JPPIPA 10(8) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Design Smart Farming in Rice Field for Monitoring Soil Fertility and Pest Rate Using Internet of Things

Nurdina Widanti[1*], Aditya Alamsyah[1], Actor Albus[1], Ahmad Nur Ikhsan[1], Sri Wiji Lestari[1], Wike Handini[1], Sasmito Adi Raharjo[1]

[1] Jayabaya University, Electrical Engineering, East Jakarta, Indonesia.

Received: February 23, 2024
Revised: June 27, 2024
Accepted: August 25, 2024
Published: August 31, 2024

Corresponding Author:
Nurdina Widanti
dina.dinawidi.widi7@gmail.com

DOI: 10.29303/jppipa.v10i8.8288

Abstract: Rice fields in Indonesia have a strategic role in providing food for the Indonesian population. The Central Statistics Agency (BPS) noted that domestic rice consumption also continues to increase, 98.35% of households in Indonesia consume rice. There are many influencing factors for production rice such as pest, climate change. The aim to optimize rice production by monitoring soil moisture and soil pH and adding protection features to detect rat pests. This tool was built using an Internet of Things-based system integration method, where the system output can be monitored on the blynk and email applications for the reading history of rat pests if they are caught on camera. The results obtained from the system are Soil moisture sensor readings have a system accuracy of 99% with an error value of 0.01. And the pH sensor reading has an accuracy of 99% with an error of 0.015. The most optimal PIR sensor reading is 1 meter and this data is sent simultaneously with the camera sensor via email. Monitoring data on rice agricultural land by adding rat pest protection features, as well as historical data can be captured wellcan provide a strong basis for the development of more effective and sustainable.

Keywords: IoT; Monitoring; Pest; Rice; Soil fertility

Introduction

Rice fields have many benefits for humans, one of which is as a source of food and also a source of income for farmers. According to The Central Statistics Agency (BPS) noted that domestic rice consumption also continues to increase, showing that 98.35% of households in Indonesia consume rice (CNBC Indonesia, 2023; Ministry of Public Works, 2016). Rice fields include artificial land created by farmers to grow crops, one of which is rice. The criteria for good soil to use for growing rice is soil that has a fine to somewhat fine texture (Sudrajat, 2015).

Soil fertility is one of the keys to rice productivity. The problem that is currently emerging is that rice productivity is always decreasing due to problems with fertilizer, nature, or failure harvest due to pests. In reality, in the field, soil fertility is decreasing due to the continued use of chemical fertilizers which causes the soil to become hard and lose its porosity (DINPPKP, 2023). In line with that, soil pH is also a controlling factor in soil fertility, if the soil pH value is outside the optimal limit, so soil fertilization will not be effective because the fertilizer given will not be absorbed by the plants in the expected amount. Choosing the type of fertilizer without considering soil pH can also worsen soil pH (Agriculture, 2023).

Handling pests in rice fields is also an important factor in increasing rice productivity, where currently pest management is still done manually, namely by using scarecrows and this cannot cover all pests, especially rats, which are the main enemy of farmers, in where mice will actively attack at night. Apart from that, mice have a very fast breeding cycle, and mice can eat

How to Cite:
Widanti, N., Alamsyah, A., Albus, A., Ikhsan, A. N., Lestari, S. W., Handini, W., & Raharjo, S. A. (2024). Design Smart Farming in Rice Field for Monitoring Soil Fertility and Pest Rate Using Internet of Things. *Jurnal Penelitian Pendidikan IPA*, *10*(8), 5782–5788. https://doi.org/10.29303/jppipa.v10i8.8288

rice stalks and rice seeds, so that rice cannot grow optimally or even dies (Kulon Progo Regency Agriculture and Food Service, 2023).

The development of the times makes us learn more and more about the concept of smart farming, where smart farming will accommodate plant monitoring and also monitoring crop yields, regulating watering and also applying fertilizer. The use of the Internet of Things (IoT) is a technology to support monitoring, detection, learning based, security (Indra et al., 2023; Dewanto et al., 2023; Safiatuddin & Asnawi, 2023; Immanuel et al., 2024; Siregar, 2023; Diharja et al., 2022). By utilizing IoT technology, it is hoped that a rice field management technology can be developed that can monitor soil fertility, rice growth and development and most importantly can be integrated with monitoring to eradicate rat pests in one dashboard system so that farmers can monitor rice fields and also rice productivity anytime and anywhere even.

The trend in the development of smart farming is selecting sensors to detect soil fertility and which sensors are optimal for detecting soil fertility using both humidity and pH sensors (Ghosh et al., 2022). Then a comprehensive IoT system for detecting agricultural systems from monitoring soil fertility to plant productivity (Kumar et al., 2024; Derpsch et al., 2024; Islam et al., 2023; Rajak et al., 2023; McCole et al., 2023; Mathi et al., 2022; Wicaksono et al., 2021; Tomczyk et al., 2024), so far also digitalizing a system has also been developed with a combination of IoT (Subeesh & Mehta, 2021; Singh et al., 2022) there is also a description of the microbials that are in the soil if the soil is fertile in rice soil where to monitor the dynamic changes of various N and soil organic-C (SOC)(Wang et al., 2024), apart from that, IoT applications are used to see increases in food safety (Morchid et al., 2024), also used to detect NPK in soil (Mohanty et al., 2024), appropriate technology such as using cameras to identify rice (Putra et al., 2022), then there is also identifying soil fertility starting with IoT-based technology to using artificial intelligence (Daniel et al., 2020; Rosyidin et al., 2023; Firmansyah et al., 2023), Detecting soil fertility levels through several variables, namely soil pH, soil moisture, soil color and also the electricity of the soil itself. Likewise for managing rice pests (Untoro, et al, 2021; Ratnawati & Setiadi, 2019). Research by monitoring rat pests and plant diseases as well (Materne & Inoue, 2018; Fang, 2020; Rohmah et al., 2024; Nenotek et al., 2022; Cardoso et al., 2022; Amnerkar et al., 2023; Passias et al., 2023).

Based on previous research, a tool was built with integration between detecting soil fertility, rice productivity and also monitoring and detecting rat pests as protection to increase IoT-based productivity. This system was built to monitor water content and fertility of rice fields as well as provide protection and early notification to farmers about rat pests. The features of this tool are equipped with a camera and PIR sensor to detect pests and a soil moisture sensor and a pH sensor to monitor water content in the wetland and also soil fertility. This research offers an innovative approach that combines rice plant monitoring with plant pest monitoring. It is hoped that the results of this research will provide a strong basis for the development of more effective and sustainable intervention strategies, helping to increase crop productivity.

Method

Making this prototype begins with hardware design then proceed with software design using the Blynk application, where the system hardware is built using Node MCU ESP 32 as the main processor, then this processor is integrated with soil moisture sensors, PIR sensors, pH and also Camera, all data on the sensors will be sent on a server that was built using a server from the Blynk application, then from that server the data is processed. The output of this system is divided into 2, namely for visualization of PH sensor data, Humidity sensors using the Blynk dashboard, and for output from PIR sensor and camera data it will be sent to email via mail.google for detection of mouse pest movement then the system will trigger a buzzer to sounds when the sensor detects a rat pest in Figure 1 is a block diagram of the system created.

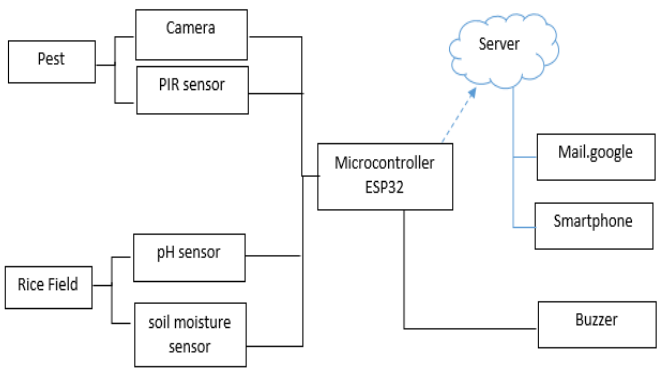

Figure 1. Block diagrams

Hardware Design

This system was built using a pH sensor, humidity sensor, to detect soil fertility and water adequacy in rice fields. The PIR sensor is used to detect the movement of rat pests which is equipped with a camera which will then send the system output to the IoT application created and also a buzzer to provide information in the rice fields. In fig2 shows the system hardware that was built. Table 1 shows the specifications of the system created. Figure 3 shows a panel image.

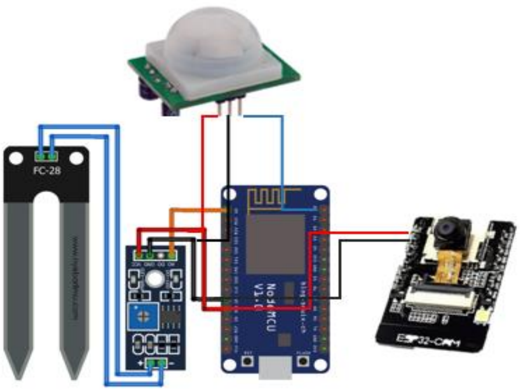

Figure 2. Hardware systems

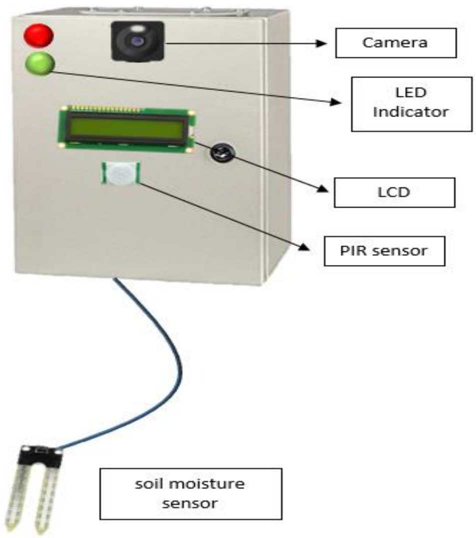

Figure 3. System panels

Table 1. System Specifications

Specifications	Details
Dimensions	
long	190mm
Wide	280mm
Tall	100.50mm
Heavy	400 grams
Material	Waterproof, Cover/ABS plastic
Hardware specifications	
Input voltage	5 – 12 VDC
Processor	NodeMCU ESP32
Sensor input	PIR sensor, humidity sensor, pH sensor
Outputs	Buzzer and smartphone

User Interface Design

The system will send data to the IoT application created and also input images captured by the ESP32 camera will be sent via email and will be saved on the system SD card.

Calibration and Analysis

This calibration is used to prepare the sensor used so that it can collect data to the maximum value of its calibration set up taken using linear regression, according to formula 1.

$$y = a + bX \tag{1}$$

Where (y) is linear regression, (a) constant (intercept), intersection with the vertical axis. (b) regression constant (slope). (X) = independent variable. After the values from the linear regression are obtained, the results are entered into the program code. After that, to analyze system accuracy and errors using formulas 2 and 3.

$$eror = \frac{|\text{aproximate} - \text{exact}|}{\text{exact}}\ x\ 100\% \tag{2}$$

$$accuracy = 100\% - ((3)\frac{|\text{aproximate} - \text{exact}|}{\text{exact}}\ x\ 100\%) \tag{3}$$

Results and Discussion

Hardware Testing

In this test, a comparison tool will be used to carry out the test. Table 2 shows the results of the humidity sensor. In Table 3 the results of testing the pH sensor, in Table 4 the results of testing the PIR sensor with an ESP camera.

Soil Moisture Testing

In the test, moisture measurements were taken by comparing water use, namely dry soil conditions without water. Soil moisture data sampling was carried out on 4 pieces of soil media with the following criteria: 1) The soil is very wet, (ratio of soil: water = 2:1); 2) Wet, (soil: water ratio = 3:1); 3) Medium soil (soil watered from 7:00 AM and 13 hours later used for measurements); 4) Dry Soil (soil watered from 07:00 AM and 35 hours later used for measurements); 5) all tests were also repeated by adding water level parameters starting from 200 ml to 750 ml and the results obtained were as in Table 2.

Table 2. Humidity Sensor Test Results

water (ml)	Censorship (%)	Comparison tool (%)	Error (%)	Accuracy (%)
200	40	39	0.026	97.4
250	45	45.2	0.004	99.5
300	48	48	0	100
500	50	50	0	100
550	55	56	0.18	98.2
600	60	61	0.16	98.3
700	72	71.9	0.001	99.8
750	75	75	0	100
Average			0.01	99

From the data above, the results show that the error from the tool is 0.01% and the accuracy results are 99%, so it is found that the results of the measurement tool have an error of ≤5% so that the tool has a small error value and high precision, and is supported by 99% for accuracy, which indicates that the tool has high accuracy.

pH Sensor Testing

To test the pH sensor, it is done by dissolving the buffer powder and then dipping the pH sensor in the buffer solutionwith a comparison tool, the reading results obtained are as in Table 3.

Table 3. pH Sensor Test Results

pH buffers	Censorship	Comparison tool	Error (%)	Accuracy (%)
4	4.2	4.1	0.024	98
4	4	4	0	100
4	4	4	0	100
6	6.3	6.1	0.033	97
6	6.2	6.1	0.016	98
6	6	6.1	0.016	98
9	9	9	0	100
9	9.2	9	0.022	98
9	9.2	9	0.022	98
Average			0.015	99

From the data above, the results show that the error of the tool is 0.015% and the accuracy results are 99%, so it is found that the results of the measurement tool have an error of ≤5% so that the tool has a small error value and high precision, and is supported by 99% for accuracy, which indicates that the tool has accuracy. tall.

PIR Sensor and Camera Testing

PIR sensor testing is carried out by placing the animal in one place so that the optimal distance for taking measurements is known. Obtained from the measurement results, the optimal distance that can be read by the sensor is 1 meter. And when the PIR sensor detects rat pests, the buzzer in the system will sound. In Figure 4 are the results of data collection at a distance of 1 meter.

Figure 4. PIR sensor data retrieval

User Interface

The results obtained from all sensors will be entered into the smartphone for the soil moisture sensor component, pH sensor and for PIR sensor and camera data will be sent via email and image data will also be saved on the system SD card. Figure 5 shows the reading results on a smartphone and Figure 6 shows the data sent to email with notification details.

Figure 5. Reading results on smartphone

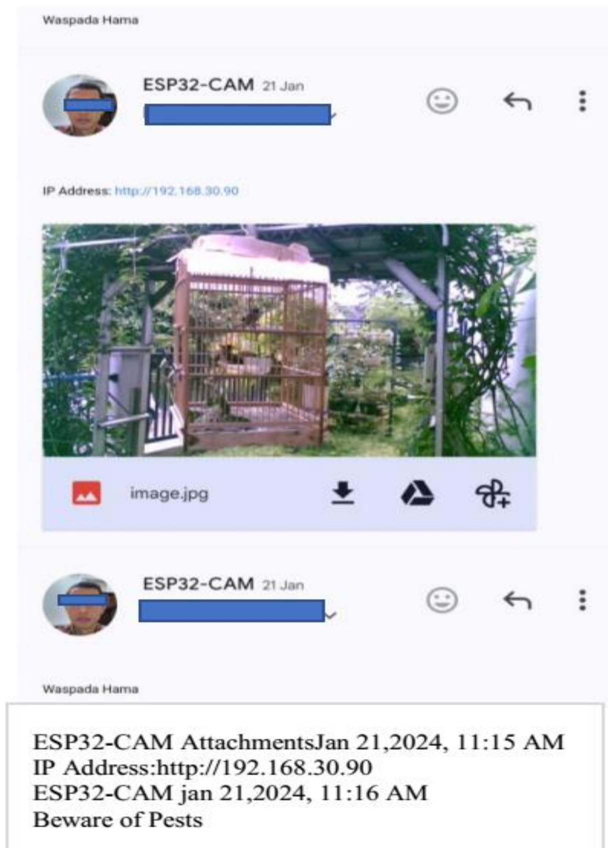

Figure 6. Email reading results

Conclusion

This smart farming prototype design was built to Monitor data on rice field by adding rat pest protection features, as well as historical data can be captured well can provide a strong basis for the development of more effective and sustainable. The results obtained from soil moisture sensor readings had a system accuracy of 99% with an error value of 0.01. And the pH sensor reading has an accuracy of 99% with an error of 0.015. The optimal PIR sensor reading is 1 meter and this data is sent simultaneously with the camera sensor via email and has been successfully sent with an email notification including the time of collection and pest alert notification.

Acknowledgments
This research was funded by an internal grant from the Faculty of Industrial Technology, Jayabaya University.

Author Contributions
NW, AA, AA, ANI, SAR validation, conceptual, data preparation, calibration; SWL data analysis and writing review; WH methodology and writing review.

Funding
Is given by internal grant from the Faculty of Industrial Technology, Jayabaya University.

Conflicts of Interest
The authors declare no conflict of interest.

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