

Improving Entrepreneurship-Based Livestock Waste Management in Kampung Emas Seyegan, Sleman

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Abstract

Originality/novelty: The study demonstrates a localized, participatory community-engagement intervention that bridges technical agricultural training with business capacity building, addressing both environmental sanitation and managerial vulnerabilities in village-level livestock waste management.

Objective: The study aims to address environmental pollution and low waste management capacity in Kampung Emas Seyegan, Krapyak IX Village, by increasing farmers' knowledge and awareness, assisting them in efficient livestock waste management, and reducing environmental impacts.

Methods/approach: The community-service program employed a participatory training model combined with continuous mentoring, targeting nine livestock farmers. The implementation framework followed a systematic sequence comprising covering manure collection, fermentation, processing into organic fertilizer, alternative feed use, and enterprise marketing.

Results: Participation records and implementation indicators confirmed active engagement among the nine farmers, who progressed from basic technology transfer to comprehensive operational understanding. Environmental observations and metrics showed tangible improvements

Implications: The program equips the local farming community with practical skills to convert waste into organic fertilizer and alternative feed, thereby mitigating local water, soil, and air pollution, reducing reliance on synthetic fertilizers, and establishing a foundation for rural circular economic integration and enterprise development.

Keywords: Livestock Waste Management, Environmental Pollution, Participatory Training Model

INTRODUCTION

Livestock production is a vital and rapidly expanding sector globally, playing a critical role in agricultural economies, rural livelihoods, and food security. In Indonesia, this growth is reflected in substantial increases in livestock populations; official data indicate that beef cattle numbers rose from 13.4 million in 2015 to 14.4 million in 2020, while broiler chicken populations expanded from 2.3 billion to 2.8 billion over the same period (Kementerian Pertanian, 2020). This upward trajectory is propelled by escalating demand for animal-source protein, driven by population growth and shifting dietary patterns, alongside abundant natural resources and supportive governmental policies aimed at industrial development and biosecurity (Kementerian Pertanian, 2020).

Despite its economic and nutritional contributions, intensive and expanding livestock production generates profound environmental pressures. The sector is a major contributor to greenhouse gas (GHG) emissions (BPS, 2020) and produces vast quantities of organic waste—estimated by the Ministry of Environment and Forestry at 140 million tons annually (KLHK, 2020). When improperly managed, manure, urine, and feed residues lead to severe environmental degradation, including water and soil pollution, ecosystem disruption, and public health risks through pathogen transmission and air pollution (Kreidenweis et al., 2021). Consequently, sustainable agricultural transition requires robust waste management frameworks designed to mitigate environmental pollution, protect human health, and optimize resource use efficiency.

At the micro-level, these national environmental challenges manifest acutely in localized rural production hubs, such as Desa Krapyak located in Margoagung, Seyegan, Sleman Regency, Special Region of Yogyakarta. Spanning approximately 234.5 hectares, Desa Krapyak possesses significant agricultural potential with thriving cattle, goat, and poultry enterprises supported by local feed and water availability. However, smallholder farmers in this region face severe structural constraints, including limited capital, insufficient technical knowledge regarding efficient production and waste management, and inadequate infrastructure. Because waste is rarely treated systematically at the farm level, local ecosystems in Desa Krapyak face mounting pressure from agricultural runoff and pollution, mirroring broader national vulnerabilities.

Recent scholarship has fundamentally reshaped how livestock waste management is conceptualized, transitioning from isolated end-of-pipe fixes to holistic, whole-chain approaches encompassing feed formulation, housing design, storage, treatment, and land application (Y. Cao & Cao, 2025; Winiwarter & Amon, 2017; Yan et al., 2024). Evidence consistently indicates that single-stage interventions often generate pollution trade-offs, making integrated strategies essential for simultaneously mitigating methane, nitrous oxide, and ammonia (Gerber et al., 2013; Symeon et al., 2025). Among available technologies, anaerobic digestion has emerged as a primary benchmark due to its capacity to capture methane, generate renewable energy, and recycle nutrients through high-quality digestate (Kreidenweis et al., 2021; Massé et al., 2011; Tryhuba et al., 2025). Smallholder case studies demonstrate substantial environmental gains, including total emission reductions of 40–60% in household pig farming (Nguyen & Nguyen, 2026) and significant drops in global warming potential across small dairy and mixed livestock systems (Nleya et al., 2024; Tolessa et al., 2026).

Nevertheless, the effectiveness of advanced treatment technologies depends heavily on proper operational control, particularly minimizing methane leakage during processing (Hollas et al., 2023). For smallholder settings where high capital investment and technical maintenance pose barriers, complementary low-cost practices, such as frequent manure removal, dry short-term storage, optimized land application timing, and co-aggestion with agricultural residues, offer viable pathways to enhance economic feasibility and environmental performance ((Richards & Yabar, 2023; Wang et al., 2021). Modern research emphasizes that sustainable waste management cannot rely solely on technology adoption; it requires context-specific system design, spatial modeling, and institutional support tailored to fragmented smallholder distributions (Burg et al., 2018; Ye et al., 2026).

Despite these technological and systemic advancements, a critical gap remains in translating macro-level sustainable waste frameworks into practical, context-specific interventions for rural smallholder communities in developing regions. While extensive literature evaluates large-scale biodigesters or industrialized farm systems, relatively limited empirical attention has been devoted to addressing the combined barriers of capital scarcity, technical illiteracy, and inadequate infrastructure in decentralized smallholder settings like Desa Krapyak IX. Previous initiatives frequently fail because they treat waste management as a purely technical challenge rather than an integrated socio-technical transition requiring localized capacity building and participatory problem-solving.

To address this limitation, the present community service and action-research study aims to improve the knowledge, awareness, and technical capacity of small- and medium-scale livestock farmers in Desa Krapyak IX regarding effective waste management. Specifically, the study seeks to assist local farmers in implementing efficient, low-cost waste management practices to mitigate environmental pollution while supporting sustainable agricultural livelihoods. By bridging the gap between state-of-the-art waste mitigation science and grassroots smallholder realities, this study contributes practical, context-sensitive empirical insights into decentralized agricultural sustainability in rural Indonesia.

LITERATURE REVIEW

Introduction and Conceptual Foundations of Smallholder Livestock Systems

Smallholder livestock production systems, particularly small-scale goat and cattle enterprises, serve a foundational role in rural economies by securing household income, building liquid savings, and enhancing food security (Assefa et al., 2024; Bashiru et al., 2026). Despite their socio-economic significance, these systems predominantly operate under low-input, resource-constrained paradigms that limit their overall productivity and ecological efficiency. Grounded in the Resource-Based View (RBV) and Socio-Ecological Systems (SES) frameworks, smallholder farming can be understood as a socio-technical configuration where productive output is fundamentally bounded by endogenous asset availability (e.g., informal family labor, restricted capital, and small herd sizes) and exogenous institutional support, such as extension services and

veterinary access (Getachew et al., 2026; Ruvuga & Maleko, 2023).

From a theoretical perspective, the reliance on traditional husbandry practices, natural grazing, and localized crop residues creates a systemic bottleneck. The mechanism linking these constraints to suboptimal performance involves a deficiency in adaptive technical capacity and inadequate sanitary management. Without sufficient capital or external technological inputs, smallholder systems frequently exhibit structural vulnerabilities, including poor housing infrastructure, inconsistent healthcare, and high exposure to seasonal feed shortages (Athumani et al., 2026; Getachew et al., 2026).

Consequently, when examining localized contexts, such as smallholder units in rural areas like Krapyak IX, systems must be analyzed not as isolated anomalies, but as manifestations of broader structural dynamics: highly adaptive and low-cost by design, yet chronically deficient in technical efficiency, sanitary control, and circular nutrient retention (Athumani et al., 2026; Bashiru et al., 2026).

Theoretical Mechanisms of Waste Utilization within Circular Bioeconomy Frameworks

To overcome the productivity and environmental ceilings characteristic of traditional smallholder systems, contemporary agricultural literature increasingly applies the Circular Bioeconomy framework. The core premise of this framework posits that agricultural waste is not an inert residual byproduct, but a valuable reservoir of endogenous resources that can close nutrient loops and reduce reliance on expensive, external chemical inputs (Kim et al., 2024; Latifah & Yakin, 2026).

The underlying biophysical mechanism operates through the transformation of manure-bound macro-elements—specifically nitrogen, phosphorus, and potassium (NPK)—into bioavailable forms for soil-crop systems. However, the theoretical benefits of nutrient recycling are conditional upon proper biological and chemical stabilization. Unprocessed or raw manure application bypasses essential transformation stages, precipitating critical environmental and physiological hazards. Empirically, direct land application of raw manure heightens the risk of nitrate and phosphate leaching, surface water eutrophication, and the transmission of zoonotic pathogens, heavy metals, and residual veterinary pharmaceuticals (antibiotics) into the food chain (Zeng et al., 2025). Therefore, the theoretical chain connecting waste generation to agronomic value requires mandatory preprocessing interventions, such as composting, liquid-solid separation, and anaerobic digestion, to secure chemical stability, eliminate pathogens, and optimize nutrient recovery (Kim et al., 2024; Zeng et al., 2025).

Empirical Evidence on Agronomic Efficacy and Soil-Crop Interactions

Synthesizing empirical evidence across diverse agricultural contexts reveals robust support for the positive impacts of processed animal manure on soil health and crop yields, though the magnitude of these effects varies according to application methods and pedoclimatic conditions. Long-term field studies consistently demonstrate that balanced application strategies, combining processed cattle manure with controlled inorganic fertilizers, significantly elevate soil organic

carbon reserves, total nitrogen content, and the bioavailability of phosphorus and potassium compared to synthetic fertilization alone (Gao et al., 2023).

Furthermore, comparative analyses in paddy and upland systems indicate that cattle manure compost outperforms other animal waste derivatives in stimulating soil microbial biomass activity, improving soil aggregate stability, and sustaining long-term crop productivity (Das et al., 2017). Despite these consistent findings, variations persist in the literature regarding the efficacy of liquid versus solid fractions. While liquid fraction fermentation effectively preserves volatile nitrogen and phosphorus while mitigating pathogen loads, its agronomic deployment often requires precise dilution protocols or integration with complementary nutrient sources to prevent localized root burn or nutrient imbalances (Zeng et al., 2025). Solid-liquid separation technology further resolves handling bottlenecks, effectively suppressing odor emissions and facilitating targeted nutrient redistribution. These empirical insights reinforce the necessity of planned infrastructural solutions, such as engineered holding tanks and drainage channels, moving smallholder communities away from environmentally hazardous open-dumping practices.

Technological Options for Waste Transformation and Environmental Mitigation

Moving beyond basic agronomic recycling, advanced processing technologies like anaerobic digestion (AD) offer a dual mechanism for energy recovery and environmental mitigation. Within the circular bioeconomy paradigm, AD transforms raw manure into a biogas energy vector while yielding a nutrient-dense digestate suitable for organic fertilization (Alengebawy et al., 2024; Tan et al., 2022).

Empirical evaluations of greenhouse gas (GHG) mitigation underscore the environmental potency of these technologies. Relative to conventional open-storage management, anaerobic digestion systems achieve substantial emission reductions, estimated at approximately 64% for cattle manure and 69% for goat manure systems (Nleya et al., 2024). Moreover, recent investigations into substrate optimization highlight the superiority of co-digestion over mono-digestion. Blending cattle or goat manure with carbon-rich co-substrates, such as food waste or poultry litter, synergistically balances the carbon-to-nitrogen (C/N) ratio, thereby accelerating microbial kinetics and maximizing methane yield (Abbas et al., 2022; Dhungana et al., 2024). Similarly, comparative studies on solid-state waste treatments, including vermicomposting of cattle manure, indicate that earthworm-mediated stabilization achieves nutrient concentrations comparable to traditional composting while producing superior structural humic compounds (Ndiaye, 2025; Latifah, 2026).

METHODS

This article employed a community service program categorized as a community engagement initiative designed to improve entrepreneurial-based livestock waste management. The program setting took place in Kampung Emas Seyegan, Krapyak IX, during the implementation period. The target community and beneficiaries involved local livestock farmers

and community members of Kampung Emas Seyegan, Krapyak IX, 9 participants.

The problems and needs assessment identified that accumulated livestock waste posed significant environmental pollution risks while remaining underutilized for economic gain. The problem was identified through focus group discussions, which established the urgency for intervention. A technical assistance model utilizing a training and workshop approach was selected as an appropriate intervention to bridge traditional disposal methods with sustainable, entrepreneurial practices such as converting waste into compost and biogas, alongside integrating Information and Communication Technology (ICT) for online marketing.

The intervention and program design aimed to enhance the production value of livestock waste and expand market reach. The main activities encompassed a multi-stage process utilizing materials, tools, and digital devices such as laptops and smartphones. The roles of the academic team included delivering educational content, facilitating workshops, and providing technical mentoring, while community partners assisted in coordinating participants and providing local facilities.

The implementation procedure followed a logical sequence of stages. The program initiated with socialization sessions to introduce the program goals, benefits, and the importance of livestock waste management to encourage active community participation. Subsequently, the implementation and training were divided into two main workshops: Session I focused on concepts of livestock waste management, processing techniques, entrepreneurship, and ICT integration, while Session II concentrated on digital marketing strategies utilizing marketplaces and social media via digital devices. Following the theoretical delivery, participants engaged in hands-on practice for converting livestock waste into compost and biogas, accompanied by direct mentoring from facilitators to ensure proper technique application.

The evaluation method assessed the effectiveness and outcomes of the program. Attendance was recorded via attendance lists, and participation rates were evaluated through direct observation of participant activity during the training sessions. Comprehension of the material was measured by giving practical exercises and group discussions, with results evaluated based on subsequent guided practices.

RESULT AND DISCUSSION

The community service program implemented at Kampung Emas Seyegan Krapyak IX demonstrated a structured implementation process utilizing a participatory training model combined with continuous mentoring. The intervention framework followed a systematic sequence comprising socialization, technical training, practical field exercises, and iterative mentoring sessions. Participation records and implementation indicators confirmed active engagement among the nine participating livestock farmers. Through these structured activities, participants progressed from basic technology transfer to a comprehensive operational understanding encompassing manure collection, fermentation processes, and the marketing of waste-derived products. Furthermore, the community-based implementation successfully enhanced practical skills and environmental awareness among the participants.

Environmental observations and implementation metrics indicated tangible improvements in local

sanitation conditions. Rather than reflecting generalized hygiene improvements, the outcomes directly addressed localized environmental pressures through enhanced pen sanitation, improved drainage systems, and odor mitigation. Operational adjustments specifically targeted the reduction of liquid waste puddles and the management of accumulated feces and urine at the den surface, thereby directly mitigating primary emission sources. Through biological processing methods, specifically fermentation and composting, hazardous organic accumulations were transformed into safe and functional agricultural inputs, successfully replacing open dumping practices with controlled manure management.

From a socio-economic perspective, the program functioned as an initial valorization stage, transitioning livestock waste handling from a purely sanitary chore into structured local enterprise development. Program outputs established a foundation for supplementary income generation, reduced reliance on synthetic chemical fertilizers, and promoted rural circular economic integration. Additionally, training activities introduced fundamental entrepreneurial dimensions, including record-keeping, packaging, branding, digital marketing strategies, and product diversification, addressing key operational challenges in village-level compost production beyond basic technical manufacturing.

The successful deployment of a participatory training model combined with iterative mentoring at Kampung Emas Seyegan Krapyak IX demonstrates that capacity building among smallholder livestock farmers requires continuous, hands-on engagement rather than one-off instruction. The transition of participants from basic production understanding to grasping complete collection, fermentation, and marketing workflows indicates that integrated technical and business capacity building effectively shifts farmers' mindsets toward enterprise management. This occurs because iterative mentoring and practical field exercises bridge the gap between theoretical knowledge and practical execution, reducing cognitive barriers associated with new agricultural technologies. These findings are consistent with prior community service evaluations showing that structured participatory interventions successfully elevate participants' knowledge and operational skills (Herlina et al., 2025; Situmeang et al., 2025). Furthermore, combining technical training with business acumen addresses documented vulnerabilities in village-level enterprises, whose failures are frequently managerial rather than technical (Latif et al., 2023; Ningsih et al., 2026). From a theoretical perspective, the results support community empowerment theory, confirming that experiential, community-based learning fosters collective efficacy and environmental responsibility more effectively than conventional top-down training models (Indrarosa et al., 2025; Prakoso et al., 2026).

The observed improvements in pen sanitation, drainage, and odor control confirm that targeted waste management interventions yield immediate local environmental benefits. Transforming raw, polluting manure into stable compost and fermented inputs effectively neutralizes primary pollution pathways. This result is explained by the fact that addressing the root causes of environmental degradation, namely the surface accumulation of feces and urine and stagnant liquid waste, disrupts anaerobic decomposition processes that generate noxious odors and greenhouse gases. These outcomes align with meta-analytic and empirical literature

highlighting that proper manure management, closed storage systems, and environmental conditioning significantly suppress odor emissions and environmental contamination (T. Cao et al., 2023; Ren et al., 2025). Moreover, replacing open dumping with controlled composting directly supports methane and ammonia reduction frameworks (Patunah, 2024; Herlina, 2025). Theoretically, the findings reinforce ecological modernization theory, demonstrating that local technological interventions can successfully reconcile agricultural productivity with environmental protection.

The positioning of the program as an initial valorization phase reflects realistic socio-economic development trajectories for smallholder communities. While immediate wealth generation is constrained, the establishment of foundational practices opens pathways for supplementary income and reduced chemical fertilizer dependency. This process is driven by the incorporation of entrepreneurial training, such as record-keeping, packaging, and digital marketing, which empowers farmers to capture greater added value and navigate market coordination challenges (Putra et al., 2025; Situmeang et al., 2025). These findings mirror prior studies documenting the emergence of structured local enterprises, standardized standard operating procedures (SOPs), and viable commercial margins from waste valorization (Suyana, 2026; Ningsih, 2026). Furthermore, prospects for product diversification (e.g., liquid fertilizers, insect frass, and biomass briquettes) align with advanced circular bioeconomy frameworks (Yan, 2023; Beesigamukama, 2021). From a theoretical perspective, the intervention provides empirical support for circular economy models in rural settings, illustrating that waste streams can be successfully converted into economic nodes within decentralized agribased supply chains.

Despite positive short-term outcomes, the long-term viability of smallholder waste management initiatives remains contingent upon structural institutional support. Short-term behavioral changes and technical success do not automatically translate into permanent enterprise survival without ongoing institutional scaffolding. This vulnerability occurs because technology adoptions frequently stall due to high initial costs, fluctuating market prices, and weakening internal group organization once direct mentoring ceases (Abdullah et al., 2024; Latif et al., 2023). This corroborates literature emphasizing that continuous monitoring, quality standardization, and secure market linkages are prerequisites for stable economic impacts (Putra et al., 2025; Zeng et al., 2025). Strategically, the initiative contributes to sustainable development frameworks, specifically aligning with SDG 8 (Decent Work and Economic Growth) and SDG 12 (Responsible Consumption and Production), by demonstrating how localized waste management simultaneously drives environmental remediation and sustainable rural livelihoods (Patunah & Pradani, 2024; Ram & Bracci, 2024).

CONCLUSION

This community service program successfully enhanced the knowledge and practical skills of nine livestock farmers in sustainable waste management, covering waste fermentation techniques, pen drainage systems, and the conversion of solid waste into organic fertilizer. Additionally, the integration of digital marketing training via marketplaces and social media expanded participants' awareness of economic opportunities within smallholder farming. The

findings demonstrate that combining technical training and entrepreneurship fosters behavioral shifts toward more productive and environmentally friendly farming practices, contributing directly to SDGs 8 and 12.

While the initiative faced constraints regarding small participant scale, limited processing equipment, and baseline digital proficiency, as well as a lack of long-term economic and environmental evaluation, the approach proves that combining technical, entrepreneurial, and digital training serves as an effective model for eco-entrepreneurship empowerment in rural areas. Future initiatives should incorporate longitudinal evaluations, larger participant cohorts, and continued mentoring. Further studies may extend this work through quantitative assessments of social, economic, and environmental impacts to support program replication across other regions.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

AI Usage Statement

The authors declare that AI tools were used solely for language editing, grammar checking, and improving the clarity and readability of the manuscript. AI tools were not used to generate core research ideas, conduct substantive analysis, interpret data, or draw scholarly conclusions. The authors take full responsibility for the originality, accuracy, and academic integrity of the content.

Author Contributions Statement

ANR, IRPSS, and EP contributed to the conceptualization, project administration, methodology, and overall program execution.

HD, AA, and HS contributed to the design and implementation of simple technology for odor reduction, drainage systems, and technical assistance.

DFR and ZM contributed to data collection, community training on organic fertilizer processing, alternative feed development, and manuscript drafting.

All authors reviewed and approved the final version of the manuscript

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