



Agricultural monitoring system using esp32 microcontroller with IOT-Based LORA transmission

Achmad zuchriadi¹, Fajar Rahayu², Silvia Anggraeni³, Muhamad Alif Razi⁴, Muchamad Oktaviandri⁵, Irga⁶

^{1,2,3,4,6}Department of Electrical Engineering, UPN Veteran Jakarta, Indonesia

⁵Department of Mechanical Engineering, UPN Veteran Jakarta, Indonesia

ARTICLE INFO

ABSTRACT

Article history:

Accepted Jun 05, 2023

Revised Jun 22, 2023

Accepted Jul 13, 2023

Keywords:

Agricultural Monitoring;

ESP32;

Internet of Things;

LoRa;

Smart Farming;

System

Smart farming is an agricultural management plan based on precise monitoring and calculation of agricultural parameters that are useful as a reference in taking appropriate actions. The application of Smart Farming is inseparable from the IoT system that supports processing and data collection. Remote large agricultural area, far from the public, limited access to electricity and difficult cellular network access. Responding to this, this research designed an IoT-based agricultural monitoring system by implementing the ESP 32 microcontroller and LoRa Transmission which uses solar panels as a power supply and is displayed via the Web Server Dashboard. Tests are carried out in the form of sensor readings, dashboard displays, and data transmission. The results obtained are that the agricultural monitoring system design works well with the sensors used to work and the ESP32 microcontroller to process data. LoRa and Internet data transmission can be sent properly indicated by synchronous data access. The monitoring dashboard can work properly as shown by the appropriate home page and graphic page.

This is an open access article under the [CC BY-NC](https://creativecommons.org/licenses/by-nc/4.0/) license.



Corresponding Author:

Achmad zuchriadi,

Department of Electrical Engineering,

UPN Veteran Jakarta,

Jalan RS. Fatmawati Raya, Pd. Labu, Kec. Cilandak, Kota Depok, Jawa Barat, Indonesia 12450

Email: achmad.zp@upnvj.ac.id

1. INTRODUCTION

Smart Farming or in another term, namely Precision Agriculture, is an agricultural management plan based on monitoring and calculating agricultural parameters with precision (Rachmawati, 2020) (Rahul et al., 2018), which is useful as a reference in taking appropriate actions. Generating accurate data and proper management are the mainstays of precision agriculture (Mahendra Data et al., 2019). This concept in its implementation collaborates with the Internet of Things (IoT) system which is a future technology in every field that affects everyone's life by making everything smarter (Doshi et al., 2019), the IoT (Internet of Thing) system that is applied to the agricultural sector can support processing and data collection (Chamara et al., 2022; Farooq et al., 2019), so that farmers can take quick action on problems and changes in the surrounding environment by utilizing the necessary sensors (Kunisch, 2016). Soil condition sensors

and weather condition sensors installed on agricultural land. The data obtained from this sensor includes air and soil moisture, temperature, soil pH, and weather. The data helps farmers to monitor, measure and record crop conditions and can determine the best action for land conditions by farmers (Rachmawati, 2021). For example, this system can be applied to a Mango Plantation considering that its productivity in the Sliyeg Indramayu area is influenced by temperature, rainfall and humidity (Triani et al., 2019).

An agricultural monitoring system requires a device that can manage sensor data and can transmit this data to the user, this can be handled using a microcontroller. Microcontroller is a complete microprocessor system combined into one part on a chip. contains programmable memory, inputs and outputs (Sokop et al., 2016). The microcontroller that is compatible with the agricultural monitoring system is ESP32 which supports IoT technology. ESP32 is a microcontroller produced by the company Espressif Systems (Alexander et al., 2017). Espressif Systems is a publicly traded multinational fabless semiconductor and semiconductor company located in Shanghai, China. The company focuses on developing low-cost wireless communications and IoT. Reliable on-chip system on ESP32 with dual mode Bluetooth version 4.2, integrated Wi-Fi 802.11 b/g/n and various peripherals. Dual core applications with different versions have clocks up to 160 MHz. ESP32 updated GPIO pin count to 36 pins, updated PWM channel count per 16, and included 4MB of flash memory (Marek Babiuch et al., 2019).

LoRa is a wireless communication system developed for IoT. This system has the advantage of being able to communicate over long distances of up to 15 km under LOS (Line of Sight) conditions. This system was popularized by the LoRa Alliance for use in battery-powered devices with long endurance times. LoRa technology is also highly resistant to transmission system noise. The LoRa system is efficient in saving communication channels because it only uses a channel for the gateway instead of using a channel for each IoT device (Nurhadi et al., 2021). The use of LoRa is very suitable for agricultural monitoring systems because agricultural land has a large area and is far from settlements and limited access to Internet network access (Citoni et al., 2019; Elijah et al., 2018). What's more, LoRa is very power-efficient in its use which is also suitable for applications on microcontrollers in transmitting data.

IoT devices that are located on agricultural land require an electric power supply to operate, but agricultural land that is located far from access to direct electricity supply from PLN (State Electricity Company) requires the device to use a battery. The battery has its own capacity if there is no external energy, the battery energy will run out. The use of new renewable energy sources can overcome this so that the supply of electrical energy for these devices is still fulfilled and the devices work (Erwan Septa et al., 2022). A new renewable energy source that can be utilized is the use of solar cells. A solar cell is a device that converts sunlight energy into electrical energy by means of the photovoltaic effect, therefore it is also called a photovoltaic cell. (Maninder Singh et al., 2016). Solar cells as an alternative energy source will keep the IoT monitoring system maintained and sustainable (Andreas S., 2017).

This research aims to create an IoT-based agricultural monitoring system by implementing the ESP 32 microcontroller as the main system and LoRa as access to data transmission between devices in agricultural areas by using solar cells as new renewable energy for power supply then the data from the embedded sensors will be processed and can be accessed by farmers or other users through the Web Server. This is also done to be able to answer several challenges in the application of IoT for agriculture, which must be easy to implement and cost-effective, especially for traditional farmers. (Glaroudis et al., 2020; Sivanraju, 2018).

2. RESEARCH METHOD

This research uses literature studies as a reference and basis for conducting research based on references that are relevant to the research being carried out. As well as designing the design of an IoT-based agricultural monitoring system tool. Data collection is carried out to find out the input data from each sensor on agricultural land and then the sensor input data will be compared between the microcontroller data and the result data on the data base system, data collection is carried out every 5 minute intervals based on data delivery updates.

The workings of the first tool Microcontroller node Is a microcontroller that has a function as a data collector, microcontroller nodes are installed in certain areas to retrieve information using certain sensors then the information will be transmitted to the gateway. Second, on the microcontroller, the gateway is a gateway for gathering information from one or more nodes, which then the information will be forwarded to the server. The following are the stages of how the device works which can be seen in the flowchart and in the block diagram.

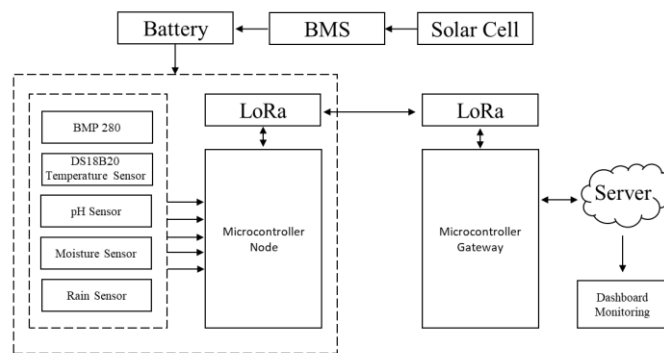


Figure 1. Block Diagram of The Agricultural Monitoring System

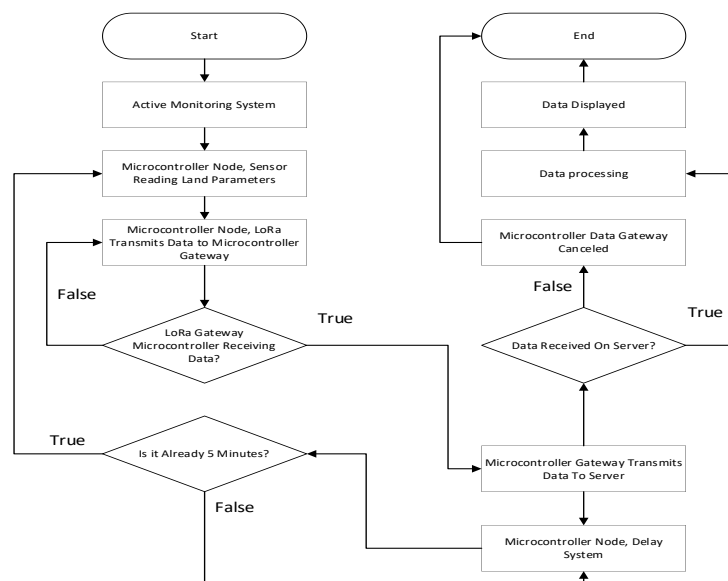


Figure 2. Flowchart of The Agricultural Monitoring System

There are two parts to the design of the software in this research, namely the design of the microcontroller software and the design of the software on the Web server. Arduino IDE is used for programming design for microcontroller nodes. Arduino IDE stands for Integrated Development Environment, which is an integrated environment used for development. Through the Arduino IDE, Arduino and other microcontrollers that support the Arduino IDE are programmed to perform embedded functions through programming syntax (Peerasak & Nuttapun, 2018). The microcontroller node will be programmed so that it can read the necessary sensors and then the sensor data will be transmitted using Lora. The second programming as a receiver will be entered for the receiver or gateway microcontroller and programming will also be entered to send data sent from the transmitter, the receiver sends it again to the database.

Visual Studio Code is a code editor developed by Microsoft for Windows, Linux, and macOS. Visual Studio Code supports debugging, GitHub, built-in git control, syntax highlighting, smart code completion, snippets, and code refactoring. Visual Studio Code in this study functions as a programming writing application to design dashboard pages for monitoring agricultural land, using languages such as PHP, CSS, and JavaScript. XAMPP is a complete web programming package that can be used to learn web programming, especially PHP and MySQL. Its functionality is as a standalone server (localhost), consisting of the Apache HTTP server program, MySQL database, and a language translator written in the PHP programming language. XAMPP in this study functions as a server management and database storage.

This hardware design will be carried out on each microcontroller that will be tested, the hardware that will be tested will be used as a transmitter with various sensors in order to work as expected (Navarro et al., 2020). The sensor to be used is like the Rain Sensor as a sensor that functions as a detector for the presence or absence of raindrops (Parapat et al., 2020). DS18B20 is a temperature sensor, because the output data from this sensor is digital data, data degradation does not occur, so it is suitable for use in difficult locations that can be used as soil temperature. pH sensor as a measure of soil acidity (Jupri et al., 2017). Moisture sensor as a measure of soil moisture by inserting it into the soil. Barometric Pressure 280 (BMP 280) uses air pressure to detect the height of an object when it is above the air in a certain area, the BMP 280 is used as a sensor for measuring air temperature, surface elevation and air humidity (Khaery et al., 2020). The LoRa module acts as a transmitter between the microcontroller nodes and gateways.

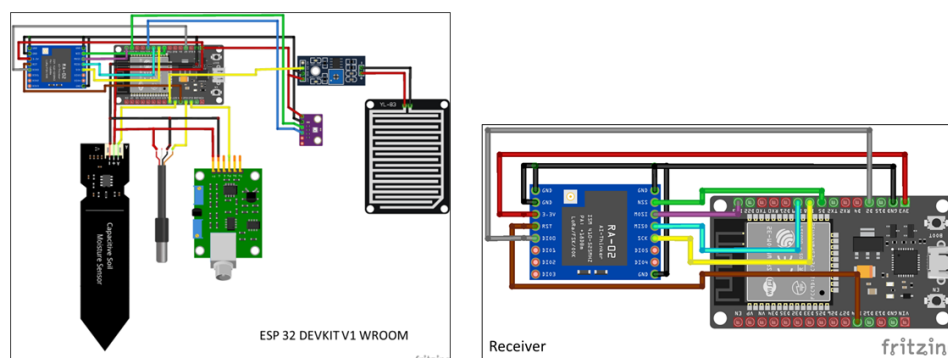


Figure 3. Design of Agricultural Monitoring System

3. RESULTS AND DISCUSSIONS

The design of the microcontroller hardware is the stage in installing each component from both the microcontroller and the sensors and modules used. The media used is bread board media as a medium for wiring and installation of microcontrollers and supporting components. After the designer on the bread board is appropriate, the design is carried out on the PCB (printed circuit board), which is the design of the agricultural monitoring system device.



Figure 4. Monitoring System Design on Bread Board and PCB

The software design is divided into designs for microcontrollers and for web server dashboards. The design of the microcontroller is the stage for programming the microcontroller. This programming design work uses the Arduino IDE application. The programming that is made has two programming, namely programming on the node microcontroller and programming on the gateway microcontroller.

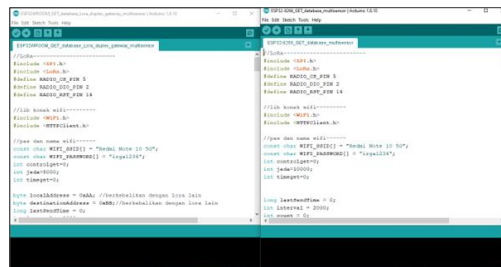


Figure 5. Microcontroller Programming Process Display

The design of Web Server software is the stage for designing the appearance of the Agricultural Monitoring Dashboard. This dashboard will display the parameters of each sensor used on the microcontroller. Web Server is also a data storage area or as a data base of sensor parameter values that have been sent from the gateway microcontroller.

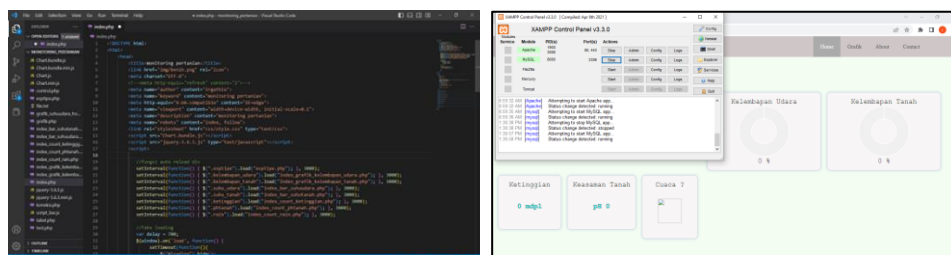


Figure 6. Dashboard monitoring programming process display

The testing of the tool was carried out, namely testing to see the results of data retrieval, sending data between gateways and nodes, sending data between gateways and

servers, as well as testing on servers, namely the results of the dashboard display. The first test is testing on the device to find out the results of data retrieval from the parameters found on agricultural land through embedded sensors. Sensor data will be checked through the PC display and can be seen in the figure 7 which shows that all sensors have been able to work.

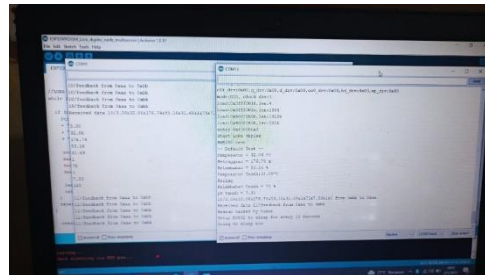


Figure 7. Sensor data testing

The second test is testing data transmission via LoRa transmission between microcontroller nodes and microcontroller gateways or sending via the internet between gateway microcontrollers and servers. This trial is also a trial to view the dashboard page of the agricultural monitoring system. Can be seen with the display results either in the form of numbers or data that has been processed in the form of diagrams.

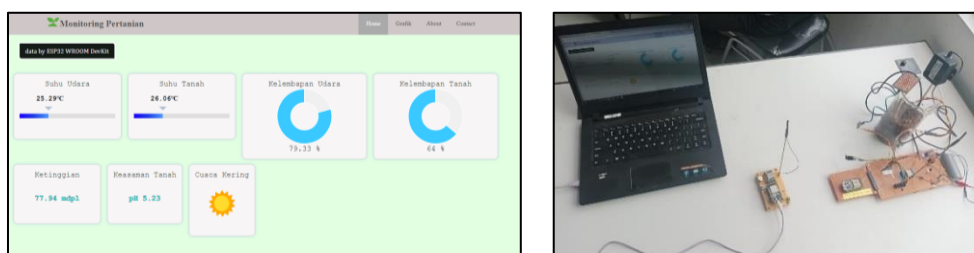


Figure 8. Testing of Dashboard Display and Data Transmission

The results of the agricultural monitoring system are in the form of dashboards that can be monitored by farmers or other users. The Dashboard page has a Home page that displays the seven sensor data, both in the form of numbers and in the form of diagrams. Soil temperature and air temperature data are displayed in the form of a bar level, air humidity and soil moisture are displayed in the form of a pie chart, weather conditions are displayed in the form of an icon if the data value is 1 it will display the sun indicating dry weather 0 to display a cloud icon indicating rainy weather.



Figure 9. Dashboard Display Menu Home

The second dashboard page displays sensor data in graphical form, divided into two, namely a comparison graph between air temperature and soil temperature, then a comparison between soil moisture and air humidity.

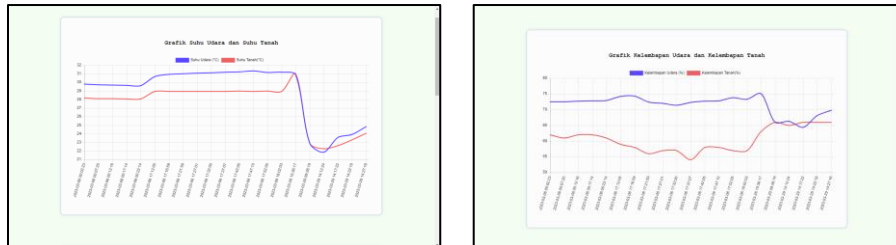


Figure 10. Dashboard Display Graphic Menu

Data collection is carried out on sensor data that has been collected and data comparison will be carried out when the data is at the microcontroller node, when the data is at the gateway microcontroller, and when it is on the server. The data will be matched from the uniformity of data every update of data transmission. The following is an excerpt of trial data as much as 5 data.

Table 1. Comparison of Sensor Data

Data to	Sensors	Data on Node	Data on Gateway	Data on Server	Description
1	Air temperature	29.01 °C	29.01	29.01	appropriate
	Soil Temperature	28.38 °C	28.38	28.38	appropriate
	Height	151.36 m	151.36	151.36	appropriate
	Air Humidity	78.46 %	78.46	78.46	appropriate
	Soil Moisture	53 %	53	53	appropriate
	Soil pH	pH 5.74	5.74	5.74	appropriate
	Rain Sensor Response	1	1	1	appropriate
2	Air temperature	28.96 °C	28.96 °C	28.96 °C	appropriate
	Soil Temperature	28.38 °C	28.38 °C	28.38 °C	appropriate
	Height	151.64 m	151.64 m	151.64 m	appropriate
	Air Humidity	78.63 %	78.63 %	78.63 %	appropriate
	Soil Moisture	54 %	54 %	54 %	appropriate
	Soil pH	pH 5.62	pH 5.62	pH 5.62	appropriate
	Rain Sensor Response	1	1	1	appropriate
3	Air temperature	28.85 °C	28.85 °C	28.85 °C	appropriate
	Soil Temperature	28.06 °C	28.06 °C	28.06 °C	appropriate
	Height	158.59 m	158.59 m	158.59 m	appropriate
	Air Humidity	79 %	79 %	79 %	appropriate
	Soil Moisture	51 %	51 %	51 %	appropriate
	Soil pH	pH 5.94	pH 5.94	pH 5.94	appropriate
	Rain Sensor Response	1	1	1	appropriate
4	Air temperature	28.94 °C	28.94 °C	28.94 °C	appropriate
	Soil Temperature	28.38 °C	28.38 °C	28.38 °C	appropriate
	Height	152.05 m	152.05 m	152.05 m	appropriate
	Air Humidity	78.8 %	78.8 %	78.8 %	appropriate
	Soil Moisture	54 %	54 %	54 %	appropriate
	Soil pH	pH 5.6	pH 5.6	pH 5.6	appropriate
	Rain Sensor Response	1	1	1	appropriate
5	Air temperature	28.86 °C	28.86 °C	28.86 °C	appropriate
	Soil Temperature	28 °C	28 °C	28 °C	appropriate
	Height	158.64 m	158.64 m	158.64 m	appropriate
	Air Humidity	79.01 %	79.01 %	79.01 %	appropriate
	Soil Moisture	51 %	51 %	51 %	appropriate
	Soil pH	pH 5.89	pH 5.89	pH 5.89	appropriate
	Rain Sensor Response	1	1	1	appropriate

The table shows the results of data matching from microcontroller node data, microcontroller gateway data, and data on the server. The seven-sensor data from 5 data shows that the three data locations show the same results. This shows that the agricultural monitoring system has been able to work well.

4. CONCLUSION

Based on the process of design, manufacture, test results it can be concluded that the design of the agricultural monitoring system is functioning properly where the sensors used can work and the ESP32 microcontroller is able to process data. Data sender transmission works properly, when using LoRa from microcontroller node to microcontroller gateway, or transmission using internet from gateway to server, which is characterized by data synchronization from three locations, namely data on microcontroller node, microcontroller gateway and server. The monitoring dashboard page can work well as indicated by the home page and corresponding graphical pages and the data can be presented properly. This design can be applied to traditional farmers. Communication Systems using LoRa Modules themselves are still not widely used. Further research on the use of Lora modules in other fields can be done.

REFERENCES

- Alexander, M., Andrew, S., & Yuriy, V. (2017). Comparative Analysis and Practical Implementation of the ESP32 Microcontroller Module for the Internet of Things. *2017 Internet Technologies and Applications (ITA)*.
- Andreas S., S. (2017). Solar Energy Management as an Internet of Things (IoT) Application. *2017 8th International Conference on Information, Intelligence, Systems & Applications (IISA)*.
- Chamara, N., Islam, M. D., Bai, G. (Frank), Shi, Y., & Ge, Y. (2022). Ag-IoT for crop and environment monitoring: Past, present, and future. In *Agricultural Systems* (Vol. 203). Elsevier Ltd. <https://doi.org/10.1016/j.agry.2022.103497>
- Citoni, B., Fioranelli, F., Imran, M. A., & Abbasi, Q. H. (2019). Internet of things and LoRaWAN enabled future smart farming. *IEEE Internet of Things Journal*, 2(4), 14–19. <http://eprints.gla.ac.uk/204499/http://eprints.gla.ac.uk>
- Doshi, J., Patel, T., & Bharti, S. K. (2019). Smart Fanning using IoT, a solution for optimally monitoring fanning conditions. *Procedia Computer Science*, 160, 746–751. <https://doi.org/10.1016/j.procs.2019.11.016>
- Elijah, O., Rahman, T. A., Orikumhi, I., Leow, C. Y., & Hindia, M. N. (2018). An Overview of Internet of Things (IoT) and Data Analytics in Agriculture: Benefits and Challenges. *IEEE Internet of Things Journal*, 5(5), 3758–3773. <https://doi.org/10.1109/JIOT.2018.2844296>
- Ervan Septa, I., Angga, R., & Irwan, P. (2022). Rancang Bangun Sistem Catu Daya Pada Smart Agriculture Rover Berbasis Internet of Things. *EProceedings of Engineering*.
- Farooq, M. S., Riaz, S., Abid, A., Abid, K., & Naeem, M. A. (2019). A Survey on the Role of IoT in Agriculture for the Implementation of Smart Farming. In *IEEE Access* (Vol. 7, pp. 156237–156271). Institute of Electrical and Electronics Engineers Inc. <https://doi.org/10.1109/ACCESS.2019.2949703>
- Glaroudis, D., Iossifides, A., & Chatzimisios, P. (2020). Survey, comparison and research challenges of IoT application protocols for smart farming. *Computer Networks*, 168. <https://doi.org/10.1016/j.comnet.2019.107037>
- Jupri, Abdul, M., & Muliadi. (2017). Rancang bangun alat ukur suhu, kelembaban, dan ph pada tanah berbasis mikrokontroler ATmega328P. *JEPIN*, 3(2).
- Khaery, M., Harditio Pratama, A., Wipradnyana, P., Agung Ngurah Gunawan, A., Studi Fisika, P., Matematika dan Ilmu Pengetahuan Alam, F., Besar Meteorologi, B., & dan Geofisika, K. (2020). Design of Air Pressure Measuring Devices Using a Barometric Pressure 280 (BMP280). *BULETIN FISIKA*, 21(1), 14–19. <https://ojs.unud.ac.id/index.php/buletinfisika/article/view/56941>
- Kunisch, M. (2016). Big Data in agriculture – perspectives for a service organisation. In *landtechnik: Vol. 7 1(1)* (pp. 1–3). <https://doi.org/10.15150/lt.2016.3117>

- Mahendra Data, Widhi Yahya, & Andika Kurniawan. (2019). Implementasi Teknologi Virtualisasi Berbasis Kontainer untuk Perangkat Internet of Things pada Pertanian Presisi. *CYBERNETICS*, 3(01), 1–7. <https://openjurnal.unmuhpnk.ac.id/index.php/CN/article/view/1448>
- Maninder Singh, Jaspreet Singh, Anshula Garg, Ekambir Sidhu, Vatanjeet Singh, & Aman Nag. (2016). Efficient Autonomous Solar Energy Harvesting System Utilizing Dynamic Offset Feed Mirrored Parabolic Dish Integrated Solar Panel. *2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*.
- Marek Babiuch, Petr Foltýnek, & Pavel Smutný. (2019). Using the ESP32 Microcontroller for Data Processing. *2019 20th International Carpathian Control Conference (ICCC)*. <https://ieeexplore.ieee.org/document/8765944>
- Navarro, E., Costa, N., & Pereira, A. (2020). A systematic review of iot solutions for smart farming. In *Sensors (Switzerland)* (Vol. 20, Issue 15, pp. 1–29). MDPI AG. <https://doi.org/10.3390/s20154231>
- Nurhadi, A. A., Darlis, D., & Murti, M. A. (2021). Implementasi Modul Komunikasi LoRa RFM95W Pada Sistem Pemantauan Listrik 3 Fasa Berbasis IoT. *Ultima Computing: Jurnal Sistem Komputer*, 13(1), 17.
- Parapat, A., Syaechurodji, & Surya, F. (2020). REKAYASA PERANGKAT LUNAK ALAT KENDALI JEMURAN OTOMATIS MENGGUNAKAN ARDUINO DAN SENSOR HUJAN/AIR, KELEMBABAN DHT11 DAN CAHAYA LDR. *Jurnal Ilmiah Sains Dan Teknologi*, 4(1), 19–26. <https://ejournal.lppm-unbaja.ac.id/index.php/saintek/article/view/824>
- Peerasak, S., & Nuttapun, N. (2018). Smart Farm Monitoring via the Blynk IoT Platform - Case Study: Humidity Monitoring and Data Recording. *IEEE - Sixteenth International Conference on ICT and Knowledge Engineering*.
- Rachmawati, R. R. (2021). SMART FARMING 4.0 UNTUK MEWUJUDKAN PERTANIAN INDONESIA MAJU, MANDIRI, DAN MODERN. *Forum Penelitian Agro Ekonomi*, 38(2), 137. <https://doi.org/10.21082/fae.v38n2.2020.137-154>
- Rachmawati, R. R. (2020). Smart Farming 4.0 Untuk Mewujudkan Pertanian Indonesia Maju, Mandiri, Dan Modern. In *Forum Penelitian Agro Ekonomi* (Vol. 38, pp. 137–154).
- Rahul, D., Subhranil, S., & Sunil Kumar, K. (2018). Smart Farming – IoT in Agriculture. *Proceedings of the International Conference on Inventive Research in Computing Applications (ICIRCA 2018)*.
- Sivanraju, K. (2018). IoT in Agriculture : Smart Farming. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, 181–184. <https://doi.org/10.32628/cseit183856>
- Sokop, S. J., Mamahit, D. J., Eng, M., Sompie, S. R. U. A., Mahasiswa,), & Pembimbing,). (2016). Trainer Periferal Antarmuka Berbasis Mikrokontroler Arduino Uno. *Journal Teknik Elektro Dan Komputer*, 5(3).
- Triani, F., Jurusan, A., Pertanian, B., & Pertanian, F. (2019). Dampak Variasi Iklim Terhadap Produktivitas Mangga (*Mangifera indica*) Di Kabupaten Indramayu, Jawa Barat Impact of Climate Variation on Mango (*Mangifera indica*) Productivity In Indramayu Regency, West Java. *Plantropica Journal of Agricultural Science*, 2019(1), 49–56.