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Original Article

# Empowering the Fatayat NU's Group in Karimunjawa Village Through IoT-Based Hydroponic

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## A B S T R A C T

[Title: **Empowering the Fatayat NU's Group in Karimunjawa Village Through IoT-Based Hydroponic**] Karimunjawa Village, located on Karimunjawa Island in Central Java, faces persistent food security issues due to geographical geographic isolation, limited agricultural area, and dependence on imported vegetables from Jepara at considerably elevated rates. Extreme weather causes transportation disruptions, leading to significant vegetable shortages. This community empowerment initiative concentrated on the Fatayat NU's Group. The intervention by combining hydroponic vegetable cultivation with Internet of Things (IoT) technology. Activities included institutional strengthening, training on hydroponic systems, IoT-based monitoring for optimum water.

The program facilitated access to hydroponic equipment, IoT devices, and vegetable seeds by providing structured training and mentoring. Fatayat NU's organizational capacity was improved, its members' technical skills in sustainable cultivation were improved, and the awareness of balanced nutrition was promoted. In turn, the implementation of IoT ensured a more consistent local vegetable production by reducing water consumption by 30% and the duration of the harvesting process.

In conclusion, the sustainable approach of empowering groups via IoT-based hydroponic farming offers a method to bolster economic resilience, and fortify food security in island communities such as Karimunjawa.



## 1. Background

Karimunjawa Island in Central Java Province has been established as a nat ional park since 2001 [1]. The Karimunjawa archipelago has numerous villages, namely Karimunjawa, Kemujan, Parang, Nyamuk, and Genting. Karimunjawa village is situated 137 km from Semarang city, with a population of 2,754 residents. It requires five hours to travel from Semarang and two hours from Jepara Regency [2]. Access to the Karimunjawa Islands is exclusively via PELNI ferry from Semarang Port and private speedboats from Jepara Regency Port. Unpredictable weather conditions have an impact on the availability of boat transportation. Schedule cancellations transpired due to inclement weather from January to February 2025, enduring for a duration of 7 days. This has affected the availability of food supplies [3]. A decrease in the availability of staple foods, particularly vegetables, has resulted from transportation disruptions, which has had an adverse effect on food security in the Karimunjawa Islands [4]. Processed fish, which comprised 79% of the total commodity in 2023, was consumed by the residents of Karimunjawa Village, totaling 14,850 tons [1], [3], [5].

Current circumstance analysis Karimunjawa Village continues to rely on vegetable imports from Jepara, with prices that are threefold higher; for instance, mustard greens cost Rp45,000/kg and lettuce costs Rp60,000/kg. Water spinach (32–43%), spinach, mustard greens, and spring onions [4], [6] are the primary vegetables required. Residents of

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Karimunjawa Village are only supplied with 21% of their requirements during periods of inclement weather (November–February). It is feasible to implement local cultivation, particularly during periods of extreme weather [7]. The government encourages food security by implementing the Free Nutritious Meal Program (MBG), which includes animal protein as a critical component. Vegetables, as a source of plant-based protein, can function as a fiber-rich supplement. These activities are consistent with the 2030 Sustainable Development Goals (SDGs) numbers 2 and 3 (8,9,10) and Indonesia's 2045 Golden Age Vision number 2. The economic income of Karimunjawa can be sustained by the demand for vegetables, as it is a tourist destination [3], [8].

**Figure 1**. Illustrates the outcomes of fish commodities and their processing.

Conventional cultivation is rendered unsustainable in Karimunjawa Village due to the sandy soil, and a limited supply of freshwater. To mitigate these limitations, hydroponic farming offers a feasible option. This technique expedites plant growth and enhances vegetable quality regarding size, color, and flavor, consequently augmenting their nutritional worth relative to traditional agriculture. Hydroponic methods encompass the formulation of growing media, seed propagation, regulated nutrient management, and methodical harvesting and distribution. In coastal regions like Karimunjawa, the implementation of hydroponics necessitates supplementary technical assistance to maximize limited freshwater supplies. The incorporation of Internet of Things (IoT) devices facilitates accurate monitoring and management of water and fertilizer utilization, enhancing efficiency and guaranteeing stable crop yields.

Approximately 9,000 residents and visitors have access to internet speeds of up to 75 Mbps through the 4G LTE network coverage in Karimunjawa, which is facilitated by three base transceiver stations (BTS). The island has been provided with a 24-hour electricity supply since 2015, which has established a dependable infrastructure for the implementation of Internet of Things (IoT) technologies. By precisely controlling the distribution of water, IoT-enabled hydroponic farming can save up to 30% on water use and 25% on fertilizer inputs when compared to traditional techniques. Because freshwater resources are limited in coastal places, this efficiency is especially important. Additionally, by reducing the harvest cycle from 40 to 30 days, IoT integration raises crop frequency by about 25%. These benefits demonstrate how IoT-based hydroponics can improve Karimunjawa's food supply and sustainability [9].

Despite the growing demand for vegetables, the Fatayat NU Women's Group has not yet completely maximized its potential in agricultural activities, particularly during periods of unpredictable extreme weather. Health services (Integrated Health Post), fish processing, and religious outreach comprise the group's routine responsibilities. The Fatayat NU community in Karimunjawa must be empowered through hydroponic vegetable cultivation, which is supported by Internet of Things (IoT) technology, in order to improve local food security and given the aforementioned circumstances.

## 2. Methods

The empowerment program was implemented in response to the Fatayat NU Group's inadequate knowledge and capabilities regarding hydroponic vegetable cultivation, in addition to the ongoing hazard of extreme weather conditions to vegetable supplies. Enabling the community to operate automated hydroponic systems more effectively is anticipated to be facilitated by the improvement of technological literacy in food production management. The goal of this project is to address local nutritional needs by producing high-quality vegetables with shorter production cycles and effective resource management. The program's ultimate goal is to increase food security and encourage self-reliance among Karimunjawa Village's inhabitants. This community empowerment program was implemented through a participatory approach that included socialization, training, technology implementation, mentoring, and sustainability evaluation.

The first stage was socialization, which was designed to increase the Fatayat NU Group's awareness of the the potential of hydroponic farming, which is facilitated by Internet of Things (IoT) technology. Hydroponic techniques for limited land areas, seed propagation, and the utilization of IoT devices for water and nutrient supply monitoring comprised the second stage of training. To evaluate the participants' increased knowledge and proficiency, a pre-test and post-test were administered. The third stage was the implementation of technology, which included the provision of hydroponic facilities, IoT devices, and vegetable seedlings. Participants actively participated in crop management, system installation, and digital plant growth tracking. In order to guarantee program efficacy, the academic team and students from the pharmacy, agriculture, and informatics departments offered ongoing technical and administrative support during the fourth stage, known as mentoring.

The last phase, evaluation and sustainability, was completed by tracking crop production, calculating water efficiency, and evaluating Fatayat NU's organizational capability. In order to improve food self-sufficiency in the coastal village of Karimunjawa, methods for program continuity were designed using the assessment results. This program's supplies and machinery included both biological inputs and hydroponic farming implements. About 600 planting holes were made possible by the hydroponic system's raft installation with PVC pipes, which was held up by 5V 6A water pumps to guarantee constant nutrient circulation. An ESP32 microcontroller served as the primary controller and gateway to the Internet of Things platform, and the system was coupled with a number of IoT-based sensors, such as pH, EC/PPM, water temperature, ambient temperature and humidity, water level, and light intensity sensors. The system was powered by a 555 Wp solar panel connected to 12V 100Ah batteries to provide energy sustainability in the island location. An electronic control panel was added to guard against corrosion and humidity damage. Tubing, net pots, timers, nutrient tanks, and a monitoring app for smartphones were additional auxiliary equipment.

The biological elements were vegetable seeds, such as mustard greens (Brassica juncea), water spinach (Ipomoea aquatica), spinach (Amaranthus spp.), and lettuce (Lactuca sativa), which were chosen as the main crops because of the strong demand in the area. Growing media consisted of rockwool and rice husk charcoal, and the main source of nutrients was AB Mix nutrient solution, which was diluted in the island's freshwater. This technology and material combination was designed to maximize agricultural productivity within Karimunjawa's environmental limits.

## 3. Discussion

The community service program is founded on the genuine circumstances of Karimunjawa Village, a coastal region where food security is substantially impeded by both environmental and geographical constraints. The availability of vegetables is contingent upon the transportation of provisions from the mainland, which are frequently disrupted by periods of severe weather. The local soil is primarily sandy and possesses little nutritional content, rendering conventional farming operations unsustainable. These issues collectively result in a persistent deficiency of vegetables, especially during the monsoon season, when transportation routes are often obstructed. Due to this, local residents are compelled to purchase vegetables at prices that are up to three times higher than those on the mainland, which is indicative of a significant dependence on external distribution networks that are inherently unstable and unpredictable.

Prior community-based programs with a comparable emphasis had been implemented in Karimunjawa. Nonetheless, these first endeavors uncovered enduring difficulties, especially in the administration of irrigation and fertilization timelines. Local residents frequently encountered difficulties in ascertaining the optimal period for irrigation and fertilizer application, both of which are essential elements in hydroponic gardening. Consequently, the yields obtained were often suboptimal, and the sustainability of the program could not be preserved over time. This underscores a prevalent obstacle in technology transfer initiatives, wherein the lack of straightforward yet efficient control methods constrains communities' ability to maintain agricultural innovation over the long run.

The introduction of automated systems capable of monitoring and moderating the hydroponic environment with precision allows the integration of Internet of Things (IoT) technology to directly address these limitations. The system utilizes sensors and

computer controls to modulate water and fertilizer delivery according to the real-time requirements of plants, thereby guaranteeing uniformity in crop quality and output. In addition to reducing the manual burden on community members, this also enhances resource efficiency, as evidenced by studies that indicate water consumption savings of up to 30%. Moreover, the cultivation cycle can be abbreviated, facilitating more frequent harvests and enhanced food security. Integrating automation into the hydroponic process, IoT technology improves the efficiency and sustainability of community farming programs, rendering them more resilient to human error and external interruptions.longterm agricultural innovation [10]–[13].

In addition, this initiative is in close alignment with the Sustainable Development Goals (SDGs) and the Kampus Berdampak initiative. This platform enables students from a variety of academic disciplines to engage in real-world problem solving, thereby enabling them to integrate knowledge from agriculture, pharmacy, and information technology within a single community based initiative. In addition to enhancing students academic and professional experiences, this kind of multidisciplinary collaboration develops critical thinking, flexibility, and teamwork skills that are crucial for dealing with difficult societal issues.

The community derives tangible benefits from the involvement of students, as the transfer of knowledge and technology is implemented in a manner that is contextually pertinent and practical. While pharmacy offers insights into nutrition, public health, and the role of vegetables in preventing non-communicable diseases, the agricultural sciences contribute their expertise in hydroponic cultivation and food security, and informatics makes sure that Internet of Things (IoT) technologies are applied effectively to improve sustainability and efficiency. This synergy in conjunction generates a more comprehensive paradigm of community empowerment. The initiative shows how higher education institutions may have a significant social impact and help accomplish SDG's 2 (Zero Hunger), 3 (Good Health and Well-Being), and 17 (Partnerships for the Goals) by connecting academic learning with local needs.

The hydroponic system, which is supported by solar energy and is IoT-based, is specifically designed to be operated independently by community partners when considering sustainability. While lowering reliance on outside electrical sources, the use of renewable energy guarantees that the system operates dependably without placing an undue strain on the limited local resources. In addition to enhancing local food production resilience, this strategy creates a replicable and scalable model for other small island communities dealing with comparable environmental challenges. By encouraging the use of solar electricity in agricultural production, the program directly supports SDG 7 (Affordable and Clean Energy). It also supports SDG 12 (Responsible Consumption and Production) by encouraging resource-efficient farming methods.

The program develops opportunities to increase production capacity beyond household consumption, in addition to enhancing food self-sufficiency. To incorporate hydroponic farming into the island's broader economic activities, surplus yields may be marketed to restaurants, hotels, and tourist facilities. The project also has the potential to grow agro-tourism, where tourists may interact with and learn from sustainable agricultural methods, given Karimunjawa's prominence as a developing tourist destination. Diversifying local livelihoods in this manner is consistent with SDG 8 (Decent Work and Economic Growth) by establishing new sources of income and with SDG 2 (Zero Hunger) by guaranteeing more consistent access to nutritious vegetables. In this way, the initiative links food security, renewable energy, and community-based economic empowerment in a comprehensive framework, advancing several aspects of sustainable development at the same time.

**Figure 1.** The Hydroponic System

In conclusion, this empowerment program illustrates that the specific challenges encountered by island communities can be effectively addressed by adapting basic yet appropriate technologies. The practical solution to surmount environmental limitations, such as sandy soils, scarce freshwater resources, and unpredictable transportation links, is provided by the integration of hydroponics with IoT-based automation. This solution also improves local food security and nutrition. This initiative's success serves as an example of the value of context-sensitive

innovation, which adapts technology to local capabilities and requirements rather than implementing it uniformly.

Beyond the pilot phase, the primary obstacle is guaranteeing long-term sustainability. Strong institutional support from both local government and higher education institutions, continuous growth of capacity for community partners, and systematic monitoring of outcomes are all necessary for this. These components are necessary for the program to develop into a reproducible model of coastal food security that enables communities to become resilient to outside shocks. The initiative has the potential to contribute to the well-being of local communities, as well as to regional and national strategies for sustainable agriculture, food sovereignty, and rural development, by integrating these programs into broader development agendas.

This community service program illustrates the potential of adapting simple, context-specific technologies to resolve the food security challenges faced by island communities. The unique environmental conditions of Karimunjawa, including infertile soil, limited freshwater resources, and a high reliance on vegetable imports from the mainland, are directly addressed by the integration of hydroponics with Internet of Things (IoT) technology. In addition to enhancing crop yields, the Internet of Things (IoT) also contributes to the sustainability of local food systems by guaranteeing the efficient administration of water and nutrients.

The alignment between technology, local capacity, and community engagement is fundamental to the success of agricultural programs, as evidenced by prior community empowerment initiatives for instance, showed how urban farming empowered Kalisegoro Village and allowed communities to make better use of idle land, which increased household self-sufficiency [14]. Similar to this emphasized the necessity of decentralization and community-level empowerment to support larger government initiatives, pointing out that national food security policies are inextricably linked to local and regional resilience [15]. In Karimunjawa, where enhancing local production capacity is essential to lowering vulnerability brought on by interrupted food deliveries, these findings are immediately applicable.

Additionally, hydroponic development in Karimunjawa has the potential to have economic and tourism impacts in addition to its nutritional benefits. Research on eco-friendly agro-tourism, demonstrates how incorporating eco-friendly farming methods into tourism can boost local economies and bring in extra revenue [13]. The handover of the hydroponic facilities was formally conducted by the Rector of Wahid Hasyim University and the Head of the Institute for Research and Community Service (LP2M) to the Chairperson of Fatayat NU in Karimunjawa Village, representing the institution's commitment to supporting the sustainability of the program.

**Figure 3.** Handover of the hydroponic set equipped with IoT system

Hydroponics could be promoted in Karimunjawa as a food security strategy and as a point of interest for visitors, thereby diversifying the livelihoods of the community. This dual function, which enhances nutrition while generating revenue, highlights the wider significance of hydroponics as a model for long-term community empowerment.

## 4. Results

The application of Internet of Things (IoT)-based hydroponic technology in this community service initiative demonstrates that it is a suitable solution to the issue of food insecurity in Karimunjawa Village. Hydroponic cultivation that is efficient, water-saving, and sustainable can be employed to address challenges such as porous soil, limited freshwater resources, and a high reliance on external vegetable supplies. The integration of IoT has been demonstrated to facilitate community efforts in managing water and nutrient supply, thereby enhancing crop yields and ensuring the long-term sustainability of the program. Additionally, the program enhanced the institutional capacity of the local partner, the Fatayat NU women's group, by providing training, mentoring, and a more explicit distribution of roles, in addition to enhancing food security and community nutritional status. The involvement of students from a variety of disciplines demonstrates the synergy between agriculture, pharmacy, and information technology in generating tangible benefits for the community.

The program has the ability to satisfy family nutritional requirements while generating economic opportunities through food marketing and the establishment of hydroponic-based agro-tourism. Continuation of institutional support and systematic monitoring could enable this initiative to develop into a replicable model of coastal food security for other island communities in Indonesia.

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