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SUSTAINABLE AND RELIABLE IOT-BASED SOLUTION SYSTEM FOR SMART FARMING IN INDONESIA

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ABSTRACT

This developed IoT-based solution system for smart farming in Indonesia agriculture system in particular has the advantage of installing electronic modules, namely solar panel power supply, weather station, air quality module, soil quality module, ESP32 Devkit, 3G/4G cellular communication module that is connected to the internet, and a relay actuator for water pump that works automatically based on the level of soil moisture. By using an IoT-based smart farming system, it can solve traditional agricultural problems, namely monitoring weather conditions, air quality, farming soil quality in real time and controlling automatic water pumps using smartphones, which cannot be solved in traditional farming in Indonesia. The advantage of this IoT-based system is that it uses sensors that are quite complete to monitor environmental and agricultural soil conditions. Then this system is also portable by using a solar panel power supply derived from renewable energy, so that this system can provide its own electrical power. It also uses a 3G/4G cellular communication module which has a much larger range than the Wi-Fi communication module in other systems.

Keywords—IoT system, smart farming, ESP32 Devkit, monitoring and control application

I. INTRODUCTION

Nowadays, the Indonesian government will support and encourage key innovations and research in digital technology for the purpose of efficient economy. This is the concept of an officially launched road map of "Making Indonesia 4.0" that refers to the world's 4th revolution of industry. This is in accordance with Agriculture 4.0 that it could be thought as smart farming or data-driven farming system which include remote monitoring and control, data management and precision agriculture in its components [1-3].

Smart farming has become the government focus as about 57 million hectares or 31.36% of Indonesian land area are basically deployed as farming economic activities. The agricultural sector plays a role in contributing to 14.43 % of the national GDP, including in estimate 70 million employees or around 41% of the total employment [4]. It is important for the performance of agriculture, to monitor, control and record the real time soil and weather conditions so that the collected data may be used for better farmer's decision making [5][6].

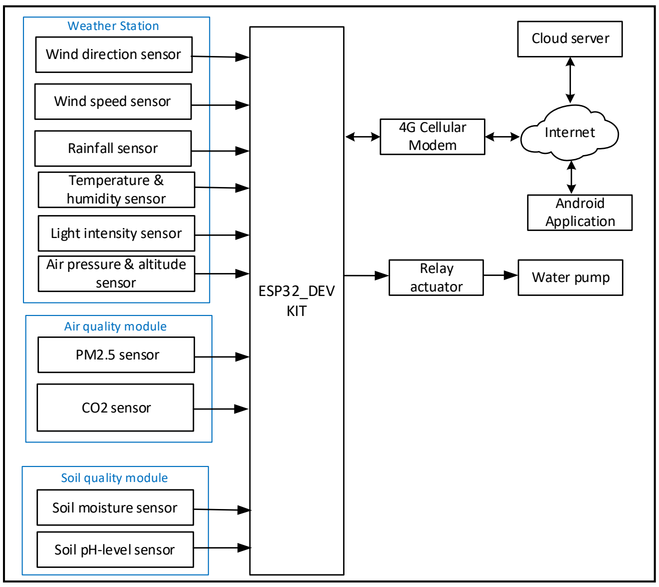
According to Li et al. (2017), IoT sensors play a vital role in collecting data from various farming parameters, including soil moisture, temperature, humidity, and crop health. Researchers have focused on developing cost-effective and energy-efficient sensor nodes for large-scale deployment in agricultural environments [7]. Farmers have historically visited their fields to assess crop conditions and make decisions relying on their experience. However, this conventional method raises concerns regarding efficiency, sustainability, and accessibility. Conversely, an IoT-driven agricultural system can address these challenges, enhancing farmers' well-being. Furthermore, it standardizes and streamlines farm management practices, leading to reduced operational expenses and improved agricultural product quality [8]. Kamilaris et al. (2017) [9] review the use of IoT in agriculture and found that IoT-generated data is processed using machine learning and predictive analytics to provide insights into crop growth, disease detection, and yield forecasting. These algorithms help farmers make informed decisions and optimize their operations. In contributing to sustainable development goals, energy efficiency is promoted by IoT-based solutions by automating e.g., irrigation, fertilization, pest control and lighting process. These solutions help reducing resource wastage and environment impact in agriculture [10]. However, the economic viability of the IoT-based solution should be assessed to whether the investment in implementing and utilizing these technologies generates positive financial returns and sustainable benefits for farmers and agricultural businesses.

In this paper, we report the design and deployment of an IoT-based solution system for smart farming in Indonesia. This system consists of a weather station that monitors temperature, relative humidity, air pressure, wind speed and direction, light intensity, rainfall, and altitude of the farm; soil conditions module that monitors soil moisture and soil pH level and monitoring module of other environmental parameters, i.e., levels of CO_2 and PM2.5 particles in the air. This IoT system is also integrated with a pump relay actuator to activate the water pump when the soil moisture sensor indicates a dry soil condition. It is designed and built as an integrated system, which uses several agricultural and environmental sensors and is then connected to a 3G/4G wireless cellular network as a gateway system, which is useful for collecting data from all sensors to cloud server. Data from cloud server can be further processed and displayed by a specially made Android-based application for remote monitoring and control [11].

The primary objective of implementing this integrated IoT solution system is to enhance both the quality and quantity of agricultural products. Presently, the majority of farmers lack the capability to remotely and instantly monitor the precise state of their farming land. As an illustration, with access to soil moisture data from this system, farmers can proactively anticipate dry seasons and make necessary preparations and adjustments. Consequently, the IoT system serves as a valuable tool for minimizing the risk of crop failure and the inefficiencies associated with adverse weather conditions, while also providing insights into soil parameters post-fertilization.

II. Research Method

As a control center and data processor in our designed IoT system, ESP32 Devkit has specifications such as Single or Dual-Core 32-bit LX6 Microprocessor with clock frequency up to 240 MHz, 520 KB of



SRAM, 448 KB of ROM and 16 KB of RTC SRAM, it supports 802.11 b/g/n Wi-Fi connectivity with speeds up to 150 Mbps, Support for both Classic Bluetooth v4.2 and BLE specifications, 34 Programmable GPIOs and so on. Our made IoT system consists of a ESP32 Devkit, a weather station module, an air quality module, a soil moister sensor, a soil pH level sensor, a relay to activate a water pump, a 3G/4G cellular communication system, cloud server, and a monitoring and control Android application. The detailed explanation of above components/modules is given in the subsections below. Block diagram of our designed IoT system can be found in Fig.1.

Fig. 1. Block diagram of IoT-based solution system for smart farming.

From continuous testing and analysis of hardware prototypes, reliability and robustness of the modules/components used are obtained. If the results of the analysis find a module that is not reliable and does not last long, then the module is replaced with a similar module of higher quality. Following is the selection of components and modules after testing and analysis in the first stage on hardware prototypes.

A. *Wind Direction Sensor*

Fig. 2 shows a weather-resistant wind direction sensor which is reliable & sustainable and capable of providing precise wind direction readings in the range of 0 to 360 degrees with high accuracy. Constructed using aluminium alloy material, this sensor is resistant to corrosion and is not affected by rust over a long period of time. This sensor maintains good stability and is resistant to interference (anti-interference), thereby increasing measurement accuracy.

B. *Wind Speed Sensor*

The wind speed sensor used (Fig. 3) is capable of measuring wind speeds ranging from 0 to 60 m/s with a resolution of 0.1 m/s. This wind speed sensor is made of weather-resistant carbon fibre. Its composition

includes a mixture of polycarbonate, making it resistant to acids, alkalis and anti-oxidation, so it has a longer life than ordinary plastic which is easily damaged/rotted when exposed to heat and rain. This sensor is also designed to be resistant to moisture and corrosion. This material composition allows the sensor to experience very low friction, thereby increasing its sensitivity to even being able to read weak wind speeds.

Fig. 2. Wind direction sensor used.

Fig. 3. Wind speed sensor used.

C. *Rainfall Sensor (Rain Gauge)*

The rainfall sensor used, as shown in Fig. 4, implements the tipping bucket method to detect rainfall. The level of accuracy of this sensor reaches 0.1 - 0.2 mm. The diameter of the rain gauge designed here is 200 mm. The angle of inclination of the mouth of the sensor to collect rainwater is 40° to 45°. The inner

wall of the sensor is smooth so that rainwater easily enters this sensor, and results in a high level of precision of this sensor. This rainfall sensor is made of a material that is anti-corrosion or rust resistant.

Fig. 4. Wind speed sensor used.

D. *Stevenson Screen*

In the casing of the Stevenson Screen used, as seen in Fig. 5, there are temperature and humidity sensors, light intensity sensor, air pressure sensor and location altitude sensor. Light intensity sensor is used here so that farmers can adjust the best types of plants to cultivate according to the range of light intensity on their agricultural land. All of these sensors are integrated in the Stevenson screen which allows the temperature and humidity of the surrounding air to still be

detected by the sensors but will not cause these sensors to be damaged/disturbed by the external environment. This casing is made of ABS material with IP54 protection, which can work in environments with temperatures of -40°C to 75°C. The temperature and air humidity sensor has a measuring range from

-40°C to +125°C and air humidity from 0-100%.

Fig. 5. Stevenson screen used.

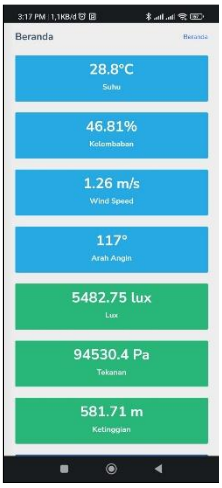
E. *Solar Panel Power Supply*

The electrical power supply of this IoT system is made using 30 WP solar panels so that this system can function independently without other electricity sources such as from electrical energy company. This power supply is equipped with a 12 V VRLA battery as a power supply and maximum power point tracking (MPPT) to maximize the performance of the solar panels in charging the battery.

Fig. 6. Layout of the developed IoT-based solution system for smart farming

The packaging and layout of each module are analyzed and designed to meet the criteria of reliability and durability in an agricultural environment. After going through various discussions, the layout of the sensors, the electronic system protective packaging, the solar panel power supply on the support poles was designed as shown in Fig. 6. The electronic system protection box packaging is made of iron plate material coated with anti-rust paint, so This box is waterproof and can withstand hot and rainy weather.

Fig. 7 shows the dashboard display of the Android application for monitoring and control of the IoT-based system that was created. The appearance of this monitoring and control application has been made more artistic and comprehensive, meaning that many monitored parameters are displayed on one page so that users get comprehensive and concise information. This application is connected to a cloud server to



transmit data from the hardware device to the smartphone via the cellular telephone internet network.

Fig. 7. Dashboard of the developed monitoring and control Android application for IoT-based solution system for smart farming in Indonesia.

III. Results and Discussion

Testing and analysis of hardware modules is carried out to find out whether the modules used and the overall system created can work according to the desired function. There are five modules tested, namely the weather station module, air quality module, soil pH sensor, automatic water sprinkler module, and solar panel power supply module.

A. *Experiment and Analysis Results of the Weather Station*

Weather station experiments are carried out to test the success of the weather station in monitoring and displaying monitoring results on a serial monitor. The weather station consists of temperature and humidity sensors, rainfall sensors, wind direction and speed sensors, light intensity sensor, air pressure sensor and location altitude. Experiments were performed 4 times on August 15th, 2023. This testing was carried out in the morning, afternoon, afternoon and evening. The test results of the weather station according to the sensors used can be seen in Table 1.

It can be seen in Table 1 that the test results for the weather station module ran without problems with all the module reading results being as desired. This shows that the weather station module can perform data collection on the parameters mentioned above well, so it can be concluded that the weather station module can work well.

Monitored Parameters	**Time**			
	09:00	**13:00**	**17:00**	**22:00**
Temperature	27.1	33.8	28.3	21.6

(°C)	0	0	5	0
Humidity (%)	53.00	34.80	46.90	78.00
Rainfall (mm)	0	0	0	0
Wind speed (m/s)	0.25	0.57	0	0
Wind direction (°)	209	322	72	210
Light intensity (lux)	9680.7	18453.5	2490.6	0
Air pressure (Pa)	95113.4	94776.8	94725.4	65038.8
Location altitude (masl)	530.5	560.0	564.6	537.0

TABLE I. EXPERIMENT RESULTS OF WEATHER STATION

B. *Experiment and Analysis Results of the Air Quality Module*

Experiment of air quality module is carried out to test the success of the air quality module in monitoring and displaying monitoring results on a serial monitor. The air quality testing module can be placed on the terrace of the house. The terrace of the house was chosen because it is an open space, so the air quality must be considered. The air quality module consists of CO_2 and PM2.5 air quality sensors. Data collection in this experiment was carried out 4 times on August 15th, 2023, in the morning, afternoon, afternoon and night. The data taken is data on CO_2 and PM2.5 levels which can be seen in Table 2.

Time	**CO_2 (ppm)**	**PM2.5 (µg/m^3)**
09:00	0.50	13.2
13:00	2.10	14.6
17:00	1.65	12.5
22:00	1.95	13.2

TABLE II. EXPERIMENT RESULTS OF AIR QUALITY MODULE

From the data obtained in Table 2, CO_2 and PM2.5 levels show that the air condition is Good. According to Meteorological**,** Climatological, and Geophysical Agency (BMKG), the threshold value is the limit for the concentration of air pollution that is allowed to be in the ambient air, which is 55.4 µg/m^3. This shows that the air quality module can properly collect data on CO_2 and PM 2.5 levels so that it can be concluded that the air quality module can work as expected.

C. *Experiment and Analysis Results of Identify the Automatic Water Sprinkler Module*

Experiment of the automatic water sprinkler module was performed to test the success of this module in automatically watering plants and displaying the results of monitoring soil moisture levels on the serial monitor. This automatic water sprinkler module consists of a soil moisture sensor and a water pump and relay connected to an ESP32 microprocessor. Soil moisture sensors are embedded in the soil of the house yard. The program on the microcontroller sets the soil moisture limit, namely that the soil is declared dry if the soil moisture is below 50% so that the microcontroller turns on the water pump; and the soil is declared wet if the soil humidity is above 50% so that the microcontroller turns off the water pump. This test was carried out on dry soil 2 times and wet soil 2 times. The results of soil moisture measurements and related water pump conditions can be seen in Table 3. It can be seen from the table that the soil moisture sensor works as expected and the measurement data can be displayed on the serial monitor by the microcontroller.

Likewise, the microprocessor can adjust the condition of the pump according to the level of soil moisture that is read.

Soil Condition	**Soil Moisture (%)**	**Water Pump Condition**
Dry	38	On
Dry	42	On
Wet	86	Off
Wet	82	Off

TABLE III. EXPERIMENT RESULTS OF THE AUTOMATIC WATER SPRINKLER MODULE

D. *Experiment and Analysis Results of Solar Panel Power Supply*

The power supply used by this system is supplied by solar power, so it does not depend on other electricity supplies. The solar panel power supply module consists of a solar panel with dimensions of 350 x 650 x 25 mm with a maximum power supply of 30 W, a maximum voltage of 18 V and a maximum current of 1.67 A; solar controller which functions to regulate solar charging on dry batteries; and dry battery with a capacity of 12 V, 7 Ah. Testing the solar panel power supply module aims to test whether this module can supply sufficient power to the entire system so that the system functions properly. The experiment results of this module show that the current and voltage are greater when the weather is sunny and the two electrical quantities will decrease if the weather is cloudy or overcast.

Based on the results of previous tests and analyses, the Android application created can display information according to current environmental conditions and can control a water pump. The information displayed in the developed Android application is sensors' data connected to the cloud server. All functions of the entire application system can work well as expected. Furthermore, the integration between hardware device and the application on smartphone is tested and refined continuously so that it meets the requirements to be implemented on real agricultural land in Indonesia.

IV. CONCLUSION

Based on the results and discussion, several remarks can be drawn from our designed system. The weather station is able to collect data on air temperature, humidity, wind direction and speed, light intensity, air pressure and altitude. As expected, the air quality module could retrieve data on the levels of CO_2 and PM2.5 in the air. The water pump starts automatically when the soil was dry and stop when the soil was wet enough, based on data from the soil moisture sensor. The serial monitor's output was forwarded to a cloud server through internet by 3G/4G cellular communication module.

Furthermore, the Android application is successfully connected to cloud server via internet and can display monitored information according to the current environmental and soil conditions and can execute water pump control. Our developed IoT-based system could be suitable to be implemented in farming fields in Indonesia.

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