Strategies to optimize the use of organic fertilizers in smallholder coffee plantation

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Abstract. The demand for organic coffee is increasing in line with increasing competition and consumer preferences for healthier products. On the other hand, the application of organic fertilizers in smallholder coffee plantations is still low. The research aims to map the constraints of organic fertilizers usage and develop strategies to accelerate organic fertilizers application in smallholder coffee plantations. Data analysis was performed using the scoring method. The results showed that farmers applied more inorganic fertilizers. Constraints of organic fertilizers application are related to technical, economic, and institutional aspects. Strategies to optimize the use of organic fertilizers in smallholder coffee plantations include providing capital and financial support with subsidized interest rates and strengthening farmer institutions as the priority. Other strategies include introducing an integrated coffee livestock system and providing local government incentives for promoting and organic certification assistance. Institutions involved in implementing the strategy include local governments, research institutes, financial institutions, coffee processing industries, exporters, extension officers, certification bodies, farmers’ groups, cooperatives, and associations. The strategies are essential to overcome the existing problems and constraints in organic coffee farming development and increase farmers’ interest in applying organic fertilizers.

1. Introduction
Sustainable production is an essential issue in the development of coffee in Indonesia. There has been a shift in consumer preferences towards specialty products and healthier products produced with environmentally sound farming systems from the demand side. From the supply side, climate change has a relatively significant impact on the performance of coffee plantations and affects sustainability aspects. The direct impact of increasing extreme climate events such as drought due to El Nino resulted in a 10% decrease in coffee production. Conversely, the long rainy season due to La Nina reduced coffee production by 80%. On the other hand, the condition of smallholder’s coffee plantations is also characterized by less intensive plant cultivation, replanting has not been carried out, and technology adoption is still limited [1].

The majority of coffee in Indonesia is Robusta which reaches 80.89% or 1.02 million hectares, while Arabica is 19.11% or 242.15 thousand hectares. Lampung is the leading Robusta coffee-producing area in Indonesia. This province accounts for 20.85% of Robusta coffee production or 14.63% of the total national coffee production in 2018 [2]. Robusta coffee has a bitter taste, is slightly sour, and contains much higher levels of caffeine than Arabica coffee. From a cultivation side, Robusta coffee is more resistant to pests and diseases [3]. Robusta coffee originating from Lampung has a high reputation and
is in demand due to its thick characteristic with high caffeine content. The high production of coffee in South Sumatra and Bengkulu, has made Lampung Province the main export gateway for Indonesian coffee with a share of more than 70% of Indonesia’s total coffee exports [4].

Sustainable coffee development, such as organic farming, is considered one of the essential instruments that farmers can apply [5]. Organic coffee certification has provided benefits in increased cost efficiency and transaction fairness [6]. One of the essential components in organic coffee cultivation is the use of organic fertilizers. Coffee plants require a relatively high organic matter because it serves as a water reservoir, provides nutrients, and develops soil management [7]. In Indonesia, most coffee farmers use organic fertilizers processed from animal manure and dried leaves or branch cuttings [8]. However, fertilization using organic fertilizers is not well implemented at the farmer’s level. Some of the problems and constraints are the lack of proper coffee counseling, the emergence of diseases and pests, the lack of inputs for productivity packages, and fluctuating coffee prices [9]. Therefore, this study aims to map the constraints to using organic fertilizers and develop strategies to accelerate the usage of organic fertilizer in smallholder coffee plantations.

2. Research method
2.1. Location and time of research
Data collection was carried out in Sumberejo District, Tanggamus Regency, the center of coffee production in Lampung Province. The research was conducted in 2019. The plantation is a smallholder coffee plantation of the Robusta coffee and cultivated for about 15-30 years.

2.2 Data collecting method
The coffee farmers used as respondents in this study were determined using a simple random sampling technique. The number of selected samples was 24 farmers. Data was collected through surveys and interviews using questionnaires. Strategies are formulated based on field observations and discussions with farmers, agricultural services, and researchers.

2.3 Analysis method
The analysis consists of descriptive statistics to describe the respondent’s profile and farming activities, while the strategy formulation is carried out using the scoring method. Descriptive statistics provide core information from the existing data set. The information obtained from these descriptive statistics includes the size of the data concentration, the size of the data spread, and the tendency of a data set. The scale used in the scoring method is 1-5, where 1 indicates a low value and 5 indicates a high value. Assessment is carried out on each strategy based on technical, economic, and institutional aspects. The total value is calculated using the formula:

\[ x_i = \frac{x_{iT} + x_{iE} + x_{iI}}{3} \]  (1)

Description:
- \( x_i \) = total score strategy-
- \( x_{iT} \) = score value of Technical aspect
- \( x_{iE} \) = score value of Economic aspect
- \( x_{iI} \) = score value of Institutional aspect

3. Result and discussion
3.1. Characteristics of respondents
The character of the farmer influences technology adoption in coffee production [10]. The farmer’s age, the condition of the farm, the size of the area are factors that significantly influence the use of organic fertilizers at the farmer level [11] [12]. Based on age group, the highest number of farmers are in the range of 41-50 years (58.33%), then 31-40 years (33.33%) (Figure 1).
Age affects the decision to adopt technology [13]. As farmers get older, their curiosity and desire to try new things will decrease, so the potential for technology adoption will decrease. This behavior is related to taking risks, increasing into adulthood and decreasing after that [14]. The knowledge-affected characteristics of farmers are thought to affect risk-taking [15]. The group that will potentially continue the coffee agribusiness, namely the group under 40 years, is lower. In addition, the age composition will open up opportunities for the land to be divided into smaller areas in the next generation. The implication of this condition causes the coffee development in Lampung to tend to decrease.

![Figure 1. Distribution of farmers by age.](image1)

![Figure 2. Distribution of farmers by coffee cultivation experience.](image2)

From the experience of farmers, the data shows that most of the farmers have experienced between 11-20 years (62.50%) (Figure 2). Farmers have sufficient experience in coffee cultivation. Factors influencing technology adoption are more affected by conditions within the farmers, such as formal education level, age, land area, experience, farmer motivation, farmer activity in extension, farmer perception, and farmer cosmopolites. Therefore, this long experience has the potential to become an obstacle to accepting new technologies.

3.2. Profile of coffee plantation and use of organic fertilizers

The age of coffee plants owned by farmers tends to vary. As many as 50% of farmers own crops at 21-30 years (Figure 3). This figure is far above the average age of coffee plants in development centers in Indonesia. In terms of production per tree, the data show that the achievement of coffee production is below the achievable production potential. Coffee plants reach peak production at the age of 5-15 years and experience a gradual decline after that. Coffee plant productivity is influenced by the application of GAP and replanting decisions [16]. Replanting requires a large amount of money so that, in practice, not all farmers do replant even though the coffee plants are no longer productive. As a result, the productivity and quality of coffee are getting lower. This condition is getting worse with limited GAP implementation.
The Sumberejo area has potential resources to develop coffee plantations based on agro-climatic and land suitability analysis, in suitability class S1 or appropriate [16]. However, the achievement of plant productivity is strongly influenced by the application of recommended cultivation techniques. Most farmers (75%) achieved 501-1000 kg/ha/year (Figure 4). The productivity is still below the potential production of varieties.

Fertilization is one of the most important aspects of coffee cultivation. Fertilization is crucial in Robusta coffee cultivation because nutrient fulfilment is vital for optimal coffee growth and production [19]. The main problems related to the low productivity of coffee are the limited use of planting material resulting from vegetative propagation of superior genetic material and the lack of fertilization to meet plant nutrient needs [17].

**Table 1. Inorganic and organic fertilizer usage.**

|                        | Minimum | Maximum | Mean    | Std. Deviation |
|------------------------|---------|---------|---------|----------------|
| Inorganic fertilizer   | .1000   | .8438   | .426684 | .2676939       |
| used (kg/tree/year)    |         |         |         |                |
| Organic fertilizer     | .0000   | .9091   | .325446 | .3221342       |
| used (kg/tree/year)    |         |         |         |                |

In general, the fertilizers needed by coffee plants are organic and inorganic. Fertilizer requirements may vary by location, plant growth stage or plant age, and variety. Organic coffee uses fully organic fertilizers. Organic fertilizers application provides benefits in providing nutrients for plants and improving soil structure.

The use of fertilizers at the farm level varies greatly. The average use of inorganic fertilizers is 0.268 kg/tree/year and 0.325 kg/tree/year for organic fertilizer (Table 1). The inorganic fertilizers used are urea, KCl, SP-36, and NPK. Inorganic fertilizers are still below the GAP of 1 kg/tree/year [19]. The recommended dose of organic fertilizer application is 10-20 kg/tree/year. The impact of using organic fertilizers is a decrease in fertilization costs, and the long term can support sustainable land management efforts [18]. However, respondent farmers’ average use of organic fertilizer is below recommendation, and some do not use organic fertilizer.
3.3. Constraints of organic fertilizers application

The development of organic Robusta coffee cultivation related to processing organic matter as a biofertilizer has not been intensive. In addition, the quality of superior seeds and integrated plant pest management is not optimal [19]. Coffee plants on smallholder plantations are not adequate nutrition, so the yield is less than optimal. In Arabica coffee plantations, problems with using organic fertilizers are related to capital, limited experience in adopting coffee livestock integration, low concern for environmental aspects, land ownership status, and limited counseling [20]. Farmers’ lack of capital to buy fertilizer is an important issue [21]. In smallholder oil palm plantations, the obstacles to using organic fertilizers are related to the availability of raw materials, the availability of processing equipment and auxiliary materials, the availability of capital, the availability of labor, marketing and distribution, as well as the interest and knowledge of farmers [22].

Constraints in using organic fertilizers on smallholder plantations are related to technical, economic, and institutional aspects. Constraints to applying organic fertilizers on smallholder coffee plantations in Tanggamus Regency are listed in Table 2.

Table 2. The constraints of the application of organic fertilizers on smallholder coffee plantations.

| Constraint type     | Description                                                                                                           |
|---------------------|-----------------------------------------------------------------------------------------------------------------------|
| Technical Constraints | Limited availability of organic fertilizer                                                                     |
|                     | Limited access to organic fertilizer sources                                                                          |
|                     | Availability of additional labor for organic fertilizer application                                                  |
| Economic Constraints | Limited availability of capital for additional production costs and application of organic fertilizer               |
|                     | Investment in fertilizer processing equipment and machinery at an economic scale                                      |
|                     | Investment for the purchase of livestock                                                                             |
| Institutional Constraints | Undeveloped farmer organization                                                                                     |
|                     | Transfer of knowledge and limited land management technology so that knowledge of farmers is still minimal          |
|                     | There is no business unit owned by farmer groups that manage commercial fertilizer production and marketing       |

Technical constraints are related to the operational aspects of organic fertilizer application, where farmers face constraints on the availability of organic fertilizers because farmers do not apply coffee livestock integration. Access to sources of organic fertilizer providers is relatively tricky. In addition, fertilizer application also requires additional labor, which depends on the number of plants and the frequency of fertilization. The use of organic materials such as manure or compost requires a relatively large volume. Manure from farmers, with limited livestock and scattered cage locations, makes collection and transportation more difficult.

Economic constraints are related to limited capital, both for the procurement of fertilizer and investment in tools and machinery, and the purchase of livestock if the fertilizer procurement will be carried out through the application of coffee livestock integration. Another constraint is related to the institutional aspect. Fulfilling economies of scale, it is advisable to produce organic fertilizers in groups. However, farmers’ corporations have not yet been established, and farmer groups have not yet engaged in commercial production units. Another issue is the lack of knowledge transfer and land management technology implicating farmers’ knowledge and skill.

3.4. Strategy for encouraging the application of organic fertilizer in coffee smallholder plantations

Based on the constraints faced by farmers, strategies are needed to encourage the application of organic fertilizers to smallholder coffee plantations in Tanggamus Regency. This strategy is an effort to
overcome the existing constraints and increase farmers’ interest in applying organic fertilizers. Farmers play an essential role in achieving the performance and sustainability of the Robusta coffee agroindustry supply chain in Tanggamus Regency [23]. By implementing the strategies, sustainable organic cultivation will be developed. The strategies to encourage the application of organic fertilizer to smallholder coffee plantations are listed in Table 3 and complemented by the institutions involved. The collaboration among stakeholders will avoid overlaps and generate synergy to achieve sustainable coffee development.

**Table 3. Strategies to encourage the application of organic fertilizers and involved institutions mapping.**

| No | Strategies                                                                 | Institutional Involved                           |
|----|---------------------------------------------------------------------------|--------------------------------------------------|
| 1. | Introduction of coffee livestock integration                              | Local government, Research institutions, Financial institutions |
| 2. | Provision of tools and machines for producing organic fertilizer for farmer groups | Local government                                |
| 3. | Financial support from financial institutions with subsidized interest     | Financial institutions                            |
| 4. | Strengthening farmer organizations                                       | Local government, Coffee Processing Industry, Exporter |
| 5. | Development of demonstration plots and counseling related to land management | Research Institute, Extension Agency              |
| 6. | Assistance in implementing sustainable organic cultivation to obtain organic coffee certificates | Certification body, Research Institute            |
| 7. | Initiation of cooperation between farmer groups and large breeders in the supply of raw materials for organic fertilizers | Local government, Farmers Group, Cooperation     |
| 8. | Local government incentives in the form of promotion and assistance for organic coffee certification | Local government, Association, Certification body, Coffee Processing Industry, Exporter |

The institutions involved include local governments, research institutes, financial institutions, coffee processing industries, exporters, extension workers, certification bodies, farmer groups, cooperatives, associations. The institutions involved have different roles and intensity of contribution according to the functions of each institution.

Analysis of strategic priorities to encourage the application of organic fertilizers on smallholder coffee plantations in Tanggamus Regency is carried out by analyzing the strategy’s influence on technical, economic, and institutional aspects (Table 4). The strategies developed are related to the coffee livestock integration, tools and machines, capital, farmer institutions, collaboration with stakeholders, incentives, and technology support.
Table 4. Analysis of priority strategies to optimize the application of organic fertilizers on smallholder coffee plantations.

| No | Strategies                                                                 | Technical Aspect | Economic Aspect | Institutional Aspect | Total Score | Priority |
|----|---------------------------------------------------------------------------|-----------------|----------------|----------------------|-------------|----------|
| 1. | Introduction of coffee livestock integration                             | 4               | 5              | 2                    | 3.67        | 2        |
| 2. | Provision of tools and machines for producing organic fertilizer for farmer groups | 5               | 2              | 2                    | 3.00        | 4        |
| 3. | Financial support from financial institutions with subsidized interest    | 4               | 5              | 3                    | 4.00        | 1        |
| 4. | Strengthening farmer institutions                                         | 3               | 4              | 5                    | 4.00        | 1        |
| 5. | Development of demonstration plots and counseling related to land management | 4               | 2              | 2                    | 2.67        | 5        |
| 6. | Assistance in implementing sustainable organic cultivation to obtain organic coffee certificates | 4               | 2              | 3                    | 3.00        | 4        |
| 7. | Initiation of cooperation between farmer groups and large breeders in the supply of raw materials for organic fertilizers | 3               | 3              | 4                    | 3.33        | 3        |
| 8. | Local government incentives in the form of promotion and assistance for organic coffee certification | 3               | 2              | 5                    | 3.33        | 3        |

The strategy of providing capital and financing support from financial institutions with subsidized interest and strategies for strengthening farmer institutions are the main priorities. These strategies were followed by introducing an integrated system for coffee livestock integration and providing local government incentives in the form of promotion and assistance for organic coffee certification. The participation of farmers in the certification program has encouraged farmers to improve managing environmental risks; hence a sustainable coffee plantation is expected to be achieved [24].

The application of organic fertilizer is the initial step in implementing sustainable coffee cultivation. The coffee livestock integration program can support the expansion of the use of organic fertilizers. This integration system is expected to increase farmers’ awareness about sustainable practices, encourage agricultural diversification to increase the profitability of coffee farming, and ensure environmentally friendly crop management practices [14]. By implementing this strategy, the foundation will encourage the sustainable development of smallholder coffee plantations.

4. Conclusion
The use of organic fertilizers by farmers on smallholder Robusta coffee plantations in some production areas is still limited. The constraints in using organic fertilizers on smallholder plantations are related to technical, economic, and institutional aspects. The strategy of (1) providing capital and financing support from financial institutions with subsidized interest, (2) strengthening farmer institutions, and (3) introducing a coffee livestock integration are the main priorities in increasing the application of organic fertilizers in smallholder coffee plantations. Institutions involved in implementing the priority strategies include local governments, research institutes, financial institutions, coffee processing industries, and exporters. Through implementing this strategy, there will be adequate support for smallholder
plantations to use organic fertilizers as recommended. Improvements in cultivation are expected to encourage increased production and quality as well as sustainable coffee production.

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