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System Monitoring and Controlling Agricultural Activities with Arduino-Based Internet of Things

M. Syahril Ramadhani
Software Engineer Technology,
Agriculture Polytechnic Samarinda,
Samarinda, 75242, Indonesia
muhammadsyahrilramadhani081@gmail.com

Eko Junirianto*
Software Engineer Technology,
Agriculture Polytechnic Samarinda,
Samarinda, 75242, Indonesia
eko@politanisamarinda.ac.id
**Corresponding author*

Eny Maria
Software Engineer Technology,
Agriculture Polytechnic Samarinda,
Samarinda, 75242, Indonesia
enymaria@politanisamarinda.ac.id

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Abstract— Agriculture is one of the most important economic sectors in Indonesia. However, the Center for Indonesian Policy Studies (CIPS) estimates that agricultural production will decline by 1.64% to 6.2% due to supply chain disruptions affected by the Corona pandemic. But on the other hand, during the corona pandemic as it is today, the information technology sector, mainly digital, hich requires internet access, has experienced a rapid increase. In this modern era, an innovation that utilizes the latest technology is needed to create an innovation that can increase the potential of the plantation sector towards industry 4.0. Therefore, a will be developed in this research Arduino-based Internet of Things monitoring and control system can provide information about soil pH, soil moisture, air humidity, air temperature, and wind speed from plants in real-time, and control water pumps for watering. The Arduino technology can make it easier for farmers to control the conditions in plants so plants can grow and develop optimally.

Keywords—Monitoring System, IoT, Arduino, Agriculture, Control System

I. INTRODUCTION

Indonesia is an agrarian country because most of the population has a livelihood in agriculture or farming. As a country with fertile soil, Indonesia is one of the countries with abundant agricultural products, so the farm sector supports food needs on all islands in Indonesia. Indonesian plantations have gone through a long history. More than five centuries ago, the seas of the archipelago were bustling with trade traffic for the primary commodities of plantation products, such as pepper, nutmeg, cloves, and spices, then developed various additional items such as coffee, palm oil, cocoa, and rubber (Maria & Junirianto, 2021).

Agriculture is one of the most important economic sectors in Indonesia. However, the Center for Indonesian Policy Studies (CIPS) estimates that agricultural production will decline by 1.64% to 6.2% due to supply chain disruptions affected by the Corona pandemic. In addition, the show also decreased due to a 1.63-4.87% decrease in labor in the agricultural sector due to the corona outbreak. However, on the other hand, during the corona pandemic today, the information technology sector, mainly digital, which requires internet access, has experienced a rapid increase. It has proven that digital businesses such as YouTube, zoom, and google meet have experienced significant user growth, especially when the government implements the WFH policy. (Work From Home), where all activities are done from home (Junirianto & Franz, 2021).

Soil is a natural medium needed in farming activities. Plants will grow well if the soil is fertile, several things affect soil fertility, one of which is nutrients. The amount of nutrient content in the soil is an indicator of the level of soil fertility that will affect the process of plant growth and development. The level of soil fertility is influenced by several factors, one of which is the degree of soil acidity (soil pH) (Rima et al., 2018).

The potential in the agricultural and plantation sectors is very potential, but the possibility has not been fully exploited. Most farmers tend to lack knowledge about soil content. This results in less than optimal agricultural yields due to inappropriate treatment with the actions that must be taken on plants (Rawa et al., 2016).

Based on the background described previously, the problem formulation is obtained, how to design and create a Monitoring and Control System for Agricultural Activities with Arduino-Based Internet Of Things. The limitation of the plant problem used as the object of research is the kale plant in the Digital Farming Garden of the Nabil Husein Islamic Boarding School on Jalan Puspita Bengkuring. Soil quality measurement parameters are soil moisture, pH, air humidity, air temperature, and wind speed. And use NodeMCU ESP8266 to send data to Thingsboard. The goal to be achieved in this research is a system for monitoring and controlling agricultural activities with an Arduino-based Internet of things that can provide information about soil pH, soil moisture, air humidity, air temperature, and wind speed from plants in real-time and control water pump sprinkling.

The expected results of utilizing Arduino technology can make it easier for farmers to control plant conditions to maximize agricultural yields.

II. LITELATURE REVIEW

A. Internet of Things

Internet of Things or IoT is a technology concept connecting various objects to the internet network. This allows the object to operate automatically. In addition, these objects can provide real-time data to the user on an ongoing basis. Interneta of Things (IoT) is a concept that aims to expand the benefits of continuously connected internet connectivity (Arafat, 2016).

1. Element of the IoT
   a. Sensors

      This element is an element that distinguishes IoT machines from other sophisticated machines. With this sensor, the machine can determine the instrument that can change the IoT machine from a passive one to an active and integrated machine or tool.

      1) Arduino Mega Microcontroller

         Arduino is an open-source single-board microcontroller derived from the Wiring platform, designed to facilitate the use of electronics in various fields. The hardware has an Atmel AVR processor, and the software has its own programming language. Arduino is also an open hardware list aimed at anyone who wants to create interactive electronic prototypes based on flexible and easy-to-use hardware and software. Arduino uses the ATMega microcontroller family released by Atmel as a base, but there are individuals/companies that make Arduino clones using other microcontrollers and remain compatible with Arduino at the hardware level. For flexibility, programs are loaded via the bootloader, although there is an option to bypass the bootloader and use the downloader to program the microcontroller directly through the ISP port (Devinta et al., 2022).

      2) Soil Moisture

         A soil moisture sensor is a sensor capable of detecting the intensity of water in the soil (moisture). This sensor consists of two probes to pass current through the soil, then read its resistance to get the value of the moisture level. More water makes it easier for soil to conduct electricity (small resistance), whereas dry soil is very difficult to conduct electricity (large resistance). Both of these problems are media that will deliver analog voltages whose values are relatively small. This voltage will be converted into a digital voltage for processing in the microcontroller (Issn & Latif, 2021).

      3) Soil pH Sensor

         A soil pH sensor is a sensor for detecting the level of acidity or wetness of the soil. The soil pH scale that can be measured by this soil pH sensor has a range of 3.5 to 8. This sensor can be directly connected to Arduino analog pins or other microcontroller analog pins without having to use an additional gain module.

      4) DHT22

         The DHT 22 sensor is a digital sensor that can measure the temperature of -40oC – 125oC and 0%-100% humidity in the surrounding air. This sensor is very easy to use in conjunction with Arduino. Has an excellent level of stability and features a very accurate calibration. The temperature and relative humidity sensor used in the manufacture of this tool is DHT22. This module can be used as a temperature and humidity sensor in room temperature and humidity control applications as well as room temperature and relative humidity monitoring applications.

      5) Anemometer

         Anemometer is a testing tool commonly called a wind speed measuring device which is usually used in the field of Meteorology and Geophysics or in weather forecasting stations. Anemometer used to measure or determine wind speed. In addition to measuring wind speed, this tool can also measure the magnitude of wind pressure, weather, and sea wave height.

      6) ESP8266

         A wifi module that functions as an additional microcontroller like Arduino so that it can connect directly to Wi-Fi and make TCP/IP connections. This module requires around 3.3v of power and has three wifi modes, namely Station, Access Point, and Both. This module is also equipped with a processor, memory, and GPIO, here the number of pins depends on the type of ESP8266 that we use. So that this module can stand alone without using any microcontroller because it already has equipment in the form of a microcontroller (Devinta et al., 2022).

      7) Module Relay 2 Channel 5 V

         A liquid Crystal Display (LCD) is a component that can display text. One type has two rows, with each row consisting of 16 columns. LCDs like that are usually called 16x2 LCDs, and there are also those consisting of 4 rows, with each row consisting of 20 columns as well, commonly called 20x4 LCDs (Issn & Latif, 2021).

      8) LCD

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      9) RTC

         Real-Time Clock or often called RTC, is one of the active electronic components that can store date and time data in it. The form of data communication from RTC is I2C which only uses two communication lines, namely SDA and SCL(Putra et al., 2020).

   b. Connectivity

      Connectivity is also commonly referred to as the connection between networks. In the IoT world itself,

there is a possibility for us to create a new network, a network specifically used for IoT devices.

2. The benefits of the internet of things in various fields
   a. Agriculture

      IoT in the agricultural sector can be applied in various ways. One of them is in terms of data collection. The data collected can be in the form of temperature, humidity, rainfall, the water content in the soil, and pest monitoring.
   b. Health

      In the world of health, the internet of things continues to be developed. In the future, all examination results can be directly received by medical personnel or hospitals. The data sent include blood pressure, disease history, current illness, and others.
   c. Transportation

      IoT can help humans integrate, control, and process information in transportation systems. The application of the internet of things is proliferating and can be implemented on vehicle engines or the steering function
   d. Home Automation

      Internet of things devices can also not only be used in the business sector, but they can also be used for personal purposes. Such as developing the house fully automatic, starting by turning on the lights, turning on electronic devices, and opening the house door. These devices are referred to as intelligent home peripherals or smart home devices.
   e. Environment

      Usually, this environmental sector uses IoT applications and devices that use sensors.

B. Fritzing

Fritzing is open-source software for designing electronic circuits. The software supports electronics enthusiasts in creating product prototypes by designing Arduino microcontroller-based circuits. Allows even novice electronics designers to create custom PCB layouts. *Fritzing's* appearance and explanations can be easily understood by someone who is using it for the first time (D. Aryani, M. Nur Ihsan, 2017).

C. Arduino IDE

The software used to program Arduino, which is very well known today, is Arduino ide, the programming language used is called the sketch language or almost the same as the C programming language. The Arduino idea software is easier and simpler because inside, there is a library according to what you want to develop. Following the initial appearance of Arduino Software, the idea of IDE is short for Integrated Development Environment, or in simple language, it is an integrated environment used for development. It is called an environment because it is through this software that Arduino is programmed to perform the functions embedded through programming syntax. Arduino uses its own programming language that resembles C language. The Arduino programming language (Sketch) has been changed to make it easier for beginners to programming from the original language. Before being sold to the market, the Arduino microcontroller IC was implanted with a program called Bootloader which functions as an intermediary between the Arduino Compiler and the Arduino. And the advantage is that it does not need a chip programmer device because it already has a bootloader that will handle program uploads from the computer.

D. Thingsboard

Thingsboard is an open-source Internet of Things (IoT) platform. Thingsboard is a web server that can be used as a platform for device management, data collection, and website-based data visualization. The data that has been read by the sensor is then sent to the things board web server (Windarto et al., 2020).

E. Firebase Realtime Database

Firebase is a BaaS (Backend as a Service) currently owned by Google. Firebase itself is a solution offered by Google to make the work of Mobile Apps Developers easier. With Firebase, app developers can, of course, focus on developing applications without having to put a lot of effort into backend matters. Firebase Realtime Database itself is a NoSQL cloud-based database that syncs data across all clients in real-time and provides offline functionality. The inputted data is saved into the Realtime database as JSON. All connected and shared clients at one time will automatically receive updates with the latest data. This database itself is a database provided by Google and has two database solutions in its use. The first solution is called Cloud Firetstore. Cloud Firestore is Firebase's newest database for mobile app development. This database continues the success of the Realtime Database with a new, more intuitive data model (Kurniawati & Bachtiar, 2020).

F. Power Supply

1. Battery

   A battery is a chemical, electrical device that stores energy and releases its energy in the form of electricity. One of the tools for energy storage and conversion works is based on electrochemical principles. A battery consists of three important elements, namely:
   a. Carbon rod as an anode (positive pole).
   b. Zinc (Zn) as a cathode (negative pole).
   c. Paste as electrolyte

   Based on how it works, the battery has an electrochemical cell which is divided into two, namely a galvanic cell and an electrolytic cell. Galvanized cells are also called voltaic cells which can convert chemical energy into electrical energy, while electrolysis cells convert electrical energy to drive non-spontaneous chemical reactions. In use, the battery is divided into two types, rechargeable, and non-rechargeable. The type of battery that cannot be recharged is called a primary battery, and one that can be recharged is called a secondary battery (Hidayat, 2015).
2. Solar Panel

   Solar Panel is a device that can convert sunlight energy into electrical energy through the photovoltaic process. The development of solar panel technology was started in 1839 by the French physicist Antoine Cesar Becquerel. Solar Panels were first made around

1883 by Charles Fritts using a layer of Selenium joined with a very thin layer of gold (Hidayat, 2015).

3. Solar Charge Controller

In the use of solar panels with off-grid systems, there is an important tool to consider. The device is the SCC (Solar Charge Controller), installed between the solar panel and the battery. SCC is an electronic device that is useful for regulating the electric current that enters the battery (Rofiq, 2018).

G. Soil Quality

Soil quality includes soil quality physically, chemically, and biologically. These three things have their own parameters and cannot be separated from each other and influence each other. Parameters of physical properties that determine soil quality include, among others, texture, structure, aggregate stability, the ability of the soil to hold and pass other soils as well as soil resistance to erosion, and so on. Then the chemical parameters that affect the quality of the soil are the availability of nutrients, CEC, KTA, pH, the action of pollutant substances, and so on. Several parameters that can affect soil quality include:

1. Temperature

Temperature affects the metabolic activity of plants, for example, in the processes of photosynthesis, respiration, and evapotranspiration. Temperature also describes the proportion of solar radiation received by plants, so it can also represent the overall level of solar radiation received. Defining the temperature is not easy, but the temperature can be a degree cold or hot which is measured based on a certain scale. Measuring air temperature can use a thermometer.

2. Humidity

Bulk density is often used to calculate the total porosity (assuming that the Particle Density is 2.65 g/cc) and the amount of water available (% by volume). Optimum soil moisture is a combination of wet soil moisture levels. There are also plants that need protection for good growth, which means these plants cannot receive direct sunlight. Factors that affect soil moisture content, namely soil organic matter, have far more pores than soil mineral particles, which means that the absorption surface area is also more so that the higher the soil organic matter content, the higher the level and availability of groundwater. Another factor that affects soil water content is soil texture, with different types of soil texture describing the level of the soil's ability to bind water. For example, clay textured soils are better able to bind water in large quantities than sandy textured soils, while sand textured soils are better able to absorb water. Binds water than dust-textured soil.

3. Reaction (pH) of Soil

The degree of acidity or pH describes the concentration of hydrogen ions in the soil. The higher the level, the soil is said to be acidic. Conversely, if the hydrogen content in it is low, then the soil becomes alkaline. Soil acidity is expressed in grams per liter (gmol/l). The following ranges of soil reaction rates can be seen in the Table 1.

Table 1. Soil Reaction Rate Range (Soil pH)

No	Soil Reaction	pH
1.	Very Alkaline	9,0
2.	Alkaline	8,5 – 9,0
3.	Slightly Alkaline	7,5 – 8,5
4.	Netral	6,5 – 7,5
5.	Slightly Sour	5,5 – 6,5
6.	Sour	4,5 – 5,5
7.	Very Sour	4,0 – 4,5
8.	Most Acidic (Extreme)	<4,0

H. Water Spinach

Water Spinach (Ipomoea spp.) is one of the most popular leaf vegetables in Southeast Asia. Water Spinach is also known as 'swamp cabbage', 'air convolvulus', and 'kangkung'. Flowering kale plants with colors that vary from white to pink and stem from green to purple. The leaves are a source of protein, vitamin A, iron, and calcium. The planting guide presented is based on lowland conditions in Taiwan. Some adjustments are required with climatic conditions, soil, seasons, pests, and diseases. Water Spinach adapts to a variety of climatic and soil conditions but will require relatively high soil moisture for optimal growth. Soil with organic matter content is preferred. Water Spinach can provide optimal results in tropical lowland conditions with high temperatures and short light. The ideal plant temperature ranges from 25-30oC, while below 10oC, it will be damaged. There are two types of water spinach, namely land spinach (*Ipomoea reptans*), which has narrow leaves and adapts to moist soil and is harvested only once; and water spinach (*Ipomoea Aquatica*) which has wider leaves and is arrow-shaped. This species adapts to flooded conditions and is harvested several times (Febriyono et al., 2017).

III. RESEARCH METHODS

A. Research Procedure

This study also has a research procedure so that this system is structured and runs as expected. Research Procedure can be seen in Picture 1.

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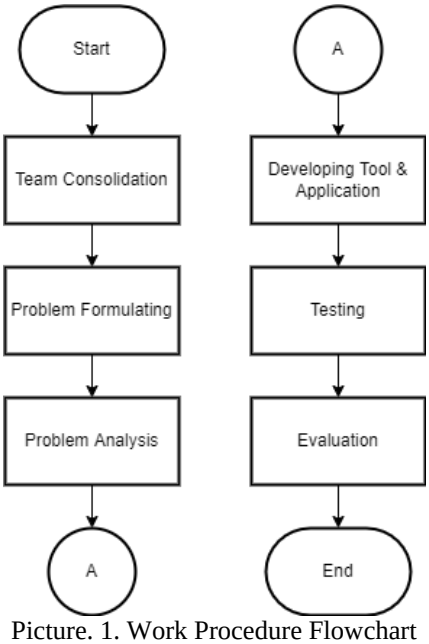


Picture. 1. Work Procedure Flowchart

From the flowchart in Picture 1, it can be explained that the stages of the research procedure are as follows:

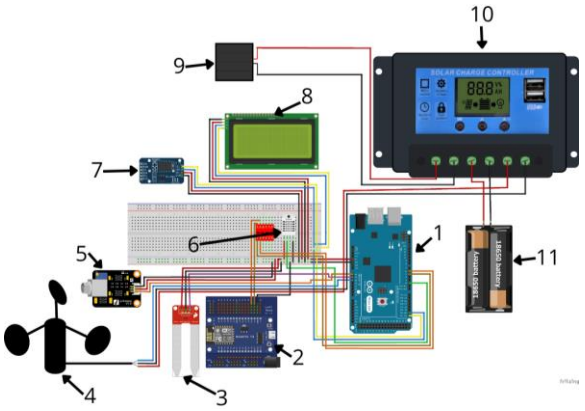
1. Team Consolidation, at this stage, good communication will be built between the production team, management, and customers
2. Problem Formulation, At this stage, the formulation of information sources such as time limits and information that can explain the project is determined
3. Problem Analysis, At this stage, we will define several conditions from the analysis carried out to obtain a solution based on the formulation of the problem.
4. Developing Tools and Applications: At this stage, we will begin to design and form prototypes of tools and applications.
5. Testing, At this stage, the application development is carried out, which is intended to be tested and installed and provides things that can be added for the project's success.
6. Evaluation, Customers/Users of the application will provide input based on the results obtained at the stage of developing tools and applications and testing. System Development Techniques.

B. System Design

In this study, before developing the tool, a system design was carried out to facilitate assembling the tool.

1. Toolkit Design
   a. Monitoring System

   Before developing the first tool, make a design first so that developing the tool later will be more accessible. the the design of the toolkit can be seen in Picture 2.



Picture. 2. Toolkit Design

Picture 2 describes the workflow of the tool in the monitoring system.

1) Arduino mega
2) esp8266
3) soil moisture
4) wind speed (anemometer)
5) Soil pH
6) Air Temperature
7) RTC
8) LCD
9) Solar Panel
10) Solar Charge Controller
11) Batteries

Soil pH, soil moisture, air temperature, and wind speed sensors are connected to the Arduino mega, the data from the sensor will first enter the Arduino and then be displayed on the LCD, in the Arduino data from sensors is processed and analog data is then sent to esp8266 and sent again to Thingsboard then retrieved by Android as a result. This tool also uses RTC to display the time in real-time. For resources, this tool uses solar panels to generate electrical energy from the sun which will be accommodated in batteries which are distributed through the solar charge controller.

b. Controlling System

Then the control circuit to turn the water pump on and off remotely can be seen in the picture 3.

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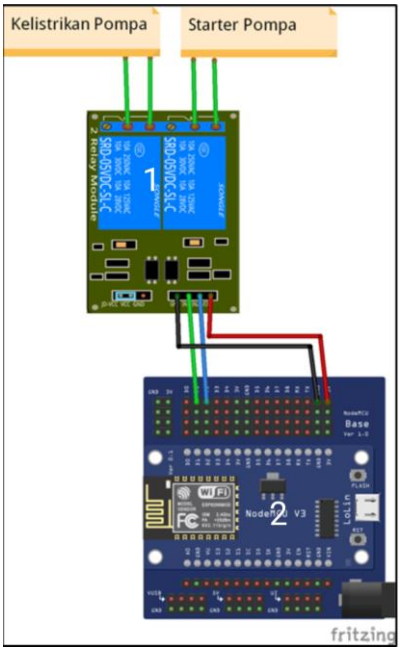
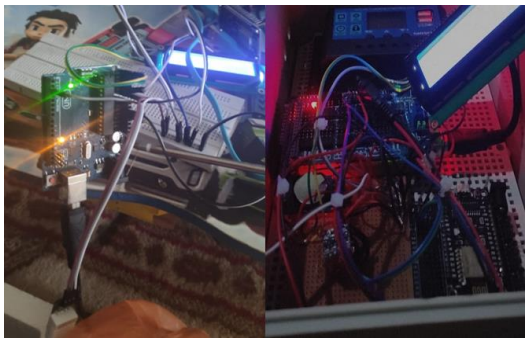


Picture 3. Controlling System

Picture 3 is a series of control tools. The pump is connected to Relay and esp8266, esp8266 acts as a liaison between the relay to run the pump and Firebase which gives commands to the relay. The command to run the pump is sent via android and then received by firebase and then sent again to esp8266 which then runs the command to activate or deactivate the pump.

2. Tool Prototype

After the tool's design has been completed, enter the next stage, namely developing the tool. An overview of the prototype tool can be seen in Picture 5.


Picture. 4. Early Stage Tools

IV. Result And Discussion

A. *Tools*

1. Monitoring System

Picture 6 is a series of Arduino components interconnected with sensors for air temperature, humidity, pH, soil moisture, wind speed, and RTC using jumper cables to connect other components. Besides Arduino Mega, relay, and ESP8266, there is also a solar charge controller to regulate the power voltage from the solar panel to the battery and the appliance.


Picture. 5. System Monitoring And Controlling Agricultural Activities With Arduino-Based Internet Of Things

2. Controlling System

This control system is to turn on and off the pump in charge of watering the plants. With this system, the pump can be turned on from anywhere and anytime as long as it is connected to the network. The system uses Firebase to help send commands to the equipment on the pump. The control system can be seen in Picture 6.


Picture 6. Controlling System

B. *Thingsboard Data Display*

Dashboard display from Thingsboard that displays data from sensors in the tool. From Thingsboard, an API will be taken for the process of displaying data on Android.

1. Soil pH Sensor Result Data Display

The results of the pH sensor are used to determine the pH levels in the soil used as planting media. A good soil pH ranges from 6 - 7. Picture 7 below shows the results of the soil pH sensor.

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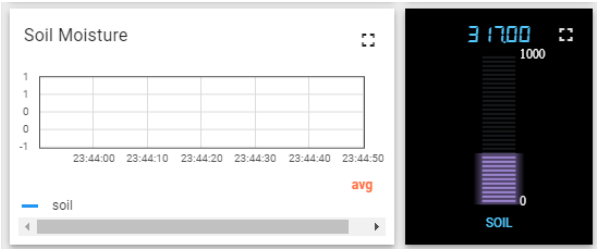
Picture 7. Soil pH Result

2. Soil Moisture Sensor Result Data Display

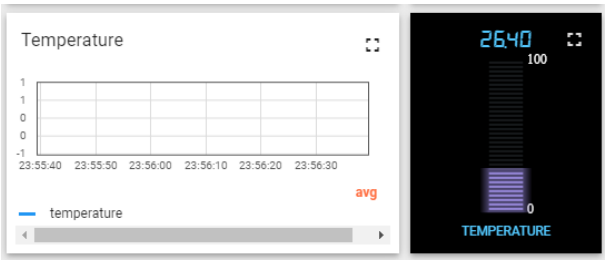
Soil moisture serves to measure soil moisture to carry out watering plants so that the soil is always in a state that is suitable for plants. Good soil moisture values range from 450 - 670. Picture 8 below shows the results of the soil moisture sensor.



Picture 8. Soil Moisture Result

3. Temperature Result Data Display

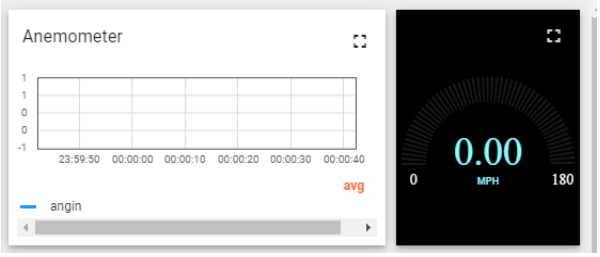
Temperature is useful for measuring the temperature of the air around the plant to be able to find out the temperature and determine what the plant needs. Picture 9 below shows the results of the temperature sensor.



Picture 9. Temperature

4. Anemometer Result Data Display

Anemometer or wind speed sensor is useful for measuring wind speed and is useful for knowing the wind has the potential to rain or just ordinary strong winds. Picture 10 below shows the results of the anemometer sensor.

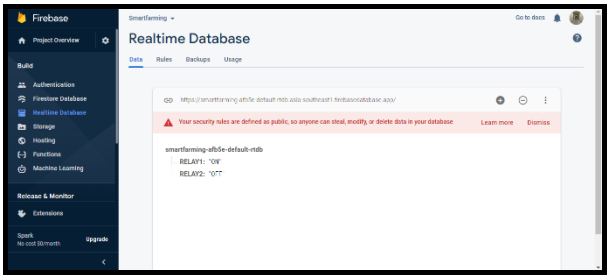


Picture 10. Anemometer

The above shows the results of the data from the anemometer 0, that's because the data was taken when the tool was installed or activated in a room with no wind.

C. Firebase

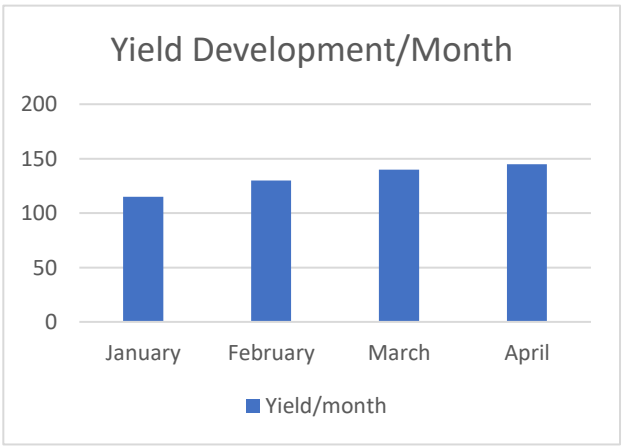
Firebase is useful for giving commands to the pump so that the pump can turn on or off. Firebase can be seen in Picture 8.



Picture. 11. Firebase Starting and Stopping Pumps Remotely

D. Testing Tools on Water Spinach

Testing the Internet of Things-Based Agricultural Activity Monitoring and Control System with Arduino was carried out on water spinach plants at Nabil Husain's Digital Farming Pompes Nabil Husein for four months, from January – April 2022. The monitoring tool was placed on Land A, which has an area of 8m x 5m. Within four months of the development of the kale crop yields after the Internet of Things-Based Agricultural Activity Monitoring and Control System was installed with Arduino, the kale yields increased because farmers knew better when to apply fertilizer and water the kale because the fertilizer and watering were carried out in the right time can make kale plants develop for the better which makes crop yields increase. The following is Picture 12. Graph of improving the quality of kale.



Picture 12. Chart of Water Spinach Yield Yield/Month

1. In January or the first harvest of agricultural products, it reaches 110kg of kale,
2. In February the yield increased by about 20 kg to 130 kg,

3. In March the yield increased from 130 kg to 140 kg, although the increase was only 10 kg but the yield continued to increase,
4. In April the yield increased from 140 kg to 145 kg, this month the last harvest being the highest yield. This crop is only produced on 1 plot of land measuring 8 x 5 m.

V. CONCLUSION

From the results of the system design process and source code creation of the Internet of Things-Based Agricultural Activity Monitoring and Control System with Arduino, it can be concluded that the tool has been successfully created. This tool has been tested at the Digital Farming Ponpes Nabil Husein on Jalan Puspita Bengkuring from early January 2022 to the present. This tool, of course, can be useful for farmers or people who use this application to be helped by activities in monitoring agricultural activities in the field and also so that the results of kale vegetable farming are maximized. This tool or system will then be developed so that it can automatically water plants using parameters taken from the soil moisture sensor.

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