Design and Implementation of a Weather Monitoring System Base on IoT Blynk Display and Solar Panel

Widayanti[1*], Ashadi Fajarrohman[2]
[1,2] Department of Physics, Sunan Kalijaga State Islamic University. Yogyakarta 55281, Indonesia.
[1*] widayanti@uin-suka.ac.id

ARTICLE INFO

Article history:

Received August 25, 2024
Revised September 22, 2024
Accepted October 16, 2024

Keywords:

Weather Monitoring System
ESP32
Solar panel
IoT
Blynk

ABSTRACT

In order to support precision agriculture, this project intends to design, develop, and test a weather monitoring system based on the ESP32 microcontroller coupled with solar panel and an Internet of Things (IoT) -based display via Blynk. Blender was used to model the system, while Fritzing was used to produce the circuit diagrams. It uses the appropriate sensors to measure temperature, humidity, rainfall, and wind speed. Performance testing revealed repeatability precision values of 98,97%, 89,22%, 95,27%, and 9,19%, respectively, and accuracy levels of 99,76% (temperature), 99,48% (humidity), 98,41% (rainfall), and 89,83% (wind speed). The findings show limitations in the accuracy of wind speed measurement but show good performance for the majority of metrics. Weather-based agricultural decision-making can be improved by this method, especially in isolated locations without adequate monitoring infrastructure.

Cite Article:

Widayanti, A. Fajarrohman, "Design and Implementation of a Weather Monitoring System Base on IoT Blynk and Solar panel," in *Sunan Kalijaga of Journal Physics*, vol. 6, no. 2, pp. 47-52, October, 2024, 10.14421/physics.v6i2.5209.

1. INTRODUCTION

Agriculture is an activity that involves managing biological natural resources with the technology, labor, capital and management support to produce agricultural commodities including holticulture, plantation, food crops and livestock within an agroecosystem. The increasingly unpredictable climate change in Indonesia is one of the challenges faced in the management [1], that caused by several factors including global warming. Consequently, seasonal calendars are no longer accurate and are no longer useful. Climate change has caused air temperature variations and droughts that impact the agriculture industry [2]. A decrease in rice output has been observed in Vietnam and Indonesia as a result of pests and diseases spreading among rice plants due to changes in air temperature [3]. Due to the unpredictability of wet and dry seasons as well as irregular rainfall patterns within a season, Plant-Disturbing Organisms (PDOs) have proliferated and frequently cause complete crop loss [4]. Numerous studies indicate that damages to agricultural infrastructure brought on by climate change, especially drought and flooding, can drastically lower crop yields and potentially result in crop loss [5].

Rainfall in agricultural areas is physically measured and recorded as part of the Climate Change Aware Farmers Association's (PPTPI) initiatives. However, because this data collection approach is manual, its efficacy and efficiency are limited. Therefore, there is an urgent demand for real-time climate monitoring technology as the government continues to promote the use and application of technology in agricultural management. Anticipating and adapting to current and future climate variability is the goal of developing a system that can respond to climate changes [4], and addressing climate-related challenges requires both technical and non-technical techniques [6]. Temperature, air humidity, precipitation, wind speed, and light intensity are some of the variables that make up the weather from 15°C to 40°C is the ideal temperature and humidity range for plant growth [7]. Beyond this range, plants chemical and physical functions are compromised. Water is also essential for plants, especially for photosynthesis and the production of cell protoplasm. As a result, plants' growth is greatly influenced by the amount of rainfall they receive. The growth of salak trees, for example, is significantly impacted by irrigation techniques; rainwater must be appropriately managed to guarantee ideal development [8].

Weather information is provided by the Meteorology, Climatology, and Geophysical Agency (BMKG) using data from weather monitoring stations placed throughout the country. Farmers can use this data to access weather information that is essential for managing their agricultural operations. BMKG uses sensors to gather weather data, data loggers to record it, and GSM networks to send it to the central BMKG server via General Packet Radio Service (GPRS). The present system is limited, nevertheless, in that not all agricultural areas are covered by its installations. Farmers in areas without these stations thus lack access to reliable local weather information [9]. The weaknesses of the weather monitoring system owned by BMKG lie in the choice of wireless network. The use of General Packet Radio Service (GPRS) in the system can be further developed by adopting other networks such as 4G LTE (Long Term Evolution). The 4G LTE network offers superior performance in terms of throughput, packet loss, and energy consumption compared to GPRS [10]. Additionally, the use of data loggers as data recorders is relatively expensive. Moreover, BMKG's weather monitoring systems are not installed in all agricultural areas across Indonesia, which means that agricultural regions far from the monitoring system do not have access to accurate weather data. This is significant because weather conditions can vary from one location to another depending on the time of day—morning, afternoon, evening, or night [11]. A number of researchers have created substitute weather monitoring systems in an attempt to get around BMKG's shortcomings. Ambar [12] used the NodeMCU ESP8266 and Raspberry Pi, whereas Narulita [13] used the Arduino Mega 2560 to create a system. While the Raspberry Pi microcomputer served as a data processing unit and uploaded the data to a database, the microcontrollers were utilized to receive data from sensors and upload it to other devices. In both investigations, an effort was made to develop more reasonably priced weather monitoring systems by utilizing microcontrollers and microcomputers. Both systems, however, still depend on traditional power sources, thus the installation needs to be near an electrical outlet and is extremely susceptible to power outages.

The Raspberry Pi is still thought to be somewhat pricey. As a result, the system must be optimized with a less expensive but no less effective substitute, like the ESP32 microcontroller. With its integrated BLE (Bluetooth Low Energy) and built-in WiFi module, this microcontroller is a great option for creating Internet of Things application systems. To lessen the dependency on non-renewable energy, the system can also be improved by adding an independent power source, such as solar panels. The sensor data is displayed on the Blynk IoT platform. Users may create IoT apps more easily with Blynk that provides an intuitive and user friendly interface, making it easier for users to develop IoT applications.

2. METHODS

This research was conducted in three main stages: design, development, and testing of the weather monitoring system conducted at Integrated Laboratory of UIN Sunan Kalijaga Yogyakarta and at the Climatology Station in Yogyakarta.

In the system design stage, an Acer E-5-475 laptop, and software like Blender, Fritzing. In the development stage, Arduino ID software, a Redmi Note 9 smartphone, Blynk Software, and a voltmeter were used. In the testing stage, a calibrator from Yogyakarta Climatology Station (SKY) was required, namely Automatic Weather Station (AWS) and an ombrometer.

During the design stage, the circuit schematic was created using Fritzing software, and the entire system design was created using Blender software. This was done to make the process of building the system easier. After preparing the necessary equipment and supplies and verifying that every component was operating as intended, the process proceeded to the construction stage. Hardware assembly was completed in accordance with the previously created design and circuit schematic. The sensors and solar panel were positioned outside the electrical box, while the SCC, battery, and NodeMCU components were housed inside. After attaching the solar panel to the SCC and connecting it to the battery, the power supply block was put together. Jumper wires were used to link the DHT22, anemometer, and ombrometer to the NodeMCU in order to construct the input and processing block. The software development stage came next, during which the sensors were configured to measure temperature, humidity, wind speed, and precipitation. The NodeMCU was then configured to receive, process, and transmit the sensor data to the database. The system program was developed in the Arduino IDE by creating a program sketch and integrating several libraries, namely DHT.h, WiFi.h, HTTPClient.h, and BlynkSimpleEsp32.h. The Blynk interface was created by first downloading the Blynk application, adding a new template, and configuring the interface by adding widgets such as Labeled Value and SuperChart. The Labeled Value widget was used to display the weather parameters being measured. Finally, Blynk was connected to the monitoring system by inserting the Auth Token into the system program. The last step was system testing, which included determining the accuracy by comparing the results with those from the AWS and the ombrometer and calculating the repeatability precision of the system. Using the DHT22 sensor and anemometer, which were placed in the same environment as the SKY-owned AWS unit, temperature, humidity, and wind speed data were collected incrementally every three hours for a 24-hour period, while rainfall data was collected separately using a tipping bucket ombrometer and compared to a standard ombrometer owned by SKY using water volume variations ranging from 20 to 160 ml at 20 ml intervals.

For the repeatability precision test, temperature and humidity data were collected every 3 hours over a 24-hour period, with each measurement repeated 10 times. For the wind speed parameter, data were collected in three different variations, with each variation measured 10 times. As for the rainfall parameter, testing was conducted using water volume variations ranging from 20 to 160 ml at 20 ml intervals, with each variation repeated 5 times. Accuracy was calculated using Equation (1) by [14] and according to SNI ISO 17025:2017, the minimum accuracy standard for measuring instruments is at least 98% (BSN, 2018).

$$Accuracy(\%) = 100\% - \left|\frac{X_{system} - X_{standard}}{X_{standard}}\right| \tag{1}$$

Meanwhile, the repeatability precision was calculated using Equation (5), where a good measuring instrument is expected to have high precision. According to SNI ISO 17025:2017, the minimum standard value for accuracy in measuring instruments is at least 98% [14].

$$\bar{x} = \frac{\sum_i^n x_n}{n} \tag{2}$$

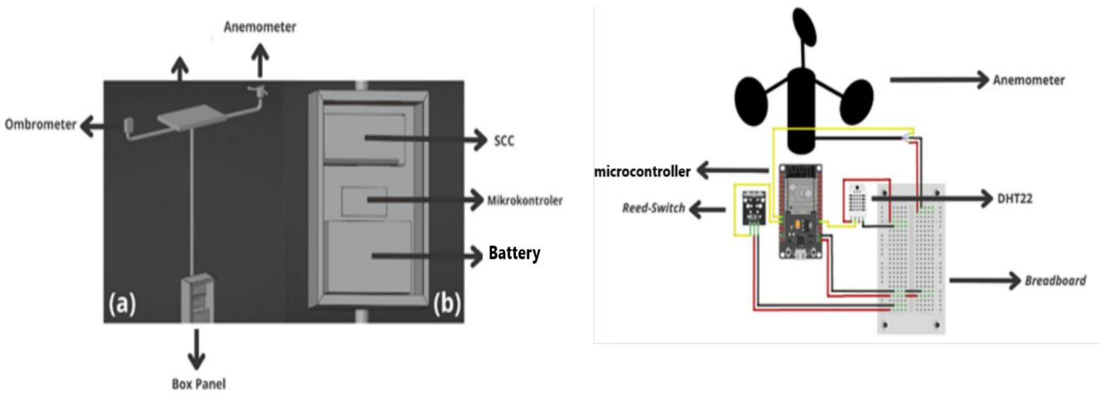
$$SD = \frac{\sqrt{\sum_i^n (x_i - \bar{x})^2}}{n-1} \tag{3}$$

$$\%RSD = \frac{SD}{\bar{x}} \times 100\% \tag{4}$$

$$Precision = 100\% - \%RSD \tag{5}$$

3. RESULTS AND DISCUSSION

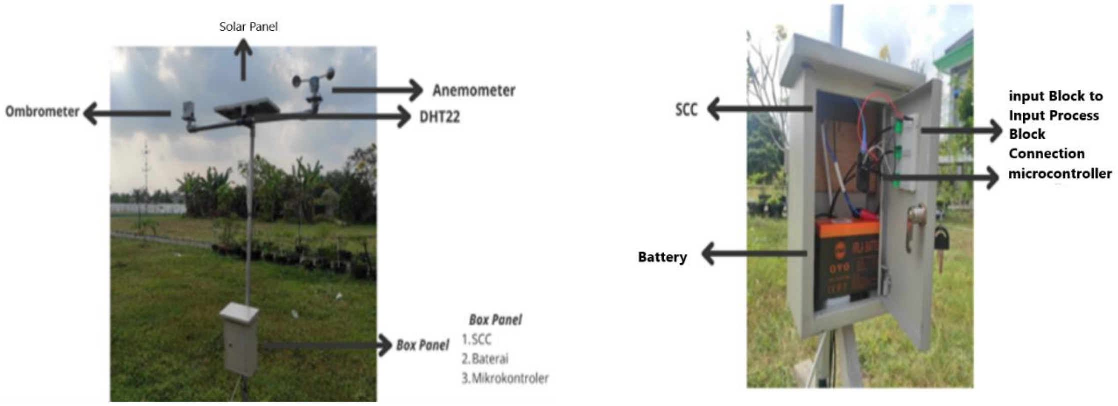
The design and circuit schematic produced during the design phase are shown in Figures 1 (a) and 1 (b).



(a) (b)

Figure 1. System Design (a) and Circuit Schematic (b)

The resulting design was used as a reference in constructing the weather monitoring system based on the NodeMCU ESP32 microcontroller, solar panel, and web display using PHP. The hardware development process is shown in Figures 2(a) and 2(b). The completed system consists of a power supply block (10 WP solar panel, SCC, and battery), an input block (DHT22, anemometer, and ombrometer), a processing block (NodeMCU ESP32), and an output block (web interface and database). These four blocks include several integrated components, each serving its specific function.



(a) (b)

Figure 2. System external view (a) and System internal view (b)

The solar panel functions to convert solar energy into electrical energy. The SCC (Solar Charge Controller) regulates the flow of electrical energy from the solar panel to the battery, and from the battery to the system. The battery stores the excess energy produced by the solar panel that is not immediately used by the system. The DHT22 sensor measures temperature and humidity based on capacitive principles, the anemometer measures wind speed using the Hall effect principle, and the tipping bucket ombrometer (reed switch sensor) measures rainfall. The NodeMCU ESP32 commands the sensors to perform measurements, reads the data, and then sends the readings to a database, which stores the sensor data transmitted by the processing block via WiFi. The Blynk interface functions as a display for temperature, humidity, wind speed, and rainfall data.

The weather monitoring system software was successfully developed using the Arduino IDE and the Blynk IoT application. The interface was built using the Blynk application, which is integrated with the system program created in the Arduino IDE. The interface display on the Blynk application is shown in Figure 3.

Figure 3. The display at Blynk application

The four weather parameters are displayed in numerical form for real-time monitoring. In addition, temperature and humidity data are also presented in graphical form to observe historical data patterns. The testing result of weather monitoring system are shown in Table 1.

Table 1. Result of accuracy test

No.	Monitoring Parameter	Accuarcy (%)
1.	Temperature	98.97%
2.	Moisture	89,22%
3.	Rainfall	95,27%
4.	Wind Speed	9,19%

Table 2. Result of precision test

No.	Monitoring Parameter	Precision (%)
1.	Temperature	99,76%
2.	Moisture	99,48%
3.	Rainfall	98,41%
4.	Wind Speed	89,83%

According to SNI ISO 17025:2017, the accuracy value of a measuring instrument must reach a minimum of 98% (BSN, 2018). The measurement results obtained by this system for temperature, humidity, wind speed, and rainfall parameters were 98.97%, 89,22%, 95,27%, and 9,19%, respectively. These accuracy values indicate that the system still requires improvement, particularly in the measurement of wind speed. Meanwhile, the precision test results for temperature, humidity, rainfall, and wind speed parameters were 99.76%, 99.48%, 98,41%, and 89.98%, respectively, indicating that the instrument meets the precision standards set by SNI ISO 17025:2017. Therefore, based on these findings, further development is needed, especially in selecting a more accurate wind speed sensor.

4. CONCLUSION

The weather monitoring system based on NodeMCU ESP32, solar panel, and PHP-based web display has been successfully designed and developed, and it is capable of displaying real-time changes in temperature, humidity, wind speed, and rainfall parameters. Accuracy and precision testing indicate that further development is needed, particularly in the measurement of wind speed.

DECLARATION

Author Contribution

A. Fajarrohman, processed the experimental data, performed the analysis, drafted the manuscript and designed the figure. Widayanti was involved in planning and supervised the work. All authors discussed the results and commented on the manuscript.

Funding

Our thanks go to Sunan Kalijaga State Islamic University Yogyakarta for the full support the financial assistance from Research, Publication, and Community Service Department (LPPM) UIN Sunan Kalijaga Yogyakarta is also greatly acknowledged.

Acknowledgments

Our thanks go to Sunan Kalijaga State Islamic University Yogyakarta for the full support in carrying out this community service activity.

Conflict of Interest

The authors declare no conflict of interest.

REFERENCES

[1] Kementerian Pertanian, *Rencana Strategis Kementerian Pertanian Tahun 2020–2024*, Salinan Keputusan Menteri Pertanian Republik Indonesia, pp. 1–161, 2022.

[2] S. Zhai, G. S. Yang, Q. Xin, Y. E. Chen, X. Yue, and M. Leipnik, "Climate change and Chinese farmers: Perceptions and determinants of adaptive strategies," *J. Integr. Agric.*, vol. 17, no. 4, pp. 949–963, 2018. [Online]. Available: https://doi.org/10.1016/S2095-3119(17)61753-2.

[3] N. T. Chung, A. Jintrawet, and P. Promburom, "Impacts of seasonal climate variability on rice production in the Central Highlands of Vietnam," *Agric. Agric. Sci. Procedia*, vol. 5, pp. 83–88, 2016. [Online]. Available: https://doi.org/10.1016/j.aaspro.2015.08.012A.

[4] S. Kartawisastra, I. Agency, A. Dariah, and M. Hikmat, *Manajemen Sumber Daya Alam dan Produksi Mendukung Pertanian Modern*, 1st ed., M. A. Fadjry Djufry, E. Pasandaran, and B. Irawan, Eds. Bogor: IPB Press, Oct. 2019.

[5] R. A. Robet, "Climate change and food sovereignty in Indonesia," *Sosio Informa*, vol. 1, no. 3, pp. 293–309, 2015.

[6] A. S. O. Asep, G. C. Alman, S. Rahmayanti, M. Asa, A. Yusuf, A. R. Anggun, D. C. Manukalo Danga, F. Avisha, P. L. Yudho, Y. Sutrasna, and E. Sulistyadi, "Kebijakan ekonomi ketahanan pangan dengan strategi blue ekonomi menghadapai ancaman perubahan iklim," *J. Innov. Res. Knowl.*, vol. 2, no. 4, p. 12, 2022.

[7] N. Sunarmi, R. Hasanah, R. Fitriana, and I. N. Hamidah, "Analisis unsur cuaca pada pertanian bawang merah Kabupaten Nganjuk tahun 2019 dengan Principal Component Analysis," *Prosiding Senkim*, vol. 2, no. 1, pp. 40–50, 2022.

[8] I. N. Rai, I. W. Wiraatmaja, C. G. A. Semarajaya, and N. K. A. Astiari, "Application of drip irrigation technology for producing fruit of salak ‘Gula Pasir’ (Salacca zalacca var. Gula Pasir) off season on dry land," *J. Degrad. Min. Lands Manage.*, vol. 2, no. 1, pp. 219–222, 2014. [Online]. Available: https://doi.org/10.15243/jdmlm.2014.021.219.

[9] Stasiun Klimatologi Yogyakarta, "Alat Pengamatan BMKG – Staklim Yogyakarta," accessed Feb. 29, 2023. [Online]. Available: https://staklimyogyakarta.com/alat-pengamatan-bmkg/.

[10] I. W. K. Bima, V. Suryani, and A. A. Wardhana, "A performance analysis of General Packet Radio Service (GPRS) and Narrowband Internet of Things (NB-IoT) in Indonesia," *Kinetik: Game Technol., Inf. Syst., Comput. Netw., Comput., Electron. Control*, vol. 4, no. 1, pp. 11–20, Feb. 2020.

[11] A. Retnawati, M. I. Ihwan, and M. I. Jumarang, "Estimasi keadaan cuaca di Kota Pontianak menggunakan aplikasi jaringan syaraf tiruan (JST) algoritma Hopfield," *Positron*, vol. 3, no. 2, pp. 43–46, 2013.

[12] D. Ambarwari, K. A. Wahudi, and A. Wahudi, "Sistem pemantau kondisi lingkungan pertanian tanaman pangan dengan NodeMCU ESP8266 dan Raspberry Pi berbasis IoT," *J. RESTI (Rekayasa Sist. dan Teknol. Inf.)*, vol. 5, no. 3, pp. 496–503, 2021.

[13] H. Narulita, A. Rusdinar, and D. Darlis, "Sistem monitoring weather station pada pertanian berbasis IoT," *e-Proc. Eng.*, vol. 9, no. 5, pp. 2468–2480, Oct. 2022.

[14] Riyanto, *Validasi dan Verifikasi Metode Uji Sesuai dengan ISO/IEC 17025*, Yogyakarta: Deepublish, 2014.