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Monitoring Smartfarm Using IoT Based for Rice Agriculture

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Abstract (TNR 9pt Bold Italic)
Indonesia is an agrarian country where the majority of its population chooses farming as their occupation, especially for those living in village areas. The most crucial factor influencing agricultural outcomes is the quality of farmland, which depends on environmental conditions such as soil moisture, humidity, and temperature in the farmland itself. These environmental factors are affected by the seasonal changes in Indonesia, namely the rainy season, which provides abundant water for plant energy, and the dry season, which has limited and irregular water supply. The implementation of technology is expected to help the agricultural sector withstand climate change and improve agricultural productivity, thereby increasing farmers income. This research utilizes technology for monitoring agricultural land, particularly focusing on soil moisture, humidity, temperature, and water levels in rice fields. The smart farm monitoring system can assist farmers in monitoring the condition of agricultural land, with criteria including soil moisture, humidity, temperature, and water levels. The smart farm monitoring system is designed to connect to the Internet of Things (IoT), where the monitoring system sends data on soil moisture, air humidity, air temperature, and water levels detected through devices. The detected data is then transmitted to the smart farm web, accessible through smartphones or laptops, allowing remote monitoring. The research results indicate a success rate of 95.9% for soil moisture sensors, 98.6% for ultrasonic sensors, 97.3% for humidity measurements, and 95.3% for temperature measurements. This translates to: Which means that the research to develop this monitoring tool was successful, as evidenced by the high success rate in its experimental use.

Keywords:
Monitoring;
Soil Moisture;
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Ultrasonik;
Smartfarm;

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INTRODUCTION

The technological advancements in the industrial era demand every sector [1] to keep up with the use of technology in various fields, including agriculture [2]. The utilization of this technology must be tailored to the needs of different sectors.

Indonesia is an agrarian country where most of its population chooses farming as their occupation, especially for those living in rural areas. The most crucial factor influencing agricultural outcomes is the quality of farmland. The environmental conditions, particularly soil moisture, humidity, and temperature, significantly affect the land's quality. The availability of water for irrigation and seasonal factors will impact the conditions of agricultural land [3]–[5]. These environmental factors are influenced by the seasonal changes in Indonesia, such as the rainy season, which can provide abundant water for plant energy, and the dry season with minimal and irregular water supply, leading to difficulties in the planting process and potential crop failure [6]–[8].

High humidity can increase fungal activity, disrupting plant health, while low humidity can lead to plant drought, both of which increase the risk of crop failure [3]. The agricultural sector contributes nearly 15% of the gross domestic product [4]. As agriculture significantly influences the national economic movement in Indonesia, there is a need for technology that can support national economic development [9]–[11]. Technology application in agriculture has been implemented in several countries, including Ghana [6], Nigeria [7], and Indonesia [8], under the national agricultural research system. The application of technology is expected to help the agricultural sector withstand climate change and increase agricultural productivity, thereby improving farmers' income [12]–[16].

Rice is a dominant food commodity in Indonesia [17], and it's processing still relies on conventional methods, making it less competitive with technology from other countries, resulting in suboptimal rice quality. Additionally, the demand for organic rice products is increasing linearly with public awareness of food safety and health. The smart farm monitoring system can assist farmers in monitoring the condition of agricultural land, measuring criteria such as soil moisture, air humidity, air temperature, and water levels. Wetland rice production is highly influenced by the availability of irrigation water and rain to maximize growth. The required criteria include an optimum relative humidity of 80-85% for rice stem growth and 70-80% relative humidity during the flowering process. The air temperature should be between 28-33°C, and air humidity around 30-65% [18]. The irrigation water requirement is approximately 3.79 mm/day with a water level of 2 cm per hectare [19].

Smart farming (modern agriculture) is defined as agriculture that applies technology based on scientific principles supported by existing technological and financial resources. Technology is not only used in the production process but also plays a role in pre- and post-production processes. With smart technology such as Artificial Intelligence (AI), robotics, and the Internet of Things (IoT) [20], [21], it contributes to improving agricultural productivity. The application of this smart technology is carried out by utilizing a combination of various types of technology, ranging from microcontroller systems, various types of sensors, to various types of outputs [21]–[23].

This research is necessary so that the agricultural sector can continue to produce rice without being hindered by climate change in Indonesia, thereby enhancing agricultural outcomes in various agrarian countries, especially Indonesia [19].

The utilization of technology involves the monitoring process of agricultural land, particularly focusing on soil moisture, air humidity, air temperature, and water levels in paddy fields. The monitoring process is carried out to maintain plant quality 24 hours a day until the harvesting process. With the implementation of technology, it is expected to eliminate concerns about pest attacks and low-quality yields [23], [24].

The development of the tool applies a monitoring system based on the Internet of Things (IoT) to facilitate land monitoring activities. This can be done through smartphones or laptops by accessing a website connected to the device [24]–[26].

In research process of this tool, sensors are used as input components. Sensors are transducers that work by converting mechanical, light, magnetic, heat, and chemical quantities into voltage and electrical current. Sensors are commonly used in detection and control of objects. Various types of sensors are often applied in electronic circuits, such as light sensors, temperature sensors, and pressure sensors. Transducers are devices used to convert one form of energy into another. The input from the transducer is known as a sensor because it senses a physical object and converts it into another form of energy [27]–[29].

Several types of sensors will be used, including soil moisture sensors, air humidity sensors, and water level sensors [30], [31]. These sensors are selected to address challenges in determining the irrigation process. To function, the sensors need to be connected to a control device in the form of a microcontroller. In this study, a microcontroller required is one that can control multiple sensors, has low power consumption, and can connect to Wi-Fi, such as the ESP32 [29].

The Internet of Things (IoT) is a concept that connects devices using the internet in their access. With IoT, the exchange of information can be carried out from one source to another connected device [31]. This information exchange process is connected in real-time connections with objects embedded with sensors to connect to the internet [32]–[34].

METHOD

The smart farm monitoring system operates based on the following principles: the smart farm monitoring will detect soil moisture using a soil moisture sensor and detect air humidity and air temperature using DHT sensors. The measurement results data will be displayed on an LCD, with measurement intervals suitable for rice plants, i.e., 80-85% relative humidity for stem growth and 70-80% relative humidity during the flowering process. The recommended air temperature is between 28-33°C, and air humidity around 30-65% [18]. To detect water level, an ultrasonic sensor is positioned facing the wet (bottom) direction, measuring water height from the instrument's height minus the distance detected by the sensor from the water surface. This provides information about the water level in the paddy field. Water level measurement data will also be displayed on the LCD. In the SRI cultivation method, a water height of 1-2 cm above the soil surface is required at the age of 0-20 DAS (Days After Sowing) [19]. The data collected from sensor measurements will be processed by the ESP32 microcontroller programmed using the Arduino IDE [26].

The smart farm monitoring system is designed to connect to the Internet of Things (IoT), where the monitoring system will transmit data, including soil moisture, air humidity, air temperature, and water level, detected through the devices. The detected data will then be sent to the smart farm web accessible via smartphones or laptops for remote monitoring [33], [35], [36].

The smart farm monitoring system is also designed to be used in various weather conditions as it will be installed in an outdoor environment. Considering the existing weather conditions, the device is designed to be waterproof and heat-resistant using 3mm thick acrylic material in milk-white color to reflect sunlight and protect against water for the electronic device box. The device box is constructed using 2x2 cm iron material to withstand outdoor weather conditions that could damage the equipment. The block diagram design can be seen in Figure 1.

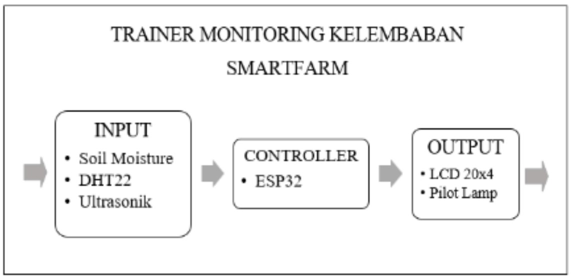

Figure 1. Diagram Block

Utilizing input from a soil moisture sensor for measuring soil moisture, a DHT22 sensor for measuring air humidity and air temperature, and an ultrasonic sensor for measuring water level. As for the controller, an ESP32 is employed, offering more input and output pins and internet connectivity due to its built-in Wi-Fi module. For output, a 20x4 LCD is used to display the readings from each sensor, and a pilot lamp serves as an indicator for dry and wet soil conditions. The 12V power source is derived from a 12V power supply to operate the switch and indicator (pilot lamp), while the 5V power source is obtained from a step-down converter to reduce the voltage from 12V to 5V. This voltage is utilized to power the ESP32, LCD, relay, and the sensors in use. The circuit configuration can be viewed in Figure 2.

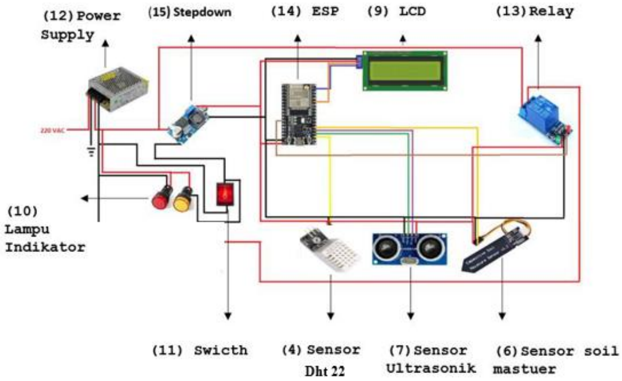

Figure 2. Schematic Electronics Circuits

RESULTS AND DISCUSSION

The smart farm technology produced is a monitoring system for soil moisture, air humidity, air temperature, and water level in paddy fields. The monitoring system device is designed to be permanently installed in the fields, with mechanical support using 2x2 cm iron legs measuring 60 cm in height and 30 cm in width. For the electrical components, an enclosure made of 3mm thick milk-white acrylic material is used, measuring 14 cm in height, and the device's height from the ground is 30 cm. The specifications of the device can be found in Table 1.

Table 1. The Spesification Size

Parameter	Size
Electronic Box	3kg
Mechanical Frame	8kg
Total Weight	11kg
Height	0.6m

Width	0.3m
Length	0.4m

Figure 3. Design Result

To facilitate a better understanding of this smart farm monitoring system, the technology display is further explained in Figure 4.

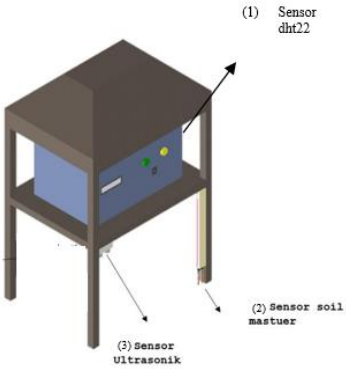

Figure 4. Device Display

The component layout is arranged to ensure the safety of each component's position and to avoid short circuits due to overlapping cables inside the box. The trainer will be enclosed in a box, considering its outdoor use as a smart farm prototype. This trainer will consist of a power supply, step-down converter, relay, breadboard, and ESP32. Then, two pilot lamps, an LCD, a switch, and a fuse will be placed at the front of the box. The design inside the box can be seen in Figure 5.

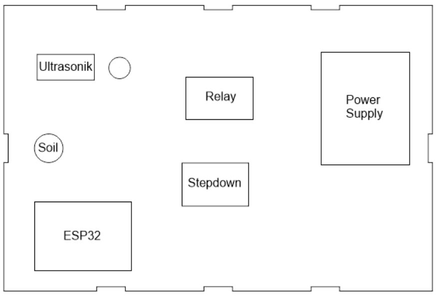

Figure 5. Inside Box View

The tool's box is used to store the components. As the trainer is intended as a smart farm prototype, the design is enclosed, considering outdoor use. The components will be placed inside a closed box with the LCD, pilot lamps, switch, and fuse located at the front. The sensors will be placed through designated openings. The box design for the tool is researchd using CorelDraw X7 software. The material used for the box is 3mm thick milk-white acrylic with dimensions: Length 30 cm, width 20 cm, and height 14 cm. The box design is shown in Figure 6.

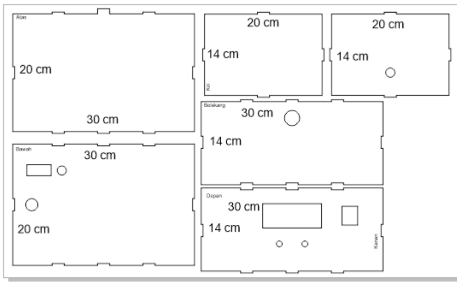

Figure 6. Box Design

The utilization of an ultrasonic sensor to measure water level becomes a consideration for creating a mount, ensuring optimal use of the sensor. The material used is 2mm thick iron, shaped into a box frame matching the dimensions of the box: length 40 cm, width 30 cm, and height 60 cm. The design of the box mount is illustrated in Figure 7.

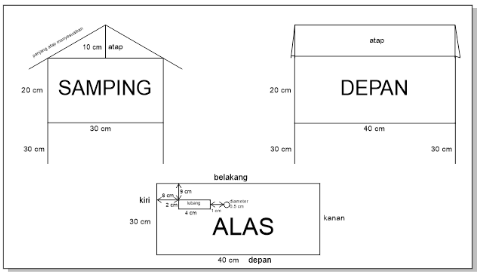

Figure 7. Box Base Design

In creating the Smart Farm Monitoring Trainer tool, program development is required. The software used for this stage is the Arduino IDE (Integrated Development Environment). The programming flowchart can be seen in Figure 8.

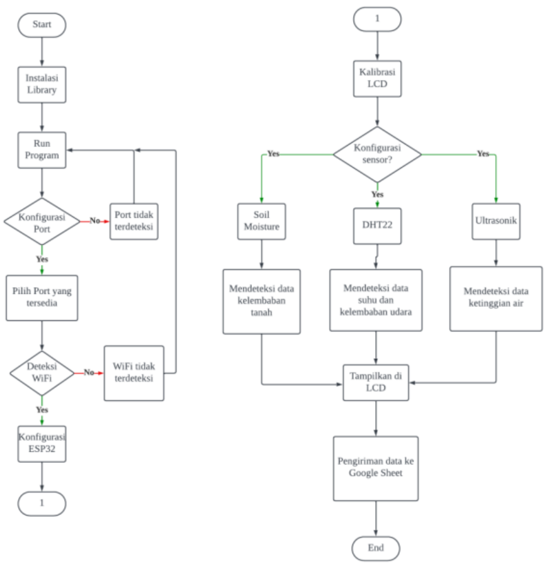

Figure 8. Program Flowchart

The results detected by the sensors can be viewed on the website: https://bit.ly/SpreadsheetSmartfarm. The monitoring process is based on an IoT system to send real-time sensor reading data. The web interface can be seen in Figure 9.

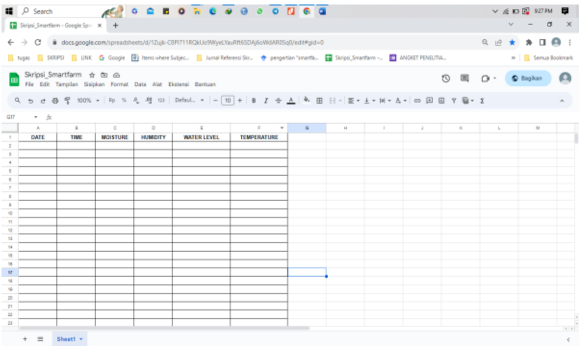

Figure 9. Monitoring Smartfarm Based on Google Spreadsheet

The monitoring system conducted by the device involves monitoring the rice field area under various conditions: dry soil, soil one day after irrigation (wet 1), soil two days after irrigation (wet 2), soil three days after irrigation (wet 3), and soil after rainfall (wet 4). The measurement results are processed in software containing commands to display the ADC sensor values and convert the output from voltage to humidity units. Soil moisture sensor testing is performed by inserting the sensor into the soil at a depth of 0.02 to 0.03 m. The readings are then displayed on the LCD. Sensor data is connected to pin A0 on the ESP32 microcontroller. The performance of the soil moisture sensor can be seen in Table 2.

Table 2. Result of Soil Moisture Measurement

Dry (%)	**Wet 1 (%)**	**Wet 2 (%)**	**Wet 3 (%)**	**Wet 4 (%)**
24	47	26	24	44
20	48	25	23	41
9	48	24	23	40
7	48	23	22	40
6	48	23	10	40
6	47	23	10	48
12	47	24	34	40
6	47	28	33	40
6	47	24	32	40
5	46	24	32	40
4	46	24	30	40
4	46	25	29	40
4	46	24	29	39
4	45	27	29	39
5	45	25	28	40
11	48	25	28	39
5	45	25	32	40
6	45	28	29	40
4	44	25	28	40
4	44	25	26	39

When soil humidity is <20% RH, it is categorized as dry, and when soil humidity is >20%, it is categorized as wet. The sensor detection results processed on the ESP32 involve detecting soil humidity values by measuring the soil water content using two electrical conductors. The measured resistance value is then processed and can indicate the detected water content in the soil. The ADC sensor value can be obtained using the following formula:

$$ADC = \left(\frac{1023 - \text{measurement result}}{673}\right) \times 100$$

The value 1023 is the maximum data bits value, and the value 673 is the difference between the humidity in wet soil and the humidity in dry soil.

Measurements using the soil moisture sensor involve 20 samples, measuring the soil under 4 conditions: dry, wet 1, wet 2, wet 3, and wet 4. From the sensor testing results, it can be concluded that the total average error is 1.41%, and the success rate is 95.9%.

Next, measurements with the ultrasonic sensor in detecting water height in the rice field area. Measurements are taken on the soil surface under 4 conditions: dry, wet 1, wet 2, wet 3, and wet 4. After the device is turned on, the sensor will start detecting water height measurements conducted in predetermined sample areas to obtain water height data in the rice field. The water height measurement results can be seen in Table 3.

Table 3. Result of Ultrasonik Measurement

Dry (cm)	**Wet 1 (cm)**	**Wet 2 (cm)**	**Wet 3 (cm)**	**Wet 4 (cm)**
24	13	23	23	26
23	24	23	23	26
23	24	23	23	23
23	24	23	23	23
23	24	23	23	26
23	24	23	23	26
23	24	23	23	25
23	24	23	23	26
23	24	23	23	26
23	24	23	23	26
23	24	23	23	23
23	25	23	23	23
23	24	23	23	23
23	25	23	23	26
23	24	23	23	23
23	24	23	23	26
23	26	23	23	23
23	24	23	23	23
23	25	23	23	23
23	25	23	23	26

The measurement of the ultrasonic sensor is based on the principle of ground height defined as the sampling location. This ground height will decrease due to reflections on the ultrasonic sensor, indicating the actual water height. The calculation of water height is obtained through the following formula:

$$\text{Ground Height} = \text{distance between sensor and ground} - \left(\frac{\text{sound speed} \times \text{time}}{2}\right)$$

The sound speed is the air speed at a specific temperature and pressure, with a constant of 343 m/s. The variable time represents the duration the ultrasonic signal takes to travel from the sensor transducer, reflect off the water surface, and be received by the sensor receiver. The division by two is obtained from the travel time of the signal to the water surface and back to the sensor; the actual travel distance is half of the total distance.

Measurement with the ultrasonic sensor involves 20 samples, measuring the soil under 4 conditions: Dry, Wet 1, Wet 2, Wet 3, and Wet 4. From the sensor testing results, it can be concluded that the total average error is 0.14%, and the success rate is 98.6%.

Next, measurements using the DHT sensor to measure air humidity and air temperature. Measurements are taken on the soil surface under 4 conditions: Dry, Wet 1, Wet 2, Wet 3, and Wet 4. The DHT sensor works by measuring the level of air humidity and air temperature in the rice field area. The sensor operates on the principle of capacitance change in the dielectric material between two plates in the DHT sensor. The air humidity measurement results can be seen in Table 4, and the air temperature measurement results can be seen in Table 5.

Table 4. Result of Humidity Measurement

Dry (%)	**Wet 1 (%)**	**Wet 2 (%)**	**Wet 3 (%)**	**Wet 4 (%)**
89.90	88.60	95.20	88.70	85.60
88.90	88.60	93.80	88.00	85.40
88.00	87.20	92.80	87.60	85.20
87.50	86.50	92.10	87.30	85.00
87.00	86.20	91.60	87.20	84.80
86.60	86.00	91.10	87.10	84.80

86.30	85.60	90.80	85.40	84.80
86.20	85.40	90.40	85.00	84.70
86.10	85.40	90.10	85.00	84.50
85.90	85.40	89.90	84.70	84.40
85.90	85.30	89.60	84.60	84.30
85.80	85.20	89.40	84.50	84.30
85.90	85.00	89.20	84.50	84.30
85.70	85.00	89.10	84.40	84.30
85.50	84.90	89.00	84.60	84.30
85.60	85.00	88.80	84.40	84.40
85.20	84.90	88.70	84.50	84.40
85.40	84.90	88.70	84.50	84.40
85.50	84.80	88.60	84.60	84.50
85.30	84.70	88.50	84.80	84.50

Table 5. Result of Temperature Measurement

Dry (^{0}C)	**Wet 1 (^{0}C)**	**Wet 2 (^{0}C)**	**Wet 3 (^{0}C)**	**Wet 4 (^{0}C)**
24.70	25.50	26.00	26.50	26.30
25.00	25.70	26.30	26.60	26.30
25.10	25.80	26.50	26.70	26.40
25.30	25.90	26.60	26.80	26.40
25.30	26.00	26.70	26.80	26.40
25.40	26.00	26.80	26.80	26.40
25.40	26.00	26.90	27.20	26.40
25.50	26.00	26.90	0	26.50
25.50	26.00	27.00	0	26.50
25.60	26.00	27.10	0	26.50
25.60	26.10	27.10	27.30	26.50
25.60	26.10	27.10	27.30	26.50
25.70	26.10	27.20	27.30	26.50
25.70	26.10	27.20	27.30	26.50
25.70	26.10	27.20	27.30	26.50
25.70	26.10	27.20	27.30	26.50
25.80	26.10	27.20	27.30	26.50
25.80	26.10	27.30	27.30	26.50
25.80	26.10	27.30	27.30	26.50
25.80	26.10	27.30	27.30	26.50

Measurements with the DHT sensor involve 20 samples, measuring the soil under 4 conditions: Dry, Wet 1, Wet 2, Wet 3, and Wet 4. From the sensor testing results, it can be concluded that the total average error is 0.23%, with a success rate of 97.3% for air humidity measurement. Meanwhile, the average error is 0.47%, with a success rate of 95.3% for air temperature measurement.

The performance results of the Smart Farm Monitoring Trainer learning media show good test results. Data obtained from the soil moisture sensor testing can measure from 0 to 50% in soil and 0 to 70% in water, the DHT22 sensor can measure air humidity from 50 to 90% and air temperature from 20 to 300, and the ultrasonic sensor can measure water height from 1 to 12 cm. The learning media can work well and can read according to the needs in rice field farming. With an average percentage error of 4.16% for Dry land conditions, then 2.56% for Wet 1 land conditions (after irrigation), then 3.19% for Wet 2 land conditions (2 days after irrigation), when measuring for Wet 3 land conditions (3 days after irrigation) the average error is 3.56%, and in Wet 4 land measurement conditions (after rain), the average error is 2.28%. Thus, the total measurement results with an average percentage error of 3.15%. With these results, it can be concluded that the tool can work well because the calculated average error is less than 5%. This error occurred due to disruptions in the network used to connect the microcontroller to the website, so some data was not sent to the website, and the data displayed on the website showed previously detected data or showed a value of 0. In soil moisture sensor measurements, there were also difficulties in collecting data for conditions where the soil was too Dry, so the data sent was not very accurate. Besides the above factors, all sensor measurements for agricultural land conditions have worked well and quite accurately.

CONCLUSION

This research study revolves around smart farm technology as a monitoring system for agricultural land conditions, specifically monitoring soil moisture, air humidity, air temperature, and water height in rice fields. The study yielded results indicating that the smart farm monitoring system can assist farmers in monitoring field conditions through an IoT system. The tool generated from the measurements is already functioning well and accurately, with a total average percentage error of 3.15% across five different agricultural land conditions. The main reason for less accurate readings is the instability of the internet network used to connect the microcontroller to the website. Additionally, the soil moisture sensor readings are less accurate in excessively dry soil conditions, attributed to the sensor's difficulty in reading the resistance values in extremely dry soil.

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