestically, the existence of coffee plantations themselves face threats to their existence from various factors, such as climate change [7]-9], land availability, and land conversion [10-11]. To determine the best strategy for preserving existing coffee plantations, it is a good idea to first carry out a sustainability analysis of the practices carried out.

As a concept, sustainability cannot be measured directly. Appropriate indicators should be selected to determine the level of sustainability [12]. To measure the level of sustainability of an agricultural system, there are so many ways that can be used. Many sustainability assessment methods have been developed by experts collaborating with international organizations, policymakers, governments, and local institutions to gain insight into the sustainability performance of agricultural systems, such as Response-Inducing Sustainability Evaluation (RISE), Sustainability Assessment of Farming and the Environment (SAFE), Sustainability Assessment of Foof and Agriculture Systems (SAFA) and Sustainability Monitoring and Assessment Routine (SMART). However, measuring sustainability using these methods will require technical data with extra costs, energy, and time [13-14]. Existing methods can be adapted to the agricultural conditions to be assessed, by first knowing the relevant criteria and how these criteria should be assessed [15]. Therefore, to obtain indicators appropriated to the state of coffee plantations in this research, an investigation was carried out regarding the most influential factors and the current state of coffee plantations, especially from the perspective of coffee farmers as the main actors in the upstream coffee supply chain.

This research was conducted on coffee plantations in Pangalengan District, Bandung Regency with a coffee plantation area of around 1,028.10 Ha [16]. The coffee products produced have been marketed domestically and abroad. Bandung Regency itself is an area that has the largest plantation area and coffee production in West Java Province [17]. The coffee farming system implemented is an agroforestry practice, where the agroforestry system itself is an

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application of sustainable agriculture [18]. Coffee agroforestry in Pangalengan was planted on land owned by Perhutani in 1997. Perhutani itself is a State-Owned Enterprise in the form of a Public Company (Perum) which has the task and authority to manage state forest resources on the islands of Java and Madura. This coffee agroforestry is implemented to restore the function and sustainability of forests that were previously damaged due to horticultural farming practices carried out by local communities. Maintaining the sustainability of coffee agroforestry in Pangalengan needs to be done because this agricultural practice not only has a high economic role but also has an environmental role as an effort to conserve soil and water as well as a social role for farmers and surrounding communities [19].

Through this research, it is hoped that it can provide an overview of what the current application of coffee agroforestry in Pangalengan is like and provide useful information in determining assessment criteria for coffee agroforestry sustainability analysis through the views of coffee farmers who are directly involved in the implementation of coffee plantations.

2 Methodology

This research was conducted using a qualitative descriptive approach. Qualitative descriptive research is a research approach aimed at describing existing phenomena, both natural and man-made. This type of qualitative descriptive research displays data as it is without manipulation or other treatments. The aim is to fully describe an event or is intended to expose and clarify a phenomenon that occurs [20].

The data used is primary data and secondary data. Secondary data was obtained through literature studies to support primary data. Meanwhile, primary data was collected through semi-structured interviews to gain insights from the perspective of coffee farmers as the main actors in the upstream coffee supply chain. Semi-structured interviews have topics that are prepared as interview guidelines to obtain the same information from all informants [21]. The main topic that will be raised in the interview is the current practice of coffee agroforestry in Pangalengan and the factors that influence the sustainability of coffee agroforestry carried out by farmers.

The informants who met for the semi-structured interviews were agroforestry coffee farmers in the Pangalengan sub-district. The population of coffee farmers in the Pangalengan sub-district is 1333 farmers [16]. The population number is entered into the formula to calculate the minimum sample size required. The formula used is the Slovin formula.

$$N = N / (1 + Ne^2) \quad (1)$$

n: Sample size needed
N: Population size (1333 farmers)
e: Acceptable margin of error (0.12)

The value obtained was 66 informants needed and rounded up to 70 informants. The 70 informants to be interviewed were selected randomly using randomizer software. The interview results were then analyzed and presented descriptively. The Study site is located in eight villages in the Pangalengan sub-district where the informants are located. A map of the research location can be seen in **Fig.1**.

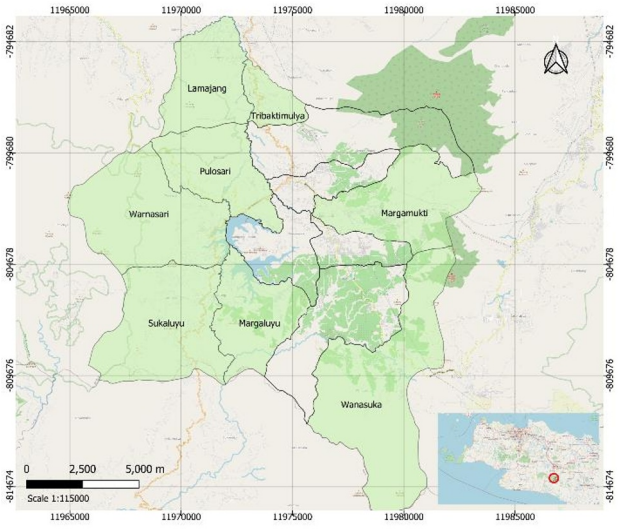

Fig. 1. Research location map

3 Result and discussion

3.1 Informant's general information

The informant's general information provides an overview of 70 agroforestry farmers who were interviewed to obtain their opinions regarding the main issues in this research. These coffee farmers were randomly selected and spread across eight villages in Pangalengan District, namely: Lamajang, Margaluyu, Margamukti, Wanasuka, Sukaluyu, Pulosari, Tribaktimulya and Warnasari. There were seven female and 63 male informants, but in daily plantation practice, all informants stated that management was carried out jointly with all family members with the same workload. The only difference is that heavy work, such as carrying crops and delivering the produce, is mostly done by men. The average age of informants is 57 years with a range of 27 to 80 years. Farmers also have varying experiences because of the varying lengths of farming, an average of 13 years with a range of 5 to 30 years. The educational background of the farmers is also varied as can be seen in Table 1.

Table 1. The educational level of the coffee farmers

Educational level	Total
Did not graduate from elementary school or did not go to school	12
Elementary school / public school (SR)	39
Junior high school	10
High school / vocational high school	9

Even though most farmers have a low education background, to be able to implement coffee agroforestry practices well, farmers receive various appropriate training. These trainings are provided by various institutions, including the Plant Management Farmers Association / Paguyuban Petani Pengelola Tanaman Pangalengan (P3T), the Forest Village Community Institute / Lembaga Masyarakat Desa Hutan (LMDH), the Forest Farmers Group / Kelompok Tani Hutan (KTH), the government, and campuses such as Bogor Agricultural Institute (IPB) and Padjadjaran University (UNPAD). Some farmers still receive regular training until now from local farmer groups, but there are quite a few who no longer receive training. The participation of coffee farmers in farmer groups was 59 out of 70 people, the remaining 21 people did not join farmer groups for various reasons, including not knowing if there were farmer groups and the farmer groups were being felt to be inactive.

3.2 Current condition of Pangalengan coffee agroforestry

In order to have a better understanding of why the factors mentioned by the informants are considered important for the sustainability of coffee agroforestry in Pangalengan, knowing the current condition of the coffee plantations they work on might provide a clearer picture of the things they are facing.

Agroforestry has various definitions, one of which is that agroforestry is a collective term for land use systems and technologies, that are planned to be implemented on a unit of land by combining woody plants with agricultural plants and/or animals (livestock) carried out at the same time or in turns, so the ecological and economic interactions are formed between the various existing components [22]. Agroforestry systems can be described into five types, namely Agrisilviculture, Silvopastoral, Agrosilvopastoral, Apiculture with trees, and aquaculture with trees [23]. The coffee agroforestry system in Pangalengan is agrisilviculture, a combination of seasonal or perennial plants (agricultural activities) and perennials / woody plants or annual plants (silvicultural/forestry activities).

In seventy coffee farmers' agroforests, there are various protective trees (woody trees), including surian trees, eucalyptus, pine, rasamala trees, puspa trees, kulai trees, mindri trees, mangosteen, avocado, jackfruit, guava. The shade level provided by the trees also varies, as can be seen in Fig. 2. Characteristics and functions of shade trees as well as their strata are important in efforts to improve the sustainability of agroforestry coffee. The shade trees have ecological functions as environmental services such as recycling nutrients, driving soil conservation, and improving growth productivity and quality of coffee. It also could give other economic functions for its product, such as fruit or timber, as a source of alternative income for the farmers [24].

The seasonal crops planted in the agroforestry coffee Pangalengan are also varied, 54 farmers only grow coffee and 16 farmers grow coffee and other crops. Other crops planted on the same land are chilies, cloves, eggplants, long beans, cucumbers, bamboo, cabbage, mustard greens, tomatoes, onions, lemongrass, and lemons. The coffee agroforestry land used itself is land

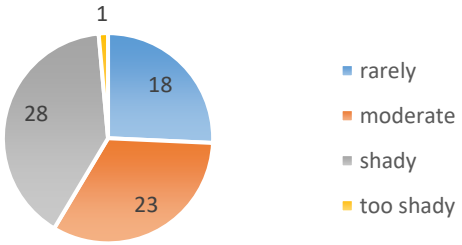

Fig. 2. Level of shade coverage in Pangalengan coffee agroforestry

owned by Perhutani which has an agreement with the farmers. The agreement that was formed was that farmers had to ensure that the wood trees on the agroforestry land were protected and could not be cut down and that the harvest was shared with Perhutani as the land owner.

Pangalengan District is a suitable location for planting coffee because it has suitable environmental conditions, with an altitude of between 984 − 1571 meters above sea level and cool temperatures ranging from 16°C − 25°C [25]. The optimum habitat for the coffee plant itself is under the canopy of subtropical and tropical forests with a temperature of 15°C − 24°C and an optimum altitude of 1000 - 2000 meters above sea level [26]. Suitable rainfall for coffee plants is around 1500 − 2500 mm per year with an average of three dry months [27]. In 2019, rainfall in Pangalengan was 2148 mm/year [28], but in the last three years, rainfall has continued to increase, so the dry months have not reached three months because it rains all year round. Based on information from informants, only in 2023 will there be a dry season starting in June, which will be the coffee harvest season. The increase in rainfall in the last three years has had a significant impact on coffee production. According to

farmers, the most significant impact is decreased productivity because the flowers fall first in the rain, the fruit turns black easily and cannot be harvested, the quality of the fruit decreases, the fruit takes longer to ripen, and productivity even falls by half of the results in 2019. But in areas with dryer land and difficult access to water, such as several farmers in Lamajang Village, increasing rainfall helps their productivity.

The coffee seeds used are mostly Arabica coffee with the main types being Timtim and Ateng, some farmers also plant Robusta coffee. The use of fertilizers varies, as can be seen in Fig. 3. The inorganic fertilizers used are NPK and Urea, while organic fertilizers are taken from animal waste and compost from coffee leaf waste. Seventeen coffee farmers do not use fertilizer because they do not have the money or have limited access to fertilizer. The coffee harvest period, which takes place once a year in the dry months, June − August, is also called the peak harvest season (musim panen raya). Harvest is done in other months too but not as much as during the peak harvest season. The harvest that is sold is fresh red coffee fruit or what is usually called cherry. The cherries are sold to middlemen who will then process them into processed products or resell them to larger coffee factories. Only two farmers sell in different forms and 70 informants, the products they sell are in the form of roasted coffee and luwak coffee that is ready to be brewed. The selling price of cherries varies from person to person, on average it is sold at 13,600/kg for arabica with a price range of 9000 − 16000 per kg. Meanwhile, Robusta coffee is only sold at 5000/kg. The average selling price of Arabica coffee itself in 2023 will be the highest compared to the last 5 years, 53 out of 70 coffee farmers stated that the selling price of coffee in the last 5 years has continued to increase but 16 others stated that it has increased and decreased. During the peak harvest period, the social impact can be felt more clearly because farmers will empower local communities to participate in helping harvest their coffee—especially groups of elderly people who don't have jobs and housewives who need additional income.

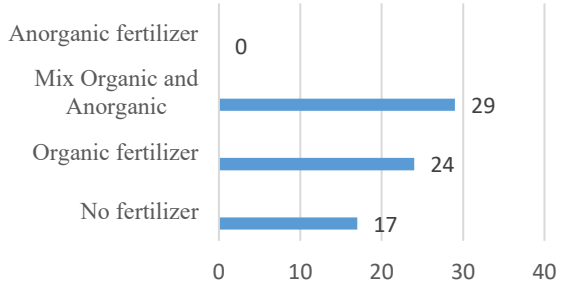

Fig. 3. Variety of fertilizers used in the coffee plantations

3.3 Factors Influencing the Sustainability of Coffee Agroforestry in Pangalengan Based on Farmers' Opinions

In general, the sustainability analysis methodology that has been put forward in various existing studies relies on a series of indicators which are usually grouped into three main dimensions of sustainability, namely economic, social, and environmental. Often there are additional dimensions that are believed to be related to the sustainability of the system to be analyzed [29]. Through values in the main dimensions of sustainability and community expectations of agricultural systems that are constantly changing, new principles can be created that can define sustainability into separate dimensions, such as governance, solidarity, transmission capital, local knowledge, and innovation [30]. Therefore, a diversity of indicator-based sustainability research tools has been formed which is very varied, based on their scope (geographical and sectoral), target groups (e.g. farmers or policymakers), and time requirements for carrying out the analysis [31].

To obtain analytical tools that are appropriate to the location to be assessed, in this research on coffee agroforestry in Pangalengan District, it would be better to know the perspective of coffee farmers as the target group regarding these factors. These factors can then be considered as measuring tools in the form of indicators for sustainability analysis. Based on interviews with 70 coffee agroforestry farmers in Pangalengan, 24 coffee agroforestry sustainability factors were obtained and divided into five sustainability dimensions: Environment (3 factors), Social (4 factors), Economy (5 factors), Technology (6 factors), and Institutional Governance (6 factors). These results can be seen in Table 2.

Based on the results obtained, it is known that the dimensions of sustainability most discussed by 70 informants were the Technology dimension, about 80%. and the environment dimension, about 58,57%. Knowledge about agricultural technology needs to be known and developed to maintain agricultural production and preserve natural resources to ensure the longevity of the farm. In this case, technology does not only revolve around the latest types of machines or tools, but various types of practices and systems to promote more sustainable plantations are also included in technological developments [32]. In the Technology dimension, the main factors most frequently mentioned by informants were good and diligent care of coffee plants and fertilization. The coffee plant care mentioned aims to maintain the coffee plant as the main star of the coffee plantation so that it continues to live and be healthy for a long time. The coffee care described by the informant is pre-harvest and post-harvest care. Pre-harvest care includes scheduling fertilization, cleaning grass around the plant,

pruning new shoots, and good irrigation. Post-harvest care includes crown pruning, re-fertilizing, replanting less productive trees, and so on. Fertilization factors are described as the use of types of fertilizer to fulfill plant nutrition, easy access to fertilizer, technology for making fertilizer, and the annual fertilization schedule.

The Environment dimension is one of the three main dimensions of sustainability. The environmental dimension reflects the complex interactions between agriculture and the surrounding environment involving causality relationships [33]. The environment dimension in sustainable agricultural practices focuses on environmentally friendly practices, preserving resources, and keeping natural biological cycles running smoothly. This dimension is also important for sustainability because it was created to reduce environmental degradation caused by agricultural practices [34]. In the Environment dimension, the factors most frequently discussed by informants were a suitable environment and favorable weather. Coffee as a sensitive plant requires the most suitable environmental conditions for its growth and development to provide maximum results. As previously explained in the conditions of coffee agroforestry in Pangalengan, currently the environmental conditions in Pangalengan are quite optimal for coffee growth. However, of course, this condition can also be influenced by the weather. Weather changes will affect the productivity of coffee plants, for example, the increase in rainfall experienced in the last three years. Apart from that, increasing temperatures can also affect the suitability of coffee plantations. By 2030, it is estimated that around 30-50%

Table 2. Result of sustainability factors for coffee agroforestry in Pangalengan from the farmer's perspective

Factor	Percentage (%)	Annotation
Environment	**58,57**	
Appropriate environment	38.57	The environment is suitable for coffee growth
Favorable weather	22.86	The weather is favorable for coffee plantation
Protecting the environment	2.86	Maintain the good condition of the surrounding environment
Social	**18.57**	
Successor	1.43	The existence of a successor who will continue the coffee farming business
Good relationship with the local communities	4.29	Good relations between fellow farmers, land managers, land owners, and other surrounding community
Farmer training and counseling	8.57	Training and counseling on good coffee cultivation systems for farmers
Farmer group activity	7.14	The activeness of farmer groups in assisting members and other farmers who are not members yet
Economy	**18.57**	
Land area	1.43	The area size of land used for coffee plantation
High productivity	1.43	High productivity of coffee plantations
Capital funding	22.86	The capital funding owned by farmers and the existence of easily accessible financial institutions that can help farmers gain other funding
Sales profit	4.29	Profits obtained from sales of products with good selling value
Subsidies for farmers	8.57	Subsidies from the government, mainly in the form of fertilizer or funding
Technology	**80**	
Plant care	52.86	Best plant care to maintain the plants in healthy and good condition
Fertilization	37.14	Use of fertilizer for plant nutrition
Environmental friendly cultivation system	1.43	Environmental friendly coffee cultivation system, including management and products used for the agroforestry
Harvest processing equipment	1.43	The existence of institutions that can lend tools to process harvests into more valuable products
Suitable seeds	1.43	Farmers using suitable seeds that are best used in the Pangalengan area
Pest control	1.43	Efforts to protect coffee plants from pests
Institutional Governance	**10**	
Land permits	2.86	Land management permits from the land owner (Perhutani)
Mutually beneficial policies	1.43	Policies between land owners and farmers that are mutually beneficial
Sales regulation of harvested crops	2.86	Government regulations that regulate sales flow and selling prices
Subsidized fertilizer policy	1.43	Elimination of fertilizer subsidy regulations from local governments which only apply to rice farming and do not apply to other farmers

Cooperatives existence	1.43	Formation of active cooperatives to help coffee farmers
Better governance of farmer institutions	2.86	The presence of the government in managing farmer group institutions in the distribution of aid and information as well as the activity of farmer groups

of land suitable for planting coffee will be reduced, especially for Arabica coffee, and 60% of wild coffee species are at risk of extinction due to the varying impacts of climate change at national and global levels [9][35].

The Social Dimension is related to meeting community needs and the welfare of farmers and the surrounding community [30][36]. The social aspect is closely related to the social dynamics that occur in agroforestry practices in society which can create unique agroforestry patterns, such as the influence on community participation, decision-making, and the division of roles in plantation management [37]. In the Social dimension, the factors considered to most influence the sustainability of coffee plantations are training and counseling for farmers and the activity of farmer groups. The training received by the informants had different intensities, from those who were still actively receiving training until now to those who had received the most recent training in the last five years. The provision of training and counseling is closely related to the activity of farmer groups, for its services can be provided by the farmer groups. Agricultural practices in Indonesia, like in other developing countries, are dominated by small-scale cultivation. Small-scale farmers face many challenges such as limited capital, low bargaining power, high transaction costs, and low welfare which would be difficult if they had to face it alone. The existence of active farmer groups can become a link for farmers to improve farmer's socio-economic development, expand their access to information, expand access to capital, infrastructure, markets, and others [38]. Based on the results of interviews, 21 coffee farmers were not part of farmer groups while the other 49 farmers participated in farmer groups. The benefits felt by farmers who actively participate in farmer groups are getting support from fellow farmers, getting help from the government and Perhutani as land owners, getting training and counseling, and the latest information regarding coffee cultivation. Apart from that, coffee farmers who are not active in farmer groups still get other benefits, one of which is getting a discount when they buy fertilizer.

In the economic dimension, the continuity of farming in general and the efficiency of the farming system are considered. The economic profits obtained from agricultural products must be high enough to provide adequate resources for farmers to maintain the productivity of their plantations and ensure that their plantations can last for a long time. Apart from that, in the economic dimension, it is hoped that the profits obtained can guarantee a decent standard of living for farmers and their families [34]. The factor that is considered the most important from this dimension is capital funding. The capital funding described includes the costs that coffee farmers must have to continue managing their coffee and the existence of institutions providing financial services. Apart from that, another factor that is considered influential is subsidies from the government. The subsidies that farmers expect include agricultural costs, seeds, or fertilizer. It is hoped that the subsidies obtained can reduce the capital funding that farmers must prepare.

The institutional governance dimension was rarely discussed by informants, there were only 7 informants who stated that this dimension influenced the sustainability of coffee agroforestry in Pangalengan. The factors mentioned are quite diverse and there is no single factor that stands out. However, the answers obtained are enough to illustrate that the sustainability of coffee agroforestry is also influenced by the regulations that cover it, such as permits to be able to work on existing land and the requirements given by land owners or government regulations such as sales regulations. It is felt that the presence of institutions that can help coffee farmers continue to develop can influence the continued existence of coffee agroforestry. Sustainability which is covered by three main dimensions (social, economic, environmental) will complement each other, it is not uncommon for some things to overlap. On the other hand, there can also be trade-offs that are not realized due to the limited knowledge of farmers regarding the impacts of the activities they carry out [39]. Maintaining the social, economic, and ecological functions of agriculture requires an effective social order (good governance), a system of mechanisms that regulates, coordinates, stimulates, and controls the behavior, actions, and relationships of business actors at various levels [40]. These institutions are often considered exogenous factors that have no influence, even though these institutions can provide governance for agricultural actors through formal and informal regulations in society. Institutional governance is a mechanism for coordinating economic transactions in key governance structures such as markets and organizations [39].

4 Conclusion

The sustainability of an agricultural system needs to be shared from various aspects, including the sustainability of coffee agroforestry in the Pangalengan sub-district. The factors obtained from interviews with seventy coffee farmers are

quite diverse, but it can illustrate that sustainability is influenced by various dimensions, not only the main dimensions of sustainability (social, economic, environment) but also other dimensions that are considered important, such as technology and institutional governance. Even though the frequency of answers for the twenty-four factors collected varies, these answers are things that are felt directly by the coffee farmers who practice coffee agroforestry every day. It is hoped that the farmer perspectives collected in this research can provide additional information to consider indicators for sustainability analysis in future coffee plantations, especially in Pangalengan coffee agroforestry and in general in other coffee plantations with characteristics similar to Pangalengan coffee agroforestry.

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