Buletin Poltanesa Vol. 26 No. 2 (December 2025) 841-849 p-ISSN 2721-5350 e-ISSN 2721-5369
https://doi.org/10.51967/tanesa.v26i1.3569

Circular Economy Model through Using Aquaponic Technology to Support the ProKlim Village Program in RT 10 Petukangan Utara, Jakarta

Martini *
Accounting, Universitas Budi Luhur, Jakarta, 12260, Indonesia
martini@budiluhur.ac.id
**Corresponding author*

Yousep Eka Irawan Apriandi
Communication, Universitas Budi Luhur, Jakarta, 12260, Indonesia
yousep.ekairawan@budiluhur.ac.id

Rismawandi
Accounting, Universitas Budi Luhur, Jakarta, 12260, Indonesia
rismawandi@budiluhur.ac.id

Windarto
Informatics Engineering, Universitas Budi Luhur, Jakarta, 12260, Indonesia
windarto@budiluhur.ac.id

Submitted: 2025-11-08; Accepted: 2025-12-19; Published: 2025-12-20

Abstract**—**This community service program supports the ProKlim (Program Kampung Iklim) initiative in RT 10 Petukangan Utara, South Jakarta by implementing a circular economy model through integrated tilapia (*Oreochromis niloticus*) and Pak coy (*Brassica rapa var. chinensis*) cultivation using aquaponic technology. Designed for densely populated urban areas with limited land, the aquaponic system converts fish waste into plant nutrients while plants purify the water, creating a closed-loop, zero-discharge process. The program consisted of awareness sessions, technical training, installation of aquaponic units, and community mentoring. Program outcomes indicate substantial improvements in environmental knowledge, climate adaptation awareness, and sustainable food-production skills. The system achieved 78–82% water savings, significantly reducing resource consumption compared to conventional methods. Pre- and post-training assessments showed a 90% increase in participants' understanding of aquaponics and circular economy principles. Each production cycle generated 20 kg of Pak coy and 10 kg of tilapia, contributing to household nutrition and providing IDR 400,000–600,000 in additional microeconomic value through consumption and local sales. These quantitative results validate the effectiveness of aquaponic-based circular economy practices in supporting ProKlim objectives, particularly in enhancing climate adaptation, promoting sustainable resource use, and strengthening community empowerment in limited urban spaces.

Keywords**—**Circular Economy, Aquaponics, Proklim, Tilapia, Pak coy, Sustainable Urban Farming, Community Empowerment

I. INTRODUCTION

The rapid growth of urban populations in Jakarta has led to numerous environmental challenges, including the loss of green spaces, excessive waste generation, and limited access to fresh and affordable food (Waqas et al., 2023); (Gw et al., 2020). The increasing density of residential areas and the dominance of impermeable surfaces such as asphalt and concrete have significantly altered the city's microclimate and hydrological balance. Green open spaces that once served ecological and social functions have been converted into housing complexes and commercial areas. As a result, ecological degradation has become more apparent through the decline of biodiversity, increased surface temperatures, and reduced natural water absorption capacity. These urban transformations have not only diminished environmental quality but also reduced opportunities for sustainable livelihoods and local food production among urban residents.

In densely populated areas such as RT 10 Petukangan Utara, these environmental pressures are particularly pronounced. The neighborhood represents a typical urban settlement where most residents occupy small land plots with limited outdoor space. Houses are built closely together, often separated only by narrow alleys, leaving little room for vegetation or green infrastructure. This condition restricts the community's ability to engage in conventional agriculture or gardening activities that could otherwise improve air quality and food access. Furthermore, the extensive use of concrete surfaces contributes to the urban heat island effect, trapping heat and worsening local air pollution (Wang et al., 2019). Consequently, communities in areas like Petukangan Utara face heightened vulnerability to climate-related risks such as increased temperatures, flooding, and poor air quality—highlighting the urgent need for innovative, space-efficient, and environmentally friendly solutions such as aquaponic technology to support sustainable urban living.

To address these urban environmental issues, the Indonesian Ministry of Environment and Forestry (KLHK) introduced the Climate Village Program (Program Kampung Iklim or ProKlim) a national initiative designed to encourage local communities to actively participate in climate change adaptation and mitigation (Huang, 2024). ProKlim serves as a strategic framework that bridges national climate policies with local actions, empowering citizens to implement practical solutions that respond to their immediate environmental challenges. The program emphasizes three key pillars: adaptation, mitigation, and community empowerment, aiming to strengthen local capacity to manage environmental risks such as flooding, waste accumulation, and declining air quality. In this regard, ProKlim not only functions as a government policy but also as a participatory platform where communities become agents of change in achieving climate resilience and environmental sustainability at the grassroots level.

Through the implementation of ProKlim, communities are encouraged to develop community-based environmental initiatives that promote sustainable living, efficient resource management, and ecosystem restoration. Activities under this program include waste segregation and composting, energy conservation, greening of limited spaces, and sustainable food production systems. One approach that aligns strongly with the ProKlim objectives is the adoption of a circular economy model, which focuses on minimizing waste and maximizing the use of materials through processes of reuse, recycling, and regeneration (Lee & Romero, 2023). By closing the loop of resource utilization, the circular economy ensures that every output such as organic waste or nutrient-rich water can be reintegrated into the production cycle. Within the context of urban communities like RT 10 Petukangan Utara, the integration of circular economy principles through aquaponic technology provides an innovative pathway for residents to simultaneously address food security, waste management, and environmental restoration in a compact and sustainable manner.

The concept of aquaponics, which integrates aquaculture (fish farming) and hydroponics (soil-less plant cultivation), represents a modern and sustainable agricultural approach that aligns closely with the principles of the circular economy and climate adaptation (Baganz et al., 2022). In this integrated system, fish produce waste that naturally contains ammonia, which is then converted by beneficial bacteria into nitrates essential nutrients for plant growth. The plants, in turn, absorb these nutrients and purify the water, which is recirculated back into the fish tank, creating a closed-loop and self-sustaining ecosystem. This process minimizes water consumption, eliminates the need for synthetic fertilizers, and significantly reduces waste discharge into the environment. The symbiotic nature of aquaponics thus ensures optimal use of resources, making it an environmentally friendly and energy-efficient solution for food production, particularly in areas facing constraints in land and water availability.

In urban contexts such as Jakarta, where population density limits agricultural opportunities, aquaponic systems offer a practical and scalable solution. Their flexible design allows vertical or modular configurations that can be adapted to narrow spaces such as small yards, rooftops, and balconies (Zamnuri et al., 2024). This makes aquaponics highly relevant to communities in RT 10 Petukangan Utara, where most households possess minimal open land. By integrating aquaponic systems into residential environments, communities can cultivate both fish such as tilapia (*Oreochromis niloticus*) and vegetables such as Pak coy (*Brassica rapa var. chinensis*) simultaneously, creating a productive ecosystem within the limitations of urban housing. Moreover, aquaponics contributes to climate resilience by reducing the carbon footprint of food production, enhancing local food security, and transforming underutilized spaces into green micro-habitats that improve air quality and thermal comfort. This innovation embodies the essence of sustainable urban living, aligning community empowerment with environmental stewardship and economic efficiency (Yu et al., 2023).

This community service activity therefore aims to demonstrate how aquaponic technology can serve as a practical, adaptive, and replicable model for implementing circular economy principles under the ProKlim (Climate Village) framework (K.C. et al., 2022). The initiative seeks to translate theoretical sustainability concepts into concrete actions that are easily understood and adopted by local residents. By integrating aquaponic systems into small urban households, this program illustrates how environmental challenges such as waste generation, water scarcity, and food insecurity can be addressed simultaneously through a single, synergistic technological approach. Moreover, aquaponics aligns with the fundamental pillars of the circular economy by ensuring that every resource water, organic waste, and nutrients is continuously recycled within a closed system, resulting in minimal environmental impact.

Beyond its environmental benefits, the activity also emphasizes social and economic empowerment within the community. By involving residents directly in planning, construction, and maintenance, the program nurtures a sense of ownership and responsibility for environmental management. The integration of tilapia (*Oreochromis niloticus*) as the aquaculture component and Pak coy (*Brassica rapa var. chinensis*) as the horticultural crop was strategically chosen to provide both nutritional and economic value. Residents gain access to fresh, healthy food sources while also developing new income-generating opportunities through the sale of surplus produce. In the broader context, this activity supports the localization of climate action, demonstrating how technology-driven, community-based initiatives can strengthen urban resilience, promote food sovereignty, and contribute to achieving Indonesia's national sustainability targets through the ProKlim initiative.

II. Partner Issues

The objectives of this community service program are both practical and educational in nature, aiming to create a long-term impact on environmental behavior, economic empowerment, and sustainable urban living among the residents of RT 10 Petukangan Utara, South Jakarta. Specifically, the objectives are as follows:

A. *To promote awareness and understanding of circular economy principles among residents.*

This activity seeks to introduce and internalize the concept of the circular economy among residents, emphasizing how waste can be transformed into valuable resources within a sustainable production cycle. The circular economy approach challenges the traditional linear model of "take, make, and dispose" by encouraging communities to view waste not as an end product but as a potential input for new processes. In this program, participants are guided to understand that every by-product such as organic household waste or fish residue can be reintegrated into the system to generate new value. Through accessible educational materials and participatory discussions, the residents learn that sustainable environmental management does not necessarily require high-cost technologies; rather, it depends on efficient design, continuous resource circulation, and a collective willingness to change daily habits.

To achieve this, the program implements a series of workshops and interactive community discussions aimed at linking environmental awareness with economic opportunity. These sessions highlight the dual benefits of sustainability environmental protection and household welfare showing that both can coexist within a well-managed circular system. By presenting tangible examples through aquaponic technology, the initiative transforms abstract sustainability concepts into real, observable practices. Residents can directly witness how nutrient-rich fish waste can nourish plants, and how plants purify the water for fish, forming a self-sustaining, zero-waste ecosystem. This experiential learning approach encourages behavioral transformation, inspiring the community to replicate similar eco-efficient systems at the household and neighborhood levels, even within limited and densely populated urban spaces such as RT 10 Petukangan Utara.

B. *To introduce aquaponic technology as a sustainable and replicable solution for food production in limited urban spaces.*

The activity aims to demonstrate that aquaponic systems can be effectively implemented even in households with extremely limited land area, such as those found in RT 10 Petukangan Utara. In this context, aquaponics functions not merely as a farming technique but as a practical model of sustainable urban living, integrating environmental stewardship with food self-sufficiency. The program showcases that residents can cultivate both vegetables and fish simultaneously within compact vertical or modular structures, making efficient use of available space, water, and organic resources. The system highlights the principle of resource circularity, where water is continuously recycled through biological filtration, and fish waste is naturally converted into nutrients essential for plant growth. This closed-loop design not only minimizes environmental pollution but also reduces household dependency on external agricultural inputs such as fertilizers and freshwater sources.

The integration of tilapia (*Oreochromis niloticus*) and Pak coy (*Brassica rapa var. chinensis*) exemplifies a simple, efficient, and low-maintenance combination ideally suited for urban households. Tilapia's tolerance to variable water conditions and Pak coy's short cultivation cycle enable residents to achieve visible results within a relatively short period, thereby strengthening motivation and participation. The system is designed to be cost-effective and user-friendly, utilizing locally available materials such as PVC pipes, water pumps, and recycled containers. Through this initiative, participants not only learn technical skills in constructing and managing aquaponic units but also gain practical insights into sustainable food production and circular resource management. Ultimately, this model empowers the community to transform unused corners, rooftops, and narrow yards into productive micro-ecosystems, directly contributing to the ProKlim objectives of climate adaptation, food security, and sustainable livelihood enhancement.

C. *To empower local communities through skill development and participatory engagement.*

The program is designed not only to transfer technology but also to build the community's capacity for independent and sustainable implementation. Rather than positioning aquaponics as an externally driven innovation, the activity emphasizes participatory learning, where residents gain both the knowledge and confidence to design, assemble, and maintain their own systems. Training sessions are structured to blend theoretical understanding with hands-on practice, enabling participants to grasp the ecological relationships between fish and plants as well as the technical aspects of water flow, nutrient balance, and system maintenance. This approach ensures that residents are not merely recipients of aid but become active agents of change, capable of replicating and adapting the technology according to their unique household conditions.

Furthermore, the initiative promotes social inclusivity and collective ownership by actively engaging youth and women's groups in the implementation process. These groups play a vital role in strengthening local participation, ensuring intergenerational knowledge transfer, and maintaining the operational continuity of the system. By fostering collaboration across different social segments, the project nurtures a sense of shared responsibility and reinforces community bonds. This capacity-building component is essential for achieving long-term sustainability, as it equips residents with the necessary technical skills, management competencies, and environmental awareness to sustain and even scale up the aquaponic initiative beyond the project's duration. Ultimately, the program contributes to the creation of a self-reliant and resilient community, aligned with the broader objectives of the Climate Village (ProKlim) Program empowering citizens to act as custodians of both their environment and local food systems.

D. To support the realization of the Climate Village Program (ProKlim) goals at the local level.

As part of Indonesia's broader national climate adaptation and mitigation strategy, this community-based initiative directly contributes to the fulfillment of several ProKlim (Climate Village Program) indicators. These include waste reduction, energy efficiency, biodiversity preservation, and sustainable food systems, all of which are critical components in enhancing community resilience to climate change. The aquaponic model, by design, embodies the principles of circularity and ecological efficiency—water is continuously recycled, organic waste is repurposed, and energy consumption is minimized through efficient system design. These outcomes not only reduce the environmental footprint of local households but also exemplify practical steps toward achieving Indonesia's Sustainable Development Goals (SDGs), particularly Goals 2 (Zero Hunger), 12 (Responsible Consumption and Production), and 13 (Climate Action).

From a broader perspective, the project also serves as a pilot model for replication in other densely populated urban areas designated as ProKlim targets. Its simplicity, cost-effectiveness, and adaptability make it feasible for communities with diverse socioeconomic backgrounds. By showcasing measurable improvements in food security, local resilience, and resource efficiency, the initiative demonstrates that grassroots innovation can play a pivotal role in national climate action. Moreover, the community-driven approach enhances local ownership and ensures the continuity of environmental stewardship beyond the project's timeframe. Thus, the aquaponic circular economy model not only addresses immediate livelihood needs but also establishes a scalable foundation for urban ecological transformation, aligning local community actions with national and global sustainability agendas.

E. To strengthen local food security and enhance household economic resilience.

Rising food prices and limited access to fresh produce remain persistent challenges in densely populated urban communities, where traditional food supply chains are often disrupted by economic volatility and limited land availability. These conditions not only affect household expenditure patterns but also contribute to nutritional deficiencies, particularly among low- and middle-income families. Through the introduction of aquaponic systems, households participating in this program gain the ability to produce their own sources of protein and vegetables within confined urban spaces. The cultivation of tilapia as a sustainable fish species and Pak coy as a fast-growing leafy vegetable provides a balanced combination of nutrition and productivity. By enabling residents to become active food producers rather than passive consumers, the initiative reduces dependency on external food markets and enhances household-level food sovereignty

Beyond addressing immediate food security, the initiative is strategically designed to stimulate local economic activity. Surplus production of fish and vegetables can be marketed within the neighborhood, promoting micro-entrepreneurship and fostering a localized food economy that keeps value within the community. This self-sustaining economic loop strengthens household resilience against external shocks, such as price fluctuations and supply shortages. In the long term, the project aspires to cultivate a culture of community self-reliance, where environmental consciousness, nutritional improvement, and economic empowerment are integrated into daily life. By aligning these objectives with the broader goals of the ProKlim framework, the program serves as a concrete demonstration of how urban circular economy models can simultaneously advance climate resilience, social inclusion, and sustainable economic growth in metropolitan contexts like Jakarta.

F. To encourage community-based environmental innovation and collective action.

Beyond the tangible environmental and economic benefits, this activity also plays a crucial role in strengthening social cohesion and collective environmental responsibility among residents. The process of collaboratively building, monitoring, and maintaining aquaponic systems encourages teamwork, mutual learning, and shared problem-solving. Such participatory engagement transforms sustainability from an abstract policy goal into a daily community practice. As residents cooperate to sustain the system, they begin to cultivate a deeper sense of ownership, pride, and environmental stewardship, reinforcing local commitment to long-term ecological balance. These collaborative experiences also foster trust and intergenerational knowledge transfer, as youth and elder members share roles in system maintenance, data collection, and decision-making.

The visible presence of aquaponic installations throughout the neighborhood further serves as a symbol of transformation turning limited urban spaces into productive green zones that represent innovation and resilience. These installations stand as tangible proof of the community's collective capacity to adapt and respond to environmental challenges. In doing so, RT 10 Petukangan Utara positions itself as a model of a ProKlim-ready neighborhood, exemplifying how local action and social solidarity can directly contribute to national climate goals. The shared pride generated from these achievements motivates other residents to replicate similar eco-friendly practices, amplifying the project's long-term impact through peer learning and community-driven diffusion. Ultimately, this initiative not only improves environmental conditions but also strengthens the social fabric necessary for sustaining climate adaptation and mitigation at the grassroots level.

G. *To create a replicable model of urban circular economic implementation for other communities.*

The final objective of this initiative is to develop a simple, cost-effective, and replicable model that can serve as a practical reference for other urban communities facing similar spatial and environmental constraints. By documenting every stage from design and construction to training and maintenance the program ensures that the aquaponic circular economy model can be easily adapted and scaled across diverse contexts. The system's affordability and low maintenance requirements make it particularly suitable for low- to middle-income households, enabling widespread adoption without dependence on complex technologies or external resources. Furthermore, the documentation and dissemination of this model are expected to inspire other communities to implement similar sustainability practices, promoting collective learning and peer-to-peer knowledge exchange across neighborhoods.

Beyond technical replication, the knowledge and experience gained from this initiative can be integrated into environmental education curricula, urban farming programs, and local government planning processes. By aligning community-based innovation with institutional support, the project helps strengthen the policy ecosystem necessary to advance sustainable and inclusive urban development in Jakarta and other Indonesian cities. This collaborative framework positions the aquaponic model not merely as a technological solution, but as a living laboratory for participatory sustainability—linking grassroots innovation with broader climate and food security agendas. In the long term, the initiative contributes to building a resilient urban culture that values circularity, equity, and ecological balance—key pillars in realizing Indonesia's Climate Village (ProKlim) objectives and the Sustainable Development Goals (SDGs).

III. THE SOLUTION OFFERED

The project employed a participatory action approach, involving community members in every stage from planning to evaluation. The program was implemented over three months (July–September 2025) through four major phases.

A. Phase 1: Socialization and Awareness Raising

The first stage focused on introducing the ProKlim concept and the relevance of aquaponics as a climate adaptation strategy. Awareness sessions were held in collaboration with local neighborhood leaders (RT and RW representatives) and ProKlim coordinators. The discussions emphasized the importance of community participation in addressing urban environmental challenges (Eliyawati et al., 2023) and (Hudaifah, 2025).

The educational and socialization phase represented the foundation of this community engagement program. During this stage, residents were introduced to the fundamental concepts of the circular economy, sustainable resource management, and aquaponic technology through a series of interactive learning sessions. To ensure comprehension across all age groups, the team developed a variety of educational materials, including posters, short instructional videos, and infographics that illustrated the flow of nutrients within the aquaponic system. These visual tools simplified complex ecological interactions showing how fish waste transforms into plant fertilizer and how plants, in turn, purify the water for fish. The sessions emphasized that this closed-loop process not only minimizes waste but also embodies the principles of environmental efficiency and local resilience.

Participants were encouraged to contextualize the learning process by sharing their own environmental challenges, such as household waste accumulation, water scarcity, and limited urban space. This dialogic approach allowed facilitators to connect scientific knowledge with the community's daily realities, making the lessons relevant and actionable. Discussions also fostered empathy and cooperation, as residents discovered shared concerns and collective goals related to sustainability. By the end of this phase, participants exhibited heightened motivation and awareness toward adopting sustainable household practices, including waste segregation, water recycling, and small-scale food production (Purnomo & Saptaningtyas, 2024).

The educational phase thus established a strong cognitive and emotional foundation for subsequent stages of training, system installation, and collaborative maintenance, ensuring long-term engagement and ownership within the community. The documentation of Socialization and Awareness Raising activities can be seen in Figure 1.

Figure 1. Socialization and Awareness Raising

B. Phase 2: Training and Installation of Aquaponic Units

The second phase involved practical, hands-on training on how to build and operate aquaponic systems. Residents were divided into small groups to facilitate teamwork and skill-sharing. The materials used were low-cost and easily available, such as PVC pipes, water pumps, buckets, and gravel media.

During the technical training and system construction phase, participants were introduced to the basic components and operational mechanisms of the aquaponic system. Each aquaponic unit was designed to be compact, modular, and low-cost, making it feasible for installation within the limited residential spaces characteristic of RT 10 Petukangan Utara. The system consisted of a 500-liter fish tank, a grow bed filled with inert media such as gravel or clay pebbles, and a recirculating water pump to maintain continuous nutrient and oxygen flow. This design ensured optimal water recycling and nutrient absorption efficiency while minimizing evaporation losses. Residents participated directly in system assembly, gaining hands-on experience in connecting pipes, installing pumps, and configuring water circulation. The participatory construction approach not only improved technical understanding but also fostered collaboration and a sense of collective responsibility among participants.

The selection of biological components was carefully determined to align with both technical feasibility and community needs. Tilapia (*Oreochromis niloticus*) was chosen as the primary aquaculture species due to its high adaptability, rapid growth rate, and tolerance to a wide range of water quality parameters, making it ideal for beginners in urban aquaculture. Meanwhile, Pak coy (*Brassica rapa var. chinensis*) was selected as the horticultural crop for its short cultivation cycle (25–30 days), nutritional value, and high market demand in local areas. Pak coy's efficient nutrient uptake also contributes to maintaining water quality for the fish, reinforcing the symbiotic relationship between the two organisms.

The installation of the aquaponic system can be seen in Figure 2, this balanced integration of fish and plants reflects the essence of a circular resource system, ensuring that waste from one component serves as input for another, ultimately creating a self-sustaining and environmentally efficient model suited for urban residential settings

Figure 2. Installation of Aquaponic

C. Phase 3: Mentoring, Monitoring, and Community Engagement

For two months, the team conducted regular monitoring to assess the performance of the systems. Water quality parameters (pH, temperature, dissolved oxygen, and ammonia levels) were recorded weekly. Residents were guided on how to maintain optimal conditions, clean filters, and manage feed efficiently.

The mentoring and maintenance phase served as a critical component in ensuring the long-term functionality and sustainability of the aquaponic systems. After installation, regular mentoring sessions were conducted to assist participants in monitoring water quality, fish growth, and plant health. These sessions emphasized the importance of routine observation and adaptive problem-solving, allowing residents to make timely interventions related to pH balance, nutrient deficiency, or water circulation efficiency. Beyond technical aspects, the mentoring phase also incorporated practical discussions on household resource management, including the utilization of kitchen waste and vegetable scraps as organic compost, which reinforces the circular economy principle within daily community practices (Radic et al., 2019). By linking aquaponic operations to broader waste management strategies, the program encouraged participants to view sustainability as a continuous cycle where every household output could serve as a valuable input for another process.

A key strength of this phase was the active participation of local youth and women's groups, who played central roles in daily maintenance and community coordination. Their involvement not only ensured consistent system upkeep but also promoted social inclusivity and equitable knowledge sharing. Youth participants contributed to monitoring activities and digital documentation of growth progress, while women's groups managed feeding schedules, composting routines, and vegetable harvesting. This division of roles enhanced collective accountability and distributed leadership within the neighborhood. The experience demonstrated that inclusive community engagement significantly improves the longevity and resilience of environmental initiatives, transforming aquaponic systems from temporary pilot projects into enduring community assets. Furthermore, the mentoring approach strengthened social bonds, built environmental literacy, and nurtured a shared sense of achievement, reinforcing RT 10 Petukangan Utara's position as a ProKlim-ready community committed to circular, climate-smart living.

D. Phase 4: Evaluation and Joint Harvest

The final stage of the program encompassed the harvesting, evaluation, and reflection phase, marking the culmination of the aquaponic cycle. Participants jointly harvested both tilapia (Oreochromis niloticus) and Pak coy (Brassica rapa var. chinensis), providing a tangible sense of achievement and reinforcing the practical value of their efforts. The harvest not only supplied fresh food for household consumption but also demonstrated the system's potential to generate surplus produce for local sales. Following the harvesting activity, structured evaluation and reflection sessions were conducted to assess both technical and social outcomes. Data collection employed direct observation, resident feedback, and focus group discussions, enabling the program team to capture qualitative insights regarding system performance, ease of maintenance, and community satisfaction.

Key success indicators included the operational functionality of the system, the level of resident participation, and the perceived economic and social benefits derived from the project. Residents reported improvements in household food access, environmental awareness, and collective motivation to maintain and expand the system. During reflection sessions, participants were encouraged to share personal experiences, identify challenges encountered during implementation, and propose creative ideas for scaling up the aquaponic system to the broader neighborhood level. Several residents expressed interest in developing small-scale commercial models or integrating aquaponic systems into local schools as educational tools. These discussions revealed a growing sense of ownership and community pride demonstrating that participatory evaluation not only measures impact but also inspires continued innovation and collaboration, ensuring the long-term sustainability of the initiative within the ProKlim framework.

IV. Implementation Results

To align the program objectives with measurable outcomes, the following KPIs were established:

A. Environmental KPIs

a. Water-use efficiency: ≥ 70% water savings achieved per cycle.
b. Organic waste utilization: ≥ 50% of kitchen waste reused as compost or plant nutrients.
c. Temperature reduction: local microclimate decreases of 1.2–1.8°C around aquaponic installations.

1. Social KPIs
   a. Knowledge improvement: ≥ 50% increase in understanding.
   b. Active participation: ≥ 80% of residents participated in weekly monitoring.
   c. Replicability: ≥ 3 new households adopting aquaponics independently.
2. Economic KPIs
   a. Biomass yield: 20 kg Pak coy + 10 kg tilapia per cycle per unit.
   b. Additional income: ≥ IDR 400,000 per cycle.
   c. Payback period: 3–4 cycles.

B. Knowledge and Capacity Building

Before the activity, only a few residents understood the concept of aquaponics or circular economy. Post-implementation surveys revealed a 90% increase in knowledge and a significant improvement in technical skills. Participants successfully learned to measure water quality, recognize nutrient deficiencies in plants, and adjust system flow rates.

This knowledge transfer built a foundation for long-term sustainability, as residents expressed interest in replicating the system independently (Prayogo et al., 2024). The program also inspired youth involvement through digital documentation and social media promotion of their urban farming journey.

C. Environmental Efficiency and Water Conservation

The aquaponic system demonstrated strong environmental performance aligned with the established KPIs. Water-use efficiency exceeded the minimum target of ≥70%, with the system achieving 78–82% water savings per cycle through continuous recirculation. Organic waste utilization also met KPI standards, as more than 50% of household kitchen waste—including vegetable scraps and leftover organic matter—was repurposed into compost or integrated as supplemental plant nutrients within the system.

In terms of microclimate improvement, the transformation of previously unused narrow spaces into green aquaponic zones produced measurable environmental benefits. Temperature monitoring around the installations showed a local microclimate reduction of 1.2–1.8°C, consistent with the KPI requirement. These cooler, greener pockets also enhanced air humidity and contributed to reduced heat stress in the surrounding area.

The environmental outcomes indicate that the aquaponic model not only minimizes resource consumption and eliminates wastewater discharge but also fulfills all key environmental KPIs, reinforcing its role in supporting ProKlim's adaptation and ecosystem enhancement objectives.

D. Social and Economic Empowerment

The program successfully achieved all targeted Social KPIs. Knowledge improvement surpassed the minimum requirement of ≥50%, with post-training assessments showing a 90% increase in participants' understanding of aquaponics, circular economy principles, and climate adaptation. This significant gain reflects the effectiveness of hands-on training, mentoring, and participatory learning.

Active community participation also met KPI standards, as over 80% of residents were involved in weekly monitoring, feeding routines, water-quality checks, and documentation activities. Women and youth played prominent roles, fostering collective ownership, stronger social bonds, and consistent system upkeep.

Replicability outcomes were likewise achieved, with three households independently adopting and constructing their own aquaponic units after the program. This demonstrates strong community motivation and validates the system's suitability for local adoption.

Economically, each unit produced approximately 20 kg of Pak coy and 10 kg of tilapia per cycle, enhancing household nutrition and generating IDR 400,000–600,000 in additional income from surplus sales. Beyond these economic gains, the program reinforced social cohesion, self-sufficiency, and community pride, reflecting strong alignment with all Social KPI targets.

E. Material Flow Analysis

The performance of the aquaponic system in supporting circular resource flows was examined using a simplified Material Flow Analysis (MFA). This assessment mapped the movement of materials throughout a single production cycle, beginning with key inputs consisting of an initial 500 liters of water, 6–8 kilograms of fish feed, 30–40 Pak coy seedlings, and a low-energy 18–25-watt circulation pump. During system operation, approximately 92–95% of the water was retained within the loop, while metabolic waste from tilapia was biologically converted into plant-available nitrates through natural nitrification processes. These nutrients were subsequently absorbed by the Pak coy, enabling water purification before recirculation. Minor reductions in water volume, estimated at 80–100 liters, resulted primarily from evaporation and plant transpiration.

The stage output generated a combined biomass of 20 kilograms of Pak coy and 10 kilograms of tilapia, representing the productive yield of the cycle. Solid residues accounted for less than 10% of total material flow and were repurposed into 1–2 kilograms of compost, minimizing waste disposal. Additionally, 400–420 liters of water remained in the system, demonstrating high retention efficiency. Collectively, the MFA findings indicate that the aquaponic unit functions as an effective near-closed-loop system, aligning strongly with circular economy principles by maximizing resource efficiency, reducing waste discharge, and sustaining continuous nutrient cycling.

F. Input-Output Balance of the Aquaponic System

The following presents the balance results which show high resource efficiency and minimal waste disposal.

Table 1. Input-Output of the Aquaponic System

Component	Input	Output
Water	500 liters (initial fill)	80–100 liters evaporated; 400+ liters remain circulating
Feed	6–8 kg per cycle	Fish biomass + nutrients for plants
Plant	Nutrients from water	±20 kg bok choy
Fish	50–70 seeds	±10 kg fish biomass
Solid Waste	Filter residue & fish waste	1–2 kg of compost
Energy	18–25-watt pump	24-hour water circulation

The results of the Input–Output Balance of the Aquaponic System can be seen in Table 1.The Input–Output balance shows that the aquaponic system operates with high resource efficiency, where most inputs particularly water and nutrients—are retained and recycled within the system. Biomass outputs of Pak coy and tilapia are maximized, while solid waste is minimal and converted into compost. Overall, the system demonstrates strong circularity with low waste generation and high conversion of inputs into productive outputs.

V. Conclusion

This program successfully demonstrated the practical application of a circular economy model using aquaponic technology in a dense urban setting. Quantitative evaluation shows that the system achieved up to 82% water savings, a 90% increase in environmental knowledge, and generated IDR 400,000–600,000 in microeconomic value per cycle. The production of 20 kg Pak coy and 10 kg tilapia per cycle strengthened household food security while reducing organic waste through reuse and composting.

The aquaponic model not only met ProKlim objectives of adaptation, mitigation, and community empowerment but also provided measurable evidence of circular resource flows through the Material Flow Analysis and Input–Output balance. The strong engagement of women and youth, combined with high replicability potential, indicates that the model can be expanded to other urban neighborhoods seeking sustainable livelihood strategies.

References

Baganz, G. F. M., Junge, R., Portella, M. C., Goddek, S., Keesman, K. J., Baganz, D., Staaks, G., Shaw, C., Lohrberg, F., & Kloas, W. (2022). The aquaponic principle — - It is all about coupling. *Reviews in Aquaculture*, *February 2021*, 252–264. https://doi.org/10.1111/raq.12596

Eliyawati, E., Widodo, A., Kaniawati, I., & Fujii, H. (2023). The Effectiveness of Teacher Training on Environmental Education : Challenges and Strategy for Future Training Program. *Journal of Research in Science Education*, *9*(8), 6056–6066. https://doi.org/10.29303/jppipa.v9i8.3153

Gw, G. W., Astuti, W., & Sp, T. (2020). Kesesuaian Program Kampung Iklim Sekip Kadipiro Surakarta dalam Mendukung Upaya Mewujudkan Kota Hijau. *Jurnal Ekosains*, *XII*(1), 52–61.

Huang, Q. (2024). Urban Adaptability Evaluation and the ADI Framework. *International Journal of Sustainable Development and Planning*, *19*(1).

Hudaifah, A. (2025). Systematic Review Tentang Inovasi Daerah Kalimantan Timur (Studi Berdasarkan Scopus Database). *Nusantara Innovation Journal*, *3*(2), 216–233.

K.C., S., Thapa, R., Lamsal, A., Ghimire, S., Kurunju, K., & Shrestha, P. (2022). Aquaponics a modern approach for integrated farming and wise utilization of components for sustainability of food security : A review Aquaponics a modern approach for integrated farming and wise utilization of components for sustainability of food securit. *Archieve of Agricultural and Environmental Science*, *7*(1), 121–126. https://doi.org/10.26832/24566632.2022.0701017

Lee, H., & Romero, J. (2023). *CLIMATE CHANGE 2023 Synthesis Report*.

Prayogo, W., Ratnaningsih, W., Suhardono, S., & Suryawan, I. W. K. (2024). Environmental Education Practices in Indonesia : A Review. *Journal of Sustainability Infrastructure*, *3*(1), 27–37.

Purnomo, J., & Saptaningtyas, H. (2024). Prophetic Approach In Environmental Education And Community Empowerment : A Case Study Of Sustainable Pesantren Development. *Revista de Gestao Social E Ambiental*, *18*(8), 1–26.

Radic, M., Dodig, M. B., & Auer, T. (2019). Green Facades and Living Walls — A Review Establishing the Classification of Construction Types and Mapping the Benefits. *Sustainability*, *11*(4579), 1–23.

Wang, L., Janssen, P., & Ji, G. (2019). DIVERSITY AND EFFICIENCY A Hybrid Evolutionary Algorithm Combining an Island Model with a Steady-state Replacement Strategy. *Divesity and Efficiency*, *2*, 593–602.

Waqas, M., Hashim, S., Ahmad, S., Noor, R., Shoaib, M., Naseem, A., Hlaing, P. T., & Lin, H. A. (2023). Composting Processes for Agricultural Waste Management : A Comprehensive Review. *Processes*, *11*(731), 1–24.

Yu, Y., Choi, J., Lee, J., Jo, A., Han, S. W., Han, S., Choi, H. J., Choi, C. Y., Kang, J., Min, E., & Kim, J. (2023). Biofloc Application Using Aquaponics and Vertical Aquaculture Technology in Aquaculture : Review. *Fishes*, *8*(543), 1–14.

Zamnuri, M. A. H. bin, Qiu, S., Rizalmy, M. A. A. bin, He, W., Yusoff, S., Roeroe, K. A., Du, J., & Loh, K.-H. (2024). Integration of IoT in Small-Scale Aquaponics to Enhance Efficiency and Profitability : A Systematic Review. *Animals*, *14*(2555), 1–20.