Multi-modal sensor integration in chicken-fish-vegetable greenhouse agriculture based on internet of things

Muhammad Risal[1], Pujianti Wahyuningsih[2], Suwatri Jura[3], Irmawaty Iskandar[4], Abdul Jalil[5]
[1]Department of Computer Systems, Faculty of Computer Science, Universitas Handayani Makassar, Makassar, Indonesia
[2]Department of Information Systems, Faculty of Computer Science, Universitas Handayani Makassar, Makassar, Indoensia
[3]Department of Informatics Engineering, Faculty of Computer Science, Universitas Handayani Makassar, Makassar, Indoensia
[4]South Sulawesi Agricultural Instrument Standards Implementation Center, Maros, Indonesia
[5]Department of Informatics and Computer Engineering, Politeknik Negeri Ujung Pandang, Makassar, Indonesia

Article Info

Article history:

Received Sep 8, 2025
Revised Jan 20, 2026
Accepted Jan 24, 2026

Keywords:

Agriculture
Chicken-fish-vegetable
Greenhouse
Internet of things
Multi-modal sensor

ABSTRACT

Integrated chicken-fish-vegetable farming is a type of agriculture that combines the benefits of them within a single ecosystem. The objective of this study is to develop a control and monitoring system for integrated greenhouse-based chicken-fish-vegetable farming using the internet of things (IoT). The monitoring method employs the integration of multi-modal sensors in the greenhouse, consisting of a camera, water level, DHT11, pH, TDS, DS18B20, light dependent resistor (LDR), and infrared (IR) sensor. The camera functions as a visual monitoring tool for the farm, water level sensor detects hydroponic water levels, DHT11 measures air temperature and humidity, pH sensor measures water acidity, TDS sensor detects water nutrients, DS18B20 measures pond water temperature, LDR detects weather conditions, and IR sensor measures sunlight intensity. The processing units used to control the sensors and output devices are the ESP32 and Raspberry Pi. The system outputs include a relay for pump control, an LCD for text messages, and IoT information visualization using the Blynk platform. The results of this study demonstrate that the multi-modal sensor device can effectively monitor the conditions of integrated greenhouse-based chicken-fish-vegetable farming, achieving an accuracy of up to 96%, with an average data transmission time of 6 seconds through the Blynk IoT platform.

Corresponding Author:

Pujianti Wahyuningsih
Department of Information Systems, Faculty of Computer Science, Universitas Handayani Makassar
Adhyaksa Baru Road, No. 1, Pandang, Panakkukang, Makassar, South Sulawesi, Indonesia
Email: ujiwahyuningsih@handayani.ac.id

1. INTRODUCTION

The integrated farming system represents an agricultural approach that combines multiple farming activities within a single ecosystem, enabling each component to mutually benefit the others based on the concept of mutualistic symbiosis [1]. In this system, chickens provide eggs for human consumption and manure that can serve as feed for fish; fish farming yields dietary protein for communities while fish waste supplies nutrients for hydroponic plant growth; and vegetables function as food for humans as well as supplementary feed for chickens and fish. The chicken–fish–vegetable integrated farming concept is highly suitable for urban or residential areas with limited land due to its simplicity and high productivity, thereby supporting food security and self-sufficiency programs. However, urban communities often face difficulties in implementing the chicken–fish–vegetable modern farming concept due to limited time for monitoring and maintaining the system, which may negatively affect agricultural productivity. To address this issue, this study proposes the development of an integrated multi-modal sensor device to enable automatic management of the chicken–fish–vegetable farming system through an intelligent control system and the internet of things (IoT), which is expected to support urban farmers in advancing modern agriculture based on intelligent and IoT-enabled technologies.

The authors conducted a literature review and analyzed previous research related to the use of intelligent system technologies and the IoT integrated into integrated farming systems. Jabade *et al.* [2] developed an "IoTs-based smart poultry farm and fish farming system", which proposed an IoT-based weather monitoring system for poultry and aquaculture using a DHT11 sensor to monitor temperature and humidity in real time, send alerts to smartphones when threshold limits are exceeded and effectively maintain environmental conditions to enhance productivity. Mahbub *et al.* [3] implemented an "IoTs-based smart poultry and fish farming system using Arduino", developing an automated smart farming system utilizing an Arduino Uno microcontroller to monitor and regulate environmental parameters in poultry and aquaculture settings, thereby reducing time and labor requirements through both simulation and hardware implementation. Alita *et al.* [4] implemented IoT-based smart farming for optimizing chicken productivity and product digitalization to improve administrative quality; their study applied an IoT-driven smart farm concept at Berkah Poultry Farm in Lampung through automated temperature and humidity control, a web-based livestock data management application, and cultivation training, which collectively improved employee capability, chicken productivity, and data accuracy. Furthermore, Dhinakaran *et al.* [5] developed an "IoT-based environmental control system for fish farms with sensor integration and machine learning decision support", which integrates machine learning algorithms to monitor and optimize water conditions and fish behavior in real time, thereby improving fish health and productivity while reducing resource wastage sustainably.

Furthermore, Dhanaraju *et al.* [6] developed "smart farming with IoT-based sustainable agriculture", which discusses the implementation of IoT technology, cloud computing, and wireless sensors in smart agriculture to enhance efficiency from cultivation to distribution, while also identifying challenges in integrating these technologies with conventional agricultural practices. Kim *et al.* [7] realized "IoTs-based fish farm control using a mobile app", in this study, the researchers developed an IoT-based intelligent aquaculture system that utilizes waste-water heat energy to control and monitor oxygen levels, temperature, pH, and water height in real time through microcontrollers and the message queuing telemetry transport (MQTT) communication protocol. Additionally, Astill *et al.* [8] developed "smart poultry management: smart sensors, big data, and the IoTs", which reviews the application of IoT-based smart poultry management systems, smart sensors, and big data analytics to improve production, efficiency, and animal welfare through automation and data-driven decision-making, while also addressing the challenges associated with their implementation in the poultry industry. Moreover, Leong *et al.* [9] developed "poultry precision: exploring the impact of IoT sensors on smart farming practices", in which the researchers demonstrated that the application of IoT sensors significantly enhances efficiency, animal welfare, and sustainability in poultry farming through real-time monitoring, data-driven decision-making, and the adoption of smart farming practices.

Furthermore, Xu *et al.* [10] implemented "intelligent dynamic quality prediction of chilled chicken with integrated IoT flexible sensing and knowledge rules extraction". This study developed an intelligent prediction model based on knowledge-rule extraction combined with flexible humidity sensors integrated into an IoT system, enabling real-time monitoring of chilled chicken quality, handling abnormal conditions within the cold chain, and delivering highly accurate quality evaluation and prediction to support more effective decision-making and e-commerce management. An IoT-enabled aquaponics system with wireless smart sensor monitoring was implemented by Menon [11]. The study demonstrated that the application of an AWSM-based IoT system equipped with wireless sensors and a GUI interface effectively addressed technical issues in traditional aquaponics through real-time water quality monitoring and remote notification, thereby improving system performance compared to conventional methods. Wang *et al.* [12] introduced the architecture "smart farming towards unmanned farms: a new mode of agricultural production," which reviews the concepts, frameworks, technological developments, and challenges associated with achieving labor-free farming by leveraging IoT, big data, artificial intelligence, robotics, and 5G as foundational technologies for future unmanned agriculture. Additionally, Hanau *et al.* [13] developed "smart farming for poultry: leveraging chicken raising with low-cost IoT-based information systems", demonstrating that a low-cost IoT-based information system for automated environmental control can improve poultry performance—particularly with weight gains of up to 25%—while reducing manual monitoring requirements, thereby enhancing operational efficiency for small-scale poultry farmers.

Based on the findings of previous researchers, it can be observed that several studies have implemented smart farming systems connected to the IoT using embedded systems, sensor fusion, and intelligent agriculture technologies. However, none of these studies have developed an integrated chicken–fish–vegetable farming system within a single platform that incorporates control and monitoring functionalities based on multi-modal sensor integration and the IoT. Therefore, the novelty of this research lies in the development of a multi-modal sensor integration system for the chicken–fish–vegetable integrated farming model within an IoT-based greenhouse environment. This research is expected to serve as a model for advancing modern urban agriculture systems that assist urban farmers in maintaining and monitoring the conditions of integrated farming operations using IoT technology. In this paper, the researchers present a detailed explanation of the research concept. In the introduction, the background and research problems are described. The methods section outlines the fundamental concepts and approaches employed to address the research problems. In the results and discussion section, the findings of the study are presented and analyzed, including the application and evaluation of the proposed methods. Finally, the conclusion and recommendations section summarizes the key outcomes of the research and provides suggestions for future studies.

2. RESEARCH METHOD

The chicken-fish-vegetable farming concept developed in this study is based on a symbiotic mutualism model, in which chickens, fish, and vegetables provide reciprocal benefits to each other. In its application, chicken manure produced during poultry farming is utilized as fish feed, while the waste from fish, combined with residual chicken manure, serves as nutrients for hydroponic vegetables. Subsequently, the harvested hydroponic vegetables and fish are used as feed for chickens. Figure 1 illustrates the integrated chicken-fish-vegetable farming concept implemented in this study. Then Figure 2 illustrates the system architecture proposed to tackle the issues identified in this study.

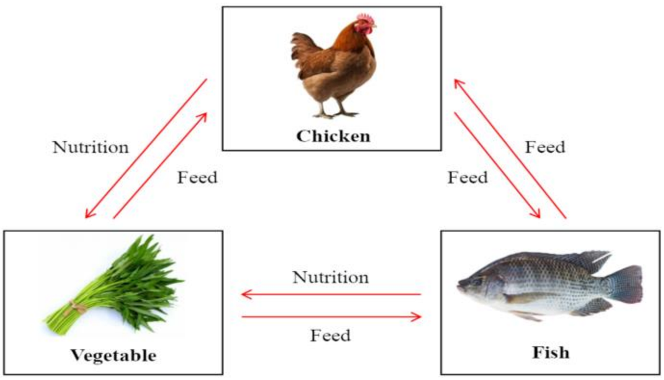


Figure 1. The concept of an integrated farming system: chicken-fish-vegetables

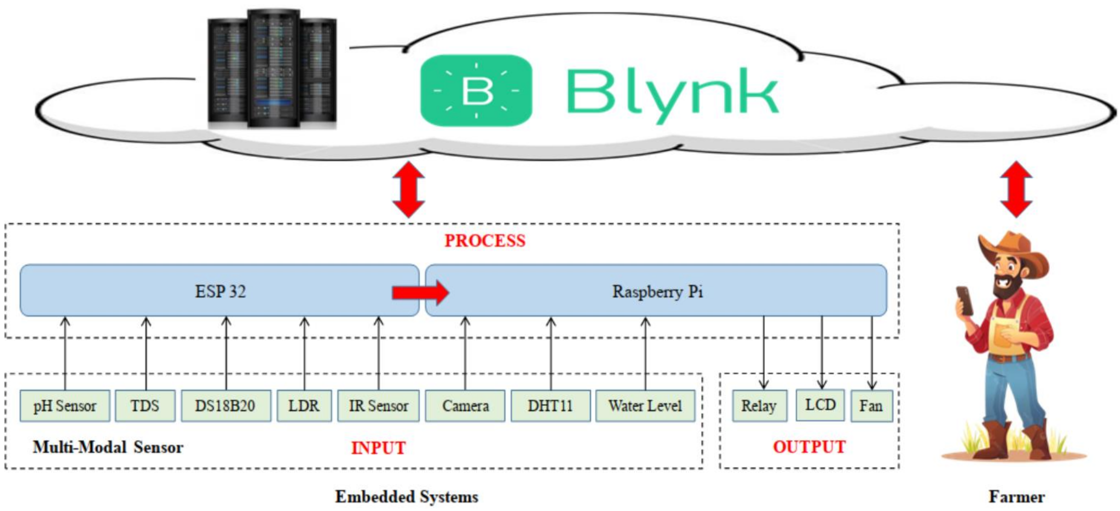


Figure 2. Architectural design of integrated farming system chicken-fish-vegetables

Based on the information in Figure 1, it can be observed that the chicken-fish-vegetable farming system can assist communities, particularly in urban areas, in establishing a food self-sufficiency model to meet local demands for chicken meat and eggs, fish, and vegetables. In practice, one of the challenges faced by communities in implementing the chicken-fish-vegetable integrated farming concept is the difficulty of continuously monitoring and maintaining the farm due to daily work commitments. To address these research challenges, the researchers conducted a literature review, formulated research hypotheses, and designed the research methodology. Furthermore, based on the information in Figure 2, the system architecture for the chicken-fish-vegetable farming control system consists of three main components: input, process, and output. The input section includes a multi-modal sensor module that integrates several sensors into a single unit [14], namely a camera, water level sensor, DHT11 sensor, pH sensor, TDS sensor, DS18B20 sensor, light dependent resistor (LDR) sensor, and infrared (IR) sensor. The camera in the developed system functions to monitor the chicken-fish-vegetable farming conditions in real-time when connected to the IoT-based system. As an input device in the computing system, the camera captures data in visual form [15]. The input section also includes a water level detection sensor [16], which measures the volume of water in the hydroponic plant pipes. Additionally, the DHT11 sensor is used to measure air temperature and humidity within the chicken-fish-vegetable farming environment [17]. The multi-modal sensor module further includes a pH sensor to measure the acidity of water in the fish pond and the hydroponic irrigation system [18], a TDS sensor to detect nutrient levels in the circulating water [19], a DS18B20 sensor to measure fish pond water temperature [20], an LDR sensor to detect light intensity during morning, afternoon, evening, and cloudy conditions [21], and an IR sensor to measure infrared light intensity irradiating the chicken-fish-vegetable farming system [22].

In the process section, an ESP32 microcontroller is used to read analog output data from sensors, convert it into digital data, and then transmit it to the Raspberry Pi via serial communication. This includes the pH sensor, TDS sensor, DS18B20 sensor, LDR sensor, and IR sensor. The ESP32 microcontroller is a system-on-chip (SoC) that comes integrated with Wi-Fi, Bluetooth, and GPIO pins for reading both analog and digital sensor inputs, as well as controlling outputs [23]. In this study, the Raspberry Pi functions to process camera input data and read digital output data from the water level sensor and DHT11. Moreover, the Raspberry Pi serves as the central data processing unit of the chicken-fish-vegetable farming control system. The Raspberry Pi is a type of microcomputer that operates similarly to a conventional computer and features GPIO pins to read sensor inputs and control hardware outputs [24]. Additionally, in this study, the Raspberry Pi acts as the central control device for transmitting IoT data from the embedded system to the farmer’s smartphone.

In this study, the advantages of the ESP32 microcontroller were utilized to convert analog sensor outputs into digital data for real-time processing by the Raspberry Pi. The strengths of the Raspberry Pi were leveraged as the central data processing unit, capable of high computational performance similar to a conventional computer. The study employed serial communication to transmit digital sensor data from the ESP32 to the Raspberry Pi. Fundamentally, there are key differences between microcontrollers and microcomputers that determine their respective advantages and limitations. One advantage of microcontrollers, such as the ESP32, is the availability of GPIO pins capable of converting analog sensor data into digital signals, whereas the GPIO pins on the Raspberry Pi cannot perform analog-to-digital conversion. In practice, a limitation of microcontrollers is their relatively slower data processing speed due to hardware constraints and the execution of single-threaded programs. In contrast, the Raspberry Pi, as a microcomputer, supports multi-processing and high-speed data handling, enabled by its hardware architecture, which functions similarly to a standard computer.

In the output section of the system architecture, a relay is used to automatically and manually turn the water pump of the chicken-fish-vegetable farming system on or off when supplying water to plants or vegetables. A relay is an electronic device containing a coil that functions as an electronic switch when triggered by an electric voltage [25]. The output section also includes a 16×2 LCD, capable of displaying 16 characters per line on both the upper and lower rows, with control options via bit-level or I2C communication [26]. Additionally, a fan is employed to cool and regulate the air temperature and humidity within the greenhouse. The fan is an electronic device that generates airflow when its blades rotate [27]. The platform used in this study to transmit chicken-fish-vegetable farming data from the embedded system to the farmer’s smartphone is Blynk, an IoT platform that enables remote monitoring and control of embedded systems via the internet [28]. Using this system, farmers can remotely monitor greenhouse conditions, including air temperature and humidity, water temperature, weather conditions, sunlight intensity, pond water pH, nutrient concentration in water, and the flow of water in the hydroponic farming system. Furthermore, farmers can also monitor the status and operation of the water pump.

In this study, we employed the waterfall technique to evaluate the effectiveness of the proposed method, which includes hardware testing, software testing, and IoT network testing. The waterfall model is a sequential testing approach conducted in stages according to the system development flow [29]. In the hardware testing phase, we evaluated the performance of the multi-modal sensor devices used to measure environmental conditions inside the greenhouse, including the water level sensor, DHT11 sensor, pH sensor, TDS sensor, DS18B20 sensor, LDR sensor, and IR sensor. After testing the multi-modal sensors, we proceeded to evaluate the processing units—specifically the ESP32 for processing analog sensor data and the Raspberry Pi as the central data processing controller. Subsequently, we tested the output devices, including the relay module, LCD, and fan. In the software testing phase, we assessed the effectiveness of the algorithms in performing their tasks to ensure that the system can properly monitor the conditions of the chicken–fish–vegetable integrated farming environment using the IoTs. Finally, we conducted IoT network testing to measure the system's capability to transmit data between devices using network and internet connectivity. The detailed results of these testing phases are presented in the results and discussion section of this paper.

3. RESULTS AND DISCUSSION

The integration of multi-modal sensors in the greenhouse-based chicken-fish-vegetable farming system, supported by the IoT, has been implemented in this study. The system consists of several interconnected components that enable farmers to remotely monitor and control the farm using IoT technology. Figure 3 illustrates the developed IoT-based chicken-fish-vegetable integrated farming system within the greenhouse. Based on the information in Figure 3, four core components can be identified in the greenhouse-based chicken-fish-vegetable integrated farming system developed in this study: the hydroponic plant section, which serves as the area for vegetable cultivation; the chicken coop, used to house laying hens; the fish pond, designated for Nile tilapia farming; and the IoT control box, which integrates all control devices to ensure interconnectivity. Furthermore, Figure 4 provides detailed views of each component of the chicken-fish-vegetable farming system constructed in this research.

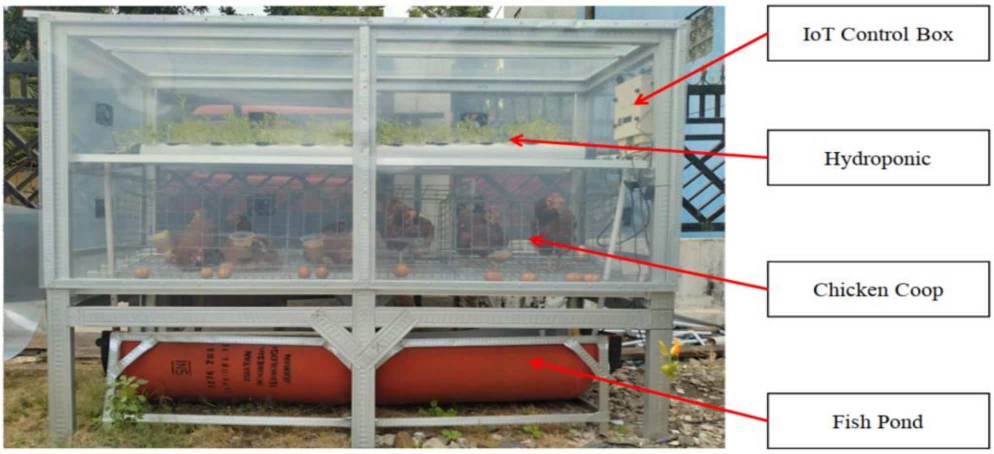


Figure 3. IoT-based integrated greenhouse farming of chicken-fish-vegetables

Figure 4. Chicken-fish-vegetable agricultural results

Based on the information in Figure 4, the type of vegetable cultivated in this study is water spinach (Kangkung), which is a hydroponic plant that is easy to grow due to its requirement of only water for survival. The farming method applied in this study utilizes hydroponic techniques. Then, as shown in Figure 4, the type of chicken raised in this study is a layer breed, which primarily produces eggs as the main output. The chicken coop design implemented in this integrated farming system is a battery cage type. Furthermore, the fish species raised is Nile tilapia, which is commonly farmed due to its ease of cultivation and feeding, with feed sources including vegetables or chicken manure. Finally, Figure 5 shows the hardware and control devices used to monitor the IoT-based greenhouse chicken-fish-vegetable integrated farming system. Furthermore, Figures 6 and 7 provide detailed views of the internal components of the IoT control box and the multi-modal sensors installed in the fish pond.

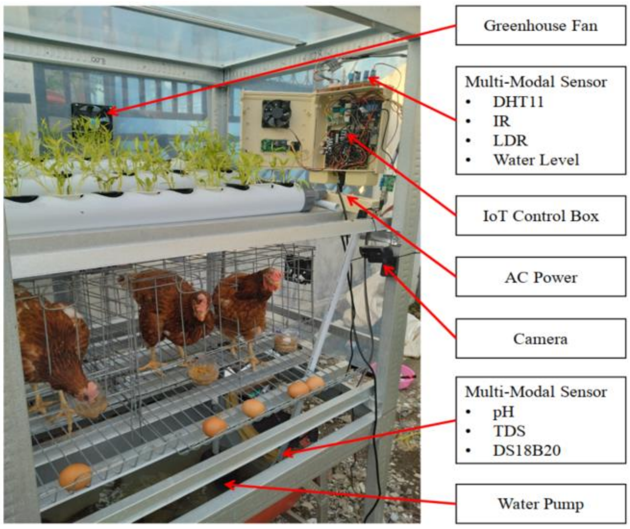


Figure 5. The results of the integration of control devices in integrated chicken-fish-vegetable farming

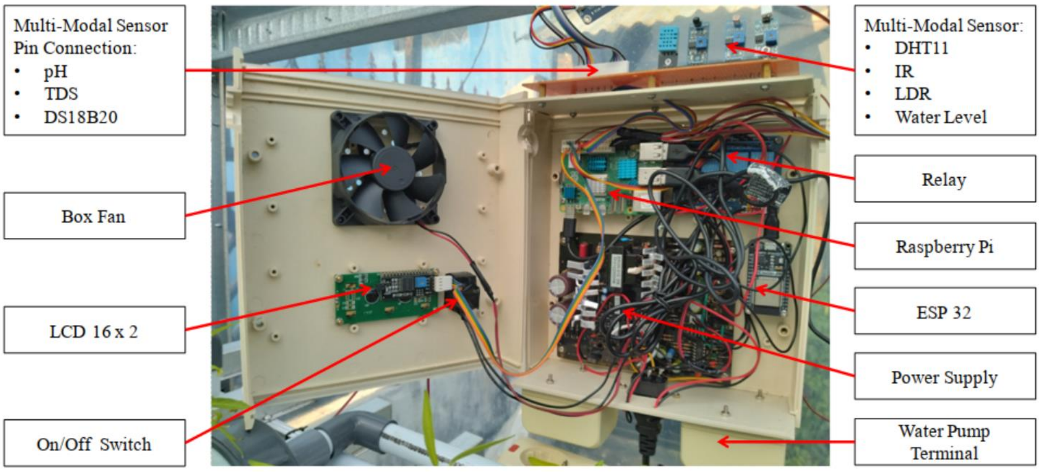


Figure 6. Integrated agricultural control device for chicken-fish-vegetables

Based on the information in Figure 6, several components were utilized in this study to control and monitor the greenhouse-based chicken-fish-vegetable integrated farming system. The system includes multi-modal sensor connection pins used to link the pH, TDS, and DS18B20 sensors in the fish pond to the IoT control box. Additionally, a fan is installed to cool the control box, a 16×2 LCD displays messages, and an on/off switch is used to power the devices within the box. Externally, the control box is connected to multi-modal sensors, including DHT11, IR, LDR, and a water level sensor. Internally, the box contains relays that automatically and manually control the fan and water pump, a Raspberry Pi as the central data processing unit, an ESP32 to read analog sensor data, convert it into digital signals, and transmit it to the Raspberry Pi, a power supply as the voltage source, and terminals used to activate the water pump. Figure 7 shows the specific sensors used to measure pond water pH, water temperature, and nutrient levels, utilizing the pH sensor, DS18B20 sensor, and TDS sensor. Additionally, a water pump is employed to supply water to the hydroponic pipes.

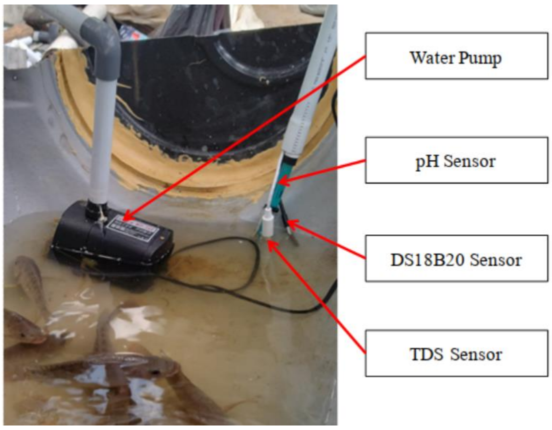


Figure 7. Multi-modal sensor device and water pump in fish pond

In this study, the researchers developed software to read analog sensor input data connected to the ESP32 and to transmit the sensor information from the Raspberry Pi to the farmer's smartphone using Python programming and the Blynk IoT platform. Figure 8 illustrates the design of the front-end interface on the farmer's smartphone for monitoring and controlling the chicken-fish-vegetable integrated farming system using the Blynk IoT platform. The interface includes buttons to control the on/off operation of the water pump, monitoring information for the fan, and an LCD display showing water temperature, water nutrients, water pH, water level, air temperature, air humidity, weather conditions, and sunlight intensity. In the Blynk IoT control system, Datastreams are used to transmit sensor data and control commands between the embedded system and the user's smartphone. Table 1 presents the Datastreams and data types used for transmitting sensor and control data in this study.

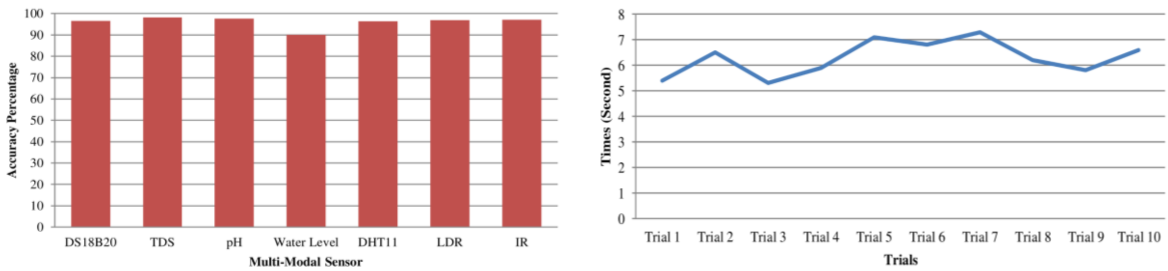
Figure 8. Blynk IoT software design results

Table 1. Datastreams and data types used to send IoT data

Interfaces	Datastream	Data type
Water pump on/off	Switch control V0 [V0]	Integer, 0/1, id=0
Cooling fun notification	Switch value V1 [V1]	Integer, 0/1, id=1
Water temperature	String V3 [V3]	String, id=3
Water nutrition	String V4 [V4]	String, id=4
Water pH	String V5 [V5]	String, id=5
Water level	String V6 [V6]	String, id=6
Air temperature	String V7 [V7]	String, id=7
Air humidity	String V8 [V8]	String, id=8
Weather	String V9 [V9]	String, id=9
Sun level	String V10 [V10]	String, id=10

In this study, the researchers conducted accuracy tests of the sensors used to monitor the conditions of the chicken-fish-vegetable integrated farming system against real measurement devices. The sensors tested include the DS18B20 for measuring fish pond water temperature, the TDS sensor for measuring water nutrient levels, the pH sensor for assessing water acidity, the water level sensor for determining the volume of water in hydroponic plant pipes, the DHT11 sensor for air temperature and humidity, the LDR sensor for weather conditions, and the IR sensor for measuring sunlight intensity in terms of infrared and lux levels. Figure 9 illustrates the accuracy of the multi-modal sensors in detecting the environmental conditions of the chicken-fish-vegetable integrated farming system and illustrates the results of the time analysis for transmitting messages from the embedded system to the farmer's smartphone.

Based on the analysis results shown in Figure 9(a) the accuracy analysis of multi-modal sensors in reading environmental conditions, it can be observed that the sensors are able to transmit environmental data with an average accuracy of up to 96%. This indicates that the developed system can be effectively used for the development of a chicken-fish-vegetable integrated farming system in terms of IoT-based monitoring and control. Furthermore, the researchers analyzed the average time required to transmit sensor data from the embedded system to the farmer's smartphone. According to the information of Figure 9(b) IoT data delivery time analysis results, it can be observed that the average time required by the system to transmit agricultural data from the embedded system to the farmer's smartphone using the Blynk platform and the internet is 6 seconds. This delay is influenced by the data transmission speed, which depends heavily on the quality of the local network and internet, as well as the stability of the server services provided by the Blynk IoT platform.



(a) (b)

Figure 9. Accuracy and transmission times analysis results; (a) the accuracy analysis of multi-modal sensors in reading environmental conditions and (b) IoT data delivery time analysis results

This study has examined the utilization of multi-modal sensor integration and the IoT to assist farmers in monitoring modern agriculture, particularly in urban areas through the chicken–fish–vegetable integrated farming system. Based on the findings obtained in this research, the developed device can be used to monitor fish pond water temperature, measure water nutrient levels, assess water acidity, determine water level, measure ambient temperature and humidity, evaluate lighting conditions, and control water pumps both manually and automatically. These capabilities provide significant benefits for farmers—especially those in urban environments—by enabling them to monitor and manage modern agricultural systems without the need for continuous and manual supervision. Moreover, the agricultural monitoring techniques introduced in this study can support communities in developing self-sufficiency food systems, thereby improving economic conditions and enhancing community welfare through modern agricultural practices.

Based on the research findings, it can be observed that the developed device functions effectively in monitoring greenhouse conditions for the chicken–fish–vegetable integrated farming system. This approach is highly efficient as it facilitates farmers in maintaining and monitoring agricultural activities by leveraging multi-modal sensor integration and IoT technologies. In practice, several researchers have developed integrated farming systems with IoT-based control and sensor monitoring, including poultry farming [4], [8]–[10], aquaculture [5], [7], and combined poultry–fish systems [2], [3]. However, these studies did not implement multi-modal sensor integration within greenhouse-based monitoring for chicken–fish–vegetable integrated farming, which represents a distinct strength and advantage of the system developed in this research. Furthermore, our findings indicate that the integrated farming monitoring and control system can operate under various weather conditions, as it is implemented within a controlled greenhouse environment.

The utilization of multi-modal sensors for monitoring various agricultural conditions within a greenhouse farming system has proven to be highly effective in this study. In integrated farming, numerous factors must be carefully monitored to ensure optimal crop yield, including weather conditions, air and water temperature, humidity, and internal greenhouse conditions. This developed system is particularly significant as it can assist urban communities in achieving food self-sufficiency, enabling individuals to engage in farming without the need for continuous manual monitoring. Furthermore, future development of this research should focus on enhancements such as harvest yield prediction analysis based on artificial intelligence integrated with IoT technologies.

4. CONCLUSION

This study utilized the integration of multi-modal sensors as a platform for monitoring and controlling the IoT-based chicken–fish–vegetable integrated greenhouse farming system, aimed at assisting urban communities in establishing modern agricultural systems. The results demonstrate that the multi-modal sensor system successfully transmitted data on water temperature, water nutrients, water pH, pond water level, air temperature, air humidity, and solar light intensity in the greenhouse integrated farming system with an accuracy rate of up to 96%. Furthermore, the average time required for the system to send IoT control and information from the greenhouse control devices to the farmer’s smartphone was 6 seconds. Based on the developed system, it can be concluded that the modern farming concept integrating multi-modal sensors and IoT can serve as a recommendation for the development of urban modern agriculture using greenhouse farming systems. Based on the research results, the limitations of this research are that it has not been able to detect the types of pests found in hydroponic plants. Additionally, future research should consider integrating Artificial Intelligence-based systems to predict harvest success and improve the effectiveness of the integrated farming system for optimal yield. The development of edge computing and long-range wide area network (LoRaWAN)-based systems should also be prioritized to advance modern IoT-based integrated farming systems.

ACKNOWLEDGMENTS

We would like to express our sincere gratitude to KEMENDIKTISAINTEK for their trust in providing the Fundamental Research Grant for Lecturers. Our appreciation also goes to Universitas Handayani Makassar and the community for their support, which enabled the successful completion of this fundamental research in accordance with the researchers’ expectations.

FUNDING INFORMATION

The funding used to conduct and publish this research was provided by KEMENDIKTISAINTEK through the Fundamental Research Program.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Muhammad Risal	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	
Pujianti Wahyuningsih	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	
Suwatri Jura	✓	✓		✓	✓	✓		✓		✓			✓	
Irmawaty Iskandar		✓		✓		✓				✓				
Abdul Jalil			✓		✓		✓	✓		✓				

C : **C**onceptualization	I : **I**nvestigation	Vi : **Vi**sualization
M : **M**ethodology	R : **R**esources	Su : **Su**pervision
So : **So**ftware	D : **D**ata Curation	P : **P**roject administration
Va : **Va**lidation	O : Writing - **O**riginal Draft	Fu : **Fu**nding acquisition
Fo : **Fo**rmal analysis	E : Writing - Review & **E**diting	

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

REFERENCES

[1] C. Thi Da, P. Anh Tu, J. Livsey, V. T. Tang, H. Berg, and S. Manzoni, "Improving Productivity in Integrated Fish-Vegetable Farming Systems with Recycled Fish Pond Sediments," *Agronomy*, vol. 10, no. 7, p. 1025, Jul. 2020, doi: 10.3390/agronomy10071025.

[2] V. Jabade, M. B. Mhetre, P. P. Mali, and A. G. Mor, "IoT Based Smart Poultry Farm and Fish Farming System," in *Proceedings - 2024 1st International Conference on Innovative Sustainable Technologies for Energy, Mechatronics and Smart Systems, ISTEMS 2024*, Dehradun, India: IEEE, Apr. 2024, pp. 1–6, doi: 10.1109/ISTEMS60181.2024.10560208.

[3] S. I. Mahbub, S. S. Ratri, S. A. Hamim, and M. H. Bhuyan, "IoT-Based Smart Poultry and Fish Farming System Using Arduino," in *Workshop on the International Conference on Bangabandhu and Digital Bangladesh (WICBBDB 2023)*, 2023.

[4] D. Alita, S. Samsugi, and M. Suhadi, "Implementation of Iot-Based Smart Farms for Optimizing Chicken Productivity and Product Digitalization to Improve Administration Quality," *International Journal of Public Devotion*, vol. 6, no. 2, pp. 156–167, 2023, doi: 10.26737/ijpd.v6i2.4779.

[5] D. Dhinakaran, S. Gopalakrishnan, M. D. Manigandan, and T. P. Anish, "IoT-Based Environmental Control System for Fish Farms with Sensor Integration and Machine Learning Decision Support," *International Journal on Recent and Innovation Trends in Computing and Communication*, vol. 10, no. 11, pp. 203–217, 2023.

[6] M. Dhanaraju, P. Chenniappan, K. Ramalingam, S. Pazhanivelan, and R. Kaliaperumal, "Smart Farming: Internet of Things (IoT)-Based Sustainable Agriculture," *Agriculture*, vol. 12, no. 10, p. 1745, 2022, doi: 10.3390/agriculture12101745.

[7] Y. Kim, N. Lee, B. Kim, and K. Shin, "Realization of IoT based fish farm control using mobile app," in *Proceedings - 2018 International Symposium on Computer, Consumer and Control, IS3C 2018*, 2018, pp. 189–192, doi: 10.1109/IS3C.2018.00055.

[8] J. Astill, R. A. Dara, E. D. G. Fraser, B. Roberts, and S. Sharif, "Smart poultry management: Smart sensors, big data, and the internet of things," *Computers and Electronics in Agricultur*e, vol. 170, p. 105291, 2020, doi: 10.1016/j.compag.2020.105291.

[9] W. Y. Leong, Y. Z. Leong, and W. S. Leong, "Poultry Precision: Exploring the Impact of IoT Sensors on Smart Farming Practices," in *IEEE International Workshop on Electromagnetics: Applications and Student Innovation Competition, iWEM 2024*, 2024, pp. 1-2, doi: 10.1109/iWEM59914.2024.10649169.

[10] J. Xu, R. Ma, S. Stankovski, X. Liu, and X. Zhang, "Intelligent Dynamic Quality Prediction of Chilled Chicken with Integrated IoT Flexible Sensing and Knowledge Rules Extraction," *Foods*, vol. 11, no. 6, p. 836, 2022, doi: 10.3390/foods11060836.

[11] P. C. Menon, "IoT enabled Aquaponics with wireless sensor smart monitoring," in *Proceedings of the 4th International Conference on IoT in Social, Mobile, Analytics and Cloud, ISMAC 2020*, Palladam, India, 2020, pp. 171–176, doi: 10.1109/I-SMAC49090.2020.9243368.

[12] T. Wang, X. Xu, C. Wang, Z. Li, and D. Li, "From smart farming towards unmanned farms: A new mode of agricultural production," *Agriculture*, vol. 11, no. 2, pp. 1–26, 2021, doi: 10.3390/agriculture11020145.

[13] C. Hanau *et al.*, "Smart Farming for Poultry: Leveraging Chicken Raising with Low-Cost IoT-based Information Systems," in *Simpósio Brasileiro de Sistemas de Informação*, 2025, pp. 125–134, doi: 10.5753/sbsi.2025.246397.

[14] A. Jalil, P. Wahyuningsih, N. Umar, M. Risal, S. Jura, and A. E. F. Anatasya, "Developing a Smart Belt for Monitoring Elderly Activities Based on Multi-Modal Sensors Integration and Internet of Things," in *Proceedings of International Conference on Artificial Life and Robotics*, 2024, pp. 1021–1024, doi: 10.5954/icarob.2024.gs5-2.

[15] N. Messikommer, C. Fang, M. Gehrig, G. Cioffi, and D. Scaramuzza, "Data-Driven Feature Tracking for Event Cameras With and Without Frames," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 47, no. 5, pp. 3706–3717, 2025, doi: 10.1109/TPAMI.2025.3536016.

[16] A. F. De Leon and F. R. G. Cruz, "Water Level Monitoring and Flood Warning System using Light Detection and Ranging (LiDAR) Sensor with Hybrid Renewable Solar-Wind Power," in *2021 IEEE 13th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management, HNICEM 2021*, Manila, Philippines, 2021, pp. 1-5, doi: 10.1109/HNICEM54116.2021.9731998.

[17] A. Indu and S. M. Kumar, "An Approach for Implementing Innovative Weather Monitoring System with DHT11 Sensor and Arduino Uno Tool based on IoT," in *6th International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud), I-SMAC 2022 - Proceedings*, 2022, pp. 274–278, doi: 10.1109/I-SMAC55078.2022.9987289.

[18] N. Nair, A. V. Akshaya, M. J. Bosco, G. K. Ananthasuresh, and J. Joseph, "A Robust Sensor for Inline pH Measurements," *IEEE Sensors Journal*, vol. 25, no. 1, pp. 167–174, 2025, doi: 10.1109/JSEN.2024.3489659.

[19] K. Ma'Ruf, R. J. Setiawan, A. Al Kafah Alam, T. Ismail, C. I. Muhammad, and J. Ali, "Internet of Things for Real-Time Monitoring of Water Quality with Integrated Temperature, pH, and TDS Sensors," in *ICECOS 2024 - 4th International Conference on Electrical Engineering and Computer Science, Proceeding*, 2024, pp. 314–319, doi: 10.1109/ICECOS63900.2024.10791209.

[20] D. Bora, D. Singh, and B. Negi, "Utilization of DS18B20 Temperature Sensor for Predictive Maintenance of Reciprocating Compressor," in *2023 International Conference on Power Energy, Environment and Intelligent Control, PEEIC 2023*, 2023, pp. 147–150, doi: 10.1109/PEEIC59336.2023.10450639.

[21] I. Cappelli, L. Parri, M. Tani, V. Vignoli, and A. Fort, "Pervasive Monitoring in the Context of Precision Agriculture: Using Low-Cost LDR Sensors for Solar Intensity Measurement," in *Conference Record - IEEE Instrumentation and Measurement Technology Conference*, 2024, pp. 1–6, doi: 10.1109/I2MTC60896.2024.10560913.

[22] M. A. Altaf, J. Ahn, D. Khan, and M. Y. Kim, "Usage of IR Sensors in the HVAC Systems, Vehicle and Manufacturing Industries: A Review," *IEEE Sensors Journal*, vol. 22, no. 10, pp. 9164–9176, 2022, doi: 10.1109/JSEN.2022.3166190.

[23] L. Samal and P. Bute, "Wireless network for Industrial application using ESP32 as Gateway," in *2023 14th International Conference on Computing Communication and Networking Technologies, ICCCNT 2023*, Delhi, India, 2023, pp. 1–5, doi: 10.1109/ICCCNT56998.2023.10306864.

[24] G. P. Pereira and M. Z. Chaari, "A Look into the Performance of the Raspberry Pi AI HAT+ for Computer Vision Applications," in *Proceedings of the 2025 11th International Conference on Communication and Signal Processing, ICCSP 2025*, Melmaruvathur, India, 2025, pp. 1620–1625, doi: 10.1109/ICCSP64183.2025.11089235.

[25] Z. Xue and B. Dong, "A Digital Simulation System For Embedded Devices Based On Configurable Platform," in *Proceedings of 2024 IEEE 7th International Electrical and Energy Conference, CIEEC 2024*, Harbin, China, 2024, pp. 338–342, doi: 10.1109/CIEEC60922.2024.10583765.

[26] M. Sharmila, Y. K. Gupta, H. U. Akole, and M. V. Chavan, "Designa and Development of Automated Smart Socket for Wi-Fi Users," in *Proceedings of the 5th International Conference on Inventive Computation Technologies, ICICT 2020*, Coimbatore, India, 2020, pp. 550–556, doi: 10.1109/ICICT48043.2020.9112510.

[27] A. Gupta, M. Gupta, and K. Markam, "Temperature Control Smart Fan: Model Analysis and Working Analysis," in *1st IEEE International Conference on Innovations in High Speed Communication and Signal Processing, IHCSP 2023*, Bhopal, India, 2023, pp. 527–530, doi: 10.1109/IHCSP56702.2023.10127120.

[28] M. Pappula, J. C. Myneni, M. Gandra, R. Tadigadapa, and B. K. M. Akella, "Blynk-Powered IoT System with Machine Learning for Personalized Plant Care," in *Proceedings - 2024 8th International Conference on Inventive Systems and Control, ICISC 2024*, Coimbatore, India, 2024, pp. 230–233, doi: 10.1109/ICISC62624.2024.00046.

[29] J. J. Labayne, L. S. Echalar, and A. V. Matute, "Efficiency Improvement in Parking: A Waterfall Model-Based Approach for Testing Online-Based Parking Slot Reservation System," in *2023 IEEE 15th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management, HNICEM 2023*, Palawan, Philippines, 2023, pp. 1–6, doi: 10.1109/HNICEM60674.2023.10589132.

BIOGRAPHIES OF AUTHORS

Muhammad Risal is a lecturer in the Department of Computer Systems, Faculty of Computer Science, Universitas Handayani Makassar. He completed his Bachelor's degree in Computer Systems at STMIK Handayani Makassar in 2006, and subsequently earned his Master's degree at the Faculty of Engineering, Universitas Hasanuddin, in 2011. He is currently active in research and publishes in journals and proceedings in the fields of control systems, microcontrollers, the internet of things, and computer science. He can be contacted at email: risal@handayani.ac.id.

Pujianti Wahyuningsih is a lecturer in the Information Systems Study Program, Faculty of Computer Science, Universitas Handayani Makassar. She completed her Bachelor's degree in Information Systems at STMIK AKBA in 2015 and earned her Master's degree in Computer Systems at the Postgraduate Program of STMIK Handayani in 2017. She is currently active in writing several computer science books, focusing on information systems and computer science. She can be contacted at email: ujiwahyuningsih@handayani.ac.id.

Suwatri Jura is a lecturer in the Informatics Engineering Study Program, Faculty of Computer Science, Universitas Handayani Makassar. She completed her Bachelor's degree in Informatics Engineering in 2010 and earned her Master's degree in Computer Systems at the Postgraduate Program of STMIK Handayani in 2015. She is currently active in writing several computer science books, focusing on informatics engineering and computer science. She can be contacted at email: suwatrijura@handayani.ac.id.

Irmawaty Iskandar is a member at the Agricultural Instrument Standards Application Center of South Sulawesi. She can be contacted at email: irmawatyiskandar@gmail.com.

Abdul Jalil is a lecturer in the Study Program of Computer and Network Engineering, Department of Informatics and Computer Engineering, Politeknik Negeri Ujung Pandang. He completed his Bachelor's degree in Computer Systems at STMIK Handayani Makassar in 2012 and earned his Master's degree in Computer Systems at STMIK Handayani Makassar in 2015. In 2023, he completed his Doctoral degree at the Department of Computer Science and Systems Engineering, Kyushu Institute of Technology, Japan. He is currently active in writing books and journals in the field of computer science and conducting research in robotics, computer vision, embedded systems, and internet of things. He can be contacted at email: abduljalil@poliupg.ac.id.