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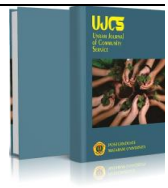

Empowering a Rural Highland Community in Getasan District through Black Soldier Fly-Based Organic Waste Management for a Circular Economy Transition

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Abstract: Waste management in Indonesia is still dominated by open burning and landfilling, causing environmental and health problems. In Jetak Village, Getasan District, Semarang Regency, located in the rural highlands of Mount Merbabu, organic waste dominates household waste streams. Although a TPS3R facility has existed since 2022, its operation remains suboptimal due to low community participation and odor issues. This condition highlights the urgent need for innovative, community-based solutions. Black Soldier Fly (BSF, Hermetia illucens) farming offers an effective alternative, capable of reducing organic waste by 50–60% while producing valuable by-products. This community service program targeted village officials, farmer groups, women's groups, youth, and TPS3R managers. Activities included awareness sessions on circular economy, training in BSF cultivation, field demonstrations using appropriate technology, digital marketing workshops, and operational assistance at TPS3R. Impact was assessed through participant questionnaires and scenario modeling of household-level BSF adoption based on waste generation data from SIPSN (2025) and BPS (2025). Twenty-five participants engaged actively throughout the program. Evaluation showed 100% agreement that BSF is effective for organic waste management, with 89% willing to adopt it at home. Products such as fresh and dried larvae and frass were successfully introduced, with estimated market value up to IDR 52,000/kg. Scenario analysis indicated potential reductions of 89–268 tons of organic waste annually and mitigation of 2.6–7.8 tons CO_2e, depending on adoption rates. The program proved that BSF technology is feasible, socially acceptable with proper education, and economically promising. It strengthened local waste management capacity, supported income generation, and contributed to circular economy transition while aligning with SDG 12 and Indonesia's low-carbon development goals.

Keywords: Black Soldier Fly (BSF), Organic Waste Management, Circular Economy, Community Empowerment, Waste-to-value.

Introduction

Waste has become an increasingly complex environmental issue, particularly due to the rising volume of generation in line with population growth. Waste management in Indonesia is still largely dominated by unsustainable practices such as open burning and landfilling, which negatively impact human health and environmental quality (Slamet, 2016; Abubakar et al., 2022). Data from the Ministry of Environment and Forestry (KLHK) indicate that 57% of the national waste stream consists of organic waste. This

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fraction, if properly managed, carries substantial potential to be transformed into economically valuable products.

Jetak Village, located in Getasan District, Semarang Regency, is one of the rural highland areas that faces serious challenges in waste management. Situated on the slopes of Mount Merbabu, the village is characterized by mountainous topography, with most land utilized for agriculture and livestock. According to demographic data, Jetak Village hosts a population of 4,322 people distributed across 12 hamlets: Setugur, Gajian, Jayan, Dukuh, Tosoro B, Tosoro A, Weru A, Weru B, Jetak, Kemiri, Legok, and Kendal. Each hamlet corresponds to one neighborhood unit (RW), comprising a total of 33 neighborhood associations (RT). Although the village established a Reuse-Reduce-Recycle Waste Processing Facility (TPS3R) in 2022, its operation has remained suboptimal. Limited community participation and odor problems have hindered TPS3R from functioning effectively. Field observations revealed that waste is still largely managed individually at the household level. Organic waste is typically disposed of in cattle barns and mixed with manure without further processing, whereas inorganic waste is more frequently burned or dumped on vacant land (Heriyanti et al., 2024). These practices not only contribute to environmental pollution but also reflect the underutilization of the economic potential embedded in organic waste streams.

KLHK data further emphasize that the high proportion of organic waste may serve as a local advantage if properly harnessed. With Jetak Village producing nearly 1.8 tons of organic waste per day, the opportunity for circular economy-based solutions is substantial. Previous studies have confirmed that empowerment models rooted in local potential can enhance community independence and productivity (Sutarto et al., 2023; Sari, 2023). One innovation currently gaining attention is the cultivation of Black Soldier Fly (BSF, *Hermetia illucens L.*), which has been proven to reduce organic waste volumes by 50–60% while generating high-value biomass (Diener et al., 2011).

BSF larvae contain essential proteins and lipids suitable for animal feed, while the by-product of the decomposition process (frass or kasgot) can be utilized as organic fertilizer (Heriyanti et al., 2024; Idris et al., 2024). Derived products may also be marketed in diverse forms, such as fresh larvae, dried larvae, BSF eggs, BSF meal, or formulated pellets (Rahmawati & Sarofah, 2022; Setiawan, 2023; Usman, 2022). This potential strongly aligns with Jetak Village's livelihood context, which relies heavily on livestock and agricultural sectors.

In response to these challenges and opportunities, a team from Universitas Negeri Semarang designed a community service program aimed at strengthening the capacity of Jetak Village residents in organic waste management through BSF farming. The program was structured around awareness campaigns, training, field practice, and operational assistance for TPS3R. Beyond promoting a zero-waste approach, the program is expected to support the transition toward a circular economy at the village level. The products derived from BSF cultivation may be directly used by local farmers or marketed through collaboration with the Village-Owned Enterprise (Badan Usaha Milik Desa, BumDes). Consequently, this initiative is projected to reduce waste generation, improve household income, and contribute to the achievement of Sustainable Development Goal (SDG) 12 on responsible consumption and production.

Method

This community service program was conducted in Jetak Village, Getasan District (Figure 1). Geographically, the area represents a rural highland with an elevation of approximately 1,004 m above sea level, located on the slopes of Mount Merbabu. The main target groups included village officials, farmer groups, women's associations, youth organizations, and the TPS3R (Reuse-Reduce-Recycle Waste Processing Facility) management.

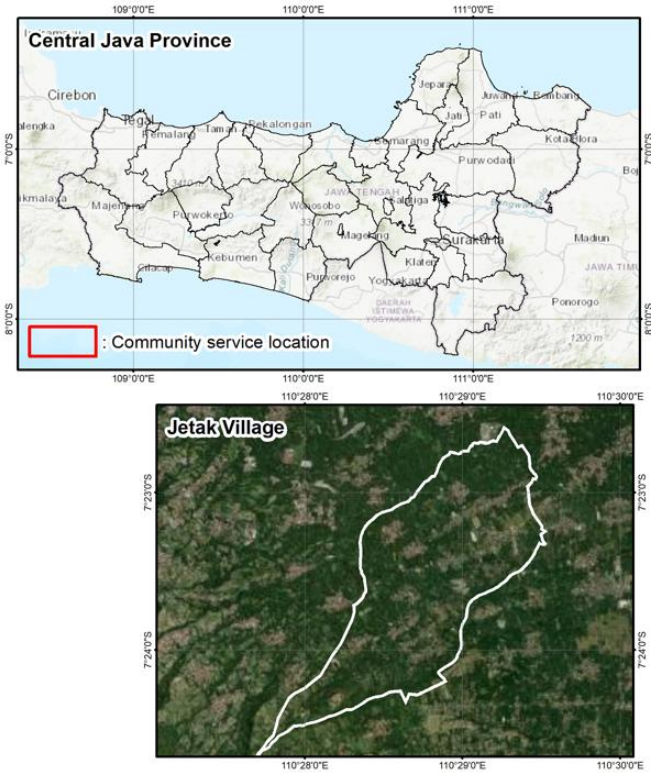

Figure 1. Community service location

The implementation was organized into several stages. The first stage consisted of awareness campaigns and extension activities to enhance community

understanding of organic waste management, the circular economy concept, and the introduction of Black Soldier Fly (BSF) farming technology. The material was delivered through presentations, leaflets, and interactive discussions designed to be accessible to participants with diverse educational backgrounds. In addition, another awareness session addressed digital marketing strategies to increase the economic value of BSF-derived products, emphasizing the use of social media platforms such as Instagram, Facebook, and WhatsApp Business for both promotion and public education on the waste-to-value concept.

The second stage involved training and field demonstrations. Participants were trained in techniques of organic waste collection, segregation, and processing using BSF larvae. Appropriate technology (AT) tools were provided, including mating cages, larval rearing containers, and an organic waste shredder. Participants were guided step by step, from container preparation to larval rearing and the harvesting of frass (kasgot).

Subsequently, operational assistance was provided for TPS3R. The service team supported the community in optimizing the role of TPS3R by integrating BSF farming technology into the existing waste management system. This assistance covered waste segregation, the utilization of BSF larvae for organic decomposition, and the processing of by-products such as frass for use as organic fertilizer.

The final stage was program evaluation, conducted through questionnaires to assess community perceptions and attitudes. The survey instruments provided insights into the effectiveness of the program, levels of acceptance of BSF technology, and challenges still encountered, such as psychological resistance from some participants who expressed discomfort with larvae.

As part of the analytical method, the service team also developed household-level scenarios for BSF adoption to estimate the potential environmental impact. These scenarios projected reductions in organic waste generation and greenhouse gas (GHG) emissions, based on waste generation data for Jetak Village extrapolated from Semarang Regency data reported in SIPSN (2025), demographic data from BPS Semarang Regency (2025), and reduction parameters from previous studies (Mertenat et al., 2019; Ermolaeva et al., 2019). This approach was employed to evaluate the extent to which BSF technology could contribute to reducing organic waste while simultaneously supporting climate change mitigation agendas.

Result and Discussion

The community service program in Jetak Village was attended by 25 participants who actively engaged in the entire series of activities. The program began with an awareness session on BSF-based organic waste management (Figure 2). Participants included village officials, farmer groups, women's groups, and representatives of livestock keepers. The session emphasized the importance of managing waste within the framework of a circular economy, where waste is no longer perceived as a burden but as a resource with value. Concrete examples were provided, such as the conversion of organic waste into organic fertilizer or animal feed, which can reach a market value of IDR 52,000/kg, thereby offering opportunities for additional household income. This is particularly relevant for Jetak Village, where many residents rely on livestock production, including layer poultry, and thus the use of BSF larvae has the potential to enhance productivity while reducing feed costs (Heriyanti et al., 2022).

Figure 2. Awareness session on organic waste management

Beyond the technical aspects of BSF cultivation, the team also introduced digital marketing strategies to expand the reach of BSF-based products (Figure 3). The materials focused on the utilization of social media platforms such as Instagram, Facebook, and WhatsApp Business. These strategies functioned not only as promotional tools but also as public education channels to advance the waste-to-value concept. This approach aligns with previous studies which highlight that the success of eco-innovations is significantly influenced by effective public communication, particularly through

low-cost and wide-reaching social media (Diener et al., 2011; Kumar et al., 2020).

Figure 3. Digital marketing awareness session for BSF-based products and product example

The next stage was the practical implementation of BSF farming (Figure 4). Participants were trained to segregate household organic waste, prepare rearing containers, and maintain larvae through different growth stages. The decomposition process lasted for several weeks, with larvae harvested at the pre-pupal stage for animal feed, while the residual frass (kasgot) was applied as organic fertilizer. This stage provided participants with hands-on skills and demonstrated how household waste could be transformed into marketable products.

Figure 4. Practical implementation

The effectiveness of the program was assessed through a questionnaire survey (Table 1). All participants (100%) reported that the awareness sessions were attractive and useful, and unanimously agreed that BSF farming was an effective and efficient solution for organic waste management. Moreover, 89% expressed willingness to adopt the technology in their own households. However, a psychological barrier was identified: 56% of participants, mainly women, reported discomfort or aversion toward larvae. This factor poses a potential challenge to broader adoption, although some participants remained motivated by the economic benefits. This phenomenon mirrors the findings of Renosori et al. (2022), who reported that initial resistance, especially among women, is a common challenge in introducing insect-based technologies. Therefore, follow-up educational strategies should focus on emphasizing both household economic benefits and wider environmental impacts to enhance acceptance levels.

Table 1. Evaluation results from participant questionnaire

Question	Yes	No
The awareness session was interesting	100%	0%
Organic waste management using BSF is effective and efficient	100%	0%
Feel uncomfortable with BSF larvae	56%	44%
Will adopt BSF technology at home	89%	11%

Overall, this program demonstrated that the waste-to-value concept can be effectively implemented in rural highland communities. The application of BSF farming reduced organic waste generation, enhanced community literacy on circular economy principles, and expanded opportunities for product marketing through digital platforms. These outcomes are consistent with Syed et al. (2024), who emphasized the role of social media as a catalyst in accelerating the adoption of environmentally friendly innovations. Thus, Jetak Village has strong potential to serve as a model of community-based circular economy practices in highland areas of Central Java.

When BSF farming is modeled at the household level, its environmental benefits become more evident. Based on SIPSN (2025) and BPS Semarang Regency (2025), Jetak Village is estimated to generate approximately 805 tons of waste annually, with food waste comprising 496 tons. If BSF technology were adopted, the potential reduction would be significant. At

an adoption level of 30% of food waste, around 89 tons per year could be diverted; at 60% adoption, 178 tons; and at 90% adoption, 268 tons. These estimates assume that frass residue accounts for approximately 40% of the wet input, within the 30–50% range reported in prior studies on BSF processing (Mertenat et al., 2019; Ermolaeva et al., 2019).

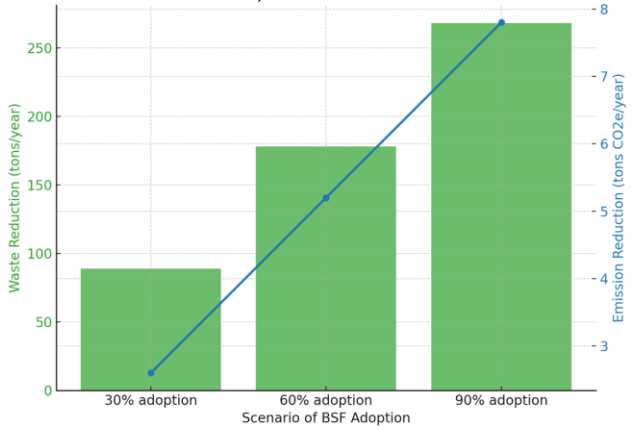

Figure 5. Scenario of organic waste and GHG emission reduction through BSF adoption in Jetak Village

The calculated scenarios (Figure 5) show that the higher the adoption rate, the greater the reductions in waste and greenhouse gas (GHG) emissions. At 90% adoption, for example, waste reduction could reach 268 tons per year, with GHG emission reductions of up to 7.8 tons CO_2e.

In terms of emissions, BSF farming has the potential to significantly reduce GHGs compared to open composting or unmanaged dumping. Previous studies have shown that CH_4 and N_2O emissions from BSF treatment amount to only 0.38 kg CO_2e per ton of food waste, or 47 times lower than open composting (Mertenat et al., 2019; Ermolaeva et al., 2019). Assuming that baseline conditions involve open composting, the application of BSF in Jetak Village could reduce emissions by 2.6 tons CO_2e annually at 30% adoption, 5.2 tons CO_2e at 60%, and 7.8 tons CO_2e at 90%. However, since the current dominant practice is burning organic waste, the absolute reduction in CH_4 emissions may be smaller. Nevertheless, the most significant benefits of BSF adoption lie in reducing local air pollution and generating economic value from larvae and frass products (Xiang et al., 2024; Gebiola et al., 2023).

These outcomes also highlight opportunities for further research. Future studies could examine the effectiveness of BSF as a decomposer agent under varying environmental conditions, as indicated by Putra & Ariesmayana (2020). The economic potential of BSF farming also warrants exploration through economic valuation approaches, especially since Jetak Village is situated in a relatively cool highland climate. Such ecological conditions imply the need for adaptive studies, given that BSF larvae grow optimally at temperatures of 30–36 °C (Putra & Ariesmayana, 2020). Therefore, BSF technology implementation not only contributes to organic waste reduction and household income but also provides broader impacts for sustainable development agendas. This effort aligns with SDG 12 on responsible consumption and production, while also supporting Indonesia's ongoing low-carbon development policies.

Conclusion

The community service program in Jetak Village, Getasan District, demonstrated that the application of Black Soldier Fly (BSF) farming can simultaneously enhance community capacity in organic waste management and create new economic opportunities. Evaluation results indicated a significant increase in participants' knowledge and skills, with 100% acknowledging the program's benefits and 89% expressing readiness to adopt BSF farming at the household level. The practices implemented successfully produced economically valuable outputs, including fresh larvae, dried larvae, and frass, with an estimated potential market value of up to IDR 52,000/kg.

Although psychological resistance toward larvae was identified as a challenge, the majority of participants remained interested in continuing the practice due to its recognized economic and environmental benefits. Scenario modeling further revealed that BSF adoption has the potential to reduce organic waste by up to 268 tons per year and mitigate greenhouse gas emissions by as much as 7.8 tons CO_2e annually. These findings confirm that BSF technology is not only effective for waste management but also relevant as a climate change mitigation strategy.

Therefore, the implementation of BSF farming in Jetak Village contributes to the transformation of waste-to-value within the framework of a circular economy. This effort supports the achievement of Sustainable Development Goal (SDG) 12 on responsible consumption and production, while also aligning with Indonesia's broader low-carbon development agenda.

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Place acknowledgments, including information on grants received, before the references, in a separate section, and not as a footnote on the title page

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