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IoT-based Smartfarm Technology for Rice Farming

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A B S T R A C T

One of the big problems in agriculture in the tropics, especially in Indonesia, is rainy and dry seasons. During the rainy season, agriculture in Indonesia in general can run smoothly because the water resource as the main supply of water for various types of plants is available regularly and in abundance. During the rainy season, agricultural products, including livestock abound, because animal feed is also available in abundance. However, a phenomenon occurs during the dry season. When the water supply is minimal or even unavailable, the planting process decreases and even fails before the harvest season. This research tried to bridge the agricultural sector so that it can continue to strive without being affected by the seasons. It is hoped that the agricultural sector can increase its production. This research integrated information and communication technologies (ICTs) through engineering variable measurements of soil water availability, soil moisture, air humidity, temperature of the planting environment, and real-time monitoring of plant conditions. The measurements of several determinant variables in agriculture were followed by responses to the measurement results. It is expected that the process of maintaining crop quality can be done all day until harvest. This technology is applicable to assist farmers in monitoring soil moisture, water level, and water discharge produced. This technology was also designed to be connected to the Internet of Things (IoT) in which data on soil moisture, water level, and water discharge are processed and sent to users. The data sent are connected to the Smartfarm web which can be accessed through smartphones. In addition, this technology is anti-theft and can be operated and monitored remotely.

INTRODUCTION

Indonesia is the second largest agricultural country after Brazil. Conventional agricultural management still adorns the agricultural model in Indonesia. This makes agricultural production still dependent on rainfall and climate [1-4]. During the rainy season, agriculture runs well because the water resource is abundant. The season also makes livestock abundant because animal feed is ample [5-7].

During the dry season, the water supply is very minimal, so the planting process is difficult and leads to harvest failure. The total Indonesian agricultural arable land is 241,880 km² (a total of 12% of the entire area), and the rest is hills/mountains [2]. The agricultural sector accounts for nearly 15% of the Gross Domestic Product [3]. It can be said that agriculture is a field that is very influential for the movement of the national economy. Therefore, agriculture needs to get a touch of technology so that it can continue to grow to support the national economy [8-10].

Increasing the productivity of the agricultural sector will improve the welfare of the farming community. The utilization of smart technology is a strategy to make this happen. The application of ICTs in agriculture has been carried out by many agricultural countries such as Ghana [5], Nigeria [6], and Indonesia [7] under the National Agricultural Research System [8]. The application of ICTs in these countries contributes to the agricultural productivity increase which has an impact on increasing farmers' income [11-14]. In this study, the smart technology used is not merely ICTs because it is supported by automatic follow-up of the information obtained.

This study is expected to help the agricultural sector so that it can continue to produce and be resistant to climate change. It is hoped that the agricultural sector can increase the quantity of production. This research integrated ICTs in agriculture by utilizing engineering measurement variables of soil water availability, soil moisture, soil aeration, air humidity, temperature of the growing environment, wind speed, sunlight conditions, and real-time monitoring of crop conditions. The measurement of several determining variables in agriculture was followed by the technology effectiveness assessment. The developed technology was expected to aid the process of maintaining crop quality for 24 hours a day until harvest. Based on the measurement data of

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several supporting variables for soil and plant fertility as well as follow-up of the measurement results, the integration of ICTs in agricultural models eliminates fears of pest attacks, soil degradation, and low-quality yields [15-17].

The need for agricultural products, especially organic rice, is increasing linearly with public awareness about food safety and health. Rice is one of the dominant food commodities in Indonesia. However, the paddy field cultivation process in Indonesia is still too conventional even in this 4.0 Industrial Revolution era. Indonesia is still unable to compete with other countries in terms of rice farming, so the quality of the rice produced is also not optimal.

Smartfarm technology is a technology that is used to assist farmers in measuring several of the criteria needed in cultivating paddy fields. Some of the criteria measured include soil moisture, water level, and water discharge settings. Plant production in wetlands is heavily influenced by the availability of irrigation water and rain, soil type, land capability, and agricultural technology. Several results from previous research show that continuous flooded irrigation does not always have a positive correlation with increased production of both grain and biomass. In rice farming, water is indeed very important in processing paddy so that its growth is maximum. Other important criteria in rice growth are the water level and water discharge. Irrigation waterlogging can be carried out continuously at the same height throughout plant growth. It can be done if the amount of water available is sufficient. With an inundation height of less than 5 cm, high production, and more efficient water are obtained.

METHOD

The principle of the Smartfarm technology is that it detects soil moisture using a soil moisture sensor, which will later be displayed on the LCD at predetermined intervals, namely dry, slightly wet, and wet. Optimization was carried out based on measurement data for three growing seasons with optimum soil moisture yields of 0.622 (wet), 0.593 (wet), 0.455 (slightly wet), and 0.350 cm3/cm3 (dry) for the early, vegetative, mid-season and late-season phases. Soil moisture at the wet level for the initial and vegetative phases is needed to provide sufficient water for vegetative growth such as roots, stems, and leaves.

Water is detected using an ultrasonic sensor installed under the device. It detects the water level from the height of the device reduced by the distance of the sensor from the water. The water level also has an internal interval that is displayed on the LCD screen. Optimal soil moisture for SRI cultivation at the beginning of growth is saturated, in which the water level in the range of 0-20 HST is 1-2 cm above the soil surface. Then, the water regime treatment is divided into 3, namely flooded (FL), moderate (MD), and dry (DR) regimes.

The water discharge that is shown by Smartfarm technology refers to the soil moisture sensor, which will later be assisted by a relay in disconnecting the solenoid valve. In this case, the soil moisture sensor will retrieve data which will later be processed by the ESP 32 microcontroller and then relay instructed via ESP 32 programmed using the Arduino-ide language.

The Smartfarm technology was designed for various conditions because later this technology will be installed in an outdoor environment. Taking into account the various types of weather conditions, the technology is also designed to be waterproof and heat resistant. Therefore, this tool was produced using acrylic material with 3 mm in width. Its' milky white color will reflect heat and be water-repellent. The Smartfarm technology was designed with a strong mechanical system using holo iron measuring 2 x 2 cm which is able to withstand extreme weather outside, strong winds, and other conditions that can directly damage it.

The Smartfarm technology is connected to the IOT (Internet of Things), so it can send information on soil moisture, water level, and water discharge. The data sent are sent to the Smartfarm WEB which can be accessed from smartphones so that it can be monitored remotely. In addition, this technology is also anti-theft because it is able to detect whether the tool is turned off or on.

RESULTS AND DISCUSSION

The Smartfarm technology is soil moisture detection and automatic water level control of the irrigation process in paddy fields. This technology was designed permanently to be installed in rice fields. The foundation of the legs on the mechanical part is made of holo iron with a size of 2 x 2 cm, 1 m in width, and 50 cm in height. The electrical components are made of milky white acrylic which is 3 mm in width and 15.8 cm in height. The height of the tool from the base is 60 cm. Table 1 shows the parameters and sizes of the Smartfarm technology.

Table 1. The specifications of Smartfarm technology

Parameter	Size
Electronics mass box	3 kg
mechanic frame mass	8 kg
Total load mass	11 kg
Height	1 m
Width	0.3 m
Length	0.5 m

To make it easier to understand this Smartfarm technology, an image is provided. Figure 1 shows what the tool looks like.

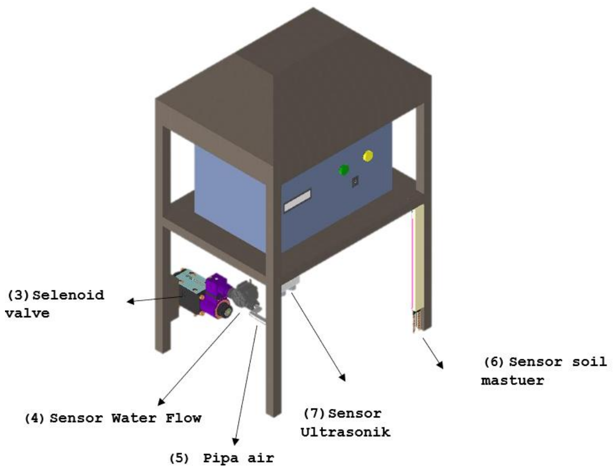

Figure 1. Smartfarm technology

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Then, Figure 2 below shows the schematic view of the electronic circuit as a whole part of the Smartfarm technology.

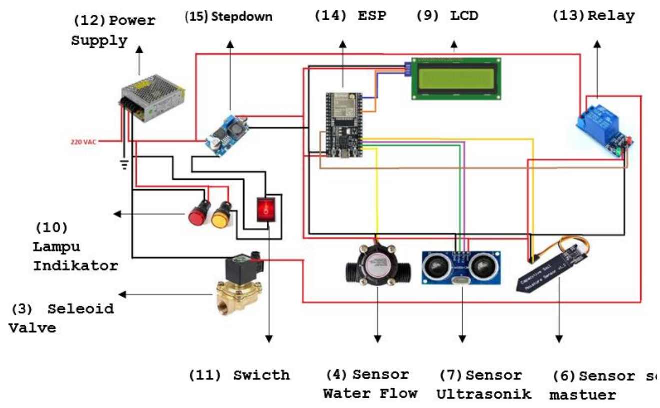

Figure 2. The schematic view of an electronic circuit for the Smartfarm technology.

The results of scanning soil moisture and water availability can be accessed on a website (smartfarmuny.com) because the tool uses IoT-based technology. The website interface is presented in Figure 3 below.

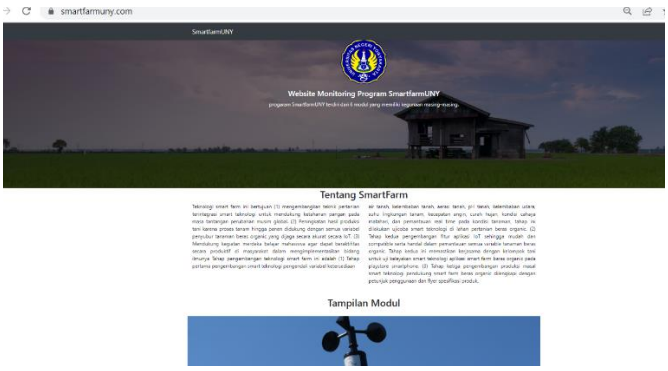

Figure 3. The Smartfarm webstite

To monitor the performance of the soil moisture sensor in measuring the soil, two types of soil (dry and wet) were assessed. The display written on the software contains commands to display the sensor's ADC value and to change the soil moisture sensor's output voltage value to humidity units. The testing was carried out by inserting the sensor into the soil as deep as 0.02 to 0.03 m.

The hardware required was two fields, the first field has dry soil and the second has wet soil. The LCD displays ADC sensor data which are connected to the AO pin located on the NodeMCU ESP 8266 microcontroller. The performance of the soil moisture sensor is shown in Table 2.

Table 2. The Parameters of LM 393 Soil Moisture Sensor

Indicator	**Sensor detection**	**ADC record**	**Humidity record On the LCD (%RH)**	**Assess the humidity using the tool (%RH)**	**Error %**
Dry	52	144.2	5	6	20
Dry	61	142.94	6	6	0
Dry	130	133.85	15	15	0
Dry	254	111.98	27	27	0
Dry	280	110.89	31	32	3
Wet/moist	590	65.00	65	65	0
Wet/ moist	657	54.38	73	73	0
Wet/ moist	789	34.76	88	88	0
Wet/ moist	868	23.03	96	95	1
Wet/ moist	887	20.20	99	97	2
Dry	79	140.26	9	9	0
Dry	110	135.66	12	12	0
Dry	230	177.83	19	19	0
Dry	237	116.79	26	26	0
Dry	246	115.45	27	26	4
Wet/ moist	567	67.75	63	63	0
Wet/ moist	635	57.65	70	70	0
Wet/ moist	793	34.17	88	88	0
Wet/ moist	814	31.05	90	90	0
Wet/ moist	819	30.31	91	90	1
Error averages					1.5

When the soil moisture is lower than 35% RH, the soil is considered dry. Meanwhile, if it is greater than >35% RH, the soil is considered wet.

The sensor detector, NodeMCU ESP 8266, can read the humidity according to the soil dielectric constant. The marks of the dielectric constant will increase if the water content increases based on soil moisture. The ADC value is obtained using the formula below:

$$\boldsymbol{ADC = \frac{1023 - Sensor\ detection\ point}{673} * 100} \tag{1}$$

1023 and 637 are the maximum value of data bits and the differences between wet soil moisture and dry soil moisture values respectively.

The check the sensor, 20 samples were used to measure soil moisture. The result of the test show that the total of error average and success rate are 1.5% and 98.5% respectively.

The ultrasonic sensor to get the water level performance on agricultural land was then assessed on the soil surface with different height levels. Then, the land began to be irrigated. Water level measurement was carried out in predetermined sample areas to obtain water level performance. The performances of water level testing are shown in Table 3 below.

Table 3. Testing Parameter of Ultrasonic HC-SR04 sensor

Water level (cm)	**Soil height (cm)**	**Ultrasonic Sensor Detection (cm)**	**Error (%)**
1	1	1	0
1.5	1	1	33.3
2	1	2	0
3	1	3	0
4	1	4	0
1	2	1	0
1.5	2	1	33.3
2	2	2	0
3	2	3	0
4	2	4	0
1	3	1	0
1.5	3	1	33.3
2	3	2	0
3	3	3	0
4	3	4	0
1	4	1	0
1.5	4	1.5	0
2	4	2	0
3	4	3	0
4	4	4	0
Error averages			4.99

The measurement of ultrasonic sensor performance was based on the principle that this study refers to a predetermined soil level. Furthermore, the soil height was reduced by the reflection of the values shown by the ultrasonic sensor. The actual water height was obtained using the following formula.

$$Soil\ height : distance\ sensor\ and\ soil - \left(\frac{sound\ speed * time}{2}\right) \tag{2}$$

The sound speed is the speed of air at a certain pressure and temperature. It has a constant of 343 m/s. The time variable is the time it takes for the ultrasonic signal to move from the sensor to the water surface and back to the sensor. The dividing factor of two arises because the signal requires a trip to the water surface and back to the sensor, the measuring distance is half of the total distance.

This study was conducted through 20 experiments using four different types of soil height and water level. It was found that there were four errors in the ultrasonic sensor test. It can be concluded that the ERROR average and success rate are 4.99% and 95.01% respectively.

Furthermore, the performance of the water flow at the plant irrigation source was assessed. This measurement was performed using a water flow sensor and the 9 VDC motor water pump. The working voltage on the water flow sensor can be activated if the 9VDC pump has pumped water and passed through the water flow sensor. The water discharge measurement mark was taken based on the propeller rotation on the water flow sensor. The water flow sensor requires a voltage of 3 to 18 VDC with a maximum flow limit of 2 to 45 liter/minute.

The working principle of detecting water flow started with the soil moisture sensor detecting the level of soil moisture. If the soil being detected is dry, the relay on the component will work to turn on the 9 VDC pump. Furthermore, the 9 VDC water pump was connected to the water flow sensor and the water flow operated the turbine and converted into a magnetic field. The circuit for the water flow sensor was made of GPIO pin 15 on the NodeMCU ESP 8266 microcontroller. Table 4 shows the performance of the water flow discharge measurement.

Table 4. The Parameter of Waterflow YF-5201 Sensor

Soil condition	**Volume (ml)**	**Time (s)**	**Water discharge (ml/s)**	**Water discharge on LCD (ml/s)**	**Error %**
dry	995	15	66	66	0
dry	991	14	70	69	1.4
dry	994	14.5	69	65	5.7
dry	996	15.5	64	64	0
dry	998	16	63	63	0
moist	0	0	0	0	0
moist	0	0	0	0	0
moist	0	0	0	0	0
moist	0	0	0	0	0
moist	0	0	0	0	0
dry	945	9	105	105	0
dry	950	9.5	100	99	1
dry	975	10	98	97	1.2
dry	960	11	87	87	0
dry	980	13	75	72	4
moist	0	0	0	0	0
moist	0	0	0	0	0
moist	0	0	0	0	0
moist	0	0	0	0	0
moist	0	0	0	0	0
Error averages					0.6

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This test used a laboratory scale and a measuring cup with a volume of 1000 ml and a capacity volume of 30 cm x 30 cm x 15 cm. The water flow sensor contains a pipe with a diameter of 0.5 inches. The calculation of water discharge can be obtained using the following formula:

$$\boldsymbol{water\ discharge} = \frac{\boldsymbol{Volume\ (ml)}}{\boldsymbol{time\ (s)}} \quad (3)$$

The water discharge is the total volume of water that passes a point in a certain period of time. Volume is the amount of space occupied by water, and the water volume is assessed in units or cubic meters. Time is the amount of time required for a certain volume of water to pass through the water flow sensor, which is measured in seconds (s).

The performance of water flow was assessed through 20 experimental works with different volumes of water and times. The results show that the total error average and success rate were 0.6% and 99.4% respectively.

Subsequently, several sensor variables had been assessed, and then the overall analysis of Smartfarming technology was determined. This Smartfarming technology integrates ultrasonic sensors as water detection and soil moisture sensors as soil moisture readers which will later be used to turn on relays and pumps water into places where water is expected to flow. While detecting the water discharge was carried out by a water flow sensor, the test was carried out through 20 experimental works shown in Table 5.

Table 5. Assessment of Smartfarming technology

Soil condition	Soil height (cm)	Soil moisture Sensor (% RH)	Ultrasonic Sensor (cm)	Water Flow Sensor (Ml/s)	Water pump	Performance
dry	1	65	2	0	Not active	fulfilled
dry	2	73	3	0	Not active	fulfilled
dry	3	88	2	0	Not active	fulfilled
dry	4	96	1	0	Not active	fulfilled
dry	5	99	2	0	Not active	fulfilled
moist	1	9	0	105	Active	fulfilled
moist	2	12	0	99	Active	fulfilled
moist	3	19	0	97	Active	fulfilled
moist	4	26	0	87	Active	fulfilled
moist	5	27	0	72	Active	fulfilled
dry	1	63	3	0	Not active	fulfilled
dry	2	70	4	0	Not active	fulfilled
dry	3	88	1	0	Not active	fulfilled
dry	4	90	2	0	Not active	fulfilled
dry	5	91	3	0	Not active	fulfilled
moist	1					
moist	2					
moist	3					
moist	4					
moist	5					

The ultrasonic sensor mark is a measurement of the initial soil conditions. The technology was assessed through 20 experimental works, and it was found that the percentage of success was 100%.

CONCLUSIONS

This study is related to the Smartfarm technology for monitoring soil moisture and water level and regulating water discharge in paddy field. This study offers the Smartfarm technology to assist farmers in cultivating paddy fields and to make it easier for farmers to supply water to the fields. The results show that the tool can assess soil moisture and water level, regulate water discharge in rice farming directly from the paddy fields, and monitor the farm online using a system based on IoT.

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