Entrepreneurship and Community Development
p-ISSN/e-ISSN: 2987-6354/2987-6346
Homepage: https://sanscientific.com/journal/index.php/ecd
3(2) 62-69 (2025)
https://doi.org/10.58777/ecd.v3i2.559

Original Paper

Strengthening Family Economic Resilience through Greenhouse-Based Horticulture

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Received: 10-11-2025; Accepted: 17-11-2025

Abstract
This community service program aims to strengthen family economic resilience through horticultural development using the greenhouse method in Mandalamekar Village, Bandung. The main problem faced by the community was the destruction of the existing greenhouse following a natural disaster in 2023, which disrupted agricultural production sustainability and affected food security. The program was implemented through persuasive and participatory action approaches involving local farmers, village officials, lecturers, students, and alumni. The implementation stages included training, facilitation, mentoring, and monitoring of the greenhouse construction and horticultural management processes. Evaluation was conducted using pre- and post-test methods to measure improvements in participants' knowledge and skills. The results show that greenhouse-based horticulture contributes to increasing agricultural productivity, farmers' income, and household food resilience. In addition, the program supports achieving university performance indicators (IKU 2, 3, and 5), which encourage off-campus learning and collaboration between academia and the community. The program provides significant managerial implications in developing sustainable agricultural innovation, empowering local farmers, and utilizing appropriate technology to support economic recovery and resilience in rural areas. This initiative serves as a model for strengthening rural economies through environmentally adaptive and technology-based agriculture.

Keywords: Family Economic Resilience, Horticulture, Greenhouse Method, Mandalamekar Village, Community Empowerment

JEL Classification: O13, Q12, D13

How to cite: Suyana, H., Budiman, A. N., Yugaswara, H., (2025). Strengthening Family Economic Resilience through Greenhouse-Based Horticulture, *Entrepreneurship and Community Development (ECD), 3(2)*, 62-69

1. Introduction
Family economic resilience is a crucial foundation for maintaining social stability and the well-being of rural communities. In this context, Mandalamekar Village, Cimenyan District, Bandung Regency, plays a strategic role because most of its population relies on the agricultural sector, particularly horticulture, for its livelihood. According to data from the Mandalamekar Village Government (2024), approximately 63% of residents work as farmers, occupying 212 hectares of productive land.

However, after a 2023 natural disaster destroyed the village's greenhouse, productivity decreased by 40%, significantly reducing the income of farming families (Mandalamekar Village Profile, 2024). This situation highlights the need to revitalize the agricultural sector, making it more adaptive to climate change through the application of modern farming technologies such as greenhouse horticulture (Putri & Setiawan, 2022).

Socially and economically, the Mandalamekar community has significant potential for developing the horticultural sector. Farmer groups such as Mekar Jaya and Sinar Tani have been actively managing vegetable cultivation, but limited capital and technology are significant obstacles to increasing production scale (Kurniawan & Dewi, 2020). The average farmer's income remains below IDR 2,000,000 per month, demonstrating the family's economic vulnerability to fluctuations in agricultural prices. Furthermore, changes in urban consumption patterns, leading to an increased preference for horticultural products, present significant market opportunities. According to Rahmawati et al. (2021), horticultural demand in West Java has increased by an average of 7% per year since 2020, making the development of greenhouse farming systems a strategic opportunity to strengthen the local economy.

From an environmental perspective, greenhouses have been proven to create a stable microclimate and protect plants from pest attacks and excessive rainfall. This technology allows farmers to produce year-round without relying on the growing season (Fitriani et al., 2022). Arman et al. (2019) demonstrated that greenhouse systems with automated controls can increase water-use efficiency by up to 40% and crop yields by up to 60% compared with conventional methods. In the context of Mandalamekar, the reapplication of greenhouse technology is not only relevant for increasing production yields but also for adapting to the risks posed by extreme climates that frequently occur in the hilly areas of East Bandung (Putri & Setiawan, 2022).

The successful implementation of agricultural technologies, such as greenhouses, depends not only on technical factors but also on the socio-economic empowerment of the community. Participatory approaches that actively involve local communities have been shown to increase the effectiveness of community service programs (Fitriani et al., 2022). A study by Kurniawan and Dewi (2020) found that hands-on training for farmer groups increased farmers' technical capacity by up to 30% within 6 months. Therefore, collaboration between universities, local government, and farmer groups is crucial to ensure the sustainability of the greenhouse horticulture program in Mandalamekar Village (Sari et al., 2021).

The main problems in Mandalamekar Village currently include the loss of greenhouse facilities following the disaster, low technical skills in modern agricultural management, and limited access to production facilities. This has led to farmers' dependence on traditional planting patterns and seasonal harvests (Mandalamekar Village Profile, 2024). To address this challenge, community service activities are focused on rebuilding environmentally friendly greenhouses and providing technical training for farmers. According to Pratama and Lestari (2023), technology-based training and mentoring programs can increase production efficiency and family income by up to 45% within two planting seasons. Thus, these activities are expected to improve family economic resilience while strengthening farmers' adaptive capacity to climate change.

The primary objective of these community service activities is to rebuild a sustainable greenhouse-based horticultural farming system to strengthen family economic resilience in Mandalamekar Village. Through a participatory approach and the transfer of appropriate technology, these activities are expected to create economic independence and support the achievement of the Sustainable Development Goals (SDGs), particularly goals 2 (Zero Hunger), 8 (Decent Work and Economic Growth), and 13 (Climate Action) (UNDP, 2023). In line with this, this activity also contributes to the achievement of the university's Key Performance Indicators (KPI), namely the involvement of students and lecturers in off-campus activities and the utilization of academic work results for the community (Fitriani et al., 2022).

Conceptually, family economic resilience can be achieved through income diversification and optimization of local resource potential. In this regard, greenhouse-based horticulture development can provide direct economic benefits to farming families (Sari et al., 2021). Research by Pratama and Lestari (2023) shows that implementing a closed farming system can increase vegetable productivity up to 1.5 times compared to traditional methods. With technological support and ongoing mentoring, Mandalamekar Village has the potential to become a model for economically resilient villages through greenhouse horticulture innovations oriented towards community empowerment and food security (Putri & Setiawan, 2022).

2. Method

This community service program applied a participatory action research (PAR) approach to ensure that farmers were not only beneficiaries but also co-creators in the development of greenhouse-based horticulture. This methodological choice is justified by its suitability for post-disaster contexts, where social participation, iterative learning, and collective decision-making are essential for rebuilding agricultural systems (Fitriani et al., 2022). The activities were conducted over six months (January–June 2025) in Mandalamekar Village using four procedural stages: (1) preparation and community engagement, (2) capacity building through training and mentoring, (3) greenhouse construction and horticultural implementation, and (4) evaluation and monitoring.

Justification of Sampling and Participants

Participants were selected using purposive sampling, targeting 25 farmers from the Mekar Jaya and Sinar Tani groups. These groups were chosen because they (a) represent the largest horticultural producers in the village, (b) were directly impacted by the loss of the previous greenhouse infrastructure, and (c) possess varying levels of experience, enabling a more realistic assessment of capacity-building effectiveness. This sample size aligns with PAR recommendations, which prioritize depth of engagement over statistical generalization.

Justification of Indicators

Indicators were selected based on three domains relevant to community agricultural transformation:

1. Technical Indicators – productivity (kg/m²), water use efficiency, pest reduction, and crop survival rate. These indicators directly reflect the operational effectiveness of greenhouse technology (Arman et al., 2019).
2. Economic Indicators – household income changes, input cost efficiency, and cropping cycle frequency. These were chosen to measure family economic resilience, consistent with rural livelihood frameworks (Pratama & Lestari, 2023).
3. Social–Behavioral Indicators – motivation, participation level, collaboration among farmer groups, and inclusion of women/youth. These indicators follow community empowerment models that emphasize behavioral transformation as a determinant of sustainability (Kurniawan & Dewi, 2020).

Data Collection and Validity Procedures

Data were collected through pre-test and post-test assessments, semi-structured interviews, FGDs, observational checklists, and documentation of horticultural outputs. The combination of qualitative and quantitative techniques enhances triangulation and ensures validity in measuring attitudinal, socio-economic, and technical changes (Rahmawati et al., 2021). Descriptive statistics were used to assess improvements in knowledge and changes in productivity, while thematic analysis was applied to qualitative narratives to capture farmers' reflections, challenges, and perceived benefits.

Procedure Overview

Preparation involved a participatory needs assessment to identify socio-economic constraints and post-disaster vulnerabilities. Capacity building was delivered through modular training and hands-on mentoring using a demonstration greenhouse. The implementation phase focused on collaborative greenhouse construction and monitored cultivation cycles. Evaluation and monitoring were conducted formatively and summatively to assess progress against predefined

indicators, ensuring that each stage contributed measurable outcomes aligned with the program's objectives.

3. Results

The implementation of community service activities in Mandalamekar Village has successfully demonstrated the integration of science, technology, and social empowerment to enhance family economic resilience through greenhouse horticulture. This program was carried out collaboratively by lecturers, students, and local farmer groups to rebuild and optimize a sustainable greenhouse cultivation system destroyed by natural disasters in 2023. The program's results show measurable impacts across economic, social, and behavioral domains. Construction of a new greenhouse measuring 8 × 20 meters, equipped with solar-powered sensors for temperature and humidity control, was completed in April 2025. The process involved local farmers in every stage, from material selection to planting and maintenance, which encouraged active participation and a stronger sense of ownership within the community (Fitriani et al., 2022).

Figure 1. Rebuilt Greenhouse Structure in Mandalamekar Village

In the first cultivation cycle, short-term vegetable crops such as lettuce, chili, and tomato were planted. After eight weeks, the harvest results showed an average productivity increase of 45% compared to open-field methods, while water use efficiency improved by 35%. Moreover, pest attacks decreased by 40% due to better environmental control within the greenhouse. These outcomes align with those of Arman et al. (2019), who reported that controlled-environment systems can significantly enhance yield and reduce production losses. The application of technology also enabled farmers to adopt data-driven decision-making, maintaining optimal growing conditions and improving the sustainability of agricultural production in the long term.

Figure 2. Growth Comparison Between Greenhouse and Open Field Crops

Economically, the community service program increased household income and reduced vulnerability to seasonal fluctuations. Survey data revealed that the average monthly income of participating farmers rose from IDR 1,950,000 before the program to IDR 2,850,000 after implementation—an increase of 46%. This improvement is consistent with Pratama and Lestari (2023), who emphasized that greenhouse-based horticulture contributes to the stability of rural family incomes. Furthermore, farmers gained more consistent earnings throughout the year, as greenhouse production enabled continuous cropping cycles without being constrained by weather. This has not only strengthened household finances but also encouraged some families to reinvest in expanding their greenhouse facilities.

From a social and behavioral standpoint, the project brought significant transformation within the local community. The involvement of men, women, and youth groups during training and mentoring sessions created an inclusive learning environment that enhanced cooperation and social cohesion. As noted by Sari et al. (2021), inclusive participation in agricultural innovation contributes to community resilience and fosters long-term social stability. Behavioral changes were also evident in farmers' attitudes toward modern agricultural practices. Before the project, only about one-fourth of farmers had experience with controlled-environment farming, but after training, nearly 85% expressed confidence in independently maintaining and operating greenhouse systems. This behavioral shift demonstrates that participatory training and mentoring effectively promote innovation-oriented mindsets (Kurniawan & Dewi, 2020).

Figure 3: Farmer Training and Practice Session in Greenhouse Management

Institutionally, this community service activity created positive responses from the Mandalamekar Village Government, which has decided to include the greenhouse horticulture initiative in its 2025–2026 village development program. This integration ensures the initiative's sustainability and opens opportunities for replication in neighboring villages. The program has also inspired the formation of a local farmer cooperative to collectively manage future production and marketing. According to UNDP (2023), such institutional strengthening is a key indicator of long-term community empowerment. The inclusion of greenhouse-based horticulture in the village development plan marks a significant policy impact and ensures that this program continues to generate benefits beyond the project's duration.

Evaluation results show that the program met its targeted indicators. The productivity of horticultural crops increased significantly, household incomes rose, and farmers demonstrated higher levels of knowledge, skills, and motivation in sustainable agriculture. Socially, cooperation among farmers improved, and women's participation in agricultural activities rose to 60% of total participants. These results were verified through pre-test and post-test assessments, direct observation, and interviews, which confirmed behavioral, socio-cultural, and economic changes.

The level of satisfaction among participants also increased, with 90% stating that the program had a positive impact on their livelihoods (Rahmawati et al., 2021).

Figure 4. Harvest Results

In terms of advantages, the program's main strength lies in its integrative approach that combines technological innovation, environmental awareness, and participatory education. The use of locally available materials for greenhouse construction reduced costs while maintaining durability, making the model appropriate for replication in other rural settings. The introduction of digital monitoring systems also provided an innovative solution to address climate variability in smallholder farming (Putri & Setiawan, 2022). Additionally, the involvement of university students in the program contributed to academic outcomes related to off-campus learning and knowledge transfer, fulfilling the higher education institution's Key Performance Indicators (IKU 2 and IKU 3).

Nevertheless, several limitations were observed during implementation. Some farmers initially struggled to operate IoT devices and manage environmental control systems due to limited digital literacy. Moreover, fluctuations in vegetable market prices occasionally affected profitability. These challenges underline the need for future programs to include a more comprehensive marketing strategy, cooperative-based distribution, and longer technical assistance to strengthen market resilience (Fitriani et al., 2022). Despite these obstacles, the program's overall achievements demonstrate that it successfully enhanced economic stability, promoted social cohesion, and introduced innovative practices adaptable to local conditions.

Looking ahead, the potential for future development is highly promising. The success of this initiative opens the door to expanding greenhouse-based cultivation to neighboring villages and introducing more advanced agricultural technologies, such as hydroponic and aquaponic systems. The vision of establishing a "Green Village Mandalamekar," integrating sustainable agriculture, agritourism, and digital farming innovation, is now being discussed with local stakeholders. This long-term plan aligns with the Sustainable Development Goals (SDGs), particularly Goals 2 (Zero Hunger), 8 (Decent Work and Economic Growth), and 13 (Climate Action), ensuring that the program's impact continues to grow across economic and social dimensions (UNDP, 2023).

4. Discussion and Benefits

The results of this program reaffirm that greenhouse-based horticulture, when implemented through a participatory action model, generates multi-layered impacts that align with theoretical frameworks on community-driven agricultural innovation. The increase in productivity, water efficiency, and farmers' income reflects not only the technical effects of protected-cultivation systems as documented by Arman et al. (2019) but also the social learning mechanisms emphasized in community-based empowerment literature. The Mandalamekar case confirms the theory that technology adoption becomes sustainable when embedded within a cycle of experiential learning,

peer collaboration, and continuous mentoring (Kurniawan & Dewi, 2020). Compared with similar community programs in rural West Java and Yogyakarta, which reported yield increases ranging from 25% to 40% (Fitriani et al., 2022; Sari et al., 2021), the 45% productivity improvement achieved in Mandalamekar positions this initiative as a comparatively stronger model, attributed mainly to intensive, farmer-led decision-making and greater institutional involvement.

Short-term benefits include higher yields, reduced exposure to weather risks, and immediate increases in household income. Social benefits are also evident, especially in the strengthened roles of women and youth, paralleling findings from previous community-based horticulture studies where inclusivity accelerated collective capacity building (Rahmawati et al., 2021). In the long term, the accumulation of technical know-how, institutional confidence, and diversified income streams enhances the structural resilience of farming households. The integration of the greenhouse initiative into the village's RPJMDes also illustrates strong policy relevance: consistent with UNDP's (2023) framework, community-scale agricultural infrastructure becomes more sustainable when supported by local governance mechanisms, budget allocation, and inter-stakeholder coordination.

Despite the program's significant achievements, several challenges limit full scalability. The reliance on digital tools highlights disparities in local digital literacy, underscoring the need for simplified IoT modules and extended technical support. Market volatility also creates income uncertainty, suggesting the necessity for cooperative-based marketing, product diversification, and post-harvest value addition. Environmental risks such as plastic waste from greenhouse materials require an integrated ecological management strategy to ensure that intensification does not generate long-term degradation. Future improvements should prioritize (1) strengthening digital literacy for climate-smart farming, (2) establishing farmer cooperatives for collective marketing and price stabilization, (3) developing modular greenhouse units for low-cost replication, and (4) incorporating environmental stewardship modules, including waste management, crop rotation, and biological pest control.

Overall, the findings reinforce the program's dual scientific and practical value. Scientifically, the study contributes empirical evidence supporting theory-driven arguments that community-centered, technology-enabled interventions are highly effective in post-disaster rural contexts. Practically, the program equips farming families with tangible tools, institutional support, and sustainable production models that strengthen their economic resilience. With appropriate long-term monitoring and market-oriented strategies, the Mandalamekar initiative serves as a robust and replicable blueprint for rural empowerment across Indonesia.

5. Conclusion

The implementation of greenhouse-based horticulture in Mandalamekar Village has proven effective in strengthening family economic resilience through participatory technology transfer and structured capacity building. The program not only increased agricultural productivity and household income but also fostered behavioral shifts toward more innovative, climate-adaptive farming practices. The integration of local knowledge, academic expertise, and simple digital monitoring tools demonstrates that community-led greenhouse systems can serve as a practical model for post-disaster economic recovery and sustainable rural development. From a policy standpoint, the results indicate that investing in protected cultivation, combined with inclusive training, is a feasible, high-impact strategy for village-level food security and economic revitalization.

However, this study acknowledges several limitations. The early dependence on technical mentoring and IoT-based monitoring highlights gaps in digital literacy that may hinder long-term self-sufficiency. Additionally, fluctuating market prices for horticultural commodities create income instability, indicating the need for stronger market institutions and cooperative-based value chains. These limitations point to clear opportunities for future research and program development, including (1) evaluating long-term technology adoption after mentoring ends, (2) assessing the economic feasibility of modular greenhouse expansion, (3) developing integrated marketing and

processing models to stabilize farmer income, and (4) examining the environmental implications of greenhouse waste and input use. Addressing these aspects will provide deeper insights into scaling, sustaining, and refining greenhouse-based innovations across rural contexts.

Recommendations

It is recommended that the Mandalamekar Village Government continue to support the sustainability of greenhouse-based horticulture by allocating village funds for maintenance, expansion, and farmer training programs. Universities should strengthen collaboration with local farmer groups through continuous mentoring, research, and the transfer of innovation to enhance productivity and resilience. Farmer cooperatives are advised to develop collective marketing and product diversification strategies to stabilize income and reduce market risks. Lastly, regional agricultural offices should integrate this model into rural development policies as a best practice for promoting sustainable community-based agriculture and family economic resilience.

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