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Enhancing Community Capacity in Integrated Organic Waste Management through Black Soldier Fly Bioconversion within GreenFlow Program

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Abstract: Organic waste management remains a major environmental challenge in Ngroto Village, Pujon District, Malang Regency, Indonesia, due to limited waste-sorting practices and inadequate facilities for organic waste processing. This community service program aims to enhance community understanding of waste management and Black Soldier Fly (BSF) bioconversion and assess participants' willingness to adopt the promoted practices through the GreenFlow program. The program integrated two components: Green-Waste, which focused on waste sorting, and Green-Grow BSF, which focused on organic waste bioconversion through BSF cultivation. Activities comprised preparation, outreach and training, hands-on assistance, BSF cultivation, and evaluation. Changes in participants' understanding were assessed using six pretest and posttest items, while their willingness to adopt the promoted practices was assessed separately using a four-point Likert-scale item. Data from 59 respondents with paired assessments, comprising members of the Family Welfare Movement (PKK) and Dasawisma groups in Ngroto Village, were analyzed using descriptive statistics, normalized gain (N-gain), and the Wilcoxon signed-rank test. Overall understanding increased from 58.3% on the pretest to 95.9% on the posttest, yielding a high N-gain of 0.90 and a statistically significant difference between pretest and posttest scores ($p < 0.001$). Understanding of waste management increased from 67.4% to 97.0%, while understanding of BSF cultivation increased from 40.3% to 93.6%. Participants' willingness to adopt the promoted practices also increased from 66.5% to 95.8% ($p < 0.001$). The Green-Grow BSF unit processed approximately 40–50 kg of organic waste per day. These findings indicate that GreenFlow improved community understanding and reported willingness to adopt integrated organic waste management practices involving BSF bioconversion.

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Introduction

Indonesia faces serious challenges in waste management, with a daily waste production of approximately 175,000 metric tons (KLHK, 2023). As much as 56% of waste generation comes from households, with organic waste constituting the largest fraction originating from food scraps, kitchen waste, and agricultural and plantation waste. Organic waste that is not properly managed decomposes easily, emits odors, and has the potential to

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pollute the environment if it accumulates over a long period (Suryani, 2020 ; Samadikun et al., 2023). East Java Province is one of the largest contributors to waste generation, with a volume reaching 1,637,819.77 metric tons in 2022 (Utami et al., 2024). Organic waste generation in Pujon Subdistrict (Malang Regency) exceeds 1 metric ton per day (Aprilliani, 2020). This situation highlights the need to strengthen community-based waste management down to the village level as part of the implementation of the national waste reduction policy (World Bank, 2021).

Ngroto Village, located in Pujon Subdistrict, Malang Regency, faces challenges in household waste management. The village comprises approximately 350 households, generating an estimated 250 kg of waste daily, predominantly consisting of organic materials. Field observations and interviews with village officials and representatives of the Family Welfare Movement (PKK) indicated that household waste management was not yet systematically organized and that centralized waste processing facilities were unavailable. Household waste was commonly disposed of in open areas and drainage channels or burned in residential backyards. These practices contribute to waste accumulation, unpleasant odors, and drainage obstruction (BPS, 2023). During heavy rainfall, clogged drainage channels can cause water overflow and carry waste into residents' yards, as observed in late January 2026 (Figure 1). Flooding can also adversely affect residential environments and local communities (Yuriadi et al., 2025). The local livelihood structure is predominantly agriculture-based, with approximately 75% of the population reportedly working as farmers, followed by livestock farmers and traders (Badan Pusat Statistik Kabupaten Malang, 2017; Dinas Komunikasi dan Informatika Kabupaten Malang, 2024). This context provides an opportunity to connect community-based waste management with local agricultural activities through improved waste sorting and the recovery of suitable organic materials.



Figure 1. The affected residential area of Ngroto

Beyond its environmental implications, organic waste also represents a potential resource within a circular economy framework, in which discarded materials are recovered and returned to productive use (WHO, 2022; WHO, 2025; Hamdani et al., 2025). At the community level, this approach requires active participation and locally appropriate waste utilization strategies (Yunisvita et al., 2025). However, limited awareness and practices related to environmentally friendly waste management, inadequate facilities, and the absence of an organized management system can hinder implementation (KLHK, 2023b; KLHK, 2025; Lestari et al., 2022). One potential strategy for processing suitable organic waste is bioconversion using Black Soldier Fly (BSF) *Hermetia illucens* larvae. BSF larvae can utilize

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various biodegradable materials as feed, potentially reducing the amount of organic waste requiring conventional disposal (Widyastuti & Sardin, 2021). The process also generates larval biomass that may be used as an ingredient in animal feed, subject to appropriate safety requirements, and a residual material known as kasgot, which has potential for use as an organic fertilizer following appropriate processing (Rahmisari & Ihram, 2025). BSF bioconversion can therefore support resource recovery and the circular use of organic waste (Defriatno & Al Habib, 2026). Compared with conventional composting, which converts biodegradable waste into compost, BSF bioconversion provides an additional pathway that can also generate larval biomass. The suitability of either method depends on waste composition, available space, operational capacity, and the intended use of the resulting products. Accordingly, BSF bioconversion is considered a complementary option rather than a universally more effective replacement for composting (Setti et al., 2020; Syafitri et al., 2024; Assidiq et al., 2026).

In response to these challenges, the GreenFlow Program was designed as a community-based initiative integrating two complementary components: Green-Waste and Green-Grow BSF. Green-Waste focuses on improving community awareness and practical skills in separating organic and inorganic waste at the household level through outreach and hands-on training. This component is intended to support more organized waste management and provide appropriately separated organic materials for further processing. Green-Grow BSF complements this effort by utilizing suitable organic waste as feed for BSF larvae and managing the resulting larval biomass and kasgot as potentially useful products. By connecting source separation with organic waste bioconversion, the program integrates technical waste processing with community participation and resource recovery. Further capacity-building activities related to product handling, utilization, and marketing may be considered to strengthen the program's long-term operational and economic sustainability. The program also aligns with Sustainable Development Goals (SDGs) 11, 12, and 13 and Indonesia's Asta Cita agenda concerning sustainable development and community empowerment.

Accordingly, this community service program aimed to strengthen community capacity in integrated organic waste management through the implementation of Green-Waste and Green-Grow BSF in Ngroto Village. Specifically, the program sought to (1) improve participants' understanding of household waste management and BSF cultivation, as measured by pre-test and post-test scores; (2) increase participants' willingness to adopt the promoted waste management practices; and (3) establish a community-based BSF cultivation unit to support the processing of suitable organic waste. Program outcomes were assessed through changes in participants' pre-test and post-test scores, their willingness to implement the promoted practices, and the implementation of the BSF cultivation unit. The findings are expected to inform the development and potential adaptation of integrated community-based waste management initiatives in other rural areas with comparable characteristics, subject to further assessment of their environmental, operational, and economic sustainability.

Method

This community service activity was conducted at the Community Service Partner Location, Ngroto village, Malang. The activity adopted a Participatory Action Research (PAR) approach, a community empowerment framework that actively engages community members in identifying problems, planning interventions, implementing activities, and evaluating their outcomes (Kemmis et al., 2014). This activity involved 59 residents as

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participants. The steps in implementing the community service program through the GreenFlow program are: preparation, implementation, post-implementation and continuation as shown in Figure 2.



Figure 2. Steps in Implementing the GreenFlow Community Service Program

To measure changes in the partners' understanding, participants completed a questionnaire before the activity (pre-test) and after the activity (post-test). The questionnaire was adapted from the GreenFlow program evaluation instrument and contained seven statements relevant to waste management and BSF maggot cultivation. The statements used a four-point Likert scale, ranging from 1 (not aware) to 4 (very aware). The questionnaire statements measured:

a) Understanding of waste sorting and management (4 items): the difference between organic and inorganic waste, the importance of sorting at home, the benefits of waste management, and how to manage organic and inorganic waste.
b) Understanding of BSF maggot cultivation (2 items): benefits and farming process.
c) Willingness to practice waste sorting and BSF maggot farming (1 item).

The pre-test and post-test were completed by 59 paired respondents. The participants were members of PKK and Dasawisma, the majority of whom were homemakers. The questionnaire statements measured several aspects, including participants' understanding of waste management, understanding of BSF maggot cultivation, and willingness to implement waste sorting, BSF cultivation, and ecobrick practices at home. For the assessment of understanding, six statements were analyzed, comprising four statements related to waste management and two statements related to BSF maggot cultivation. Each statement was scored using a four-point Likert scale. The total understanding score ranged from 6 to 24 and was converted into a percentage using the following formula:

$$\textbf{Score (\%) = (score obtained / maximum score) × 100\%}$$

These percentages are interpreted according to the following categories: 0–20% very low, 21–40% low, 41–60% moderate, 61–80% high, and 81–100% very high. The increase in understanding was calculated using the normalized N-gain (Hake, 1998). N-gain values are categorized as high ($g \geq 0.70$), moderate ($0.30 \leq g < 0.70$), or low ($g < 0.30$). Because the pre-test and post-test scores were obtained from the same respondents, differences between the two measurements were analyzed using the Wilcoxon signed-rank test (Wilcoxon, 1945), which has also been applied in recent pre–post intervention studies (Lyons-Warren et al., 2024), with statistical significance set at $p < 0.05$. Statistical analyses were performed using IBM SPSS 26 Version. Participants' willingness to implement the promoted practices was assessed separately using a four-point Likert-scale item and analyzed using the same statistical test.

$$\textbf{N-gain = (post-test score − pre-test score) / (maximum score − pre-test score)}$$

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Result and Discussion

1) Preparation phase

The preparation phase involved obtaining site permits, coordinating with the village government and community partners, identifying local waste management needs, and preparing the equipment for the Green-Grow Black Soldier Fly (BSF) cultivation unit. Initial discussions and field observations indicated that the equipment needed to accommodate the available space at the partner's site while allowing convenient access for feeding, monitoring, and harvesting activities. The BSF cultivation unit was constructed using a tiered rack made of hollow steel tubes, with containers placed on each level to hold the larvae and organic substrate. The tiered configuration was selected as a practical approach to organizing multiple rearing containers within the available floor area. The open rack structure also facilitates access to individual containers for routine maintenance and observation. However, its suitability depends on adequate structural stability, spacing between tiers, and sufficient ventilation around the rearing containers; therefore, the design should be understood as a site-adapted solution rather than a universally superior configuration.

Environmental conditions are important for successful BSF larval development and organic waste bioconversion. Previous studies indicate that larval development generally performs well at temperatures of approximately 27–30°C, although the optimum can vary with the substrate and rearing conditions (Wang & Shelomi, 2017; Amrul et al., 2022). Substrate moisture also requires attention because excessive moisture can impair aeration and make the separation of larvae from the residual material more difficult. Moisture levels around 70–75% have been suggested for balancing larval growth and residue separation in some systems (Dortmans et al., 2017; Amrul et al., 2022). Accordingly, the rearing containers were arranged with sufficient spacing to facilitate air circulation and routine inspection. These design considerations support practical operation and maintenance, although temperature and humidity were not claimed to be continuously controlled unless direct monitoring data were available.

In addition to the rack and rearing containers, protective netting was installed around the cultivation area as shown in Figure 3. The netting was intended to reduce the escape of adult flies and limit access by potential predators, while providing a physical barrier around the rearing unit. Together, the rack, containers, and protective netting formed the basic infrastructure for the Green-Grow BSF unit. The preparation phase therefore established the equipment needed for subsequent community training and organic waste processing.



Figure 3. Coordination of the assembly of BSF maggot equipment, racks, and nets

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2) Implementation and Evaluation Phase

The Green-Waste activities were carried out through outreach and training on the separation of organic and inorganic waste for partners from the Ngroto Village Working Group and the PKK group. These activities aim to build the community's initial understanding of the importance of waste sorting at the source as the foundation for the success of the Green-grow BSF pillar. The activities were held at the Ngroto Village Hall in Pujon Subdistrict on Thursday, July 9, 2026, and were attended by 59 participants from the PKK and Dasawisma groups Figure 4.



Figure 4. Documentation of the Outreach Session

Participants' understanding increased from a mean score of 14.00 (58.3%) in the pre-test to 23.02 (95.9%) in the post-test, based on a maximum score of 24. The normalized gain (N-gain) was 0.90, indicating a high level of improvement. The median score also increased from 14 to 24. The Wilcoxon signed-rank test showed a statistically significant difference between the pre-test and post-test scores ($W = 1.0$, $p < 0.001$), indicating a substantial improvement in participants' understanding following the Green-Waste and Green-Grow BSF training activities.

The improvement was observed across both assessed aspects (Figure 5). Understanding of waste management increased from 67.4% in the pre-test to 97.0% in the post-test, representing an increase of 29.7 percentage points. Meanwhile, understanding of BSF maggot cultivation increased from 40.3% to 93.6%, representing the largest improvement of 53.4 percentage points. These findings suggest that participants had a stronger initial understanding of basic waste management practices, whereas their understanding of BSF-based organic waste bioconversion was more limited before the training. The substantial increase in the BSF cultivation aspect indicates that the practical training and assistance contributed to improving participants' understanding of this waste-processing technology.

Participants' willingness to implement the promoted practices at home also increased, from 66.5% in the pre-test to 95.8% in the post-test, representing an increase of 29.2 percentage points. The Wilcoxon signed-rank test indicated a statistically significant difference in willingness scores ($W = 101.5$, $p < 0.001$). This increase in willingness provides an important basis for the continued adoption and sustainability of the Green-Grow BSF practices at the household and community levels. The improvement in participants' understanding in the GreenFlow Program is consistent with previous community

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empowerment activities that combined practical training with organic waste utilization. Qomaliyah et al. (2025) reported that a hands-on composting workshop using banana agricultural residues improved participants' understanding and skills in organic waste processing. Similarly, the GreenFlow Program combined knowledge transfer with hands-on training in waste sorting and BSF cultivation, providing participants with practical experience in organic waste valorization.

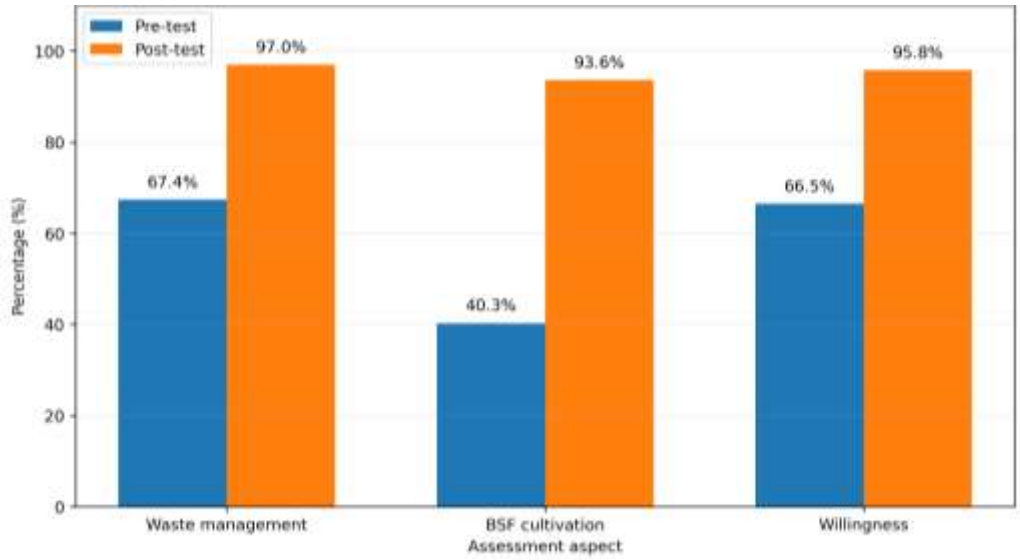


Figure 5. Changes in Participants Understanding and Willingness Following the GreenFlow Program

Green-grow BSF pillar were carried out at the Integrated Waste Processing Facility (TPST) in Ngroto Village, Pujon Subdistrict. The breeding phase began with the provision of maggot larvae in the early instar stage, which were then placed in rearing media inside racks and containers that had been assembled beforehand. The humidity and temperature of the rearing medium are maintained to ensure optimal conditions for BSF larval growth, as these two factors significantly determine the rate of feed consumption and the efficiency of organic waste bioconversion by the larvae (Rahmadayanti & Firmansyah, 2021). The rearing process involves feeding the larvae household organic waste in a gradual and scheduled manner, accompanied by routine monitoring of larval growth and the condition of the rearing medium to ensure it is neither too wet nor too dry as shown in Figure 6.



Figure 6. BSF Maggot Rearing Process

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During the program implementation, the Green-Grow BSF unit in Ngroto Village was operated for the bioconversion of organic waste using BSF maggots. The findings of the GreenFlow Program are consistent with previous evidence that BSF-based systems can support organic waste management at the community level. Nadeak et al. (2025) demonstrated that communal-scale BSF technology could be applied to household organic waste management in a rural village, with organic waste converted into BSF larvae and compost. Similarly, the GreenFlow Program established a community-level BSF unit that processed approximately 40–50 kg of organic waste per day and generated kasgot as a useful by-product. These findings support the potential of BSF bioconversion as a practical approach for integrating organic waste reduction with resource recovery at the village level. This finding demonstrates the potential of BSF larvae as an organic waste bioconversion agent at the community level and is consistent with previous studies reporting the effectiveness of BSF larvae in processing organic waste (Rahmadayanti & Firmansyah, 2021; Setti et al., 2020). In addition to reducing the amount of organic waste requiring conventional disposal, the rearing process generated kasgot, consisting of residual rearing substrate and maggot excreta, which was utilized as organic fertilizer. Thus, the Green-Grow BSF system not only supported organic waste reduction but also generated a potentially useful by-product for the program partners. Effective village-level waste management requires not only community participation but also reliable information on the spatial distribution of waste sources. Digital waste mapping can support data-based decision making by providing spatial information that helps identify waste management priorities and inform appropriate interventions (Lestari et al., 2022b, Azwar, et al., 2024). In the context of Ngroto Village, such an approach can complement community-based waste sorting and organic waste bioconversion through Black Soldier Fly (BSF) cultivation.

The program evaluation phase consisted of a post-test and observation of the continuity of the promoted practices. The post-test was administered to assess changes in participants' understanding and willingness to implement waste sorting, BSF maggot cultivation. Observation was conducted to assess the continued application of the promoted practices and the operation of the Green-Grow BSF unit after the training activities. These observations provided an indication of the program's sustainability, particularly in terms of continued waste sorting, BSF cultivation, and utilization of the resulting products. The sustainability of the program was further supported by the provision of a handbook as a self-guided reference for partners in continuing waste sorting and BSF cultivation practices. Community empowerment is an important component of sustainable waste management because the adoption of waste-processing technologies requires active community participation. The use of BSF bioconversion has also been implemented as a community empowerment strategy for addressing organic waste management challenges (Asropi et al., 2023).

Conclusion

The implementation of the GreenFlow Program in Ngroto Village demonstrated that integrating the Green-Waste and Green-Grow BSF approaches can strengthen community-based organic waste management. Participants' understanding increased from 58.3% to 95.9%, with a high N-gain of 0.90, while their willingness to implement the promoted practices also increased following the program. The Green-Grow BSF unit was operational and processed approximately 40–50 kg of organic waste per day, while producing kasgot as a useful by-product for organic fertilizer. These findings indicate that combining community

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education, hands-on practice, and BSF-based bioconversion provides a practical approach to improving organic waste management at the community level. Continued mentoring and village-level institutional support are needed to maintain the practices and strengthen the long-term sustainability of the program.

Recommendation

Based on the program outcomes, several recommendations are proposed for the sustainability of the GreenFlow Program.

1) For Partner Organizations (PKK and Village Working Groups)
   PKK members and Village Working Groups are encouraged to maintain household waste sorting practices and apply the knowledge and skills acquired during the program. Routine monitoring of waste separation and BSF cultivation activities should be conducted to ensure that the practices remain consistent. The groups should also coordinate the collection of suitable organic waste from households to support the continuous operation of the Green-Grow BSF unit.
2) For the Village Government and Relevant Government Agencies
   The village government is encouraged to support the continuity of the GreenFlow Program by facilitating coordination among community groups, providing appropriate operational support, and integrating community-based waste management into village environmental programs. Collaboration with relevant government agencies is also recommended to strengthen technical assistance, improve waste management infrastructure, and explore opportunities to expand organic waste processing in accordance with local needs and available resources.
3) For Future Community Service Teams
   Future community service teams should prioritize periodic mentoring and evaluate the long-term sustainability of household waste sorting and BSF cultivation practices. Further interventions could focus on improving the operational capacity of the BSF unit, assessing the quantity of organic waste processed over time, and evaluating the quality and potential utilization of BSF larvae and residual materials (kasgot). Additional training in product management and marketing may also be considered in future programs to explore the economic potential of BSF-derived products. These efforts should be accompanied by systematic monitoring to identify challenges and support the continued development of community-based circular waste management

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