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Socialization of the Use of Vermiculite and Several Organic Minerals to Improve Soil Fertility of Coffee Plantations in Buluh Mario Village, Sipirok District, South Tapanuli Regency

Kabul Warsito[1], Nur Asmaq[1], Indra Irawan[1], Diki Wahyudi Hutabarat[1], Dony Sahputra[2], Tawanli Manullang[2]

[1]Department of Agrotechnology, Faculty of Science and Technology, Universitas Pembangunan Panca Budi, Medan, Indonesia,
[2]Sumatra Rainforest Institute, South Tapanuli, Indonesia,

Corresponding Author: Kabul Warsito

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ABSTRACT

This community service program aimed to disseminate the use of vermiculite and organic minerals to improve soil fertility in coffee plantations in Buluh Mario Village, Sipirok District, South Tapanuli Regency, which is experiencing declining productivity. The activities were conducted from March to April 2025 through socialization methods, participatory training, and practical demonstrations including the introduction of agroforestry systems for sustainable coffee cultivation, application of vermiculite fertilizer from household organic waste, training on the use of vermiculite in arabica coffee planting media, and planting 100 perennial tree seedlings to support conservation efforts. The program results demonstrated high enthusiasm with 15 active participants who acquired practical knowledge and skills regarding vermiculite application (water retention capacity 3-4 times its weight, CEC 100-150 meq/100g), agroforestry design, and organic waste valorization. This program successfully demonstrated that sustainable coffee cultivation using vermiculite, organic minerals, and agroforestry approaches is feasible for smallholder farmers, offering economic benefits (reduced input costs, income diversification), environmental benefits (improved soil health, ecosystem conservation), and social benefits (community empowerment), while contributing to the SDGs, particularly SDG 2, 12, 13, and 15.

Keywords: *Vermiculite, agroforestry, Arabica coffee*

INTRODUCTION

The South Tapanuli Regency Government has been actively encouraging villages in the region to develop into coffee production centers. Buluh Mario Village, located in Sipirok District, represents one such area with significant potential for coffee cultivation. The village is situated in a strategic location adjacent to the Gunung Leuser National Park (TNGL), an important conservation area home to endangered species including the Sumatran tiger and Tapanuli orangutan. This proximity creates both opportunities and challenges for agricultural development, necessitating sustainable farming approaches that balance productivity with environmental conservation.

Coffee is one of the most important agricultural commodities globally, providing livelihoods for approximately 25 million households in over 80 countries, with 80% being smallholder farmers (Barreto, 2023). In Indonesia, particularly in South Tapanuli, Arabica coffee cultivation has historically been important, with the region known for producing Mandheling Ankola Sipirok coffee with unique flavor characteristics. However, coffee production in the region has experienced decline due to climate change impacts and deteriorating soil fertility.

Soil fertility management is crucial for maintaining sustainable coffee production. Coffee plants require adequate nutrient availability, particularly nitrogen, phosphorus, and potassium, along with appropriate soil structure and organic matter content. Conventional coffee farming often relies heavily on chemical fertilizers, which can lead to soil degradation, reduced microbial diversity, and negative environmental impacts over time. Furthermore, nitrogen loss in coffee plantations reduces soil fertility and directly impacts coffee production yields (Bote *et al*., 2025).

Studies have shown that soil organic matter and microbial activity play essential roles in maintaining soil fertility in coffee cultivation systems (Angadi, 2025). The chemical properties of soil, including pH, organic matter content, and cation exchange capacity (CEC), are important factors determining crop performance (Francisco *et al*., 2022). Sustainable approaches to improving soil fertility through organic amendments and mineral additives have gained increasing attention as alternatives to synthetic fertilizers (Warsito *et al*., 2024).

Vermiculite is a hydrous phyllosilicate mineral that undergoes significant expansion when heated, forming lightweight, accordion-like granules with exceptional properties for agricultural applications (Udoudo, 2015). Vermiculite possesses several key technical properties beneficial for soil improvement: (1) high water holding capacity, able to hold 3-4 times its weight in water and release it slowly; (2) excellent cation exchange capacity (CEC) of 100-150 meq/100g, allowing it to retain and supply essential nutrients like ammonium, potassium, magnesium, and calcium; (3) superior aeration and low density, preventing soil compaction and allowing oxygen to reach roots; (4) chemical inertness with neutral pH (around 7.0-7.5), making it compatible with various soil types (Ahmed et al., 2022).

As a soil conditioner, exfoliated vermiculite improves aeration in clay-rich soils and water retention in sandy soils, while reducing the likelihood of nutrient leaching (Feng & Zhang, 2021). In coffee cultivation specifically, vermiculite has been shown to support the initial development of coffee seedlings by improving physical characteristics of planting media (Caldeira, 2023). The mineral's ability to enhance nutrient availability and moisture retention makes it particularly valuable for coffee plantations in tropical regions with variable rainfall patterns.

Agroforestry Systems for Sustainable Coffee Production

Agroforestry represents an integrated land management approach that combines trees with agricultural crops, offering multiple environmental and production benefits. In coffee cultivation, agroforestry systems improve soil fertility through decomposition of leaf litter and organic materials, enhance carbon sequestration, provide microclimate regulation, conserve biodiversity, improve water management, and support economic sustainability through crop diversification (Schmitt & Perfecto, 2021)

Studies have shown that agroforestry systems positively influence soil characteristics, nutrient concentration in leaves, production, yield, and nutritional status of coffee fruits (Fitra et al., 2023). Trees in agroforestry systems enhance organic matter content in cultivations through litter production, favoring microbial life and diversity (Ferreira et al., 2011; Zake et al., 2015). The complex agroforestry

system (CAFS) significantly improves coffee farming performance and sustainability compared to simple agroforestry systems (SAFS) and coffee monoculture systems (CMS) (Prasmatiwi et al., 2025).

Community Service Rationale and Objectives

Despite the documented benefits of vermiculite, organic minerals, and agroforestry systems, adoption of these sustainable practices among smallholder coffee farmers in South Tapanuli remains limited. Farmers in Buluh Mario Village face several challenges: (1) limited knowledge about alternative soil fertility management techniques; (2) continued reliance on expensive chemical fertilizers; (3) inadequate utilization of locally available organic waste materials; (4) insufficient understanding of integrated agroforestry approaches for coffee cultivation.

This community service program was designed to address these challenges through participatory education and practical training. The specific objectives of this program were: (1) to socialize the use of vermiculite and organic minerals for improving soil fertility in coffee plantations; (2) to demonstrate agroforestry-based coffee cultivation techniques; (3) to enhance community knowledge and skills in sustainable, environmentally-friendly agricultural practices; and (4) to support forest conservation efforts in the Sipirok District through sustainable agriculture.

By implementing this community service program, we aimed to empower the Buluh Mario Village community with knowledge and practical skills to improve coffee production sustainability while contributing to conservation of the adjacent national park forests. This integrated approach aligns with Sustainable Development Goals (SDG) 2 on enhancing agricultural productivity and SDG 12 on sustainable consumption and production through recycling organic waste (Long & Khan., 2025).

MATERIALS & METHODS

Time and Location

This community service program was conducted from March to April 2025 in Buluh Mario Village, Sipirok District, South Tapanuli Regency, North Sumatra Province, Indonesia. Buluh Mario Village was selected based on its strategic location adjacent to Gunung Leuser National Park, its potential for coffee cultivation, and the community's expressed interest in sustainable agricultural practices. The village is situated in a hilly, densely-forested area with elevation ranging from 1,050 to 1,250 meters above sea level, providing suitable conditions for Arabica coffee cultivation

Community Service Team

The community service team consisted of two faculty members from University of Pembangunan Panca Budi (UNPAB): Kabul Warsito, S.Si., M.Si. (Leader Team) and Nur Asmaq, S.Pt., M.Si. (Member), along with two students: Indra Irawan and Diki Wahyudi Hutabarat. The program was conducted in collaboration with Sumatera Rainforest Institute as a partner organization supporting sustainable agriculture and forest conservation initiatives.

Approach Methods

The community service program employed three primary approach methods:

1. Survey Method

The survey method was conducted to collect information and data used as guidelines in designing the community service program. This method involved distributing questionnaires and conducting interviews with community members to understand their current agricultural practices, knowledge levels, challenges faced, and needs regarding coffee cultivation and soil fertility management. The survey provided baseline information about the community's existing resources, farming systems, and willingness to adopt new techniques.

2. Observation Method

Direct observation was conducted to assess the actual conditions of Buluh Mario Village, including examining the physical environment, agricultural land characteristics, available resources, existing infrastructure, and current farming practices. Observations focused on identifying potential for implementing vermiculite and organic mineral applications, availability of organic waste materials, suitable areas for agroforestry implementation, and environmental conditions affecting coffee cultivation. This method provided concrete understanding of the village's potential and constraints for sustainable agriculture development.

3. Socialization and Training Method

The socialization and training method involved direct participatory approaches with the community through meetings, discussions, question and answer sessions, and practical demonstrations. This method aimed to transfer knowledge and skills from the academic team to community members through interactive learning processes. The socialization activities created friendly atmospheres where participants felt comfortable asking questions, sharing experiences, and practicing new techniques. This approach emphasized hands-on learning and practical application rather than theoretical lectures alone.

Work Procedures

The community service implementation followed a systematic work procedure consisting of seven stages:

Stage 1: Survey of Regional Potential and Partner Problems

Initial survey and observation activities were conducted to identify regional resources, assess existing problems, and understand community needs and priorities.

Stage 2: Determining Program Boundaries

Based on survey and observation results, the scope and boundaries of the community service program were defined, focusing on vermiculite and organic mineral socialization, PGPR production, and agroforestry-based coffee cultivation.

Stage 3: Formulation of Approach Methods

Appropriate approach methods (survey, observation, and socialization/training) were selected and formulated based on community characteristics and program objectives.

Stage 4: Preparation of Community Service Proposal

A comprehensive community service proposal was developed, including background, objectives, methods, work plan, budget, and expected outputs.

Stage 5: Implementation of Community Service Program Activities

The main program activities were implemented in Buluh Mario Village, including socialization sessions, practical training, and hands-on demonstrations with active community participation.

Stage 6: Preparation of Activity Reports

Following program completion, comprehensive documentation and reporting of all activities, results, and outcomes were prepared.

Stage 7: Evaluation and Monitoring

Evaluation and monitoring activities were conducted to assess program success based on achievement indicators and gather feedback for future program improvement.

1. Coordination and Preparation Activities

Team Coordination and Planning

- Community service team coordination meetings to plan implementation details with focus on vermiculite-based training
- Creation of program banners and promotional materials highlighting vermiculite benefits for coffee cultivation
- Preparation of equipment and materials for vermiculite demonstration activities
- Meetings with participating students to brief them on their roles in vermiculite education and application training

Administrative and Partnership Coordination

- Submission of service proposal to LPPM (Research and Community Service Institute) and obtaining official assignment letters
- Coordination with village officials to establish community engagement for vermiculite adoption programs
- Partnership coordination with Sumatera Rainforest Institute representatives to align vermiculite training with conservation objectives
- Procurement of vermiculite samples and organic mineral materials for demonstration purposes

Material and Resource Preparation

- Acquisition of vermiculite in sufficient quantities for training and demonstration activities
- Preparation of various organic mineral samples including compost, organic matter, and natural soil amendments
- Setup of demonstration plots for comparing coffee growth with and without vermiculite application
- Preparation of educational materials explaining vermiculite properties, benefits, and application methods

Picture 1. Team Coordinator

2. Socialization of Vermiculite Production and Its Usefulness

Educational Presentations and Discussions

This activity involved comprehensive presentations and discussions about vermiculite properties and applications for coffee cultivation. The socialization session covered:

- Vermiculite fundamentals: Physical and chemical properties, including high water-holding capacity (3-4 times its weight), exceptional cation exchange capacity (100-150 meq/100g), superior aeration properties, and neutral pH characteristics
- Benefits for coffee cultivation: Water retention during dry periods, nutrient retention and slow release, improved soil aeration, prevention of soil compaction, and enhanced root development
- Organic mineral integration: How vermiculite complements other organic minerals like compost, vermicompost, and natural soil amendments to create optimal growing conditions
- Economic advantages: Cost-effectiveness of vermiculite use compared to repeated applications of chemical fertilizers, long-term soil improvement benefits, and reduced irrigation requirements
- Application techniques: Proper mixing ratios, incorporation methods, timing of application, and storage practices

Interactive Learning Sessions

The activity began with opening remarks from Buluh Mario Village officials, sub-district representatives, and the Executive Director of Sumatera Rainforest Institute. Topics discussed included:

- Traditional soil management practices versus modern vermiculite-enhanced approaches
- Case studies of successful vermiculite implementation in coffee plantations
- Economic analysis demonstrating cost savings and productivity improvements
- Environmental benefits of vermiculite use in sustainable coffee cultivation

Participants included high school and vocational school students, university students, local community members, farmers, volunteers, and foreign tourists, totaling approximately 15 active participants plus observers. The interactive format encouraged questions about vermiculite properties, application challenges, and integration with existing farming practices.

- Demonstration of Vermiculite Properties
- Practical demonstrations showed participants:
- Visual comparison of soil with and without vermiculite addition
- Water retention experiments demonstrating vermiculite's moisture-holding capacity
- Nutrient retention demonstrations using colored solutions to show cation exchange properties
- Physical examination of vermiculite structure and expansion characteristics

3. Using and Application of Vermiculite for Coffee Arabica Plantation

Hands-On Training in Vermiculite Application

Comprehensive practical training was provided on proper vermiculite application techniques specifically for Arabica coffee cultivation. Activities included:

Planting Media Preparation

- Demonstration of optimal vermiculite-soil-compost ratios (20% vermiculite, 40% topsoil, 40% organic compost)
- Proper mixing techniques to ensure homogeneous distribution of vermiculite throughout the growing medium
- Preparation of planting media for different growth stages: seedling production, transplanting, and field application
- Quality assessment criteria for properly prepared vermiculite-enriched planting media

Field Application Techniques

- Seedling Production: Six coffee plant samples were prepared using vermiculite-enriched media to demonstrate improved seedling vigor and growth rates
- Transplanting Applications: Demonstration of vermiculite application during transplanting from polybags to field locations, including root zone treatment and establishment support
- Soil Amendment Applications: Field demonstrations of incorporating vermiculite into existing coffee plantation soils to improve soil structure and fertility
- Maintenance Applications: Periodic vermiculite applications for established coffee plants to maintain soil quality and support continued productivity

Coffee-Specific Application Methods

- Root Zone Treatment: Direct application of vermiculite around coffee plant root zones to improve water and nutrient availability
- Mulching Enhancement: Integration of vermiculite with organic mulching materials to extend moisture retention and nutrient supply
- Container Growing: Optimal vermiculite ratios for coffee plants grown in containers or raised beds

PRACTICAL TRAINING COMPONENTS

Participants engaged in hands-on activities including:

- Individual Practice: Each participant prepared their own vermiculite-enriched planting media and planted coffee seedlings using proper techniques
- Group Demonstrations: Collaborative preparation of field demonstration plots comparing traditional soil management with vermiculite-enhanced approaches
- Troubleshooting Sessions: Discussion and solution of common challenges in vermiculite application, including proper storage, handling, and integration with existing farming practices
- Monitoring Setup: Establishment of simple monitoring systems to track coffee plant performance in vermiculite-treated versus untreated conditions

Picture 2. Practical training

INTEGRATION WITH AGROFORESTRY SYSTEMS

The training connected vermiculite application to broader agroforestry approaches:

- Tree Integration: Methods for applying vermiculite when establishing shade trees in coffee agroforestry systems
- Multi-Species Applications: Vermiculite use for various tree species planted alongside coffee (durian, mahogany, matoa, aren palm) to support overall system productivity
- Conservation Applications: Vermiculite use in reforestation activities to improve seedling survival and establishment rates, contributing to ecosystem conservation adjacent to Gunung Leuser National Park

FIELD MONITORING AND EVALUATION

Participants learned to:

- Observe and record coffee plant responses to vermiculite application
- Compare growth rates, leaf color, and overall plant vigor between treated and untreated plants
- Document water management improvements and irrigation requirement reductions
- Assess economic benefits through reduced input costs and improved productivity

SUSTAINABLE PRACTICE INTEGRATION

The training emphasized:

- Long-term soil health benefits of vermiculite application
- Integration with organic farming practices and reduced chemical fertilizer dependence
- Environmental sustainability aspects of vermiculite use
- Knowledge sharing and peer learning to support community-wide adoption

Through these three interconnected activity components, the community service program successfully transferred knowledge and

practical skills for vermiculite use in coffee cultivation, supporting both agricultural productivity improvements and environmental conservation objectives in Buluh Mario Village.

RESULT

OVERALL PROGRAM IMPLEMENTATION

The community service program in Buluh Mario Village was successfully implemented according to the planned schedule from March to April 2025. All major activities were completed, and program objectives were achieved. The implementation process proceeded smoothly with high enthusiasm from community participants, supportive involvement of village officials, and effective coordination with partner organizations. Table 1 presents a summary of the main activities conducted during the program implementation.

Table 1. Summary of Community Service Activities

No.	Activity	Status
1	Community service team coordination meeting	Completed
2	Making community service banners	Completed
3	Preparation of equipment and materials	Completed
4	Meeting with participating students	Completed
5	Submission of service proposal to LPPM and receipt of assignment letter	Completed
6	Implementation of community service activities in Buluh Mario Village	Completed
7	Team coordination meeting for final report preparation	Completed
8	Preparation of final report	Completed
9	Submission of final report to LPPM UNPAB	Completed

Results of Socialization on Agroforestry-Based Coffee Cultivation

The socialization activity on agroforestry-based coffee cultivation was conducted as the opening program component. This activity provided comprehensive information to community members about sustainable coffee farming practices that integrate tree species with coffee plants.

PARTICIPANT ENGAGEMENT AND ENTHUSIASM

The socialization attracted diverse participants including high school and vocational school students, university students, local farmers, community members, volunteers, and even foreign tourists interested in sustainable agriculture. Approximately 15 core participants actively engaged in the full program, with additional observers attending the opening sessions. Participants demonstrated high enthusiasm throughout the activity, asking numerous questions about vermiculite properties, organic mineral applications, agroforestry design, and implementation challenges.

Topics Covered in Socialization

The main topics discussed during the socialization included:

1. Principles of Agroforestry Systems: Explanation of how combining coffee with annual trees creates multiple benefits including improved soil fertility, microclimate regulation, biodiversity conservation, erosion control, and income diversification.
2. Vermiculite Properties and Applications: Detailed presentation of vermiculite characteristics, including its high water-holding capacity, excellent cation exchange capacity, ability to improve soil aeration, and methods for incorporating it into coffee planting media.
3. Organic Minerals for Soil Fertility: Discussion of various organic minerals and amendments that can enhance soil fertility, including compost, organic matter decomposition products, and naturally available minerals in the local environment.
4. Household Waste Utilization: Demonstration of how household organic waste such as vegetable scraps, fruit

peels, and oil palm leaf waste can be transformed into valuable agricultural inputs rather than being discarded or burned.

5. Conservation Benefits: Explanation of how sustainable coffee cultivation using agroforestry approaches contributes to protecting the adjacent Gunung Leuser National Park by reducing pressure for forest conversion, controlling erosion, and maintaining ecological corridors.

PRACTICAL DEMONSTRATION

Following the lecture and discussion sessions, practical demonstrations were conducted. Six plant samples were prepared using polybag media enriched with organic compost fertilizer and ecoenzyme. The demonstrations showed participants how to:

- Prepare planting media by mixing soil, compost, and vermiculite in appropriate ratios
- Incorporate organic amendments evenly throughout the media
- Fill polybags properly to ensure adequate drainage and root development
- Plant coffee seedlings at correct depths
- Apply PGPR fertilizer as a growth stimulant

These hands-on demonstrations provided participants with concrete understanding of the techniques discussed during the socialization, making the knowledge more accessible and applicable to their own farming contexts.

COMMUNITY RESPONSE AND FEEDBACK

Participants responded very positively to the socialization activity. Many expressed that this was their first exposure to information about vermiculite and its applications in coffee cultivation. Several farmers mentioned that they had been experiencing declining coffee yields and were interested in trying these new approaches. The discussion sessions revealed that while most participants were familiar with traditional composting, the concepts of vermiculite application, and systematic agroforestry design were relatively new. Participants appreciated the practical focus of the training and requested follow-up sessions for continued learning.

CONCLUSION

This community service program successfully implemented socialization of vermiculite and organic mineral use for improving soil fertility in coffee plantations in Buluh Mario Village, Sipirok District, South Tapanuli Regency. The program achieved its primary objectives through participatory approaches involving survey, observation, socialization, and practical training methods.

Key accomplishments include: (1) successful socialization of agroforestry-based coffee cultivation concepts and practices to community members; (2) training of 15 community members in (3) demonstration of proper Arabica coffee cultivation techniques using vermiculite-enriched planting media; (4) planting of 1,000 annual tree seedlings (durian, mahogany, matoa, and aren palm) supporting both agroforestry development and forest conservation; and (5) enhancement of community knowledge and skills regarding sustainable, environmentally-friendly agricultural practices.

Recommendations

Based on program implementation and outcomes, several recommendations are proposed:

1. **Follow-up Programs:** Implement systematic follow-up activities to monitor adoption of introduced practices, provide ongoing technical support, and address challenges encountered during implementation. Regular visits and farmer field days can sustain momentum and facilitate peer learning.
2. **Farmer Group Formation:** Support establishment of farmer groups focused on sustainable coffee cultivation to facilitate knowledge sharing, collective action, and economies of scale in input procurement and market access.

3. **Scale-Up to Adjacent Villages:** Expand similar programs to adjacent villages in Sipirok District and broader South Tapanuli Regency, leveraging lessons learned and utilizing successful participants as trainers and champions.

Declaration by Authors

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