Journal of Applied Science, Technology & Humanities
Volume 2, Issue 2, March, 2025, Pages 199-222

ISSN 3032-5765
DOI : https://doi.org/v10.62535/5w3gk317

Journal of Applied Science
Technology & Humanities

Intelligent Hydroponic Control System with IoT and Fuzzy Logic on Kale Plants

Khairunnissa Zahran Ansyafa[1]*
[1]Computer Engineering Technology, College of Vocational Studies, IPB
zahransyf1802ansyafa@apps.ipb.ac.id

Arda Dwiyana[2] , Aqim Try Kurnia[3], Daryn Ramadhani Az Zahra[4], Hafiz Agi Alfasih[5], Mahatmadi Ariq Mayangkara[6], Muhammad Fakhri Alauddin[7], Muhamad Al Habsy[8], Yana Nurrohman[9], Inna Novianty[10], Faldiena Marcelita[11]
[234567891011]Computer Engineering Technology, College of Vocational Studies, IPB
ardadwiyana@apps.ipb.ac.id , aqimkurnia@apps.ipb.ac.id , razzdaryn@apps.ipb.ac.id , hafizagialfasih@apps.ipb.ac.id , mahatmadiariq@apps.ipb.ac.id , fakhri17muhammad@apps.ipb.ac.id , muhamadalhabsyhabsy@apps.ipb.ac.id , yana03nurrohman@apps.ipb.ac.id, innanovianty@apps.ipb.ac.id, faldiena.m@apps.ipb.ac.id

Abstrak : The research in our project illustrates the application of hydroponic technology in Indonesia with a focus on nutrient control systems using the Internet of Things (IoT) and fuzzy logic for kale plants. Hydroponic methods such as Deep Flow Technic (DFT) are used to optimize plant growth in confined spaces, utilizing nutrient solutions that are controlled by pH and PPM. The system supports the efficiency and effectiveness of modern agriculture by monitoring environmental conditions such as temperature, humidity, and TDS values. This study shows that the system developed has an average error of 11.755% with an accuracy level of 88.65%. In addition, the system also managed to control the output of the nutrient pump with an error of 1.12% and an accuracy of 98.89%, as well as a water faucet with an average error of 0.47% and an accuracy of 99.75%. These results show the potential of IoT technology applications in increasing the productivity and sustainability of hydroponic agriculture in the future

Keywords: Hidroponik, Internet of Things, Kale Plants,PPM (Part Per Million) ,Sensor TDS

INTRODUCTION

Indonesia is a country because most of the Indonesian people depend on agriculture, (Ronaldo et al., 2020). However, along with the development of the times and the increase in the number of populations, the available agricultural land is decreasing, especially in urban areas. This condition causes various problems in the agricultural sector, such as a decrease in crop production, difficulties in maintaining production sustainability, and dependence on increasingly narrow land.

In addition to the problem of limited land, conventional agriculture in Indonesia also faces other challenges such as climate change, excessive use of pesticides, and declining soil quality. As a result, agricultural productivity is often suboptimal and potentially detrimental to smallholder farmers who rely heavily on their crops.

In this context, hydroponic farming methods have emerged as an innovative solution that can overcome some of these problems. Hydroponics is a technique for cultivating plants without using soil, but instead using water enriched with nutrients. In some parts of Indonesia, hydroponic farming methods are used to grow without using land and utilize water with a focus on plant nutrient needs. The hydroponic method will be more effective when applied in areas with little green space (Rahmad Doni, 2020), so that this system can take advantage of narrow land (Roidah, 2014).

The Deep Flow Technic *(DFT) hydroponic method* is a method that uses a constant flow of nutrients and has a halfway inundation of the diameter of the pipe that inundates the plant roots (Efimov & Salama, 2012). Hydroponics itself is the Greek word "hydroponic" which comes from the word

Commented [P1]: Expanded background regarding agricultural problems in Indonesia and the importance of hydroponic solutions for urban agriculture.

"hydroponic". It consists of two words, "*hydro*" which means "water", and "*ponous*" which means "to work" (Pratama et al., 2022)

The fulfillment of hydroponic plant nutrition requires special attention to the solution used. In solution, the two main aspects to consider are the pH and PPM values that correspond to the type of plant. The optimal pH dose for hydroponic plants is usually in the range of 6.0–6.5.

In addition, the nutrient content of the solution (ppm) must be adjusted to the needs of the plant. If ppm is less than necessary, plant development will be slow, while very large ppm can cause plant death due to too many nutrients received (Theo Syafei & Watiasih, 2021)

The kale plant (*Brassica oleracea L. var. acephala*) is a type of horticultural plant that is rich in anthocyanins, antioxidants, and carotenoids. To grow kale plants, you can use other media besides soil, such as water mixed with a nutrient solution that contains all the necessary ingredients for plant growth. (Dasumiati, Mutiara Marhaban Siregar, Ardian Khairiah, 2011). One of the causes of the decline in production is the reduction of agricultural land. To overcome land limitations, hydroponic cultivation technology can be used (Umar, 2020)

The parameters most commonly found in the environment around where we live are temperature, humidity, and PPM (Parts Per Million) (Tamaji & Utama, 2023). In the study (Dasumiati, Mutiara Marhaban Siregar, Ardian Khairiah, 2011) water used in seeding was mixed with AB mix solution of 400 ppm. The AB mix nutrient solution consists of nutrient B and nutrient A, which are diluted separately and taken at 5 mL/L. (Dasumiati, Mutiara Marhaban Siregar, Ardian Khairiah, 2011).

By using linear regression methods to control the amount of nutrients, the NFT hydroponic nutrient control system helps farmers maintain the amount of nutrients that suit the needs of the plants.(Endryanto & Khomariah, 2022).

Hydroponic systems that can be implemented are hydroponic techniques with the application of the Internet of Things (IoT) (Al Husaini et al., 2021). Internet of Things (IoT) is a term that originated from the idea of accessing electronic devices through internet media (Wulandari et al., 2020). The existence of IoT technology makes it easier for ornamental plant farmers to distribute nutrient solutions on the roots of hydroponic plants. Therefore, a tank water level monitoring system is also needed that can be done remotely and in real time (Zhou et al., 2023). Access to these devices is based on the desire to share data, share access, and also take into account security when accessing (Murtado & Imam, 2022). This proves that the agricultural sector has entered the era of digitalization by applying IoT technology (Ridlo et al., 2022).

Microcontroller-based systems have been seen to be more efficient and effective in agriculture. Microcontrollers such as the ATMega328, Arduino, have additional Wi-Fi features that allow the use of the Internet of Things (Dutta et al., 2018). Various parameters can be viewed in real time and collected from the system, namely Temperature, pH, soil moisture, and nutrient data (Karimanzira & Rauschenbach, 2019). This goal is to create an automatic nutrient system in hydroponic plants by utilizing various sensors to see the performance of IoT technology in carrying out control and monitoring (Hidayat & Amrullah, 2022).

In the study (Priyatman et al., 2022) TDS is the total amount of solid solution contained in water. There are 2 parameters that are well maintained in the system, namely *the Hydrogens (*pH) potential *value parameter and Total Dissolved Solids* (TDS).

This sensor functions to detect dissolved solids in water. This sensor has 5 labels located on the SEN0244 module, labels (-) and (+) for VCC and Ground voltage source cables, labels (A) for analog signal output cables, TDS labels to be connected to TDS probe connectors, and LED lights as LED power indicators (Nur'aeni Latekeng, Salmawaty Tansa, Raghel Yunginger, 2024).

To adjust the pH of nutrient water, it is generally still done manually. Namely by checking the pH with a pH meter and providing a pH balancing solution manually. Therefore, a control system is needed that can control the pH level in nutrient water. (Al Tahtawi & Kurniawan, 2020).

The design allows the use of IoT technology with ESP8266 microcontrollers and soil moisture sensors. Designing a system that uses temperature value conversion to control plant watering (Ariyanto et al., 2021). The amount obtained from the DHT22 sensor is then processed on the arduino, which is used to tell that the water pump will be on if the temperature is above 31°C and off if the temperature is below 31°C (Nabil Azzaky & Anang Widiantoro, 2021).

Studies (Sotyohadi et al., 2020) show that unstable TDS in hydroponics will cause leaves to turn yellow and wilt, plants to become dwarfed, and plant growth to be slow. Therefore, it is hoped that the application of fuzzy logic to regulate the pH of hydroponic nutrient content will make it possible to maintain the established PH value (Setia, 2019). The purpose of the study is to create a system that can monitor TDS values using the Internet of Things (IoT) and using the fuzzy logic method to adjust TDS values to the conditions of the plants planted (Sholihah et al., 2021).

Fuzzy logic is a logic that has the value of ambiguity or ambiguity between right and wrong (Rozie et al., 2021). This method was introduced by Ebrahim Mamdani in 1975 and involves several stages, namely the formation of fuzzy sets, application of implication functions, rule composition, and defuzzification (Theo Syafei & Watiasih, 2021).

Hydroponic technology not only answers the challenge of land limitations but also supports agricultural sustainability in the midst of climate change and rapid urbanization. Thus, hydroponics is an important and potential solution to overcome various agricultural problems in Indonesia, especially in supporting food security in urban areas.

METODHS

Time and Location

The creation of "Intelligent Hydroponic Control System with IoT and Fuzzy Logic on Kale Plants" was carried out from January 29, 2024 to June 8, 2024 at the SV IPB Electromechanical Workshop Lab while activities related to prototype performance testing were carried out at Joglo Kebun Wangi, Bogor Regency.

Tools and Materials

1. **Software**

No	Software Name	Information
1.	Arduino IDE	Creating Arduino coding and uploading to ESP32
2.	Tinkercad	Making a 3D design of a tool case
3.	MATLAB	MATLAB provides the Fuzzy Logic Toolbox (FLT), a specialized toolbox designed to build and analyze fuzzy systems.
4.	Fritzing	Used to design or visualize electronic prototypes.

Table 1 Software Requirements

2. **Hardware**

No	Hardware Name	Pins Used	Information
1.	Sensor pH Meter Module PH-4502C	P0- A0 (Arduino)	Measure the acidity or alkalinity (pH) of the solution.
2.	Ec Tds Sensor Transmitter	S1- A1 (Arduino)	AB Mix nutrient meters are based on the level of concentration in the solution.
3.	Selenoid Valve	D6 (Relay)	Katup kran air.

Commented [P2]: tables should not be separated or truncated. suggestion to create a new table with the same title

4.	Antenna WiFi 2.4GHZ	Socket	This antenna allows ESP8266 module to connect to a WiFi network
No	**Hardware Name**	**Pins Used**	**Information**
5.	LCD 20x4	SDA, SCL	The LCD is useful for displaying the results of the readings of the attached sensor
6.	Sensor temperatur suhu DS18B20	D2 - DQ	Water temperature gauge.
7.	Micro Water Pump 12v	D5 (Relay)	To distribute AB mix nutrients.
8.	Power Supply 12v 3a		Sebagai catu daya pompa dan kran solenoid.
9.	Relay 5v 4 Channel	D5, D6	Each relay line can open or close the electrical circuit independently
10.	Wemos D1 Mini	RX-PIN 12, TX-PIN 13	Transmitting data through serial communication.
11.	Arduino Uno	A0, A1, D2, D12, D13, SDA, SCL	Process input and output commands according to program code.
12.	Stepdown DC 12V to 5V	VCC, Ground	Lowering the voltage from the power supply.

Table 2 Hardware Requirements

Data Collection Techniques

The research conducted in this project uses a combination method of qualitative and quantitative methods. The qualitative method in this study focuses on understanding the process or experience of users or partners towards hydroponic systems. Here are some of the data collection techniques we did during the work on our group's Internet of Things project:

1. Interview

   We have conducted interviews and observations aimed at obtaining information about the problems faced by partners in the use of this IoT-based hydroponic system. During the interview, we also conducted field observations to find out the parameters or data needs.

2. Literature Studies and Needs Analysis

   After conducting interviews with partners regarding their needs, we conducted a literature study on hydroponics, IoT, and fuzzy logic to understand related concepts, technologies, and best practices. After that, analyze the needs of kale plants and the factors that affect their growth and health in a hydroponic system. An analysis of the needs in the reading of the tool system, made by reading the flowchart.

3. Fuzzy Parameter Data Collection

   Then for the quantitative method, which focuses on collecting and analyzing sensor data such as temperature, pH, nutrients (PPM), and crop yields. In addition, this method also produces outputs that are closer to the real state, flexible and have tolerance from existing data compared to other forecasting methods, this approach is much more efficient in using numbers (Muntahanah et al., 2021). The use of this fuzzy mamdani logic is used to determine how much nutrients are given to kale plants. After that, determine the flow of determination from the input data that has been obtained, then produce an output that is adjusted to the needs of the partner. The following is the flow of determining the rate of nutrients given to kale plants:

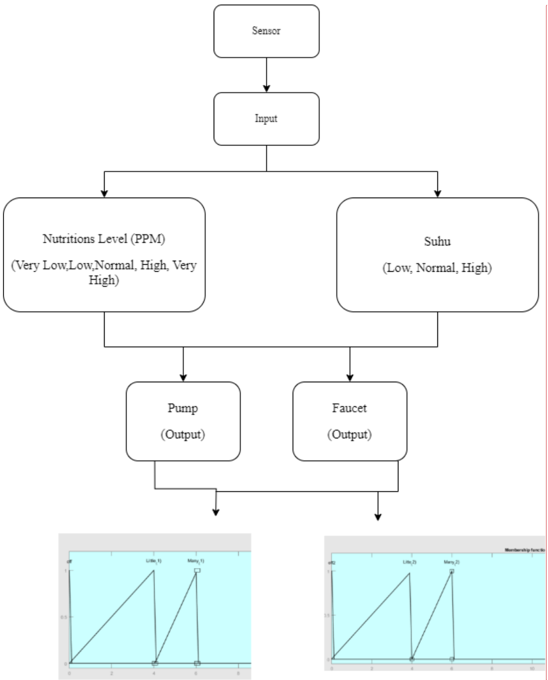


Figure 1 Flowchart for Determination of Nutrient Levels Given to Kale Plants

Commented [P3]: The flowchart must be created in English.

Data Analysis

There are several techniques used in analyzing data during the Field Work Practice (PKL) and working on tools according to the needs of partners

1. Descriptive Analysis: It is carried out to understand the characteristics and needs of potential users by analyzing data obtained from various data collection techniques such as literature studies, interviews, observations, and surveys.
2. Comparative Analysis: Comparing with accurate calibration tools and control system tools to identify strengths, weaknesses, and opportunities to improve the design and features of the tool to be made.

Working Procedure

Work procedures in a project are a series of structured and organized steps that must be taken to complete the project effectively and efficiently. The procedure for implementing this project is carried out in several stages such as problem identification, design, trial and documentation. The following is an explanation of some of the work procedures carried out on the projects we are doing:

1. Problem Identification:

   This process involves data collection, analysis, system design, trials, evaluations, and the preparation of documentation

2. Planning Design And Tool System:

   At the design stage, electronic systems, mechanical systems and software are designed. Figure **2** illustrates the process from start to finish in the implementation of this project research. The first stage is to identify problems in electronic design starting with testing the electronic components used such as: Arduino Uno, Wemos D1 Mini, Arduino Transmitter Sensor Tds Module, pH Meter Sensor Module PH-4502C, DS18B20 temperature sensor, IC ULN2003 to ensure that the components can run properly.

After that, it was continued by designing a mechanical design, namely a tool case that functions as a protector of electronic devices and components from external environmental conditions such as dust, water, and moisture. After designing the case using tinkercad software, the execution was carried out in mechanical manufacturing, namely by using a 30x40x20 outdoor Box Panel.

After the electronic design process has gone well by programming the Arduino Uno using the Fuzzy Logic method. At this stage, the system design is carried out, namely designing fuzzy logic to regulate environmental parameters based on plant conditions and measurable input variables. At the system design stage, data is recorded after conducting expert interviews and needs analysis and then implemented to fuzzy logic, some of the steps taken are:

1) Fuzzification, This stage refers to a technique to convert data obtained from observation results, into fuzzy variables that can be processed. The stage to conduct a test of the system that has been made by examining the actual data obtained from the results of the parameters
2) Fuzzy rules, Fuzzy logic uses expert thinking that is designed and incorporated into if-then rules (Lahay et al., 2023).
3) Defuzzification, is a process of modifying the fuzzy output generated by each system rule to obtain a value that can be used as a benchmark for comparison based on certain membership (Neonbeni et al., 2023). Then the design of software in the form of a website for nutrient monitoring in the reservoir in the Kale plantation, monitoring the nutrients to find out the specific amount of nutrients that have an impact on the growth of Kale plants.

3. Product Implementation :

Next, develop and implement the fuzzy controller logic using an appropriate programming language (e.g. Python or MATLAB). Selecting and installing appropriate hardware, including IoT sensors and control devices Dan is also keen to develop web-based or mobile monitoring applications to access and control the system remotely. Then it is implemented to become a product.

4. Tool Testing

Conduct a thorough test of the system in a suitable hydroponic environment. Do not forget to monitor the system's response to changes in environmental parameters and plant conditions. It then validates the performance of the system based on established criteria, such as plant growth, resource use, and response to external disturbances. The trial will be carried out at Joglo Kebun Wangi and design activities are fully carried out at the Electromechanical Workshop Laboratory, Joglo Kebun Wangi and the IPB Vocational School.

5. Evaluation and Refinement::

Evaluate the results of the trial and identify areas where the system can be improved. Then, make changes and improvements to the hardware, software, or fuzzy logic algorithm based on the evaluation findings. This stage is a test that is carried out to determine the suitability of the test results of the tool with the set objectives. An evaluation was carried out with the parameters of error percentage and accuracy (Equation 1 and Equation 2) (Wina Sumiar, n.d.)

$$\%\,error = \frac{|Comparasion\ Value\ (\ Device\ TDS\ meter) - Measurement\ Value\ (\ Sensor\ TDS)|}{Comparasion\ Value\ (\ TDS\ meter)} \times 100\% \quad (1\ )$$

$$Akuration = 100\% - \ \%error \quad (2\ )$$

6. Documentation and Documentation Preparation

After a series of trials have been successfully passed, the next step is the preparation of equipment documentation. If the test results are good, the researcher will proceed with data management. However, if the results are not satisfactory, the researcher will return to the assembly stage of the product implementation by evaluating the errors that existed in the previous trial

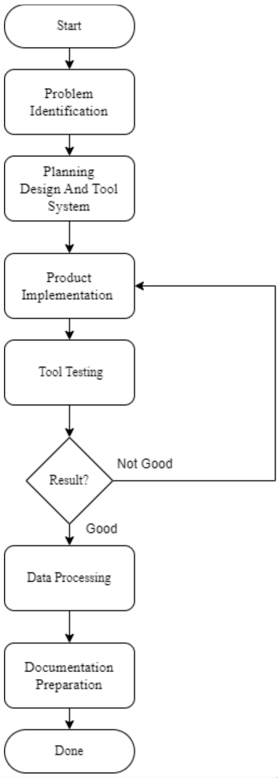


Figure 2 Working Procedure Diagram

Commented [P4]: diagram must be created in English.

Hardware Design

Hardware Design Flowchart

After identifying problems in electronic design, it begins with testing the electronic components used. After that, make a comprehensive *flowchart* starting from the sensor readings carried out by the microcontroller by reading the value of the sensor to find out the level or nutrient level (PPM) in the nutrient reservoir of the Kale Plant. The value obtained on the sensor and read by the microcontroller will be sent to the database and displayed on the website that has been provided, which is useful for monitoring and control.

Then the sensor value is processed to determine the action that needs to be taken with *fuzzy logic* calculations. The fuzzy system is used to process sensor values and determine the optimal course of action. Fuzzy logic can consider several factors, such as the level of nutrients in the reservoir, the pH of the water and the temperature of the water. After that the pump or faucet is as the output, the pump or faucet will open when the temperature sensor detects that the temperature of the nutrient solution is above the specified threshold value. Then the output will be displayed on the LCD and can also be monitored through *the website* stored in the *database.*

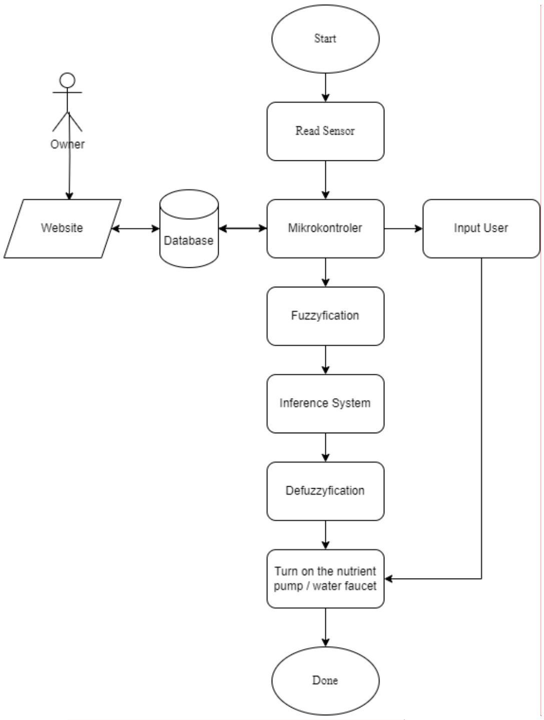


Figure 3 Hardware Design Flowchart

Commented [P5]: designmust be created in English.

Blok Diagram

This block of diagrams is a basic overview of the system to be designed. Each part of the system block has its own function, by understanding the block diagram, the designed system can be built well (Barkatulah, 2019).

The figure shows the diagram block of the hydroponic nutrient control system based on fuzzy logic showing the flow of the process. Sensor as an input device, measures the temperature and TDS of the solution. Then the results in the form of set points of plant nutrient levels are converted into linguistic values and evaluated with fuzzy logic rules to produce the duration of the nutrient pump and solenoid valve. This duration controls the addition of nutrients and water, maintains the volume of the solution, and achieves optimal conditions for plant growth.

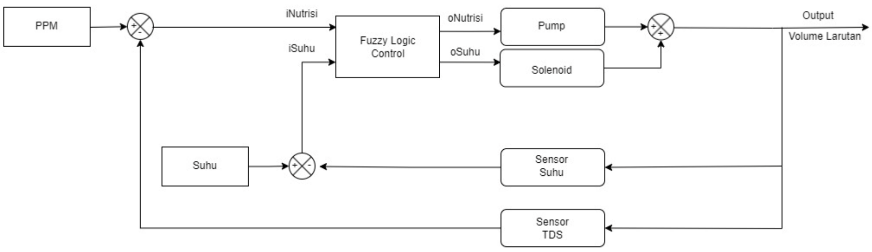


Figure 4 Block Diagram

Electronic Planning

Figure **3** is a prototype of this includes the PH Meter Module PH-4502C for Arduino Sensor for water pH measurement, as well as the DS18B20 Temperature Sensor to monitor water temperature. The 2.4GHz WiFi antenna for ESP8266 is used for internet connection so that sensor data can be accessed online. The LCD 20x4 with I2C Serial Interface Module is used to display information directly to the user. To power the irrigation system, a 12V Micro Water Pump is used which is controlled by a 1 Meter Mini DC Motor and a 12V DC Water Faucet Solenoid Valve. The 5V 4 Channel relay is used as an electronic switch to control external devices. The RTC DS3231 Series SN Real Time Clock is used to maintain time and time synchronization in the system. In addition, the EC TDS Sensor Transmitter Arduino is used to monitor water quality. A 12V 3A adapter is chosen as the primary power source for operating the device. The following is a schematic of the electronic design along with a description of the port of the device used:

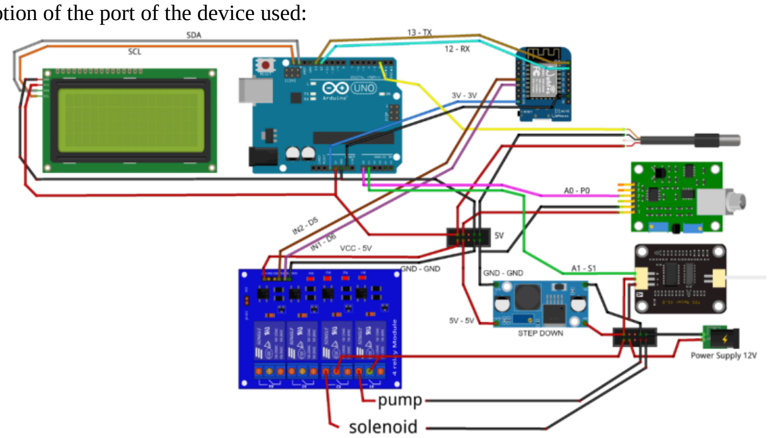


Figure 5 Schematic of Electronic Planning

Mechanical Planning

All of these components will be installed and integrated in a 30x40x20 Outdoor Box Panel for the protection and safety of the device in an outdoor environment. With this integrated hardware, it is hoped that the prototype can function well in supporting the intelligent hydroponic control system designed.

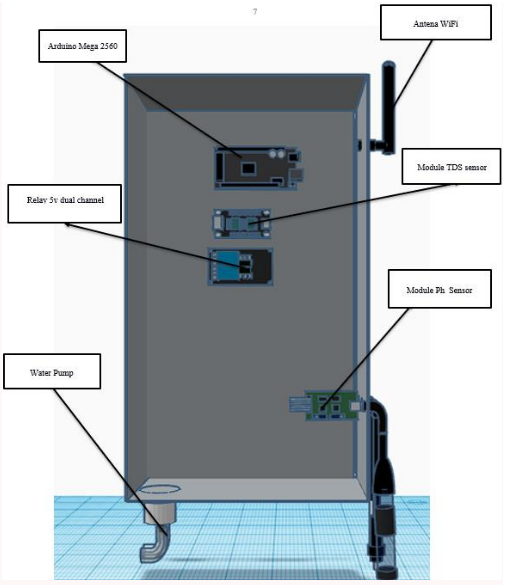


Figure 6 3D Design Shown in

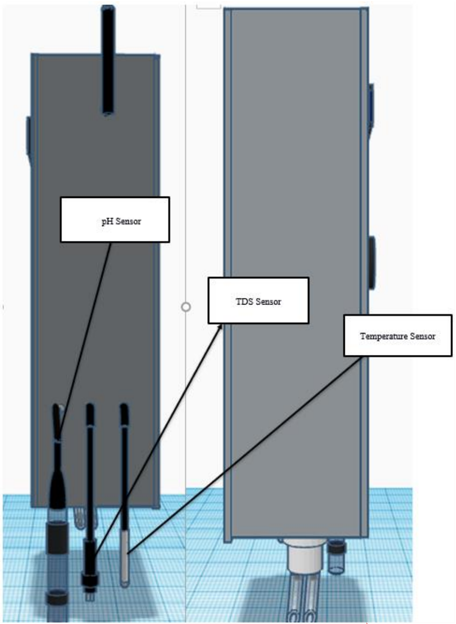


Figure 7 3D Design Side View

Commented [P6]: the image explanation is unreadable

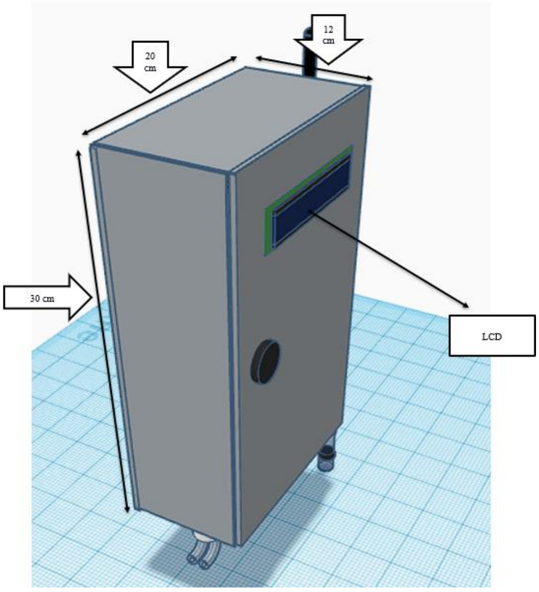


Figure 8 Overall 3D Design

In **Figure 6**, is a 3d design that shows how the components will be stored on the box panel. Then in **Figure 7** is a 3d design side view, it can be seen that later the tds sensor and pH meter will be placed outside the panel box. Then in **Figure 8** is the overall view of the box panel. This case is made of iron material measuring 20cmx12cmx30cm.

Software Design

In this phase of designing the software for the Intelligent Hydroponic Control System, the approach taken is to use an IoT system to facilitate the monitoring process. The web interface was chosen as the main medium for users to monitor the condition of kale plants directly. Through this interface, sensor data such as pH, TDS, temperature, humidity, and water level will be collected and displayed in real-time. The programming language used to develop this software is C++. JavaScript and CSS are also used to build this web monitoring tool. The software is designed with several main functions, namely enabling real-time monitoring, value setting, and visualization of sensor data in the form of graphs and tables. Thus, it is hoped that this software can provide a more effective and informative monitoring experience for users, so that the growing environment of hydroponic plants can be optimally maintained according to the needs of kale plants

1) General Description of the System

   Kale Tech-GG refers to the concept of nutrient monitoring in reservoirs in Kale orchards, monitoring these nutrients to determine the specific amount of nutrients that have an impact on Kale plant growth using IOT-based tools.

   Owners and garden administrators can monitor through the website that has been designed by our group. The website will retrieve data from ESP8266 and will be displayed in a graph on the website in real time.

2) Purpose of System Creation

   The manufacture of Kale Tech-GG aims to optimize the growth of Kale plants through the application of IOT (Internet of Things) in the Ciampea area. This tool is expected to be able to find out the amount of PPM, pH, and temperature in the reservoir in the Kale plantation by monitoring through a website that can be accessed by the owner and garden administrator.

A) Functional Needs

No Function	Function Name	Function Description
1	Viewing the PPM Value	Monitor PPM values so that plants can grow optimally
2	Viewing the pH Value	Monitor pH values so that plants can grow optimally
3	Viewing Temperature Values	Monitor Temperature values so that plants can grow optimally
4	View Graph	Monitor sensor values with graphs to determine specific nutrition patterns
5	View Maker Information	Displays a group of tool makers with their own personal contacts.
6	View Farm/Partner Information	Displaying information related to the farm or partners through the website page

Table 3 Functional Needs

B) Usecase Diagram

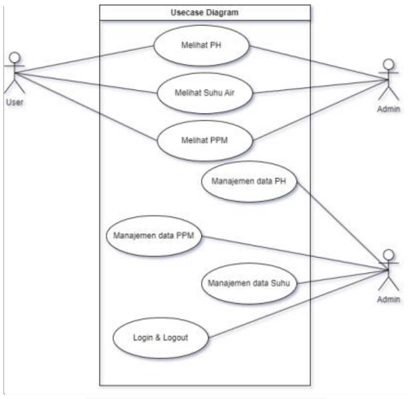


Figure 9 Usecase Diagram

C) Activity Diagram

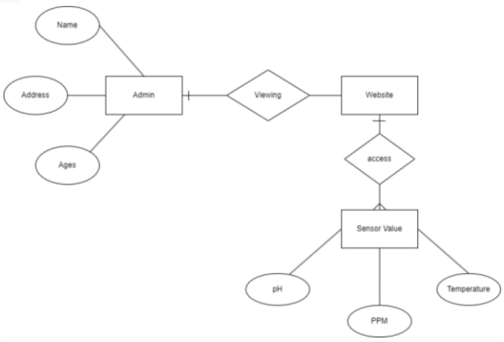


Figure 10 Activity Diagram

Commented [P7]: Must english

D) **Class Diagram**

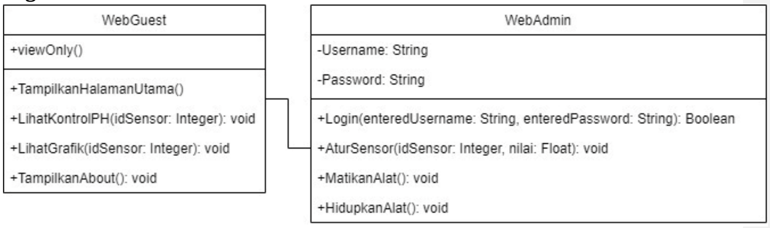


Figure 11 Class Diagram

Website Display

1) **Website Homepage Display Layout**

Figure 12 Website Homepage Display

In **Figure 12**, it is the homepage display of *the website*. On this main page there is some related information, namely:

- **Header: The** top of your *website* contains your logo, navigation bar, and account login.
- **Logo: The** logo represents the hydroponic partner visually.
- **Navigation Bar:** This bar provides links to the main page of *the website*, such as the Main Page, Sensor Values Page, Sensor Graph Page, Status Page, and Login.
- **Main Content:** The main section of the Main Page contains a brief summary of *the website* and its purpose. There is also a call-to-action button that encourages users to check the latest sensor values.
- **Meet Our Team:** The team that created "Intelligent Hydroponic Control System with IoT and Fuzzy Logic in Kale Plants" is group 2 IoT and its

job description in this project.

- **Footer:** Contains the partner's logo and address and is complemented by social media and Google Maps of the partner's location.

Here is a link for you to visit our Website: https://monitoring-iot-main.vercel.app/

2) Temperature, PPM and pH Information Layout

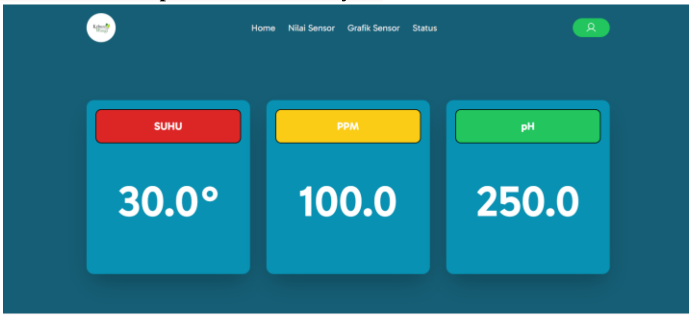
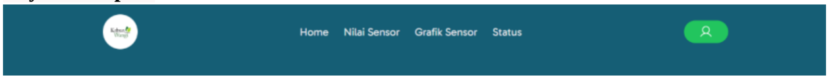


Figure 13 Layout of Temperature, PPM and pH Information

In **Figure 13**, it is the homepage display of *the website*. On this main page there is some related information, namely:

- **Header: The** top of your *website* contains your logo, navigation bar, and account login.
- **Logo: The** logo represents the hydroponic partner visually.
- **Navigation Bar:** This bar provides links to the main page of *the website*, such as the Main Page, Sensor Values Page, Sensor Graph Page, Status Page, and Login.
- **Main Content:** Displays a table of current sensor values, such as temperature, pH, and PPM. The table also shows the units of measurement for each sensor value. The above values are the result of simulation because the tool has not been integrated.
- **Footer:** Contains the partner's logo and address and is complemented by social media and Google Maps of the partner's location.

3) Layout Graphic



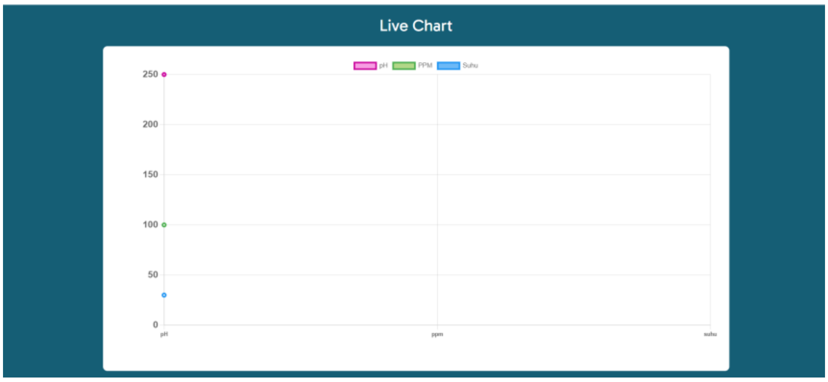


Figure 14 Graphic Layout

In **Figure 14**, is a graphical display of pH, PPM and temperature values. This value is obtained from the results of sensor readings. The above values are the result of simulation because the tool has not been integrated.

4) Layout Status

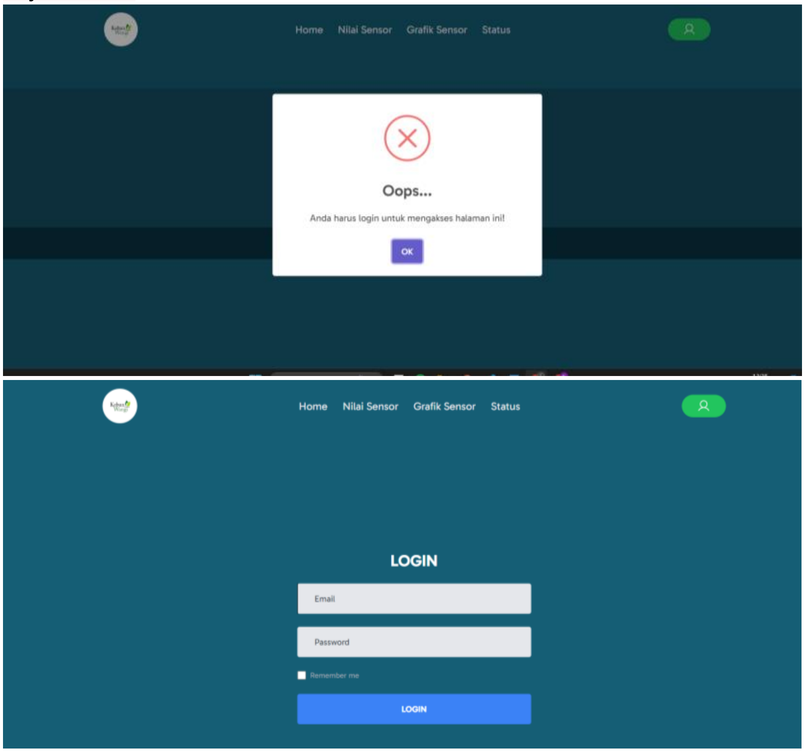


Figure 15 Login Status Layout

Commented [P8]: Explain the purpose of the website's interface.

In **Figure 14**, it is the homepage display of *the website*. On this main page there is some related information, namely:

- **Header: The** top of your *website* contains your logo, navigation bar, and account login.
- **Logo: The** logo represents the hydroponic partner visually.
- **Navigation Bar:** This bar provides links to the main page of *the website*, such as the Main Page, Sensor Values Page, Sensor Graph Page, Status Page, and Login.
- **Main Content:** Displays a page for login that must be filled in by the email and also *the password* of the user or partner.
- **Login: Enter the status page to control the hydroponic system.**
- **Footer:** Contains the partner's logo and address and is complemented by social media and Google Maps of the partner's location.

RESULTS AND DISCUSSION

The following are the results of the data obtained during the interview with our partners, namely Mr. Ir. Awal Rachman Chalik, Msc and Mrs. Ade Sri Gantini S.E., M.M., as the Owner of Mitra Joglo Kebun Wangi. The input variables used to determine the nutrient content of kale plants are PPM, and water temperature, and for the output is to determine how much nutrient content must be given to the kale plant. In determining the provision of nutrient content (PPM) in kale plants, it will go through several stages by using Matlab software for fuzzy logic calculations. This stage starts from determining the degree of membership, making rules to the final stage, namely defuzzyfication. And later the results will be given in the form of tool documentation during testing.

Membership Function in Determining Nutrition Levels (PPM)

The following Membership Function graph is the result of the data obtained during the interview with our partners, namely Mr. Ir. Awal Rachman Chalik, Msc and Mrs. Ade Sri Gantini S.E., M.M., as the Owner of Mitra Joglo Kebun Wangi. During an interview with an expert or expert in knowledge of the quality of nutrient content (PPM) measured using the TDS Meter, the parameters or data index provided were, for juvenile Kale plants around 1200 PPM. And for adult kale plants, it is around 2000 PPM.

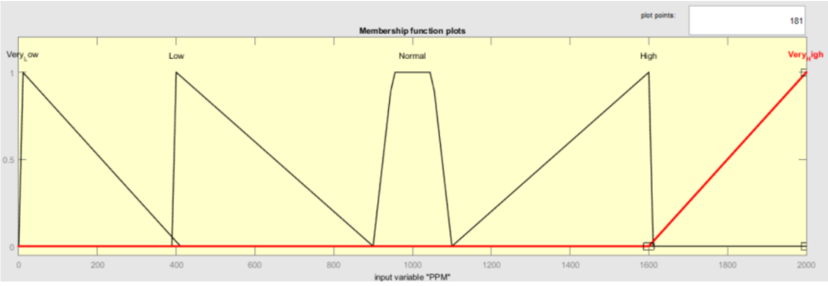


Figure 16 Input variable "PPM"

In Figure 16, is a graph of the membership function of one of the input variables, namely "PPM". This PPM variable is made with 2 types, namely Triangular and Trapezoidal, having a range between 0-2000 PPM. The following is a table in determining the parameters of each input in the PPM variable

Nutritions Level / PPM (PPM)	Conditions
0 - 400	Very Low
400 - 900	Low
900 - 1100	Normal
1100 - 1600	High
1600 - 2000	Very High

Tabel 4 Tingkat Kadar Nutrisi / PPM (PPM)

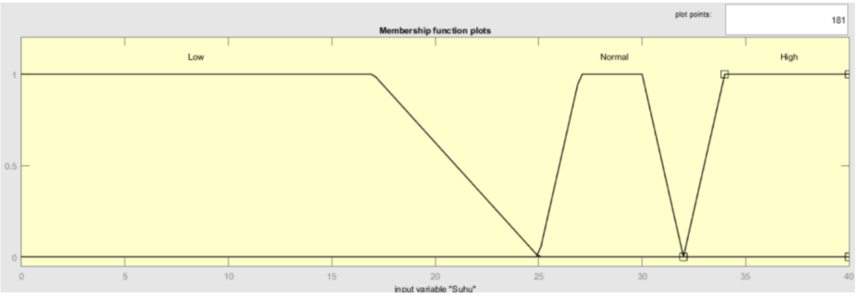


Figure 17 Input Variable "Temperature"

In Figure 17, is a membership functiom graph of one of the input variables, namely "Temperature". This Temperature Variable is made with the Trapezoidal type, has a range between 0 – 40. The following is a table in determining the parameters of each input in the Temperature variable℃:

Temperature Level ()℃	Conditions
0 - 25	Low
25 - 32	Normal
32 - 40	High

Tabel 5 Input Suhu

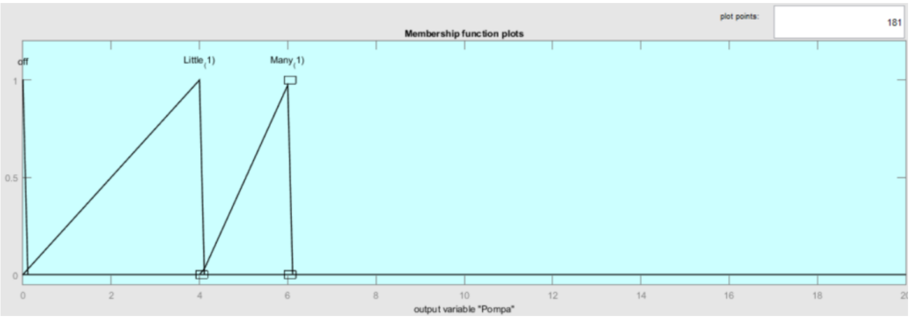


Figure 18 Pump Output Chart

In figure 13, is the output graph of the pump, which will dispense the AB mix nutrient solution according to the fuzzy calculation output. The pump will turn on when the TDS sensor detects when the nutrient level is below the predetermined value limit. The fuzzy logic will determine the level of nutrient deficiency and activate the pump to add the nutrient solution of AB mix.

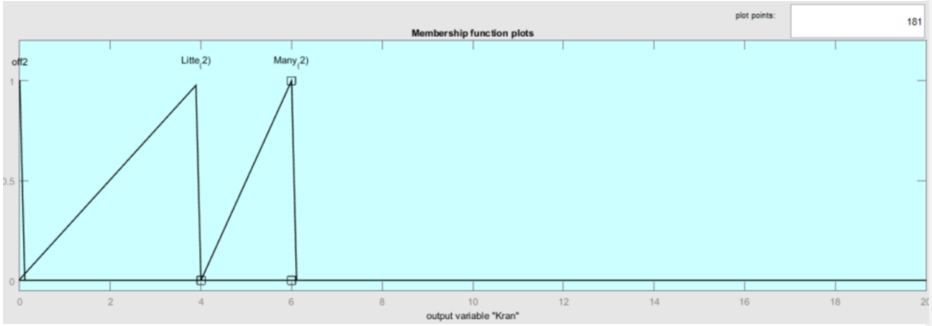


Figure 19 Faucet Output Graph

And in Figure 14, is the output graph of the water faucet, namely the faucet will open when the TDS sensor detects when the nutrient content is above the predetermined value limit. The fuzzy logic will activate the faucet to drain the water. In this study, we have several rules that will determine how much nutrient content should be given to kale plants, which are as follows:

1. If (PPM is Low) and (Suhu is Low) then (Pompa is Little_(1))(Kran is off2) (1)
2. If (PPM is Low) and (Suhu is Normal) then (Pompa is Little_(1))(Kran is off2) (1)
3. If (PPM is Low) and (Suhu is High) then (Pompa is off)(Kran is Litte_(2)) (1)
4. If (PPM is Normal) and (Suhu is Low) then (Pompa is off)(Kran is off2) (1)
5. If (PPM is Normal) and (Suhu is Normal) then (Pompa is off)(Kran is off2) (1)
6. If (PPM is Normal) and (Suhu is High) then (Pompa is off)(Kran is Litte_(2)) (1)
7. If (PPM is High) and (Suhu is Low) then (Pompa is off)(Kran is Litte_(2)) (1)
8. If (PPM is High) and (Suhu is Normal) then (Pompa is off)(Kran is Litte_(2)) (1)
9. If (PPM is High) and (Suhu is High) then (Pompa is off)(Kran is Many_(2)) (1)
10. If (PPM is Very_Low) and (Suhu is Low) then (Pompa is Many_(1))(Kran is off2) (1)
11. If (PPM is Very_Low) and (Suhu is Normal) then (Pompa is Many_(1))(Kran is off2) (1)
12. If (PPM is Very_Low) and (Suhu is High) then (Pompa is off)(Kran is Many_(2)) (1)
13. If (PPM is Very_High) and (Suhu is Low) then (Pompa is off)(Kran is Many_(2)) (1)
14. If (PPM is Very_High) and (Suhu is Normal) then (Pompa is off)(Kran is Many_(2)) (1)
15. If (PPM is Very_High) and (Suhu is High) then (Pompa is off)(Kran is Many_(2)) (1)

Figure 20 Fuzzu Rules for Nutrient Levels of Kale Plants

In this study, we get 15 rules that will determine how much nutrient levels should be given to kale plants. These rules are obtained from the results of interviews with experts and also literature studies by reading literature in the form of journals so that these rules are obtained.

Test Results

When the tool has been designed, it then enters the trial stage which produces test data. This test is carried out by taking water samples in the garden. The solution was measured with a TDS meter and then compared with the results of the nutrient level reading with the sensor that had been made. Table 6 shows the results of the sensor readings and the TDS meter. Then the relative error calculation is carried out using Equation 1. Here are 9 samples we tested:

Tabel 6 TDS Sensor Testing

No	Device	Sensor Product Tool	Relative Error (%)	Accuracy (%)
1.	PPM : 90 PH : 7 Suhu : 27,8	PPM :57 PH : 6,91 Suhu : 27,37	$= \frac{\lvert 90 - 57 \rvert}{90} \times 100\%$	63.33

	(Nilai PPM dan pH)  (Nilai Suhu) 	 (Output Pompa Nutrisi) 	$= \frac{33}{90} \times 100\%$ $= 0366 \times 100\%$ $= 36.67\%$	
2.	PPM : 273 PH : 6,7 Suhu : 28,6 (Nilai PPM dan pH)  (Nilai Suhu) 	PPM : 219 PH : 6,68 Suhu : 28,06  (Output Pompa Nutrisi)  	$= \frac{\lvert 273-219\rvert}{273} \times 100\%$ $= \frac{54}{273} \times 100\%$ $= 0.1978 \times 100\%$ $= 19.78\%$	80.22
3.	PPM : 443 PH : 6,5 Suhu : 27,9 (Nilai PPM dan pH)  (Nilai Suhu) 	PPM : 400 PH : 6,43 Suhu : 28,62  (Output Pompa Nutrisi)  	$= \frac{\lvert 443-400\rvert}{443} \times 100\%$ $= \frac{43}{443} \times 100\%$ $= 0.0971 \times 100\%$ $= 9.71\%$	90.29
4.	PPM : 636 PH : 6,4 Suhu : 28,9 (Nilai PPM dan pH)	PPM : 563 PH : 6,32 Suhu : 29,37  	$= \frac{\lvert 636-563\rvert}{636} \times 100\%$ $= \frac{73}{636} \times 100\%$ $= 0.1148 \times 100\%$ $= 11.48\%$	88.52

	 (Nilai Suhu) 	(Output Pompa Nutrisi)  		
5.	PPM : 774 PH : 6,3 Suhu : 28,4 (Nilai PPM dan pH)  (Nilai Suhu) 	PPM : 719 PH : 6,24 Suhu : 28,75  (Output Pompa Nutrisi)  	$= \frac{\|774 - 719\|}{774} \times 100\%$ $= \frac{55}{774} \times 100\%$ $= 0.711 \times 100\%$ $= 7.11\%$	92.89
6.	PPM : 892 PH : 6,2 Suhu : 28,1 (Nilai PPM dan pH)  (Nilai Suhu) 	PPM : 844 PH : 6,15 Suhu : 28,37  (Output Pompa Nutrisi)  	$= \frac{\|892 - 844\|}{892} \times 100\%$ $= \frac{48}{892} \times 100\%$ $= 0.0538 \times 100\%$ $= 5.38\%$	94.62
7.	PPM :1010 PH : 6,3 Suhu : 27,6 (Nilai PPM dan pH)	PPM : 971 PH : 6,10 Suhu :28,19  	$= \frac{\|1010 - 971\|}{1010} \times 100\%$ $= \frac{39}{1010} \times 100\%$ $= 0.038 \times 100\%$ $= 3.86\%$	96.14

	 (Nilai Suhu) 	(Output Pompa Nutrisi) 		
8.	PPM : 1380 PH : 6,3 Suhu : 27,8 (Nilai PPM dan pH)  (Nilai Suhu) 	PPM :1307 PH : 6,26 Suhu : 28,37  (Output Kran Air) 	$= \frac{\lvert 1380 - 1307 \rvert}{1380} \times 100$ $= \frac{73}{1380} \times 100\%$ $= 0.529 \times 100\%$ $= 5.29\%$	94.71
9.	PPM : 1590 PH : 6,2 Suhu : 28,1 (Nilai PPM dan pH)  (Nilai Suhu) 	PPM : 1545 PH : 6,06 Suhu : 28,5  (Output Kran Air) 	$= \frac{\lvert 1590 - 1545 \rvert}{1590} \times 100$ $= \frac{45}{1590} \times 100\%$ $= 0.0283 \times 100\%$ $= 2.83\%$	97.17
Rata-rata			11.75%	88.65

Tabel 7 Hasil Output Alat

No.	Input		Output Pompa Nutrisi				Output Kran Air			
	Sensor TDS	Suhu (℃)	Output MATLAB	Output Sistem	Error (%)	Accuracy (%)	Output MATLAB	Output Sistem	Error (%)	Akurasi (%)
1.	57	27.37	5.38	5.32	1.12	98.88	0	0	0.00	100.00
2.	219	28.06	5.18	5.20	0.39	99.61	0	0	0.00	100.00
3.	400	28.62	2.73	2.67	2.20	97.80	0	0	0.00	100.00
4.	563	29.37	2.61	2.56	1.92	98.08	0	0	0.00	100.00
5.	719	28.75	2.39	2.34	2.09	97.91	0	0	0.00	100.00
6.	844	28.37	2.16	2.11	2.32	97.68	0	0	0.00	100.00
7.	971	28.19	0	0	0.00	100.00	0	0	0.00	100.00
8.	1307	28.37	0	0	0.00	100.00	2.43	2.38	2.06	97.94
9.	1545	28.5	0	0	0.00	100.00	2.71	2.65	2.21	97.79
Rata- rata (%)					1.12	98.89			0.47	99.75

CONCLUSION

An Intelligent Hydroponic Control System with IoT and Fuzzy Logic on Kale Plants has been successfully developed. The results of our tool product have succeeded in automatically adjusting the AB mix solution level. The system can automatically adjust the AB (nutrient) solution level in the reservoir by measuring the solution level using a TDS sensor. When the sensor on our device shows that the level of nutrient solution in the reservoir is lower, the nutrient pump or water faucet will automatically work according to the pre-set using *Fuzzy's logic rules.* Table **6** shows that our tool TDS sensor is able to read the value of nutrient solution content well, which is proven in the data that the tool can read with an accuracy level of 88.65% and a relative error value of 11.75%. In addition, Table **7** shows that our tool is able to output an output in the form of a nutrient pump or water faucet with an accuracy level for the output of the nutrient pump of 98.89% and for the output of the water faucet of 99.75%.

Based on the results of this test, it can be concluded that overall our tool is able to work well according to the design made. However, there are still imperfections in terms of website appearance, because it has not been able to show the *measurement results in real-time* on our website. Therefore, it is necessary to re-evaluate so that the website can be integrated with our tools so that it can be read in real-time so that our partners can monitor more easily and efficiently.

ACKNOWLEDGMENTS

First of all, we would like to express our gratitude to God Almighty because only by His grace can we complete this research. We also thank Mr. Ir. Awal Rachman Chalik, Msc and Mrs. Ade Sri Gantini S.E., M.M., as the Owners of Mitra Joglo Kebun Wangi. We also thank our supervisors and the lecturers who participated in supporting our research. We would like to thank the reviewers who provided constructive feedback so that they could improve the quality of this journal.

REFERENCE

Commented [P9]: English pls

Al Husaini, M., Zulianto, A., & Sasongko, A. (2021). Otomatisasi Monitoring Metode Budidaya Sistem Hidroponik dengan Internet of Things (Iot) Berbasis Android MQTT dan Tenaga Surya. *Jurnal Sosial Teknologi*, *1*(8), 785–800. https://doi.org/10.59188/jurnalsostech.v1i8.163

Al Tahtawi, A. R., & Kurniawan, R. (2020). PH control for deep flow technique hydroponic IoT systems based on fuzzy logic controller. *Jurnal Teknologi Dan Sistem Komputer*, *8*(4), 323–329. https://doi.org/10.14710/jtsiskom.2020.13822

Ariyanto, P., Iskandar, A., & Darusalam, U. (2021). Rancang Bangun Internet of Things (IoT) Pengaturan Kelembaban Tanah untuk Tanaman Berbasis Mikrokontroler. *Jurnal JTIK (Jurnal Teknologi Informasi Dan Komunikasi)*, *5*(2), 112. https://doi.org/10.35870/jtik.v5i2.211

Barkatulah, M. H. (2019). *Rancang Bangun Smart Urban Gardening Berbasis Internet Of Things (Iot).* 2009.

Dasumiati, Mutiara Marhaban Siregar, Ardian Khairiah, J. (2011). *Pertumbuhan dan produksi tanaman stroberi*. *10*(April), 111–122.
Dutta, A., Dahal, P., Tamang, P., Saban Kumar, E., & Prajapati, R. (2018). IoT based Aquaponics Monitoring. *1st KEC Conference Proceedings*, *September*, 75–80. https://www.researchgate.net/publication/327953706
Efimov, I., & Salama, G. (2012). The future of optical mapping is bright: RE: Review on: "optical imaging of voltage and calcium in cardiac cells and tissues" by Herron, Lee, and Jalife. *Circulation Research*, *110*(10). https://doi.org/10.1161/CIRCRESAHA.112.270033
Endryanto, A. A., & Khomariah, N. E. (2022). Kontrol Dan Monitoring Tanaman Hidroponik Sistem Nutrient Film Technique Berbasis Iot. *Konvergensi*, *18*(1), 25–32. https://doi.org/10.30996/konv.v18i1.4494
Hidayat, M. A. J., & Amrullah, A. Z. (2022). SISTEM KONTROL DAN MONITORING TANAMAN HIDROPONIK BERBASIS INTERNET OF THINGS (IoT) MENGGUNAKAN NODEMCU ESP32. *Jurnal SAINTEKOM*, *12*(1), 23–32. https://doi.org/10.33020/saintekom.v12i1.223
Karimanzira, D., & Rauschenbach, T. (2019). Enhancing aquaponics management with IoT-based Predictive Analytics for efficient information utilization. *Information Processing in Agriculture*, *6*(3), 375–385. https://doi.org/10.1016/j.inpa.2018.12.003
Lahay, I. H., Hasanuddin, H., Giu, J. D., & Bawole, M. G. (2023). Penentuan Grade Kopra Dengan Penerapan Metode Logika Fuzzy. *Jambura Journal of Electrical and Electronics Engineering*, *5*(1), 122–129. https://doi.org/10.37905/jjeee.v5i1.17073
Muntahanah, M., Handayani, S., & Lidia, L. (2021). Penerapan Metode Fuzzy Mamdani Penentuan Strategi Belajar Siswa Pada Persiapan Ujian Nasional Berbasis Komputer (UNBK). *Pseudocode*, *8*(2), 108–117. https://doi.org/10.33369/pseudocode.8.2.108-117
Murtado, D. A., & Imam, S. (2022). Rancang Bangun Smart Irrigation Tanaman Cabai Berbasis IoT. *Repository.Pnj.Ac.Id*, 56–64. https://repository.pnj.ac.id/1030/1/Identitas Diri.pdf
Nabil Azzaky, & Anang Widiantoro. (2021). Alat Penyiram Tanaman Otomatis Berbasis Arduino menggunakan Internet Of Things (IOT). *J-Eltrik*, *2*(2), 48. https://doi.org/10.30649/j-eltrik.v2i2.48
Neonbeni, S., Mada, G. S., & Blegur, F. M. A. (2023). Analisis Perbandingan Metode Defuzzifikasi Fuzzy Inference System Mamdani Dalam Penentuan Produksi Tua Kolo (Sopi Timor) 45% Pada Pabrik Sane Up-Ana Kefamenanu. *Jurnal Saintek Lahan Kering*, *5*(2), 34–39. https://doi.org/10.32938/slk.v5i2.1994
Nur'aeni Latekeng, Salmawaty Tansa, Raghel Yunginger, I. Z. N. (2024). *Monitoring Kualitas Air Sungai (Kekeruhan, Suhu, TDS, pH) Menggunakan Mikrokontroler Atmega 328*. *6*.
Pratama, H. P., Hadi Putri, D. I., & Sudjani. (2022). Prototype Penyiraman Otomatis Berbasis IOT untuk Multi Zona Tanaman Hias. *Jurnal Sistem Cerdas*, *5*(1), 1–11. https://doi.org/10.37396/jsc.v5i1.180
Priyatman, H., Supriono, S., & Irwanto, A. (2022). APLIKASI TEKNOLOGI IOT PADA WTP(WATER TREATMENT PLANT) SISTEM PENDINGIN AIR PADA MESIN PEMBANGKIT GUNA MENJAGA NILAI pH DAN TDS UNTUK KUALITAS AIR. *Transmisi*, *24*(3), 106–113. https://doi.org/10.14710/transmisi.24.3.106-113
Rahmad Doni, M. R. (2020). Sistem Monitoring Tanaman Hidroponik Berbasis Iot (Internet of Thing) Menggunakan Nodemcu ESP8266. *Circulation Research*, *110*(10), 516–522. https://doi.org/10.1161/CIRCRESAHA.112.270033
Ridlo, R., Hakim, A., Pangestu, A., Hidayah, H. A., & Faizah, S. (2022). Pemanfaatan Teknologi IoT untuk Pertanian Berkelanjutan (IoT Technology for Sustainable Agriculture) Artificial Intelligence View project Structural Equation Modelling-Partial Least Square View project. *Seminar Nasional Inovasi Teknologi Pertanian Berkelanjutan*, *1*(1), 1–9. https://www.researchgate.net/publication/361475268
Roidah, I. S. (2014). *Pemanfaatan Lahan Dengan Menggunakan Sistem Hidroponik*. *1*(2), 43–50.
Ronaldo, R. S., Wahjudi, R. S., Subrata, R. H., & Sulaiman, S. (2020). Perancangan Smart Greenhouse Sebagai Budidaya Tanaman Hidroponik Berbasis Internet of Things (Iot). *KOCENIN Serial Konferens*, *1*(1), 1–7.
Rozie, F., Syarif, I., Harun, M. U., Rasyid, A., Satriyanto, E., Elektronika, P., Surabaya, N., Ketapang, P. N., Korespondensi, P., & Fuzzy, S. I. (2021). Aquaponics System for Catfish Farms and Hydroponic Kale Plants Based on Iot and Fuzzy Inference System. *Jurnal Teknologi Informasi Dan Ilmu Komputer*, *8*(1), 157–166. https://doi.org/10.25126/jtiik.202184025
Setia, B. (2019). Penerapan Logika Fuzzy pada Sistem Cerdas. *Jurnal Sistem Cerdas*, *2*(1), 61–66.

https://doi.org/10.37396/jsc.v2i1.18
Sholihah, A. N., Tohir, T., & Al Tahtawi, A. R. (2021). Kendali TDS nutrisi hidroponik deep flow technique berbasis IoT menggunakan fuzzy logic. *JITEL (Jurnal Ilmiah Telekomunikasi, Elektronika, Dan Listrik Tenaga)*, *1*(2), 89–98. https://doi.org/10.35313/jitel.v1.i2.2021.89-98
Sotyohadi, Wahyu Surya Dewa, & I Komang Somawirata. (2020). Perancangan Pengatur Kandungan TDS dan PH pada Larutan Nutrisi Hidroponik Menggunakan Metode Fuzzy Logic. *ALINIER: Journal of Artificial Intelligence & Applications*, *1*(1), 33–43. https://doi.org/10.36040/alinier.v1i1.2520
Tamaji, & Utama, Y. A. K. (2023). Implementasi Fuzzy Logic Untuk Kualitas Udara, Suhu, Dan Kelembaban Udara Berbasis Iot. *Foristek*, *14*(1). https://doi.org/10.54757/fs.v14i1.249
Theo Syafei, D., & Watiasih, R. (2021). *ID: 11 Aplikasi IoT Pada Sistem Kontrol dan Monitoring Tanaman Hidroponik Application of IoT in Hydroponic Plant Control and Monitoring Systems*. *November 2021*, 73–86.
Umar, U. (2020). Pengembangan Sistem Kendali Kuantitas Air Pada Tanaman Hidroponik Berbasis Internet of Thing (IoT). *Multinetics*, *6*(2), 110–116. https://doi.org/10.32722/multinetics.v6i2.3447
Wina Sumiar, N. (n.d.). *Pengembangan Sistem Pengaturan Larutan Nutrisi Otomatis Pada Budidaya Kentang Aeroponik Development of Automatic Nutrient Solution Regulatory System in Aeroponic Potato Cultivation*. *8*, 57–68. http://journal.ipb.ac.id/index.
Wulandari, P. A., Rahima, P., & Hadi, S. (2020). Rancang Bangun Sistem Penyiraman Otomatis Berbasis Internet of Things Pada Tanaman Hias Sirih Gading. *Jurnal Bumigora Information Technology (BITe)*, *2*(2), 77–85. https://doi.org/10.30812/bite.v2i2.886
Zhou, A. P., Fatah, D., Barri, D. A. F., Irwan, I., & Fujiyanti, L. (2023). Sistem Monitoring Ketinggian Air Tangki Tanaman Hidroponik Berbasis Website. *Jurnal Inovasi Teknologi Terapan*, *1*(1), 184–189. https://doi.org/10.33504/jitt.v1i1.82