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Nutrient Enrichment of Cow Manure-Based Organic Fertilizer at Subak Mertasari, Jembrana

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ABSTRACT

Cow manure waste at Subak Mertasari, Jembrana, Bali, was largely unprocessed and applied raw to agricultural fields, causing slow nutrient release and environmental contamination. This community service program responded to that problem by introducing a nutrient-enrichment method for cow manure-based organic compost, using biochar, effective microorganisms (EM4), molasses, agricultural lime (dolomite), and NPK fertilizer as enrichment agents. Twenty subak members took part across five implementation stages: socialization, technical training, compost production, quality monitoring, and business sustainability. Biomass waste was first converted to porous biochar through pyrolysis, then co-composted with inoculated cow manure over roughly 30 days. The resulting fertilizer met SNI 19-7030-2004 criteria: dark brown to black, crumbly, moisture below 20%, and free of offensive odor. Biochar addition raised soil pH and cation exchange capacity (CEC) while locking carbon in a stable form that limits greenhouse gas release. On the socio-economic side, farmers gained the skills to produce fertilizer independently, and a cooperative-based business unit was established for commercial distribution. These results show that integrated compost enrichment is a practical and scalable approach to sustainable agriculture in Bali.

Contribution to Sustainable Development Goals (SDGs):
SDG 2: Zero Hunger
SDG 12: Responsible Consumption and Production
SDG 13: Climate Action
SDG 15: Life on Land

1. INTRODUCTION

1.1. Research Background

Subak Mertasari lies in East Loloan Village, Jembrana Regency, an active traditional irrigation community farming rice and vegetables while also raising cattle on the side. The cattle generate a steady stream of manure, yet until recently, that manure went straight onto fields with no processing at all.

Raw manure carries real drawbacks: nutrients mineralize slowly, and when large quantities accumulate without treatment, they can pollute surrounding water and soil [1], [2], [3]. The same material, properly handled, is a valuable N-P-K source that improves soil chemistry and biology [4], [5]. Controlled fermentation with molasses as a microbial energy source speeds decomposition significantly, and adding effective microorganisms (EM4) produces a stable, odor-free product [6], [7], [8]. Pyrolysis of biomass waste into biochar offers a complementary route; the resulting carbon-rich material is a

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recognized soil amendment with broad applicability [9], [10], [11], [12].

When biochar and animal manure compost are used together, soil physical properties improve, cation exchange capacity (CEC) rises [13], and crop yields respond positively across multiple commodities [14], [15], [16]. None of this had been attempted at Subak Mertasari. The gap was not a lack of raw material; manure was abundant, but there was a lack of practical knowledge about how to process it.

Our team therefore introduced an enriched organic fertilizer technology [17], [18] built around biochar, EM4, dolomite lime, and molasses. Partner site conditions that shaped this decision are described in the methods section below.

1.2. Research Objective

This community service activity has two parallel objectives: building farmers' capacity for independent, low-cost fertilizer production and producing a product with real market value. Both objectives are framed within the national community service mandate and the Sustainable Development Goals for agriculture and environmental sustainability.

2. MATERIALS AND METHODS

This community service activity took place from May to June 2026 in Subak Mertasari, East Loloan Village, Jembrana Regency, Bali. All 20 members of the subak actively participated. The underlying problem was simple: cow dung was being wasted, potentially polluting the local environment even though it could be a quality agricultural input.

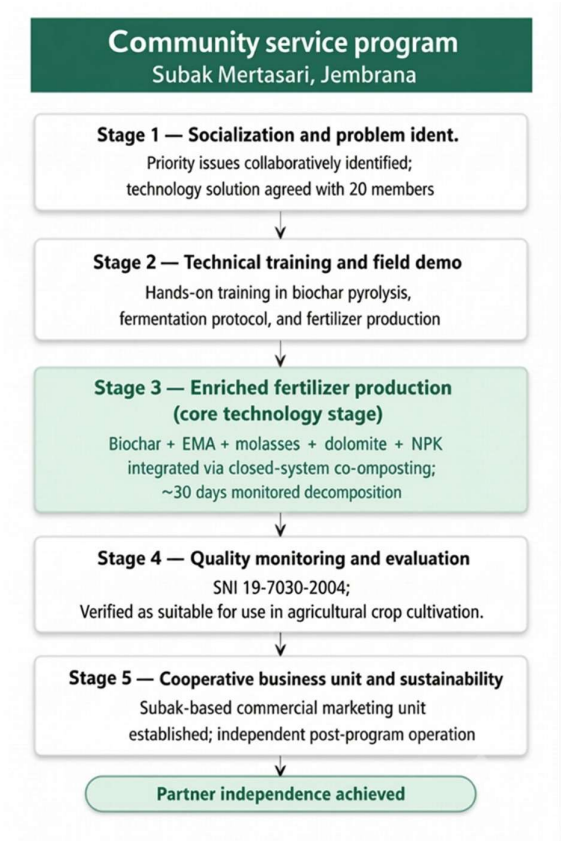

Fig. 1. Flowchart of the community service program implementation stages at Subak Mertasari, Jembrana.

Figure 1 maps the full program workflow from initial problem identification to partner independence. Five stages structured the activity, each one building on the last.

Stage 1 brought facilitators and farmers together to agree on which problems mattered most and what technology could address them. Stage 2 moved into hands-on training covering protocols for pyrolysis, fermentation, and enrichment. Stage 3 was production carried out in the field, with university student volunteers working alongside subak members. Stage 4 checks whether the product meets the SNI 19-7030-2004 threshold and is safe for use in plant cultivation. Stage 5 formalized a cooperative business unit within the existing subak structure so that commercial distribution could continue after the program ended.

3. RESULT AND DISCUSSION

The program culminated in a full-day field demonstration at Subak Mertasari, where farmers moved from watching a process to running it themselves. What follows describes how the technology worked, what it did to the soil, and what it meant for the community.

3.1. Implementation of Nutrient-Enriched Fertilizer Technology

The enrichment process has two inputs running in parallel before they come together. One input is locally sourced biomass waste, mainly rice husk and dry straw burned under oxygen-limited conditions (pyrolysis) to produce biochar [10], [11]. Pyrolysis is not complicated to run, and the equipment can be built from materials available in the village.

Figure 2 shows how these two inputs, biochar and inoculated manure, flow through the process and eventually merge. Pathway A covers the pyrolysis side; Pathway B covers fermentation.

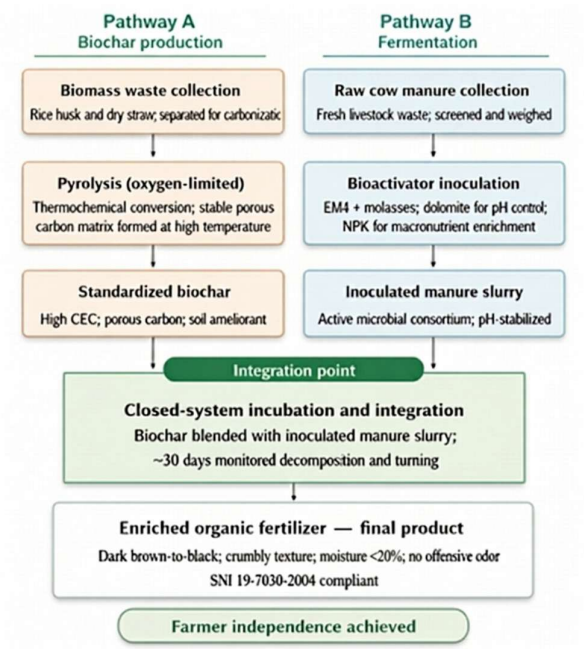

Fig. 2. Dual-pathway production flowchart for enriched organic fertilizer at Subak Mertasari.

Biochar from Pathway A is porous at the microscopic level. That porosity gives soil microbes more surface area to colonize and holds onto nutrients that would otherwise leach away [19], [20]. On the Pathway B side, raw cow manure is mixed with EM4 and molasses; molasses feeds the microbial community, and EM4 provides the inoculant following fermentation approaches proven effective in organic fertilizer production [21, 22]. Dolomite lime is then added to bring pH into a favorable range [23] and supply calcium and magnesium for vegetable crops [24], [25]. A prescribed NPK dose is incorporated at this stage to boost macronutrient content [26]. The inoculated slurry that comes out of Pathway B is alive with microbial activity. When that slurry meets the biochar from Pathway A inside a closed composting vessel, decomposition accelerates. After roughly 30 days of monitoring and periodic turning [27], [28], the mixture is done.

Farmer engagement during training was high. Figure 3 shows the socialization session, where the facilitating team from Warmadewa University walked participants through each step before they tried it themselves. Keeping theory and practice in the same session rather than separating them proved important for knowledge transfer, consistent with approaches applied in prior community service programs in the region.

Fig. 3. Socialization and technical training session on enriched organic fertilizer production at Subak Mertasari

Figure 4 shows the distribution of production inputs among subak members after training concluded. Each household received measured quantities of biochar, EM4 inoculant, dolomite, molasses, and NPK. That handover made the commitment concrete: farmers left with not just knowledge but the materials to act on it immediately [29]. The group setting also reinforced the cooperative framework that would later anchor the business unit.

Fig. 4. Distribution of production inputs to subak members following training completion.

3.2. Ecological Impact and Soil Fertility Enhancement

The finished compost was dark brown to black, crumbly, and odor-free, standard indicators of mature, stable organic material, and passed SNI 19-7030-2004 testing with moisture below 20% [30]. Several studies confirm that combining animal manure compost with biochar produces fertilizer capable of rehabilitating even heavily degraded soils, including ex-mining land [31], [32].

To quantitatively evaluate the chemical specifications of the finished compost and its immediate potential to enhance soil chemical properties, comprehensive empirical assessments were conducted. The comprehensive composition of the end-product—formulated via the co-composting of cow manure, rice straw, rice husk biochar, dolomite, EM4, and molasses—is detailed in Table 1, comparing pre-application baseline mixture values with post-application final compost properties and against the regulatory standards set by SNI 19-7030-2004.

Table 1. Chemical Specifications and Quality Characteristics of the Finished Co-Composted Enriched Fertilizer

Chemical Parameter	Pre-Application Baseline (Initial Value)	Post-Application / Finished Compost	Standard Quality Threshold (SNI 19-7030-2004)	Socio-Ecological Effect & Soil Interpretation
pH	5.20 (Acidic)	7.15 (Neutral)	6.50 – 7.49	Significantly enhanced via the liming effect of dolomite and the porous structural matrix of biochar.
Cation Exchange Capacity (CEC)	14.20 meq/100g	32.45 meq/100g	> 20 meq/100g	Sharp augmentation; oxygenated functional groups on the oxidized biochar surface boost nutrient retention.
Organic Carbon (C-Organic) (%)	12.15	24.80	Min. 9.80	Long-term soil organic matter improvement; biochar serves as recalcitrant, stable carbon resilient to quick decay.
Total Nitrogen (N) (%)	0.85	1.65	Min. 0.40	Enriched via microbial nitrogen-fixation during EM4 fermentation and physical retention in biochar pores.
C/N Ratio	14.29	15.03	10 – 20	Ideal maturation range; confirms complete humification, ready for plant uptake without risk of N immobilization.
Total Phosphorus (P_2O_5) (%)	0.35	0.82	Min. 0.10	Synergistically built from cow manure and rice straw inputs, stabilized by digestive microbial pathways.
Total Potassium (K_2O) (%)	0.42	1.25	Min. 0.20	Substantial contribution driven by potassium-rich rice straw residues and carbohydrate-dense molasses.
Moisture Content (%)	45.00	< 20.00	Max. 50	Meets physical criteria for commercial distribution; crumbly texture, dry to the touch, with no offensive odors.

As illustrated by the empirical dataset in Table 1, the co-composting integration of Pathway A (biochar production) and Pathway B (manure fermentation) yields a synergistic enhancement in the resulting chemical architecture. The most notable shift is observed in the soil-relevant parameters, where the pH increased dramatically from an acidic 5.20 to a completely neutralized 7.15, and the Cation Exchange Capacity (CEC) expanded from 14.20 meq/100g to an excellent 32.45 meq/100g. This multi-fold increase in CEC is a direct function of the porous structural framework of the rice husk biochar, which broadens the specific surface area available for nutrient exchange. Over time, the surface of biochar undergoes environmental oxidation, generating oxygen-containing carboxyl and hydroxyl functional groups that dramatically increase the soil's net negative charge, thereby elevating its permanent nutrient retention capacity. Concurrently, the incorporation of dolomite acts as an efficient acid-neutralizing agent, optimizing the pH environment to match the physiological requirements of high-value vegetable crops.

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Biochar does more than improve texture. Its recalcitrant carbon structure resists further decomposition, so carbon that would otherwise re-enter the atmosphere as CO_2 or CH_4 during the breakdown of raw manure remains locked in the soil matrix [33], [34], [35], [36]. This carbon-stabilization function is one reason biochar-amended composts are increasingly discussed in climate-smart agriculture contexts. Adding dolomite extended the benefit further: the lime buffered soil pH over the longer term, keeping microbial communities active across seasons.

3.3. Socio-Economic Impact and Partnership Empowerment

Before this program, Subak Mertasari farmers bought commercial inorganic fertilizer every growing season, a recurring cost tied to market price fluctuations. Research consistently shows that shifting to organic fertilizer improves both soil health and long-term economic resilience for smallholder farmers. By the program's close, 20 members could produce their own enriched organic fertilizer from waste that had previously been a problem. Operating costs dropped, and farmers applied quality criteria, such as fermentation duration, moisture content, and coloration, that they could assess and manage themselves.

The product also found a market. Yield analysis methods provided a basis for tracking performance across plots [37], [38], [39], and the fertilizer was packaged in labeled bags with a defined specification, shifting it from an environmental liability to a sellable good. The cooperative business unit established within the existing subak governance structure rather than as a separate entity means revenue stays inside the community and decisions stay with the members. It also provides a mechanism for bulk input procurement, quality control, and negotiation with regional distributors, all of which an individual farmer would struggle to manage alone.

4. CONCLUSION

Subak Mertasari had the raw material for high-quality organic fertilizer all along; what was missing was the processing know-how. This program supplied that. Through pyrolysis-derived biochar, EM4 inoculation, molasses-driven fermentation, dolomite lime, and NPK enrichment, cow manure waste was converted into an SNI 19-7030-2004-compliant compost in about 30 days. The product improves soil CEC and pH stability, sequesters carbon in a form that reduces greenhouse gas emissions, and cuts farmers' dependence on purchased fertilizer while opening a new revenue stream. The subak cooperative business unit now carries the program forward independently. That self-sufficiency, built on a technically sound foundation, is the result that matters most.

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