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Pentahelix Collaboration in Aquagreen Sustainable Engineering

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ABSTRACT

The increasing global demand for sustainable solutions to environmental challenges has spurred interest in multi-stakeholder approaches such as the pentahelix collaboration. While widely promoted as a transformative pathway for sustainability, there is limited empirical evidence on its practical application in indigenous and resource-constrained contexts. Challenges such as reconciling diverse stakeholder priorities, addressing language and cultural barriers, and ensuring equitable participation often hinder effective implementation, risking the framework remaining more conceptual than operational. To explore these challenges, the Aquagreen initiative was introduced in Kampung Sungai Relang through a partnership among the International Islamic University Malaysia (IIUM), CIMB Foundation, Jabatan Kemajuan Orang Asli (JAKOA), the Malaysia Institute of Sustainable Agriculture (MISA), and the Orang Asli community. By establishing an integrated aquaculture–hydroponics system powered by solar energy, the project provides insight into the process, considerations, and the practical challenges of translating the pentahelix approach into practice in indigenous, resource-constraint settings. Its recognition with the 2024 RCE Award for Outstanding Flagship Project by the United Nations University – Institute for the Advanced Study of Sustainability (UNU-IAS) highlights its contribution to advancing collaborative sustainability initiatives in marginalised communities.

Keywords: Aquagreen engineering, Orang Asli community, pentahelix collaboration, water and land

1. INTRODUCTION

The growing urgency to address global environmental challenges has catalyzed the development of collaborative and sustainable frameworks. Among these, the pentahelix collaboration model which involves synergistic engagement between academia, government agencies, industry, civil society, and local communities has emerged as a promising approach to sustainable development [1-2]. This approach was applied in Kampung Sungai Relang, Selangor, Malaysia, through a partnership involving the International Islamic University Malaysia (IIUM), CIMB Foundation, Jabatan Kemajuan Orang Asli (JAKOA), the Malaysia Institute of Sustainable Agriculture (MISA), and the Orang Asli (OA) community of Kampung Sungai Relang. Historically, the OA residing in

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remote areas with limited socio-economic infrastructure have long faced challenges, such as the absence of electricity and access to clean water [3-4].

Officially commencing in November 2022, following the award letter from CIMB Foundation to IIUM for the community grant, this project aimed to establish a sustainable Aquagreen system that integrates aquaculture, hydroponics, and renewable energy solutions to improve food and water security for the OA community in Kampung Sungai Relang. Preliminary groundwork began earlier during the COVID-19 Movement Control Order (MCO), through liaison efforts between IIUM researchers and JAKOA officers to assess the critical conditions faced by the OA community. Due to the village's remote and geographically isolated location, the delivery of food aid and essential supplies distributed by governments and NGOs during MCO is often delayed in reaching the village. Figure 1 shows the map of Kampung Sungai Relang, accessible via a one-kilometre man-made pathway from the Kuala Lumpur–Karak highway towards the Sungai Tua recreational forest. Its geographical isolation has contributed to challenges in accessibility and service delivery, particularly during national emergencies.

Figure 1. Location of the community Orang Asli Kampung Sungai Relang (Google Map).

These insights led the IIUM team to develop a resilient, community-based solution grounded in sustainable methods and local empowerment. The project's contribution in improving the lives of the OA community through sustainable development and multi-stakeholder collaboration gained international acclaim, receiving the 2024 Regional Centres of Expertise on Education for Sustainable Development (RCE) Awards for Outstanding Flagship Project from the United Nations University – Institute for the Advanced Study of Sustainability (UNU-IAS) as presented in Figure 2, further confirming its impact and potential for expansion.

Figure 2. RCE Awards 2024.

The Kampung Sungai Relang project applied the pentahelix approach to deploy the Aquagreen system, an integrated food production model powered by solar energy. By drawing from indigenous knowledge, renewable energy innovations, and multi-stakeholder collaboration, this project provides empirical evidence on both the potential and challenges of operationalising pentahelix collaboration in an indigenous Malaysian context.

2. LITERATURE REVIEW

The need for inclusive and sustainable development in rural and marginalised communities has become increasingly urgent, particularly in addressing environmental and socio-economic vulnerabilities. One strategic approach that has gained traction is the pentahelix collaboration, which brings together academia, government agencies, civil society, the private sector, and local communities [1,5]. This study framework fosters holistic problem-solving by promoting shared responsibilities and leveraging the unique strengths of each stakeholder group.

A previous study introduced a sustainable livelihood model targeting underdeveloped areas, aiming to enhance local food security, environmental stewardship, and resilience among marginalised groups [6]. Similarly, integrated systems such as Aquagreen, which combine aquaculture and hydroponics supported by renewable energy, have been identified as promising community-based interventions. The success of such initiatives is often attributed to transparent communication, shared governance, capacity building, and community empowerment [2-3], principles also embedded in the design of the present study.

At the same time, multi-stakeholder projects are not without challenges. Common barriers include language and cultural differences, conflicting stakeholder interests, and funding constraints [5,7], which complicate collaborative implementation. These challenges highlight the need for adaptive approaches to ensure inclusivity and equity in project outcomes. Research into sustainable development within indigenous communities provides valuable lessons for addressing these barriers. In Malaysia, studies of Orang Asli agroforestry practices reveal deeply embedded, sustainable methods of food production. Indigenous forest-garden and home-garden systems, for example, have been shown to enhance household income and food security while

preserving biodiversity [8]. Beyond Malaysia, projects such as Murdoch University's collaboration with Aboriginal communities in Australia, which transforms energy access from diesel generators to hybrid solar-wind systems, demonstrate how renewable energy can empower remote communities toward self-sufficiency [9].

While these studies reveal the potential of multi-stakeholder approaches to advance sustainability, there remains a lack of understanding how the pentahelix collaboration can be effectively applied in indigenous, resource-constrained settings. This gap forms the basis of the current study, which examines the implementation of the Aquagreen initiative in Kampung Sungai Relang as a practical application of the pentahelix approach.

3. METHODOLOGY

This study employed a qualitative case study to explore the implementation and effectiveness of the pentahelix collaboration in establishing a sustainable Aquagreen system for the OA community in Kampung Sungai Relang, Selangor. The case study method was selected to enable an in-depth examination of stakeholder interactions, processes, challenges, and outcomes within a real-life, context-specific environment [10].

Data collection was carried out through focus group discussions with key stakeholders representing the five helices: academia (IIUM researchers), private sector (CIMB Foundation), government agency (JAKOA), civil society (MISA), and informal interviews with OA community representatives from Kampung Sungai Relang. In addition, informal interviews with community members were conducted to capture their perspectives and lived experiences. On-site observations and visual documentation were undertaken to monitor the progress of physical infrastructure, including fish tanks, hydroponic systems, and solar panels, as well as to record participatory activities involving the OA community. Furthermore, minutes of meetings were reviewed to identify and describe challenges encountered throughout the project implementation.

4. RESULTS AND DISCUSSION

Data were analyzed thematically using Braun and Clarke's six-phase approach [11], resulting in three main thematic categories: (i) roles and contributions of each helix, (ii) infrastructure progress of the Aquagreen system, (iii) challenges and adaptive responses.

4.1 Roles and Contributions of Each Helix

Each helix contributed uniquely to the project's success as illustrated in Figure 3. Quotes from the focus group discussion were shared to illustrate their contributions. IIUM led the project, liaising with all stakeholders, and provided technical expertise and community training sessions. "We wanted to ensure the knowledge shared is practical and empowering for the community," said Dr. Ahmad Zahirani Bin Ahmad Azhar, the Project Leader. JAKOA played a vital role in facilitating communication and logistical access to the site. "Understanding the community's rhythm and respecting their customs was key," noted Mr. Ahmad Suhaimi Bin Alias, Community Development Assistant Officer from JAKOA. MISA contributed agricultural know-how, guiding the adaptation of sustainable farming methods. "We tailored our methods to suit the local soil and community capability," explained Mr. Hud Bin Sulaiman, Founder and Chairman of MISA.

CIMB Foundation contributed financial support for the project's continuity. "Beyond funding, we aimed to build lasting impact and inclusivity," shared Mrs. Aainaa Amran, Corporate Responsibility Department, CIMB Bank Berhad. Most importantly, the OA community played an

active and central role in hands-on implementation. Based on JAKOA's advice, communication with the community was primarily channelled through Intan, the daughter of *Tok Batin*[1]. Together with her husband, Tuna, they led the local participation. "This project is not just for us, it's by us," Intan expressed during the informal interview. Tuna added, "When we work together like this, we feel visible."

Figure 3. Five Helices in Pentahelix Collaboration.

The implementation of the pentahelix collaboration, uniting academia, government, industry, social enterprise, and OA communities, has been shown to enhance stakeholder synergy, mutual accountability, and sustainable development outcomes [5,7]. Table 1 outlines each helix roles and contributions.

Table 1 Roles and responsibilities of each helix in the development of the Aquagreen system at Kampung Sungai Relang

Role	Responsible Helix	Contribution
Funding & Resources	CIMB Foundation (industry)	Provide financial support
Project Coordination	IIUM (academia)	Lead planning, report progress
Community Liaison	JAKOA (government)	Facilitation, mediate communication
Capacity Building	MISA (Social Enterprise)	Conduct OA trainings, follow-up
System Operation	OA Community	Fish feeding routine, water quality monitoring, tend and harvest the plants

[1]*Tok Batin* refers to the traditional headman or village chief of an OA community [4]

4.2 Development Progress of the Aquagreen System

The development progress of the Aquagreen system at Kampung Sungai Relang is summarised in Figure 4.

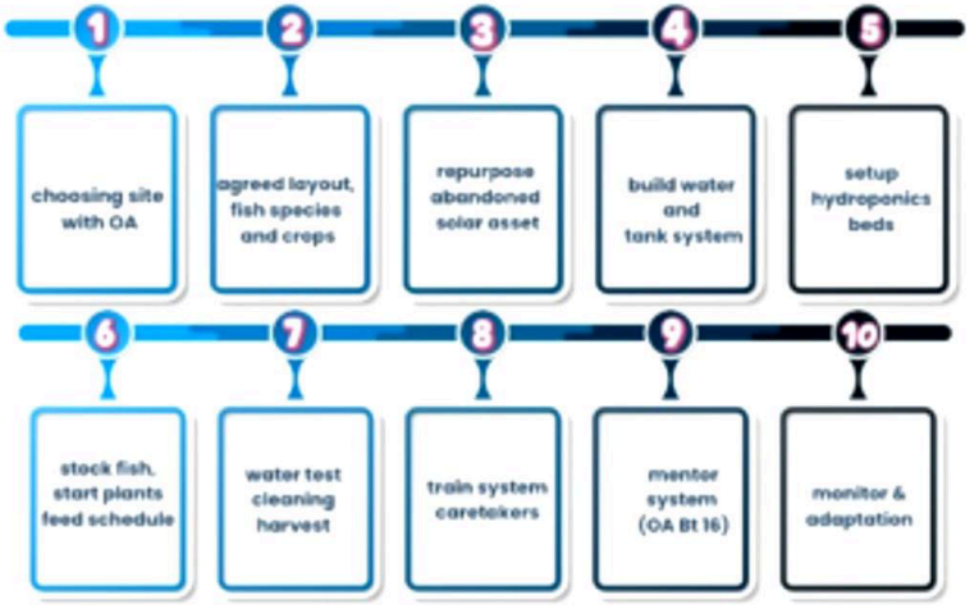

Figure 4. Development Progress of the Aquagreen System at Kampung Sungai Relang.

The proposed site was initially an undeveloped open space, as shown in Figure 5. It was subsequently transformed through the installation and commissioning of an integrated system comprising aquaculture tanks, hydroponic grow beds, and solar-powered pumps and lighting. The development process was monitored on-site through direct observation and visual documentation.

Figure 5. IIUM team, JAKOA officer, along with Intan and her children, took a photo at the proposed site for the installation of the Aquagreen system (November 2022).

Next, Figure 6 illustrates the installed Aquagreen system that began with tilapia fish and leafy greens. This setup integrates aquaculture and hydroponics, commonly known as aquaponics and has been widely recognized as a viable and sustainable solution for enhancing food security and supporting livelihoods, particularly in marginalized and off-grid communities [12].

Figure 6. Installation of Aquagreen system at Kampung Sungai Relang (October, 2023).

Meanwhile, Figure 7 shows Tuna planting salad seeds as part of the community participation activities embedded within the system. The hydroponic component, which is part of the integrated aquaponics setup, allows for the soil-less cultivation of leafy vegetables using nutrient-enriched water from the aquaculture system. This sustainable method maximises resource efficiency while promoting environmentally friendly agricultural practices [4, 12].

Figure 7. Tuna planting seed on the hydroponic set (November, 2023).

This project emphasises personalised training and mentoring guidance, ensuring that participants not only understand the technical aspects of the system but also develop the confidence to operate and manage it independently. This hands-on, tailored approach supports

knowledge retention and encourages deeper community engagement [2, 5]. By building local capacity, the project promotes long-term adoption, food security, and sustainable livelihoods in marginalised areas.

4.2.1 Renewable Energy Repurposing

A significant innovation in the project was the reuse of solar panels and battery units left over from a previously abandoned rural electrification project at Kampung Sungai Relang. These components, originally installed under a government initiative but never fully operationalised due to maintenance negligence, were refurbished and integrated into the Aquagreen system as shown in Figures 8 and 9.

Figure 8. Abandoned solar panel assets from a previous solar electrification project at Kampung Sungai Relang (October, 2023).

JAKOA plays an instrumental role in facilitating the process of repurposing solar assets and mentor system. This not only minimized costs but also embodied circular economy principles, adding value to otherwise wasted public assets and demonstrating the project's commitment to environmental sustainability [9, 13].

Figure 9. The abandoned battery units from a previous solar project at Kampung Sungai Relang (October, 2023).

The reuse of solar technology and the integration of off-grid renewable energy systems have proven effective in improving rural electrification [13]. The integration of solar panels enabled off-grid energy solutions, addressing the long-standing issue of a lack of electricity in the area. This outcome validates previous research indicating the effectiveness of renewable energy in rural farming initiatives [6].

4.3 Challenges and Adaptive Strategies

Despite the overall success of the project, several challenges emerged during the implementation phase, highlighting the complexities of multi-stakeholder collaboration in a rural, underserved context. Table 3 summarises the challenges through adaptive strategies.

Table 3 Key challenges countermeasure through adaptive management strategies

Challenges	Countermeasure
Conflicting Stakeholders Interests	Transparent Communications
Language & Cultural Barriers	Trusted Intermediaries
Funding Constraints	Repurposing Abandoned Assets
Limited Local Expertise	Peer-Mentoring System (experienced OA guiding new champions)

One major issue involved conflicting stakeholder interests, particularly in aligning institutional timelines, funding disbursement procedures, and decision-making protocols. These differences were managed through regular coordination meetings, facilitated dialogue, and transparent communication platforms that ensured all parties remained informed and engaged. In this context, adaptive management proved essential, particularly in projects involving diverse stakeholders. As a learn-by-doing approach, adaptive management embraces uncertainty and treats interventions as iterative experiments, allowing strategies to be refined over time [14-15]. Language and cultural barriers with the OA community also posed significant challenges, particularly at the initial stage of developing engagement and during technical training sessions. The involvement of the JAKOA officer, Mr Ahmad Suhaimi Bin Alias, was instrumental in overcoming these difficulties, as he had a long-standing engagement with the OA community and

possessed a deep understanding of their cultural practices and communication preferences. His trusted relationship with the community and the high level of respect the OA community placed in his role significantly facilitated smoother interactions between the project team and the OA community. His presence helped bridge communication gaps, build trust, and ensure that messages were conveyed in a culturally appropriate and respectful manner, thereby enhancing the effectiveness of the training and engagement processes. This aligns with previous findings that emphasised engagement with the indigenous community is more successful when facilitated through culturally embedded intermediaries who are trusted and respected by the local population [4,16].

Additionally, limited funding became a constraint in scaling up infrastructure and ensuring long-term maintenance. In response, the team adopted a resourceful approach by repurposing abandoned solar panels and battery units from a previous government project that had been left unused at the site. This approach has minimised project cost and, more importantly, exemplified sustainable resource utilization and circular economy principles. Given the limitations of project funding, collaborating with Yati, an experienced fish breeder from a neighbouring Orang Asli community who also operates an aquaponic system at OA community Bt 16 Gombak, served as an adaptive strategy. By leveraging her prior experience and willingness to mentor, the project strengthened local ownership and reduced reliance on external resources, thereby enhancing the sustainability of the Aquagreen system.

These adaptive strategies reflect the importance of flexibility, community participation, and shared problem-solving in ensuring the resilience and sustainability of complex development initiatives rooted in the pentahelix collaboration. This approach was supported by a previous study that reported resourcefulness, stakeholder collaboration, and local participation can help mitigate challenges in community-based projects [7,14].

5. CONCLUSION

The implementation of the Aquagreen system through the Pentahelix approach in Kampung Sungai Relang provides empirical insight into the processes of operationalising multi-stakeholder collaboration in indigenous, resource-constrained settings. By drawing on indigenous knowledge, renewable energy innovations, and collaboration between academia, industry, government agency, and social enterprise, the study highlights the coordination of aquaculture, hydroponics, and solar energy, alongside capacity-building strategies such as peer mentoring with experienced OA fish breeders. These observations illustrate the practical challenges and considerations involved in applying the Pentahelix approach for integrated, sustainable community development in geographically isolated areas.

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