

SOCIO-ECOLOGICAL INNOVATION OF ROBUSTA COFFEE PROCESSING THROUGH CIRCULAR ECONOMY TECHNOLOGY TO IMPROVE THE WELFARE OF FARMER GROUPS

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Abstract

The application of circular economy technology in robusta coffee processing is a strategic approach to improve the sustainability and welfare of the farming community. This community service aims to develop socio-ecological innovations based on community mapping in supporting the implementation of circular economy technology. Through the *Asset-Based Community Development* (ABCD) approach, this service identifies relevant social structures, local assets, needs, and partnership networks to ensure the adoption of technologies appropriate to the local context. The results of the service show that the use of coffee waste as a new raw material, technology integration, and environmentally friendly processing processes can increase production efficiency while creating economic added value. In addition, community mapping plays an important role in strengthening farmer participation, building cross-sector collaboration, and creating inclusive innovation. This study recommends a community mapping-based approach as a foundation for a more sustainable and equitable transformation of coffee processing systems.

Keywords: Technology Transfer, Circular Economy, Socio-Ecological Innovation, Welfare, Robusta Coffee Processing

INTRODUCTION

"Perkasa" Farmer Group (Poktan) located in RT. 03 Kampung Darussalam, Telaga Said Village, Sei Lengan District, Langkat Regency, North Sumatra has the potential as a producer and developer of Robusta Coffee agriculture which is supported by geographical and climatic conditions that are suitable for the growth of quality coffee plants [1]. This region has great potential as a producer of robusta coffee, but the limitations of technology and farmers' skills in processing cause the added value of coffee products to be quite low. The farmer group only uses simple traditional methods, so that the robusta coffee produced is less competitive and has less added value in the market. According to data from the Central Statistics Agency (BPS) of Langkat Regency in 2023 [1], the robusta coffee harvest area in Langkat Regency reached 22,000 hectares with a production of 33,000 tons. Of this amount, Telaga Said Village contributes around 10% with the production of 3,300 tons of robusta coffee per year. Some of

the obstacles faced by Poktan Perkasa to be able to contribute to robusta coffee production include: a) lack of access to technology and innovation; b) lack of access to a stable and sustainable market; c) challenges in providing added value of products; and d) challenges in maintaining environmental sustainability.

Moreover, related to the challenges in maintaining environmental sustainability, there is a problem that coffee waste such as coffee husks has not been managed properly or has not been utilized optimally. Not managed properly, the coffee waste has the potential to cause ecological problems in the area. This potential problem is a challenge for farmers who are not aware of the benefits of the circular economy in improving welfare and environmental sustainability. The literature has revealed that processed coffee waste can be a product of economic value and support a sustainable economy [2]. However, in this PKM target partner, there is no utilization of waste treatment based on the concept of circular economy. In fact, with the skills in coffee waste processing, efforts to improve welfare can be encouraged by utilizing coffee husk waste into by-products that have the potential to become additional income for coffee farmers [3]. Reprocessing waste into by-products will increase added value while increasing business competitiveness compared to those that do not [4]. So that agricultural waste as a resource will be able to be a solution that improves welfare through the creation of new products while avoiding waste accumulation in the environment.

Economy Circulars is an economic system based on a business model that replaces the concept of "*end-of-life*" By reducing, reusing, recycling, and recovering materials in the production/distribution and consumption process, so as to operate at the micro level (products, companies, consumers), medium level (eco-friendly industrial estates), and macro level (cities, regions, countries, and so on), with the aim of achieving sustainable development, which means creating environmental quality, economic prosperity, and social equality, for the benefit of the current generation and future generations Upcoming [5]. So that to achieve a circular economy for coffee farmers, it is necessary to minimize the use of raw materials (resources) wasted in the production process.

At the beginning of the implementation of this community service program, the Perkasa Farmers Group was invited to carry out a Focus Group Disc (FGD) to formulate a plan for the service program that will be carried out in the future together with a team of lecturers and students from Satya Terra Bhinneka University. The discussion was also attended by the Chairman of the Perkasa Poktan, *Mr. Sumardi*, with one of the topics of discussion related to efforts to improve the welfare of farmer group members so that more people are interested in producing Robusta Coffee and its by-products. Furthermore, the service team from Satya Terra Bhinneka University conducted field observations and the next FGD to see the potential of the circular economy in this farmer group. So that the limitations of the Poktan to knowledge, innovation, and technology related to the circular economy can be identified. In Table 1, the following Profile of Poktan Perkasa Target Partners in this Community Service activity is presented:

Table 1. Profile of Poktan Perkasa Target Partners

Identity	Friend
Name of Farmer Group	Mighty
Head	Sumardi
Number of Members	35 people
Business Field	Coffee Farmers and Sellers
Type of Business	Coffee
Community	Productive
Location	Langkat Regency

Based on several FGDs conducted, it has been identified that Poktan Perkasa realizes the potential and opportunities for coffee production in its region and realizes that the challenges in the era of sustainability (*green economy*) is currently not only about providing products, but also how to develop and diversify added value products in order to increase income and welfare. Until now, the production of Robusta Coffee from the Perkasa Poktan only produces raw coffee beans without any added value, even though if developed, the circular economy potential of this farmer group from the processing of coffee husk waste produced by this farmer group can produce other products with high economic value. Among them are other products as a result of the processing of coffee husk waste is Cascara Tea which has a large market share potential [6].

Looking at the background, this service program aims to empower the Perkasa farmer group in adopting a circular economy with a *Asset-Based Community Development* (ABCD) [7]. Through this approach, local assets, such as basic farming knowledge and environmental resources, are optimally utilized to improve the skills of farmer groups in processing coffee waste into value-added products. Thus, this community service program aims to improve farmers' skills and knowledge about coffee processing and marketing techniques, so that they can increase their income and strengthen the sustainability of the managed robusta coffee farming business. This ABCD approach is supported by various studies that show that local asset-based development can lead to stronger engagement and long-term sustainability. Kretzmann and McKnight (1993) explained that the ABCD approach allows people to discover their potential and strengths so that they can increase self-reliance. As an approach in community service programs, the ABCD method provides the premise that communities can organize themselves to encourage their own development process by identifying and mobilizing existing assets so that they can respond and create local economic opportunities [7].

In addition, a study of the circular economy in the agricultural sector conducted by Bocken et al. (2016) revealed that waste utilization can be an innovative strategy that reduces production costs and creates new products with high economic value [8]. Another study by Murray et al. (2017) stated that the use of coffee waste as organic fertilizer can improve soil quality and production yields, thereby supporting the sustainability of agricultural ecosystems [9]. **With the basis of the theory and results of the study**, this service program is carried out to be able to increase the capacity of the Perkasa Farmers Group in managing the robusta coffee business in a sustainable manner. The success of this activity is also expected to have a long-term positive impact on other farming communities in the surrounding area and inspire other community service programs in adopting a circular economy approach based on local potential.

Furthermore, to strengthen the concept of understanding community service, a qualitative method with a socio-ecological innovation approach is used. Where ecological social innovation is defined as social innovation, including new strategies, new concepts, new ideas, institutions, and organizations that increase the ability of the ecosystem to produce services [10]. The concept of socio-ecological innovation also encourages adaptation between ecosystems and management systems, helping to drive sustainability pathways and contribute to the resilience of all socio-ecological systems [11]. In the context of marketing management, there is an influence of price and product quality on consumer satisfaction and loyalty [12]. Then, research findings that explain that the existence of a community has an impact on a job profession [13]. Where in the context of this PKM, one of the sustainability efforts of the program is to create a community related to the circular economy for coffee farmers. In addition, there is research that is still relevant in the context of MSMEs, that socio-cultural support and financing are needed so that MSMEs can develop [14].

METHOD

The Asset-Based Community Development (ABCD) method is the main approach in this program, but it is reinforced with the concept of ecological social innovation to ensure that the activities not only empower the "Perkasa" farmer group in Langkat Regency but also produce a wider environmental and social impact [15]. Socio-ecological innovation serves as a foundation to create community-based solutions that support ecosystem sustainability while improving people's well-being [11].

1. In the initial stage, community asset mapping is carried out by involving members of farmer groups, community leaders, and other relevant parties to identify existing natural and human resources. In the socio-ecological innovation approach, this mapping also includes an analysis of the potential environmental impacts of agricultural practices carried out and exploration of ways to mitigate these risks. For example, coffee husk waste, which was previously only discarded, is identified as an asset that can be used to make organic fertilizer products, kaskara tea, or bioenergy. This strengthens the ecological perspective in waste management, creating a dual benefit for farmers and the environment.
2. Then at the socialization stage, it not only introduces the concept of circular economy but also instills the importance of socio-ecological innovation in the management of coffee farming businesses. Interactive discussions were conducted to provide farmer groups with an understanding of how their practices can make a positive contribution to the environment, for example through waste reduction, recycling, and innovative by-product utilization. Through this approach, farmer groups are invited to view their assets not only as a source of income but also as a means of maintaining the local ecosystem.
3. The education and training phase, reinforced by the application of simple but innovative technologies designed to support sustainability. The training includes fermentation techniques that not only increase the value of the product but also reduce greenhouse gas emissions from coffee waste. In addition, eco-friendly material-based packaging was introduced to support ecological principles. Intensive mentoring is carried out so that farmer groups understand not only the technical aspects but also the social and ecological impacts

of the innovations implemented.

4. Furthermore, a thorough participatory evaluation was carried out by involving farmer groups in reflective discussions to measure the success of the program from economic, social, and environmental perspectives. This evaluation includes an assessment of increasing product added value, reducing waste, and positively impacting the community. The evaluation method of ecological social innovation also assesses how farmer groups implement changes on a community scale, such as sharing knowledge with other farmer groups or involving more local stakeholders in sustainability efforts.

With the integration of socio-ecological innovations, this program has not only succeeded in increasing the capacity of farmer groups to manage local asset-based businesses but also building a more sustainable ecosystem. Farmer groups are empowered to be agents of change who are able to leverage their local assets in a way that supports environmental sustainability while improving the well-being of their communities.

The concept of circular economy technology as science and technology implemented in this community service activity is "Processing Coffee Peel Waste into Sustainable Healthy Beverage Products". Circular economy technology based on social and ecological innovation in the processing of people's robusta coffee for the welfare of the Perkasa farmer group in Langkat Regency will involve an integrated and measurable process [16]. Starting from the initial processing of coffee husk waste to becoming a healthy beverage product, this technology will utilize every process efficiently [17]. With adjustable size and capacity, this technology can be adopted by various sizes of farmer groups, ranging from small to medium-sized ones. The implementation of this service began with field surveys, literature studies, training on coffee husk waste processing, and workshops on making healthy product drinks made from coffee husk waste [18]. The material provided was related to the use of coffee husk waste into healthy beverage products as an additional product. After that, the farmer group was given training and assistance in making drinks made from fermented coffee husk waste. This training includes the introduction stage of circular economy concepts in the form of applying the concept of a closed cycle loop starting from downstream to upstream of business.

RESULTS AND DISCUSSION

1. Community Asset Mapping Application of Circular Economy Technology and Socio-Ecological Innovation in Robusta Coffee Processing Poktan Perkasa

Community mapping begins with an analysis of local assets that can support the application of technology, such as access to coffee waste raw materials or potential product diversification. This asset mapping helps match the right technology with local potential [21]. Circular economy technologies can only be successfully implemented if they are aligned with the needs of farmers and their capacities. Surveys and interviews with farmers provide critical data for designing acceptable and sustainable solutions [22]. Then analyze the social structure of coffee farmers, including the relationship between members of farmer groups, the role of key stakeholders, and organizational dynamics. A study by Anderson et al. (2024) emphasizes the importance of understanding social structures to build effective collaboration in adopting

circular technologies [23]. Coffee farming communities are often connected to a network of partners, such as cooperatives, non-governmental organizations (NGOs), and coffee companies. This network mapping allows for better integration between technology and external support, such as training, funding, or markets for recycled products [24].

At the community asset mapping stage, the community service team with the Perkasa farmer group in Langkat Regency carried out a mapping of local strengths and potentials, both in the form of human, natural, and social resources. This process is carried out through focus group discussions (FGDs) and field observations to identify community assets, such as coffee farming skills that farmers already have, as well as the potential for coffee husk waste that has not been utilized optimally.



Figure 1. FGD Community Asset Mapping in the "Perkasa" Poktan

Asset mapping shows that farmers have basic knowledge about the robusta coffee processing process, but still use traditional methods. In addition, there is great potential in the use of coffee husk waste as an organic fertilizer material that has not been widely explored. This mapping strengthens the program's orientation to develop community skills in the circular economy by utilizing existing resources. The ABCD approach in this stage provides an in-depth understanding of local potential as the basis for activity development. This is in accordance with the ABCD theory which states that asset-based development is more effective in creating community engagement and sustainability [15]. By understanding local assets, these activities are more relevant to the context of the community, as opposed to approaches that do not pay attention to internal potential.

2. Socialization, Education and Training of Circular Economy Concepts in Robusta Coffee Processing Poktan Perkasa

The socialization was carried out to introduce farmer groups to the concept of circular economy and the potential for circular economy-based coffee waste management. The community service team held interactive lecture sessions and discussions on the principles of the circular economy and the benefits that farmers can obtain by processing coffee waste into products of economic value, such as organic fertilizers and health drinks (kaskara tea). The socialization succeeded in increasing farmers' understanding of the circular economy, which can be seen from the increase in scores *Pre-test* and *post-test* Participants. In addition, farmers are becoming more enthusiastic about applying this concept in their coffee processing after

knowing its positive impact on welfare and the environment. The results of this socialization show that ABCD-based counseling is able to provide a deeper understanding to the community because it focuses on the assets they already have. Circular economy literacy in the coffee community has proven to play an important role in previous research that emphasized that waste utilization can be one of the innovative solutions to improve the welfare of farmers [8]. This indicates that increasing knowledge at the socialization stage will have a direct impact on the success of subsequent implementation.

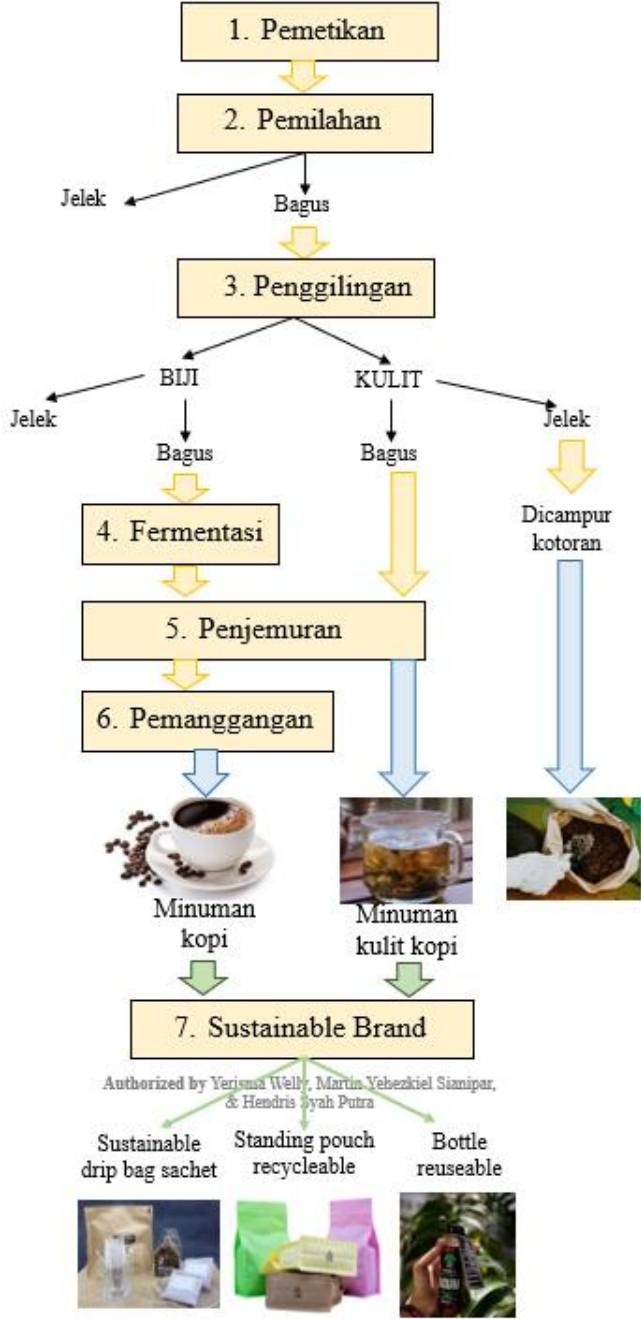


Figure 2. Coffee Management Circular Economy Technology

At this stage of education and training, the service team provides intensive training on techniques for processing coffee husk waste into kaskara tea health drinks. This training is

carried out practically using simple tools and techniques that are easy to apply. This education includes fermentation steps, sorting techniques, and product rebranding to increase the added value of coffee products. After the training, the test results showed an improvement in farmers' skills in processing coffee husk waste. The results can be seen from organic fertilizer products produced by farmers, which can then be used as an alternative fertilizer on their farmland. Coffee products that are repackaged with attractive designs are also starting to show an increase in the interest of local buyers. This training is in line with the ABCD approach that utilizes basic skills of farmers and develops them according to local needs. A study by Murray et al. (2017) shows that the use of coffee waste as fertilizer can increase soil productivity, reduce costs, and provide added value to primary products [9]. This stage emphasizes that practical training based on community assets can be more sustainable than training with complex or overly technical methods.



Image: Coffee Peel Fermentation Training and Practice

3. Implementation of Circular Economy Technology in Robusta Coffee Processing: Socio-Ecological Innovation to Improve the Welfare of Farmer Groups

Robusta coffee processing has great potential to support economic and environmental sustainability, especially through the application of circular economy technology. This technology aims to minimize waste, increase efficiency, and create added value at every stage of the processing process. In this context, socio-ecological innovation is an important element to ensure that the technology applied is not only environmentally friendly but also provides social and economic benefits for farmer groups. Circular economy technology in coffee processing includes several approaches:

1. Waste from coffee processing, such as coffee grounds and peels, can be reused. Recent research shows that coffee waste can be processed into bioenergy (biogas and biochar) or raw materials for organic compost which increases soil productivity [25].
2. IoT-based technology (Internet of Things) allows for a more efficient coffee processing process, such as temperature and humidity monitoring during fermentation as well as

quality control of coffee beans. This digitalization can help farmer groups ensure high quality standards and reduce losses due to less than optimal manual processes [26].

3. Environmentally friendly wet processing processes are now being introduced using energy-efficient water filtration technology. This technology can reduce water consumption by up to 50% compared to traditional methods [27].
4. Blockchain is used to record data related to the origin of coffee, processing processes, and distribution. This gives more trust to consumers, while increasing the selling value of robusta coffee products [28].

4. Evaluation of the Circular Economy Technology Program and Socio-Ecological Innovation of Robusta Coffee Processing

The evaluation was carried out using pre-test and post-test to measure the improvement of farmers' knowledge and skills before and after training activities. In addition, a partner satisfaction survey was carried out to assess farmers' responses to the programs implemented. The results of the pre-test and post-test showed an increase in farmers' understanding of the circular economy concept by 40%, and an increase in coffee waste processing skills by 35%. The satisfaction survey showed a partner satisfaction level of 90%, where most participants expressed interest in continuing to process coffee waste into valuable products.

Aspects	Shoes	Shoes	Increase (%)
	Pre-Test (%)	Post-Test (%)	
Understanding the Circular Economy	50	90	40
Processing Skills	45	80	35

The evaluation showed that the ABCD approach was effective in improving farmers' understanding and skills because the program was asset-based and local potential. The ABCD approach is effective in strengthening community capacity related to the circular economy through the development of existing assets. These results are consistent with previous research that suggests that asset-based training can significantly improve the competitiveness of local products [7]. As a follow-up, farmer groups began to plan activities independently and continue to produce organic fertilizer from coffee waste. This impact shows the sustainability potential of the program in the future, and farmer groups are starting to establish partnerships with local markets to expand access to their coffee products. With its long-term impact, this sustainability demonstrates the success of ABCD's approach in creating solutions that are truly relevant to the needs of society. Studies show that asset-based empowerment can create better economic resilience for local communities [20].

CONCLUSION

The conclusion of this community service activity shows that the Asset-Based Community Development (ABCD) approach is effective in achieving the goal of increasing the added value and welfare of the Perkasa farmer group in Langkat Regency through the concept of circular economy. Through the stages of asset mapping, socialization, training, and evaluation, the program has succeeded in improving farmers' understanding and skills related to processing coffee waste into valuable products such as organic fertilizers. The results of the pre-test and post-test as well as the partner satisfaction survey indicated a significant improvement in understanding and skills, which reflected the achievement of the program's targets as expected. Although this program has succeeded in achieving its goals, several obstacles such as limited infrastructure and simple tools have become challenges in the implementation of training. However, the enthusiasm and active involvement of farmer groups in this activity is the main supporting factor for success. For the continuation of the program, it is recommended to develop more adequate processing facilities and infrastructure as well as support for further training, especially in terms of digital-based product marketing so that farmer groups have wider market access. The application of this circular economy is expected to continue to be developed in other communities around Langkat Regency, so that this asset-based empowerment model can be an inspiration for sustainable and wide-impact community service programs.

Acknowledgement

We would like to thank the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia (DRTPM) for the funding provided for the implementation of this community service activity through the 2024 Community-Based Empowerment scheme. We would also like to express our gratitude to Satya Terra Bhinneka University, especially to the Institute for Research and Community Service (LPPM) for their continued support, starting from the planning stage to reporting the results of this activity. We would also like to thank the cooperation that has been established with the Government of Telaga Said Village, Sei Lengan District, Lalat Regency, as well as all members of the Perkasa Farmers Group who have actively participated and provided full support during the implementation of the activity. Thank you to Mr. Sumardi as the Chairman of the Farmer Group for facilitating us in carrying out various training programs in the field. We would also like to express our gratitude to the students of Satya Terra Bhinneka University who have been involved and contributed as field facilitators, as well as the surrounding community who have supported the success of this program.

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