Available online at :
http://ejournal.amikompurwokerto.ac.id/index.php/telematika/

Telematika

Accreditated SINTA "2" Kemenristek/BRIN, No. 85/M/KPT/2020

UNIVERSITAS AMIKOM PURWOKERTO

# Smart Farming System for Monitoring and Optimizing Paddy Field with Internet of Things Technology

**Bagus Adhi Kusuma[1], Sarmini[2], Wiga Maulana Baihaqi[3] and Sitaresmi Wahyu Handani[4]**

[1] Informatics Departement, [2] Information System Departement, [3]Information Technology Departement, Faculty of Computer Science, Universitas Amikom Purwokerto, Indonesia
[4] Computer Science Program lectrica, Engineering and Computer Science Faculty, National Taiwan University, Taiwan
E-mail: bagus@amikompurwokerto.ac.id[1], sarmini@amikompurwokerto.ac.id[2], wiga@amikompurwokerto.ac.id[3], d09922018@csie.ntu.edu.tw[4]

**ARTICLE INFO**

***History of the article:***
Received December 26, 2022
Revised January 30, 2023
Accepted February 24, 2023

**Keywords:**
Paddy field,
Internet of Things,
Microcontroller

**Correspondece:**
E-mail:
bagus@amikompurwokerto.ac.id

**ABSTRACT**

Rice is a type of plant that is very easy to find, especially those who live in rural areas. Most people make rice as a source of staple food. One of them is in Bugel Sampang Hamlet, Central Java, where the agricultural sector of the village often experiences rice harvest failure due to dry weather. The hilly geographical conditions that do not allow irrigation systems are the main problem, while the soil fertility of the hamlet is relatively good, as a result farmers find it difficult to optimize the treatment dose for agricultural land due to dry weather which often makes harvest conditions less than optimal. From the problems described above, the researcher aims to create an internet of things-based prototype by integrating a realtime firebase cloud service database, so that farmers can monitor the condition of their rice fields in real time, as well as monitor the weather that can be accessed using a website-based system. The method used is to integrate a microcontroller with sensors, namely DHT11, soil moisture sensor, barometer or air pressure sensor, anemometer or wind speed sensor, rainfall sensor, raindrop sensor using Arduino Mega 2560 and NodeMCU. Then the sensor acquisition data on the Arduino Mega 2560 is sent to the NodeMCU Lua Wifi V3 ESP8266 ESP12 using a JSON variable to be sent to Firebase with an internet connection. The prototype has gone through thirty days running tests, while testing the information system using blackbox testing with data from the firebase realtime database. The results of the study concluded that the prototype was able to monitor the condition of the land properly and the system worked well and could support the optimization of farmers in the treatment of rice fields, so that the use of fertilizers, water, and other treatment efforts became more efficient.

## INTRODUCTION

Rice plants have the term Oryza sativa, including a group of food plants that are very important and beneficial to the lives of Indonesian people. Rice plants are plants with rice production which is a source of carbohydrates for some of the world's population, especially Indonesia. Almost 95% of Indonesia's population consumes rice as a staple food, so that every year the need for rice increases with the increasing population in Indonesia (Pratiwi et al., 2016). Today, more than 50% of national rice production comes from rice fields in Java. So that if there is a drastic decrease in rice production and productivity in Java, it can affect the availability of national rice and will have a negative impact on other sectors (Fawaiq et al., 2019).

http://dx.doi.org/10.35671/telematika.v16i1.2183

Based on data from the Central Bureau of Statistics in 2019, there are 10 provinces that produce the largest rice in Indonesia, consisting of Central Java, East Java, West Java, South Sulawesi, South Sumatra, Lampung, North Sumatra, Aceh, West Sumatra and Banten. Of the 10 provinces, the largest rice producer in Indonesia is Central Java with a total of 5,539,448 tons. Where the ten largest rice-producing provinces in Indonesia, one of which is Central Java (BPS, 2019).

Bojong Village is a village located in the Kawunganten District, Cilacap Regency, Central Java Province. Bojong Village is the largest village in the Kawunganten District which has eight hamlets, including Gunung Jaya Hamlet, Bugel Sampang Hamlet, Jaya Giri Hamlet, Karya Mekar Hamlet, Krama Sari Hamlet, Mekar Sari Hamlet, Nusa Dadi Hamlet, Nusa Jaya Hamlet. Bojong Village is also the largest area in Kawunganten District, which is 2,096.86 Ha and the number of rice fields in Bojong Village is 195.69 Hectare. Most of the sources of income in Bojong Village, namely 90%, are in the agricultural sector (Bojong, 2022).

Previous research related to plant monitoring includes Precision Agriculture Monitoring System using Wireless Sensor Network and Raspberry Pi Local Server (Flores et al., 2016) in this study using low-cost sensors with sensors, temperature, humidity, soil humidity, luminosity, conductivity electricity, and PH where raspberry pi acts as a local server and data is sent and stored in SQL form and data display in the form of graphics (GUI). An Agricultural Monitoring System: Field Server Data Collection and Analysis on Paddy Field (Soontranon et al., 2014). This research was conducted in Thailand for rice, corn, cassava, rubber, sugar cane where these plants were used as objects for measuring temperature, rain volume, light intensity, soil moisture, and wind direction speed in the long term and users could access and obtain data. through a web browser in the form of a server in the field. Plant Growth Monitoring System, With Dynamic User Interface (James & Maheshwar, 2016), this research was conducted on plants in India which measured plant height, water content in the soil, soil temperature, atmospheric temperature, and humidity where raspberry pi served as a microcontroller and farmers could receive data data from plants in a mobile application that is easy to use and can see the progress of plants using machine learning algorithms (machine learning algorithms).

The other method to solve the problems that mentioned above is to use the internet as a medium to help farmers monitor paddy fields, one of which is the use of IoT (Internet of Things) technology. IoT is the concept of an object that has the ability to send data over the internet network without requiring human-human or human-computer interaction (Wahyudi et al., 2021). IoT in its application can identify, find, track, monitor projects, and trigger related events automatically and in real time, IoT can also be a bridge between the virtual world and the real world (Granell, 2020).

There have been many studies discussing IoT in agriculture including, IoT based Irrigation and Water Logging Monitoring System Using Arduino and Cloud Computing, this study aims to measure water levels and soil fertilizer in rice cultivation in Thailand. This research has helped users in taking better care of their crops and fields, it is recommended that a function to detect diseases and pests be added to improve the growth process, and also the application should be able to show the water level, date of each growing step, soil nutrition in graphs and growth status rice (Meher et al., 2019). IoT-Based Smart Irrigation System for Rice Fields (Taris et al., 2022), in this study aims to increase rice production which can be done through two approaches, namely intensification (increasing land productivity) and extensification (expanding planting area). The results of the study can control the irrigation system of rice fields in the area.

http://dx.doi.org/10.35671/telematika.v16i1.2183

The research in a paper entitled IoT based Weather Monitoring System Using Firebase Real Time Database with Mobile Application (Oo et al., 2019), this research is focused on low Internet of Things (IoT) and this research can provide information about climatic conditions in real parameters that are successfully stored in Firebase, this research can be developed to replace the sensor with more efficient results and improve the mobile application for a good graphical user interface.

Another study entitled Development of Soil Moisture Measurement with wireless sensor web-based concept (Julham et al., 2019), this study used the SENO1114 sensor, which is a sensor used to measure soil moisture levels. The communication module used is the ESP8266 module. The data obtained is sent to the web-server. This test is obtained by using the ESP8266 module, the maximum distance that can be obtained from the sensor is 16 meters. Arduino-Based Rice Moisture Monitoring System (Gunawan et al., 2020), in this study the aim of this study was to create an Arduino-based rice grain moisture monitoring system using DHT11 and Soil Moisture sensors. The designed system consists of several parts, namely: power supply, control system, mechanical circuit and program. The results of the test, it was found that the system can measure the moisture and moisture content of the rice grain, so as to minimize damage to rice when milling. Design and Implementation of Database for Cultivation of Land Kangkung with Internet of Things System (Hanuranto & Raniprima, 2021), this study aims to monitor water spinach remotely. The database used is a real-time firebase database. Based on the results of the tests that have been carried out, it is found that the database system can function properly.

Another study entitled Monitoring of Rainfall and Soil Moisture in Agricultural Land Using Sensors Based on IoT (Internet of Things) as the basis for precision agriculture (Saydi, 2021). The purpose of this research is to create a monitoring system that can measure weather automatically and soil moisture in agricultural land based on IoT. The test results of the application of the sensor show that data is recorded offline every 1 minute and online once every 1 minute. Information data becomes material for farmers in making decisions on water and fertilizer application. This monitoring system tool supports the Internet of Things (IoT) in sending weather data so that the results of sensor measurement data can be observed on the thingspeak.com website platform (Karim et al., 2017).

This research uses sensor nodes from waspmote01 which are connected to Arduino ATMega128 and use IEEE 802.15.4 ZigBee Transceiver. Each waspmote node is paired with a soil moisture sensor. This research contains about how the sensor detects the level of soil moisture and then stores the sensor data into Cloud Storage. The weakness of this research is that notifications are sent via sms only when the land is in a state of severe water shortage. Internet of Things (IoT)-Based Rice Pest Repellent Mode) (Nurhakim, 2016). This study aims to create a rice pest detection and repellent device using the sound produced by a microcontroller.

Prototype of Smart Flower Garden Management System Based on Internet of Things Technology (Case study of Persada Butterfly Park) (Nama et al., 2020), based on the results of data obtained from monitoring air temperature and humidity around the smart garden, the lowest air temperature is 25 °C at 08.00 WIB April 26 and the highest temperature was 30 °C at 12.00 WIB April 19, the average humidity value was at 95%. Meanwhile, based on the results of tests carried out using the white box testing method, the results showed that software testing from software testing was carried out as many as 9 tests, 9 tests were successful or as expected and hardware testing from hardware testing was carried out as many as 6 tests, 6 tests were successful or in accordance with which is expected.

Controlling and Monitoring of Prototype Green Houses Using a Microcontroller and Firebase, this research discusses remote monitoring of plants in greenhouses. The plants used in this study were vegetables, and monitoring in this study only monitored air humidity, temperature, and soil moisture (Syadza et al., 2018). There is the possibility of adding several sensors to monitor such as wind speed, air pressure, rainfall, rain detection, light intensity or other sensors, this is because these sensors are considered to be inefficient because they are less informative.

IoT technology can provide solutions to problems that occur in farmers. In this case the DHT11 sensor is used to measure air temperature and humidity, soil moisture sensor to measure soil moisture, barometer sensor to measure air pressure, anemometer sensor to measure wind speed, rainfall sensor to measure weather with measurements based on data from BMKG where 0 mm /day: Cloudy, 0.5-20 mm/day: Light Rain, 20-50 mm/day: Moderate Rain, 50-100 mm/day: Heavy Rain, 100-150 mm/day: Very Heavy Rain, and >150 mm /day: Extreme Rain (BMKG, 2021), raindrop sensor to measure rain detection, Arduino Mega 2560 as a microcontroller board, while the NodeMCU Lua Wifi V3 ESP8266 ESP12 microcontroller is to connect an internet connection and send data to Firebase.

Sending data in real time on Firebase is by assembling and programming tools from DHT11 sensors, soil moisture sensors, barometer sensors, anemometer sensors, rainfall sensors, raindrop sensors on Arduino Mega 2560, then sensor data on Arduino Mega 2560 is sent to NodeMCU Lua Wifi V3 ESP8266 ESP12, and Lua Wifi V3 ESP8266 ESP12 send data to Firebase. On the basis of the description above, the researchers designed a prototype tool that can monitor rice plants in real time with the help of the Firebase database to monitor rice fields, so that farmers can know the condition of the land so that they can take preventive action using rice plant maintenance efforts. This system can monitor temperature conditions, air humidity, soil moisture, wind speed, air pressure, rain detection, which can be accessed through the website in real time. Farmers can also make a logbook of any treatments carried out during the harvest using this information system, so that the optimal treatment mix can one day be reused for the next planting season.

## RESEARCH METHODS

The method used in this research is pre-design and prototype design. In the pre-design method using interview techniques and field observations or field trips (Sugiyono, 2013). At this stage, interviews were conducted with partners, namely the Ngudi Rahayu Gapoktan in Bugel Sampang Hamlet, Bojong Village, Kawunganten District, Cilacap Regency. Information about the rice enlargement process and also what treatments are applied, such as loosening the soil, fertilizing, types of seeds and yields so far. While the observation method is carried out to check the condition of rice fields in areas where the majority of them lack irrigation, causing uneven irrigation in ninety-five lands owned by each farmer. This sub-optimal irrigation causes reduced rice yields. However, with preventive rice treatment, crop failure can be minimized.

This research process is designed based on a flow chart that looks like in Figure 1. The initial process starts from designing a prototype based on a microcontroller which can be as shown in Figure 2. The tool will monitor land conditions by integrating it with eight sensors, namely, wind speed, soil moisture, air humidity, temperature, air pressure, land elevation, rain detection, and rainfall. The schematic design of this prototype board is integrated with the DHT11 sensor, soil moisture sensor, barometer sensor, anemometer sensor, rainfall sensor, raindrop sensor which is read by the Arduino Mega microcontroller with LCD embedding to display sensor reading information in real time. The microcontroller is also connected to the NodeMCU using UART (Universal Asynchronous Receiver and Transmitter) connectivity which functions to transfer sensor data on Arduino to the realtime firebase database using WiFi connectivity.

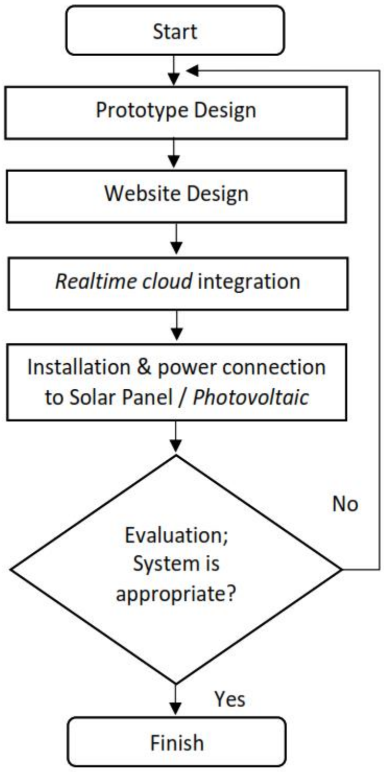


Figure 1. Research flowchart

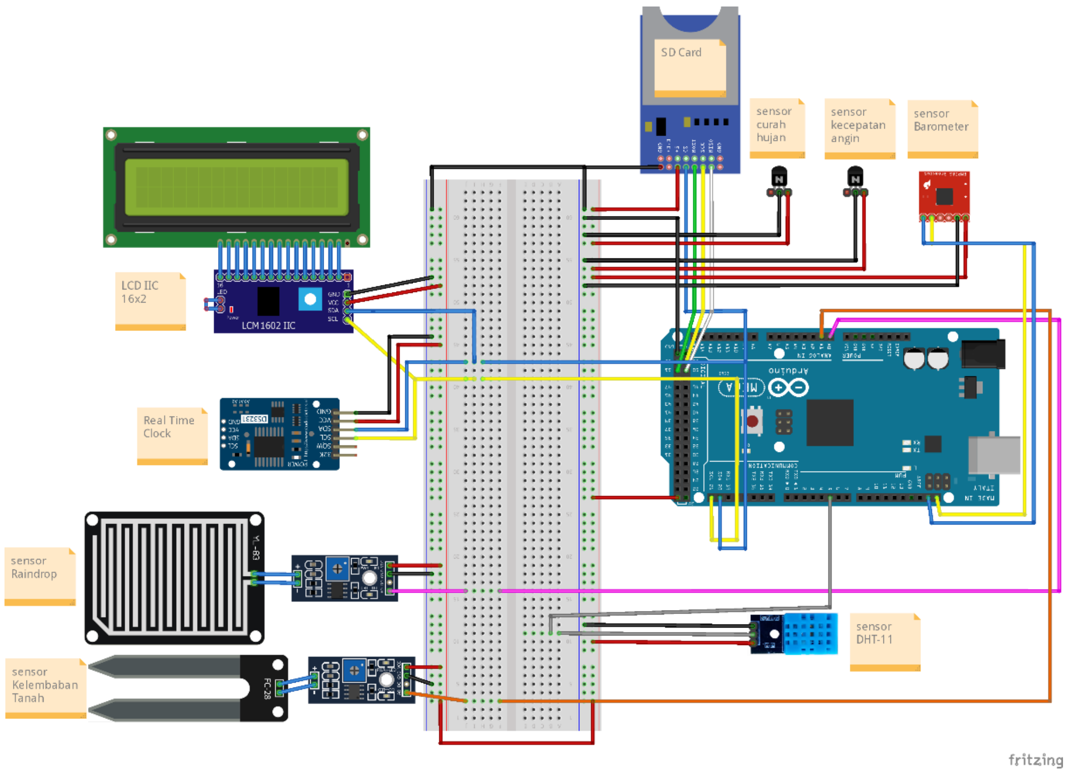


Figure 2. Prototype board design


Figure 3. Sabinusa's Website

The next step is designing a website that is the basis of an information system with a framework using CodeIgniter. The web system is used to store farmer data during the planting period, such as the treatment or treatment of farmers/users of rice plants and land, as well as monitoring data on monitoring results from sensor data. The information system is named "Sabinusa" or an abbreviation of Sabin Nusantara as shown in Figure 3. The website can be accessed via the https://sabinusa.com/ link and requires account registration to be able to enjoy website services. The account will be registered by the admin when farmers have IoT devices planted on their rice fields.

IoT prototypes as well as websites are accessed with the help of Google's firebase cloud service. The microcontroller sends data to Firebase by connecting to NodeMCU. Sending data from sensors on the Arduino Mega 2560 to NodeMCU uses UART (Universal Asyncronous Receiver and Transmitter) communication using the Json library so that data is not lost in the transmission process. Then after the data is collected on NodeMCU, the data is forwarded to the firebase server with an internet connection.

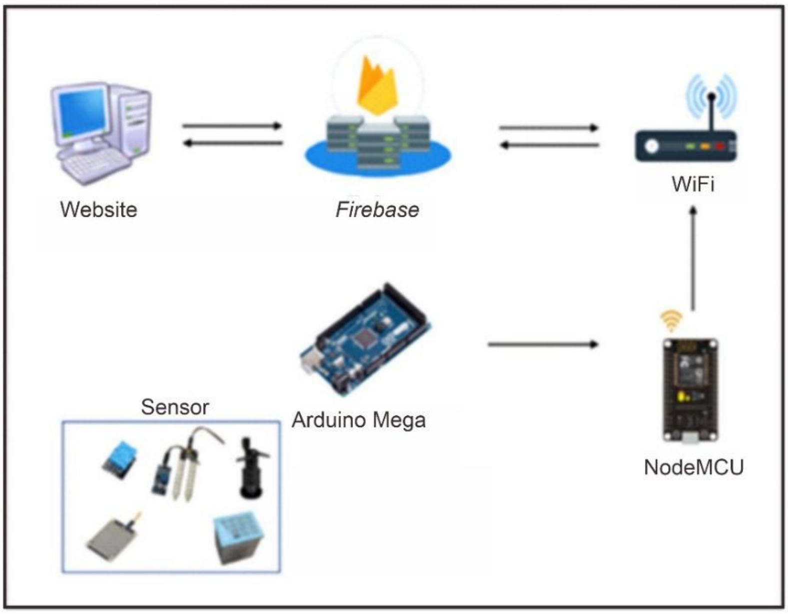


Figure 4. Arduino connectivity with NodeMCU

The evaluation phase is carried out using the running test method for testing prototypes and firebase cloud services, while the information systemuses blackbox testing. This evaluation is carried out to check the suitability of the features designed with the reality in the field.

## RESULTS AND DISCUSSION

### 1. An overview of the design results of the IoT prototype tool

This monitoring tool aims to monitor rice plants around rice fields where the tool can monitor conditions of temperature, air humidity, soil moisture, wind speed, air pressure, water level, rain detection, and weather. Data on this monitoring tool is also displayed on the LCD and Firebase in real time. The data displayed on the LCD are temperature, humidity, soil humidity, air pressure, water level, and weather data. Meanwhile, the realtime Firebase database includes temperature, air humidity, soil moisture, wind speed, air pressure, water level, rain detection and weather data. The whole IoT device prototype can be seen in Figure 5(a), which is powered using solar panels with a capacity of 50 WP and using a 20 Ampere battery/accumulator (ACCU). The process of charging the battery is controlled by a solar charge controller (SCR) with a capacity of 20 Amperes. Figure 5(b) is the result of designing a controller that functions as a data acquisition tool for sensors as well as a dataset collector. Meanwhile, internet service providers use the MiFi E5572C modem which is used to upload data from NodeMCU to Firebase.

(a) (b)

Figure 5. The prototype of an IoT tool integrated with a solar panel. (a) a view of the entire installation, (b) a view of the controller panel box

### 2. IoT Prototype and Sabinusa Information System

The IoT prototype which acts as the controller and the Sabinusa systemas the user interface becomes a single unit of this system. Testing needs to be done to find out whether data is received on the firebase cloud side properly.

This testing phase is carried out with two stages of testing, namely testing the running test prototype and testing Sabinusa using blackbox. Testing of this prototype will be carried out thirty times running tests and checking on the serial monitor controller and firebase system. The result of this test is that data from sensors is successfully acquired and appears in Firebase.

Table 1. IoT Prototype Testing

| No | Tested cases | Test scenarios | Expected results | Test results |
|---|---|---|---|---|
| 1 | Sensor DHT11 | Temperature Data : 32.00 °C<br>Air Humidity Data: 75.00 RH | Can display air temperature and humidity data in *Firebase* | Appropriate |
| 2 | Soil Moisture Sensor | Soil moisture data: 1016 RH | Can display soil moisture data in *Firebase* | Appropriate |
| 3 | *Barometer* Sensor | Air pressure data: 100766.4 Pa<br>Sea level: 110m | Can display air pressure and sea level data in *Firebase* | Appropriate |
| 4 | Anemometer Sensor | Wind speed data: 10 m/s | Can display wind speed data in *Firebase* | Appropriate |
| 5 | Rainfall Sensor | Weather data: cloudy | Can display weather data in *Firebase* | Appropriate |
| 6 | Raindrop Sensor | Detection data rain:light | Can display rain detection data in *Firebase* | Appropriate |

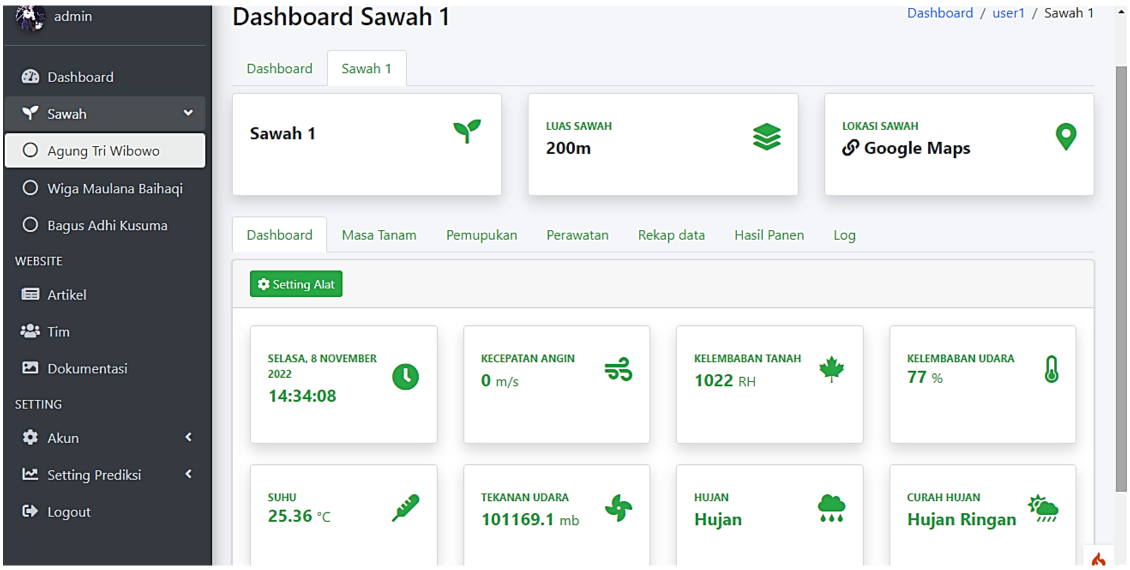


Figure 6. The Sabinusa interface for the admin section

The system interface has access for admin users and regular users. In the admin user there are several menus to display, among others, sensor data, farmer treatment, rice field identity, articles, farmer teams, prediction settings and account edits, as shown in Figure 6. While in the normal user section there is a menu for access to sensor data information, rice field identity, prediction of crop yields and settings, as shown in Figure 7. The Sabinusa account will be obtained by ordinary users or in this case farmers when they register IoT devices because they are associated with the unique code of each tool embedded in the microcontroller.

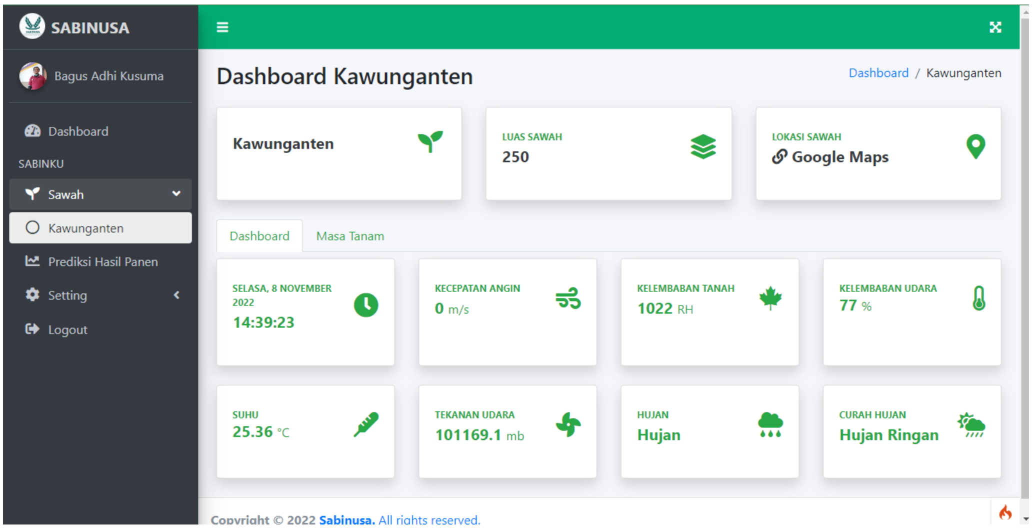


Figure 7. Sabinusa common user interface

## 3. Cloud Service Integration

The cloud service used in this research is Firebase because Firebase has realtime database support and high security. Support for the non-commercial version is very capable in terms of memory, security and speed and has high inter-platform compatibility. The data type sent from NodeMCU to Firebase is a string type with a structure as shown in Figure 8.

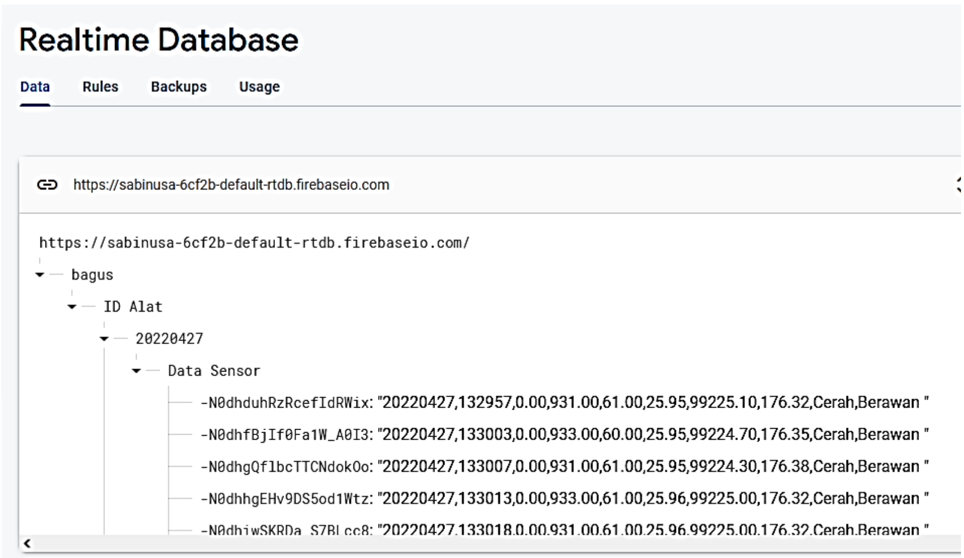


Figure 8. Firebase realtime data structure

In Figure 8 it can be seen that the database hierarchical structure starts from the user-name, tool id, date, and sensor data. The sensor data consists of date, time, wind speed, soil humidity, air humidity, air temperature, air pressure, rain detection, weather and rainfall which are converted into cumulative predictions which have thresholds according to Table 2, based on sources from BMKG (https://www.bmkg.go.id/cuaca/probabilistik-curah-hujan.bmkg). Specifically for the rainfall sensor, the value listed follows this threshold by periodically sending it to firebase.

The testing time lasted for thirty days in an outdoor environment, it was found that the performance of the device was running normally and the data acquired for 5 minutes was stored in the controller memory properly. The solar panel power supply is quite good and the power capacity generated is more than sufficient. The obstacle experienced was that the internet signal around the countryside was sometimes weak so that data could not be uploaded properly, but the controller was still able to store it locally.

Table 2. Prediction of rain intensity thresholds

| Threshold/Day (mm) | Rain Intensity Prediction | Marker Color |
|---|---|---|
| 0 | Overcast | Gray |
| 0.5-20 | Light Rain | Green |
| 20-50 | Moderate Rain | Yellow |
| 50-100 | Heavy Rain | Orange |
| 100-150 | Very Heavy Rain | Red |
| >150 | Extreme Rain | Purple |

The process of pulling data from the firebase database to the information system runs normally. Data is downloaded using the string data type and then stored in the cloud hosting so that the data can be used for weather prediction in the future. This weather detection system in the future will also serve as a support system that aims to predict rice yields combined with farmer treatment. From this sensor data, farmers can monitor and optimize their land to suit the needs of rice treatment by following the existing weather conditions. However, the sensor used is still incomplete, so that several more sensors can be used for further research such as detection of cloud cover, wind direction and detection of light intensity.

## CONCLUSIONS AND RECOMMENDATIONS

This system was built based on the concept of the internet of things and artificial intelligence which aims to assist farmers in managing rice farming land. Overall, the IoT prototype system and interface run normally after 30 days of testing. The tool can display sensor data for weather monitoring purposes through the Sabinusa interface system and a menu is also provided that can store plant care data during the planting period. Future research can add several supporting sensors related to the weather prediction system so that in the future the Sabinusa system can detect weather accurately and can also predict at least a few hours into the future. For future research, yield predictions can also be made from previously collected data on the Sabinusa system as well as data on the microcontroller's internal memory and real-time database.

## ACKNOWLEDGEMENT

Thank you to LPDP for funding this research through the Scientific Research scheme, so that the whole process went smoothly. Thanks also to the Ngudi Rahayu Gapoktan in Bugel Sampang Hamlet, Bojong Village, Kawunganten District, Cilacap Regency for being cooperative and supporting the implementation of this research well.

## REFERENCES

BMKG. (2021). Probabilistik Curah Hujan 20 mm (tiap 24 jam). https://www.bmkg.go.id/cuaca/probabilistik-curah-hujan.bmkg

Bojong. (2022). Desa Bojong Kecamatan Kawunganten Kabupaten Cilacap. http://bojong-kawunganten.cilacapkab.go.id/

BPS. (2022). Luas Panen, Produksi, dan Produktivitas Padi Menurut Provinsi 2020-2022. https://www.bps.go.id/indicator/53/1498/1/luas-panen-produksi-dan-produktivitas-padi-menurut-provinsi.html

Fawaiq, M. N., Jazuli, A., & Hakim, M. M. (2019). Prediksi Hasil Pertanian Padi Di Kabupaten Kudus Dengan Metode Brown’s Double Exponential Smoothing. In JIPI (Jurnal Ilmiah Penelitian dan

Pembelajaran Informatika) (Vol. 4, Issue 2, p. 78). STKIP PGRI Tulungagung. https://doi.org/10.29100/jipi.v4i2.1421

Flores, K. O., Butaslac, I. M., Gonzales, J. E. M., Dumlao, S. M. G., & Reyes, R. S. J. (2016). Precision agriculture monitoring system using wireless sensor network and Raspberry Pi local server. In 2016 IEEE Region 10 Conference (TENCON). IEEE. https://doi.org/10.1109/tencon.2016.7848600.

Gunawan, I. K. W., Nurkholis, A., Sucipto, A., & Afifudin, A. (2020). Sistem monitoring kelembaban gabah padi berbasis Arduino. Jurnal Teknik Dan Sistem Komputer, 1(1), 1-7. https://doi.org/10.33365/jtikom.v1i1.4

Granell, C., Kamilaris, A., Kotsev, A., Ostermann, F. O., & Trilles, S. (2020). Internet of things. Manual of digital earth, 387-423.

James, J., & Maheshwar P, M. (2016). Plant growth monitoring system, with dynamic user-interface. In 2016 IEEE Region 10 Humanitarian Technology Conference (R10-HTC). 2016 IEEE Region 10 Humanitarian Technology Conference (R10-HTC). IEEE. https://doi.org/10.1109/r10-htc.2016.7906781.

Julham, Adam, H. A., Lubis, A. R., & Lubis, M. (2019). Development of Soil Moisture Measurement With Wireless Sensor Web-based Development of soil moisture measurement with wireless sensor web-based concept. February, 514–520. https://doi.org/10.11591/ijeecs.v13.i2.pp514-520

Karim, F., Karimb, F., & Frihidab, A. (2017). Monitoring system using web of things in precision agriculture. Procedia Computer Science, 110, 402–409. https://doi.org/10.1016/j.procs.2017.06.083

Meher, C. P., Sahoo, A., & Sharma, S. (2019). IoT based Irrigation and Water Logging monitoring system using Arduino and Cloud Computing. Proceedings - International Conference on Vision Towards Emerging Trends in Communication and Networking, ViTECoN 2019, March, 10–15. https://doi.org/10.1109/ViTECoN.2019.8899396

Nama, G. F., Setia, H. N., Komarudin, M., Muhammad, M. A., Informatika, T., & Lampung, U. (2020). Prototype Sistem Pintar Pengelolaan Taman Bunga Berbasis Teknologi Internet of Things (Studi Kasus Taman Kupu-Kupu Gita Persada). 21(1), 26–33.

Nurhakim, I., Harsani, P., Si, M., Ardiansyah, D., & Kom, M. (2015). Model Alat Pengusir Hama Padi Berbasis Internet of Things (Iot).

Oo, Z., Lai, T., Ko, S., & Moe, A. (2019). IoT based Weather Monitoring System Using Firebase Real Time Database with Mobile Application. In International Symposium on Environmental-Life Science and Nanoscales Technology.

Parawansa, A. A. C., Hanuranto, A. T., & Raniprima, S. (2021). Perancangan Dan Implementasi Database Budidaya Tanaman Kangkung Darat Dengan Sistem Internet of Things. E-Proceedings of Engineering, 8(5).

Pratiwi, R., Sembodo, D. R. J., & Hidayat, K. F. (2016). Efikasi Herbisida Penoksulam Terhadap Pertumbuhan Gulma Umum Pada Budidaya Tanaman Padi Sawah. Jurnal Agrotek Tropika, 4(1), 16–21. https://doi.org/10.23960/jat.v4i1.1889

Saydi, R. (2021). Monitoring Curah Hujan dan Kelengasan Tanah Lahan Pertanian Menggunakan Sensor Berbasis Internet of Things (IoT) sebagai Dasar Pertanian Presisi. Jurnal Ilmiah Teknologi Pertanian Agrotechno, 6(1), 25-31. doi:10.24843/JITPA.2021.v06.i01.p04.

Soontranon, N., Tangpattanakul, P., Srestasathiern, P., & Rakwatin, P. (2014). An agricultural monitoring system: Field server data collection and analysis on paddy field. 2014 14th International Symposium on Communications and Information Technologies (ISCIT). IEEE. https://doi.org/10.1109/iscit.2014.7011985.

Sugiyono. (2013). Metode Penelitian Kuantitatif, Kualitatif dan R&D. Bandung: CV Alfabeta.

Syadza, Q., Permana, A. G., & Ramadan, D. N. (2018). Pengontrolan dan Monitoring Prototype Greenhouse Menggunakan Mikrokontroler dan Firebase. Eproceeding Telkom University Open Library, 4(1), 192–197.

Taris, L., Cahyadi, A., Nurmala, N., Jaya, H., & Shalihah, A. (2022). IoT-Based Smart Irrigation System for Rice Fields. Research Square Platform LLC. https://doi.org/10.21203/rs.3.rs-1265860/v1

Wahyudi, D. A., Adi Wibowo, S., & Primaswara P, R. (2021). Rancang Bangun Sistem Padi Aquaponic Berbasis IoT (Internet of Things). In JATI (Jurnal Mahasiswa Teknik Informatika) (Vol. 5, Issue 1, pp. 108–114). LPPM ITN Malang. https://doi.org/10.36040/jati.v5i1.3271.