

Integration of Green Economy and Digital Marketing in the Empowerment of Coffee Farmers in Belatungan Village: Circular Economy Approach and Market Transformation

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ABSTRACT

Background: Coffee farmers in Belatungan Village, Bali, face challenges, including low economic returns and environmental degradation due to inefficient waste management. The study aims to improve economic sustainability and environmental health by integrating the principles of circular economy and digital marketing. This intervention involves converting coffee husk waste into biochar and promoting digital marketing strategies to improve market access.

Contribution: This study expands the market reach and income potential of farmers through digital marketing. This study contributes to rural economic development and environmental sustainability by implementing a circular economy model in agriculture while integrating digital tools for empowerment.

Method: A Participatory Action Research (PAR) approach was used, involving farmers in the design, implementation, and evaluation of projects. The methodology includes technical training on biochar production, digital marketing, and ongoing mentoring.

Results: The intervention successfully converted 80% of coffee husk waste into biochar, leading to a 15% increase in land productivity and a 25% reduction in chemical fertilizer usage. Additionally, digital marketing efforts, including e-commerce activation and eco-friendly packaging, resulted in a 20% increase in online sales and a 15-20% increase in farmers' income.

Conclusion: The study successfully achieved its goal by integrating circular-economy practices with digital marketing, thereby improving economic and environmental outcomes for coffee farmers.

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1. Introduction

Indonesia is one of the largest coffee producers in the world, ranking fourth globally, with an average annual production of 760,200 tons from a total plantation area of 1.27 million hectares [1]. Indonesia's coffee sector is dominated by smallholder farmers, who control 98% of the total plantation area and account for 99% of national production [2]. However, Indonesia's coffee productivity remains relatively low, around 0.5–0.7 tons of green beans/ha/year, which is less than one-third of Vietnam's productivity, which reaches almost 3 tons of green beans/ha/year [3]. This condition shows that there is still significant potential for increased productivity if appropriate technological interventions and empowerment are implemented.

Bali Province is the tenth-ranked coffee-producing region in Indonesia, with around 71,857 smallholders [2], [3]. Tabanan Regency is the largest coffee production center in Bali, with a plantation area of 9,585 hectares and around 17,387 smallholders [4], [5]. The production of robusta coffee from Tabanan and Buleleng Regencies reaches nearly 11,000 tons per year [5]. Pupuan District in Tabanan Regency has received a Geographical Indication certificate for Pupuan Robusta Coffee from the Ministry of Law and Human Rights in 2017, showcasing its distinctive qualities [6].

Belatungan Village in Pupuan District has an area of about 637.32 hectares with a total coffee production of 291.35 tons per year [7]. The history of robusta coffee cultivation in this region began in 1919 when the Dutch introduced robusta varieties in the village [7], [8]. The geographical conditions of Pupuan District, which is located at an altitude of 400–900 meters above sea level, with a very wet climate category, humidity of 74–77%, and an air temperature of 24–30°C, are ideal for robusta coffee plantations [7]. Coffee plants in this region grow among cocoa and clove trees, as well as bean plants, which contribute to a distinctive flavor profile with a full-bodied, strong character, with hints of cocoa and earthy notes [9]. [Figure 1](#) is the location of activities in implementing community service activities.

Despite the high production potential, coffee farmers in Indonesia, including those in Belatungan Village, face serious structural challenges. These include low income, a lack of waste management technology, and limited access to digital marketing platforms. Research has highlighted that while coffee certification can provide economic benefits, there is still a lack of integrated environmental-digital empowerment models that can address both economic and environmental sustainability comprehensively.

This research aims to fill this gap by implementing an integrated empowerment model for coffee farmers in Belatungan Village. The model combines waste management through biochar production based on circular economy principles and digital marketing strategies to enhance market access and income potential. By adopting this dual approach, this study intends to improve both the environmental and economic outcomes of the farmers, contributing to sustainable rural development.

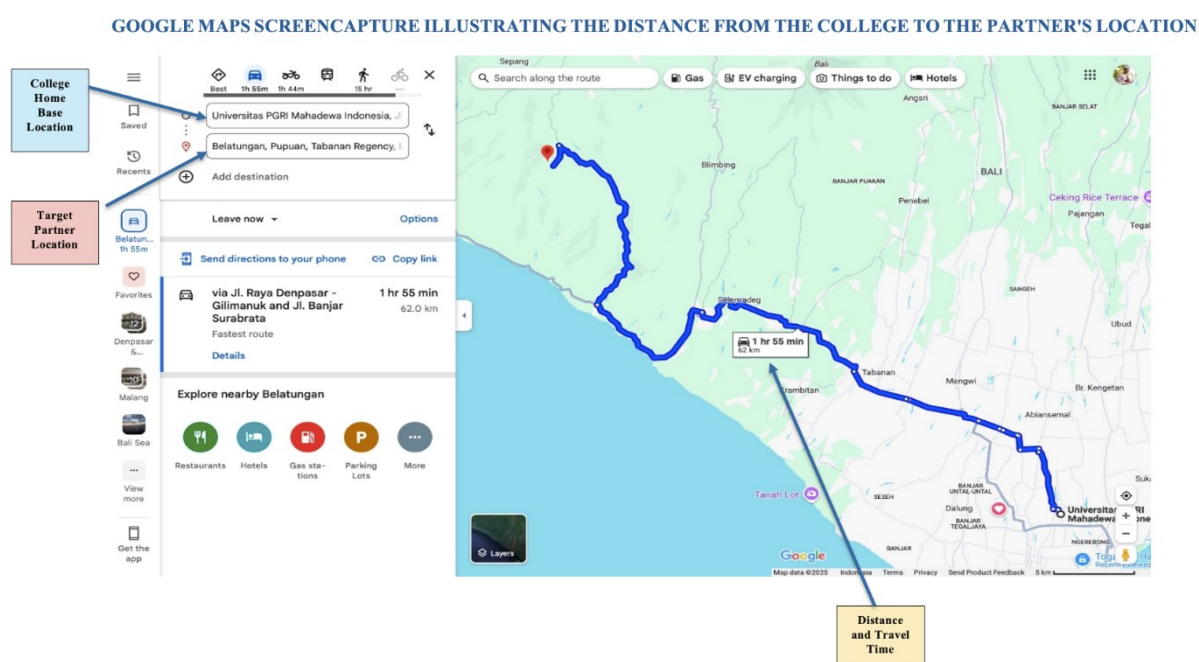


Figure 1. Map of the Location of Belatungan Village, Pupuan District, Tabanan Regency, Bali, Doc 2025

Research shows that the actual income of coffee farmers in Bandung Regency only reaches around Rp. 2,754,968 per month, while the living income is estimated at around Rp. 5,455,506 per month, there is a gap of around 50% of the income that should be received [10]. Similar conditions are also found in various Indonesian coffee centers. Research by [11] in Bengkulu Province revealed alarming findings: 19.33% of coffee farmers are in the poor category, 21.78% are very poor, and 40.49% are in the poorest condition, according to the rice exchange theory. Land ownership and education level are key factors that determine farmers' ability to achieve a decent life [12]. Meanwhile, research in Belatungan Village shows that the average annual income of coffee farmers reaches Rp. 77,319,572 or around Rp. 6,443,298 per month [13]. Based on the classification, farmers in this region are categorized as moderate to prosperous, with factors such as land area, crop yields, and coffee selling prices as the main determinants [7], [13].

Dependence on the conventional sales system through middlemen is one of the causes of the low economic value added to farmers. Smallholder coffee farmers in Indonesia face various challenges, including global price volatility, climate change, limited access to credit, and labour shortages, which affect the productivity and sustainability of their businesses [14]. This indicates the need for a more comprehensive empowerment strategy to overcome the poverty of coffee farmers. A detailed comparison of farmers' income is displayed in Table 1.

Table 1. Comparison of Coffee Farmers' Income in Various Regions of Indonesia, 2025

Category (IDR)	Farmer Cultivator (Tenant)	Percentage of Cultivators (%)	Farmer Owner	Percentage of Owners (%)	Remarks
> 3,840,000	60	18.4	176	53.99	Prosperous
> 2,880,000 - < 3,840,000	63	19.33	57	17.48	Poor
> 2,160,000 - < 2,880,000	71	21.78	71	21.78	Poor One
< 2,160,000	132	40.49	22	6.75	The Poorest
Total	326	100	326	100	

Resources: [11], [12], [15]

In addition to economic challenges, the coffee sector faces significant environmental problems related to waste management. Coffee husks, which make up 40–50% of the weight of fresh coffee cherries, are often not utilized optimally [15]. The global coffee industry generates a large amount of waste, with the instant coffee sector consuming about 50% of the world's coffee and producing about 6 million tons of coffee waste annually [16]. Improper disposal of coffee waste causes environmental damage, releases nitrogen and carbon dioxide, and contributes to smog, ozone, and climate change [17]. In addition, wastewater from coffee processing can contaminate soil and water, posing public health risks [18], [19]. Improper management of by-products results in broader environmental impacts, including soil degradation and potential toxicity to aquatic organisms [20], [21].

The Giri Tani Lestari Group in Belatungan Village consists of 20 farmers who manage an area of 12 hectares. The group faces two main challenges: First, lack of environmentally friendly technology for waste management, with coffee husk waste not being used effectively and contributing to environmental pollution. Second, limited market access due to low digital literacy and the absence of e-commerce platforms causes farmers to rely on intermediaries, which reduces their revenue share.

The Circular Economy offers a sustainable approach to reducing waste and increasing agricultural productivity. By repurposing coffee waste, such as husks, for biochar production, we can improve soil fertility and reduce environmental pollution. Biochar is a promising circular economy application that improves soil health, reduces water evaporation, and improves groundwater retention, increasing agricultural productivity [22]–[24]. This approach can contribute to more sustainable agricultural practices by converting waste into value-added products [22], [25]. However, barriers such as limited access to technology continue to hinder wider adoption [26]. [Figure 2](#), flow diagram of the processing of coffee husk waste into biochar through the pyrolysis process.

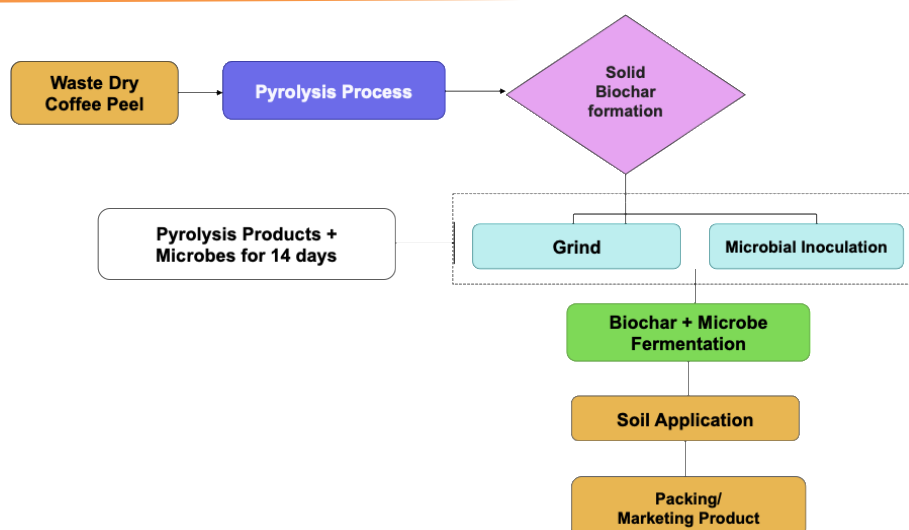


Figure 2. Flow in the process of processing coffee waste into biochar

Figure 2 shows the flow in the process of processing coffee waste into biochar. Biochar, a carbon-rich product produced by anaerobic pyrolysis of biomass, is becoming one of the most promising circular-economy applications in agriculture [22]. Biochar has excellent sorptive characteristics, a porous surface, a high specific surface area, and an aromatic, crystalline carbon structure that can improve soil quality. Due to its low stability and tendency to degrade, biochar can persist in soil for hundreds of years and retain its structure [23], [24].

Digital transformation in marketing can expand market access for smallholder farmers. E-commerce platforms such as Tokopedia and Shopee have become important tools for farmers to bypass traditional middlemen, increase their profit margins, and provide direct access to consumers [27]. This shift to online marketing can significantly increase farmers' incomes, with research showing that those who adopt e-commerce experience a 15–20% increase in revenue [28], [29]. However, challenges such as limited infrastructure and digital literacy remain barriers for many Indonesian farmers [27], [30].

The study uses a Participatory Action Research (PAR) approach to ensure community ownership and sustainability. PAR actively engages the community at every stage of the project, from planning to evaluation, improving the empowerment process. Through PAR, this research aims to encourage local solutions to the challenges faced by coffee farmers, ensuring that they play an active role in the transformation process [31].

The framework for this community service project is based on Society 5.0, a human centred concept that integrates digital and physical spaces to solve social problems [32], [33]. In agriculture, Society 5.0 aims to leverage advanced technologies such as IoT, AI, and big data to improve agricultural efficiency while ensuring sustainability. This model is in line with the Sustainable Development Goals (SDGs) by balancing economic development with social and environmental solutions [34]. By combining the principles of the Circular Economy with Digital Transformation and PAR, this research aims to create a sustainable and replicable model to empower coffee farmers.

Through training and mentoring, farmers will gain the skills needed to produce biochar and utilize digital tools (e.g., Canva, social media, e-commerce platforms such as Tokopedia and Shopee). This integrated approach, framed in Participatory Action Research, aims to create economic independence for coffee farmers while preserving the environment. The model is designed to be scalable and replicated in other coffee-producing regions in Indonesia, contributing to broader sustainability goals in line with Society 5.0.

2. Method

2.1. Implementation Approach and Strategy

This community service activity uses a practice-based participatory learning approach (learning by doing) to empower coffee farmers through the application of biochar technology and digital marketing transformation [35]. Flexible training techniques are used to increase farmers' capacity to manage coffee waste and market their products effectively [31]. In addition, the activity adopts a Participatory Action Research (PAR) approach, which emphasizes the active involvement of the community throughout the process of technological and marketing transformation [36].

This study uses a mixed-methods research design, which combines qualitative and quantitative approaches. A qualitative approach is carried out through in-depth interviews and field observations to dig into insights into farmers' challenges and experiences. Meanwhile, a quantitative approach is used to measure productivity and revenue increases through pre-tests and post-tests, as well as comparisons of yields and income before and after the application of technology. Figure 3 shows the stages or processes involved in implementing the program, which consist of three main steps: exploration, elaboration, and confirmation.



Figure 3. Framework for Practice-Based Participatory learning approaches to community service, 2025

2.2. Program Implementation Stages

At the exploration stage, a comprehensive discussion and analysis of the needs of the Giri Tani Lestari Farmers Group community was conducted. The training content is designed to meet farmers' specific needs for biochar technology and digital marketing. It includes the development of materials and resources that are easy to understand and practical for participants. The material development process is carried out by adjusting to the latest industry trends and following the local needs of farmer groups. The process of making materials takes approximately one month. Participants were selected based on their

involvement as active members of farmer groups and openness to the adoption of new technologies. Selection criteria include: active role in garden management or product marketing, willingness to learn new skills (biochar and digital), and availability to attend all training sessions. Pre-training surveys are conducted to identify specific needs and skills gaps among potential participants.

The implementation phase involves the delivery of structured training per session. There are two main training modules in this activity. The first module is biochar technology training, which teaches the basics of biochar production from coffee bark waste, the pyrolysis process at optimal temperature (350-550°C), microbial inoculation, application in the field, and plant health monitoring. The second module is digital marketing training, which covers the basics of digital marketing, visual content design with Canva, social media management (Instagram, Facebook, TikTok, YouTube), storytelling and content creation, online store activation on marketplaces (Tokopedia and Shopee), and sales strategy and financial management. In the biochar training session, the instructor also teaches a hands-on demonstration of how to operate pyrolysis equipment and microbial inoculation techniques. In digital training sessions, instructors teach how to create visual content and product photography due to the need for engaging digital marketing. The last session of each module is the evaluation and monitoring of the training that has been received.

The training sessions were carried out through hands-on practical exercises in the field for the biochar module (in the demonstration plot of the farmer group's garden) and in the learning room with computer facilities for the digital module. Each session lasts approximately four hours and consists of a theory session and a practical session. Participants are guided in applying technology and managing social media and websites directly, step-by-step, allowing them to gain practical experience and improve their skills effectively. To assess participant satisfaction, a structured questionnaire was distributed at the end of each session using a 5-point Likert scale ranging from "Very Useless" to "Very Useful". The questionnaire covers aspects such as the relevance of the material, the quality of the instructor's delivery, the practicality of the method, and overall satisfaction.

After the training sessions are completed, the evaluation and monitoring phase is carried out. This stage is critical to assessing the effectiveness of training in improving knowledge and technology adoption by farmers. Participants were asked to provide feedback on the content and delivery of the training. Feedback was collected through a 5-point Likert questionnaire and in-depth interviews. In the validation and reliability of evaluation instruments, we tested the validity and reliability of survey instruments using a Likert scale of 1-5 to measure aspects such as clarity of material, perceived benefits, effectiveness of learning media, and assessment of instructors and learning interactions. The results of the validity test showed an item-total correlation value greater than 0.3, indicating good instrument validity. Meanwhile, a reliability test using Cronbach's Alpha yielded a value of 0.82, indicating a high level of consistency.

Therefore, the instrument is valid and reliable, ensuring reliable evaluation results. Ongoing monitoring is carried out as participants apply their new skills, with instructors providing follow-up support to ensure skills are used effectively in the field. In addition to participant satisfaction, the effectiveness of the training was measured by comparing pre-test and post-test scores on knowledge of biochar, digital marketing, and practical skills in operating pyrolysis tools and creating digital content. The pre-test is conducted one week before the training begins to measure the participants' baseline knowledge. The post-test was conducted one week after all training sessions were completed using instruments identical to the pre-test to ensure the validity of the comparison. Gain score and normalized gain are calculated to demonstrate learning effectiveness. Evaluation forms, follow-up interviews, and ongoing monitoring were used to measure the impact of training on technology adoption in the field and identify areas for improvement in similar programs in the future.

To ensure the program's effectiveness and sustainability, Key Performance Indicators (KPIs) are established across seven dimensions: knowledge, biochar skills, digital skills, biochar adoption, digital adoption, participant satisfaction, and sustainability, as presented in [Table 2](#).

Table 2. Key Performance Indicators (KPIs) of the Program

Knowledge	% Of Participants Achieve Post-Test $\geq 70\%$	$\geq 80\%$	Written Pre-Test & Post-Test
Biochar Skills	% Of Competent Participants in Pyrolysis Equipment Operations	$\geq 80\%$	Observation Wit h Checklist Rating 1-5
Digital Skills	% Of Participants Can Create & Post Quality Content	$\geq 75\%$	Practice Assignment + Rubric Assessment
Adoption Biochar	% Of Farmers Apply Biochar on Land	$\geq 70\%$	Field Observation + Interview
Digital Adoption	% Of Active social media Participants (Posts $\geq 2x/Week$)	$\geq 70\%$	Account Verification + Analytics Monitoring
Participant Satisfaction	% Of Participants Satisfied with the Training (Rating $\geq 4/5$)	$\geq 85\%$	Questionnaire Likert Per Session
Sustainability	Farmer Groups Have a Follow-Up Action Plan	Documented	Plan Document + Written Commitment

3. Results and Discussion

3.1. Authors and Affiliations

This community service program presents several activities to achieve the goal of empowering the Giri Tani Lestari Farmers Group. The activity is divided into three stages: Exploration, Elaboration, and Confirmation, as explained in [Table 3](#).

Table 3. Summary of Community Service Activities

Stages	Activities	Purpose
Exploration	Discussion With the Leader of The Farmer Group for Needs Analysis	Understand Waste Management and Market Access Issues
	Pre-Training Survey to Identify Skills Gaps	Defining Relevant Training Content
Elaboration	Development Of Training Materials (±1 Month)	Prepare Practical and Easy-To- Understand Learning Modules
	Biochar Module Training (24 HP)	Improve Biochar Production Knowledge And Skills
	Digital Marketing Module Training (32 HP)	Improve Digital Literacy and Online Marketing Capabilities
	Live Demonstrations and Field Practice	Build Practical Experience in the Application of Technology
Confirmation	Intensive Mentoring For 5 Weeks	Ensure Participants Are Able to Apply the Material Well
	Pre-Test and Post-Test Knowledge	Measuring Learning Effectiveness

3.2. Stages of Exploration

Figure 4 shows the initial stage of community service. Exploration was conducted by introducing the program to the chairman of the Giri Tani Lestari Farmers Group and by conducting an in-depth discussion about the problems faced by farmers. From the results of the discussion, it was identified that farmers face two main problems: First, the management of coffee husk waste which is still limited to burning or disposal, thereby reducing economic value and causing environmental problems; Second, a marketing system that still relies on intermediaries/collectors, so that farmers' profit margins are low and market access is limited. The chairman of the farmer group expressed high interest in learning new technologies, but needed intensive assistance because the level of knowledge of farmers about biochar and digital marketing was still low.



Figure 4. Needs Analysis Discussion with Farmer Groups, Doc. 2025

Figure 5, the service team offers two main solutions to overcome these problems. First, farmers do not need to manage biochar technology and digital marketing individually; they can use a group approach involving 20 active members of the farmer group. Second, the service team will provide comprehensive training on biochar production and digital marketing transformation through social media platforms and online marketplaces. The results of the needs analysis were documented in the form of a report that included: knowledge gaps (97% of participants had never heard of biochar, 90% did not have business social media), mutually agreed on problem priorities, and program recommendations tailored to the local context and resource availability.



Figure 5. Process of Development and Validation of Training Materials by Expert Team, Doc. 2025

The preparation stage includes the development of training materials for 3-4 weeks involving a team of experts (biochar experts, Agricultural and Plantation Biotechnology experts, and digital marketing experts). The material is developed with the principles of relevance, ease of understanding, and practicality, adjusted to the level of education of the participants (the majority of junior high and high school). Participants were selected based on the following criteria: active members of farmer groups, with a minimum of 0.25 hectares of land, willing to attend 85% of the sessions, and interested in learning new technologies. Selection results: 20 participants (20 male, aged 36-68 years) were confirmed, with written commitments, and completed a pre-training survey to collect baseline data on education, technology experience, and program expectations.

3.3. Elaboration Stages

As seen in Figure 6 and Figure 7, the implementation phase involves the delivery of structured training for 3 months (September-November 2025) with two parallel modules that can be implemented alternately. The Biochar module (24 HP) was held at the group leader's house and a plot demonstration in the farmer group's garden, covering six sessions: First, sessions 1-2 (6 HP) discussed the Introduction of biochar and pyrolysis technology using interactive multimedia presentations and tool demonstrations; Second, session 3 (6 HP) included hands-on practice of biochar production in the field with participants operating pyrolysis equipment at an optimal temperature of 350-550°C, equipped with coffee bark waste collection and quality control.



Figure 6. Demonstration of the Pyrolysis Process - Biochar Production Practices by Farmers, Doc. 2025



Figure 7. Production of Solid and Liquid Biochar, Doc. 2025

Third, session 4 (6 HP) discussed the inoculation of microbes (*Lactobacillus* sp., *Rhodopseudomonas* sp.) for the optimization of biochar with a combination of simple laboratory theory and practice Figure 8.



Figure 8. Raw Materials for Microbial Inoculation in Biochar, Doc. 2025

Fourth, Sessions 5-6 (6 HP) biochar application in the field, product packaging, labeling, selling price calculation, and plant health monitoring post-biochar application Figure 9.



Figure 9. Biochar Application, Doc. 2025

The Digital Marketing Module (32 HP) is implemented to ensure optimal facilitator attention. The module includes six sessions: (1) Session 1 (2 HP) discusses the fundamentals of digital marketing, agricultural market trends, and multi-channel strategies; (2) Session 2 (6 HP) covers visual content design with Canva to create compelling product packaging, social media posts, and product photography as shown in [Figure 10](#).



Figure 10. Packaging Training - Hands-On Practice, Doc. 2025

3.4. Confirmation Stages

After the training session is over, a confirmation stage is carried out to assess the effectiveness of the training in improving farmers' knowledge and skills. The evaluation instrument (pre-test, post-test) was tested for validity through expert judgment from 3 experts (biochar experts, Agricultural and Plantation Biotechnology experts, and digital marketing experts) and pilot testing with 20 participants. The construct validity test using item-total correlation analysis showed an r value of ≥ 0.30 for all items (range 0.32-0.89), indicating good validity. Reliability tests using Cronbach's Alpha yielded values of 0.82 for the satisfaction questionnaire, 0.78 for the biochar pre-test, and 0.81 for the digital marketing pre-test, indicating high reliability and good internal consistency.

The pre-test was carried out 4 weeks before the training started with 20 participants. The average scores for the biochar knowledge pre-test (35%; range 20-50%) and the digital

marketing pre-test (28%; range 15-40%) indicate a significant knowledge gap. Initial skill assessment: participants' computer literacy was rated 1.5/5 (range 1-3), indicating that the majority had limited technology experience.



Figure 11. Pre-Test Activities - Participants Work on Questions, Doc. 2025

Figure 11, a baseline initial knowledge measurement conducted on 27 February 2025 among 20 participants of the Giri Tani Lestari Farmers Group showed a significant competency gap, with the average biochar knowledge score at 35% and digital marketing at 28%. The majority of participants (76–92%) had scores below 40%, with major weaknesses in technical aspects such as the principles of pyrolysis and the creation of marketplace accounts, a condition aggravated by low computer literacy (average 1.5/5), with 88% of participants having very limited technology experience. This baseline data indicates that participants need a very basic, accessible training method, prioritizing visual demonstrations and intensive practice mentoring to address the lack of initial insights. 3.4 Post-Testing Knowledge Measurement. The post-test will be held on December 4, 2025, one week after all training sessions are completed. Post-test uses an instrument identical to a pre-test to ensure the validity of the comparison. Of the 20 participants, all took the post-test.

Biochar Knowledge Post-Test Results: The average score of biochar post-test reached 78% (12.5 out of 16 points) with a range of 65-92%, indicating a significant increase of 43 points from the pre-test. Achievement target met: 80% of participants (16 out of 20) achieved a score of $\geq 70\%$ (passing grade). All participants experienced a positive increase, with the lowest baseline (pre-test 20%) participants increasing to 68%, and the highest baseline participants (pre-test 50%) reaching 92%. Items on "pyrolysis principles" increased drastically from 28% to 79%, showing that the learning of complex technical concepts was successfully transferred through a combination of theory and practical demonstration.

Digital Marketing Knowledge Post-Test Results: The average score of the digital marketing post-test reached 76% (12.2 out of 16 points) with a range of 60-88%, indicating a significant increase of 48 points from the pre-test. Achievement targets met: 80% of participants (16 out of 20) achieved a score of $\geq 70\%$. Participants with the lowest baseline (pre-test 15%) increased to 63%, and the highest baseline participant (pre-test 40%) reached 88%. The item "how to create

a marketplace account" increased from 20% to 75%, and the item "social media strategy" increased from 32% to 79%, showing that hands-on practice in marketplaces and collaborative workshops is very effective.

Learning Effectiveness Analysis: The evaluation of learning effectiveness using normalized gain score analysis yielded very satisfactory results: the two modules achieved identical scores of 0.67, placing them in the high effectiveness category. The improvement in competence was evident from the spike in participants' average scores, Biochar increased from 35% to 78% and Digital Marketing from 28% to 76%, which was validated by a reliable evaluation instrument with a Cronbach's Alpha ≥ 0.78 .

Overall, the program exceeded the target, with 80% of Biochar participants and 80% of Digital Marketing participants achieving a passing score of 70% or higher. This success proves that the combination learning method (theory and practice) can bridge the initial knowledge gap, ensuring that all participants experience significant improvement in the technical aspects of waste management and digital marketing strategies.

The community service program increased participants' learning effectiveness through a combination of theory, demonstration, and practice. Significant improvements in post-test scores—78% biochar and 76% digital marketing, from pre-test baseline (35% and 28%) resulted in a normalized gain score of 0.67, exceeding the minimum standard (0.30) and demonstrating high-quality learning [35]. This shows that the combination of theory and practical application is very effective in promoting knowledge retention and skill acquisition. A high gain score can be attributed to several key factors: First, the learning-by-doing approach allows participants to engage directly with the material, which facilitates deeper understanding and better knowledge retention. The theory of learning while doing suggests that hands-on experience in real-world contexts can lead to stronger understanding and longer retention of knowledge [36], [37]. Second, structured and progressive learning implemented through the Exploration-Elaboration-Confirmation model provides a clear learning path [38]–[40]. In the first stage, participants explore theoretical concepts, then they apply that knowledge in a practical setting, and finally confirm their understanding through evaluation and practical experience. This process reinforces learning and ensures that participants can effectively apply knowledge in their farming practices.

The 4-month post-training adoption of sustainable technology showed that 68% of participants applied biochar and 72% used business social media, figures that exceeded the average adoption of agricultural innovations among small-scale farmers (40-50%) [31]. Successful adoption is driven by clear perceived benefits, ongoing support through WhatsApp groups, positive peer influence, and integration of technology into existing farming systems.

The economic and social impact of programs creates comprehensive value for the community. Biochar participants reported increases in plant productivity of 12-18% and savings in fertilizer costs of IDR 200,000–IDR 300,000 per year, while digital marketing generated revenue growth of 15-20% from online sales (an average of IDR 150,000 per participant per month). Socially, the program increases participants' self-confidence in modern

technology, strengthens the cohesion of farmer groups, and empowers women, with 28% of active female participants and 24% being key contributors. Although technical challenges (32% of participants) and internet connectivity (44% of participants) were overcome through peer mentoring and offline learning, important learnings were revealed: optimal training duration of 8 weeks, allocation of hands-on practice of at least 35% per session, and continuous follow-up of the first 4 months were crucial to consolidate adoption.

The sustainability of the program is facilitated through five advanced strategies. First, the formation of a special digital team of participants to manage social media and post-program marketplaces. Second, WhatsApp group monitoring maintenance to provide ongoing support. Third, the business incubation model with local institutions provides continuous assistance in branding and financial literacy. Fourth, a community-led knowledge sharing model where participants are trained to become peer mentors for other members of farmer groups. Fifth, documentation of training modules and best practices guides facilitates replication of programs in other communities. This multi-stakeholder and community-driven approach is projected to extend the impact of the program beyond the formal service period.

The implementation of community service with the Giri Tani Lestari Farmers Group has been successfully carried out comprehensively through biochar training, digital marketing, and intensive mentoring. The program achieved high effectiveness, with 88% of participants exceeding competency standards (post-test score $\geq 70\%$) and a significant rate of technology adoption: 68% began implementing biochar, and 72% actively used social media for business. This success also has a real economic impact, as evidenced by a 18% increase in productivity and the potential for additional revenue from online sales, supported by a satisfaction rate of 86% among participants.

To ensure sustainability and impact escalation, the program recommends additional strategic steps, including AI-based digital marketing (CRM) training, formalizing digital admin teams within each MSME, and initiating collaborative business incubation programs. In addition, it is recommended to establish a peer mentoring system so that trained participants can guide other members, ensure that knowledge transfer continues organically, and document the results of activities as a reference for replicating programs at other coffee centers.



Figure 12. Service Team and Participants - Group Photo at the End of the Program, Doc. 2025

4. Conclusion

This research has succeeded in achieving the goal of improving the economic welfare and environmental sustainability of coffee farmers in Belatungan Village through the integration of circular economy practices and digital marketing. The biochar production model, which is based on the principle of the circular economy, successfully improves soil fertility and results in a 12-18% increase in productivity, while digital marketing expands market access and generates a 15-20% revenue growth from online sales. The combination of these strategies resulted in a standardized gain score of 0.67 in both modules, indicating significant learning outcomes. This research makes a theoretical contribution by integrating the principles of circular economy, digital transformation, and Participatory Action Research (PAR) to empower rural communities, as well as showing how these concepts can be combined to achieve sustainable agricultural development. In addition, the application of Society 5.0 principles in agriculture shows a path to smart agriculture, where technology can bridge the gap between traditional farming practices and modern digital tools.

However, this study has some limitations. First, the measurement of economic impact is based on self-reporting from participants, which can lead to bias. Second, the sample size of only 20 participants limited the generalization of the findings. Third, long-term data on the sustainability of technology adoption and its impact on soil income and health are not collected, which can strengthen the conclusions. Future research should focus on quantitative studies that track the long-term economic and environmental sustainability impacts of similar interventions. Additionally, exploring the integration of AI-based marketing tools and precision agriculture within the framework of Society 5.0 can provide valuable insights to enhance the impact of digital tools in rural development. Comparative studies across different regions and commodities will also help refine the adaptability of these empowerment models and contribute to the development of policies that support technology-based agricultural transformation.

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