Sugeno's Fuzzy Logic Implementation in DecisionMaking on Ph Addition and Nutrition of IoT-Based Hydroponics

Raihandra Dwi Nugraha[1], Ahmaddul Hadi, S.Pd, M.Kom.[1], Dr. Yeka Hendriyani, S.Kom., M.Kom.[1], Dr. Eng. Sandi Rahmadika, M.T., M.Eng.[1]

Department of Electronics Engineering, Universitas Negeri Padang, Prof. Dr. Hamka Street, Air Tawar Padang, West Sumatra, Indonesia

Abstract - **The development of Internet of Thing-based hydroponics using Fuzzy logic Sugeno is expected to be a solution to reduce dependence on staple food imports. The research aims to develop a fuzzy logic sugeno-based automatic control system to control pH and nutrients in hydroponic systems, in order to improve plant growth, and increase crop yields. This research process involves making a control device using a microcontroller and a number of sensors including PH-4502C and TDS Meter. Data from the sensors will be processed by Arduino involving Sugeno fuzzy logic to get a decision. All data will be sent to Esp32 to be forwarded to the Thinger.io Iot platform and data from Arduino will be executed to control the pump relay. Tool testing is only functional testing using white box testing. The results of this study show that it effectively controls pH and nutrients based on membership degrees.**

Keywords— **Hydroponics, Internet of Thing, Sugeno Fuzzy Logic.**

I. INTRODUCTION

Indonesia, known as the Emerald Equator, has abundant natural resources, yet its agricultural sector still faces major challenges. One of them is the dependence on imports of staple foods such as rice and sugar, which shows weakness in meeting domestic food needs. According to the Central Statistics Agency (BPS), Indonesia imported 567.22 thousand tons of rice in March 2024, with a value of US$371.60 million or around Rp6.02 trillion [1]. In addition, land degradation and conversion due to rapid urbanization have led to a decline in agricultural productivity, with national conversion of paddy fields varying between 60,000 and 80,000 hectares per year [2]. Climate change is also worsening conditions for the agricultural sector, causing uncertainty in the planting season and an increased risk of pest attacks, which negatively impacts crop yields.

DOI: 10.18782/ijeitel-xx
https://doi.org/10.18782/ijeitelxx-xx

Corresponding author: Raihandra Dwi Nugraha
Universitas Negeri Padang
Email: raihandradwinugraha@gmail.com,

Received: August 2024
Revised: August 2024
Accepted: October 2024
Published: October 2024

Food distribution problems also result in high prices for consumers, while farmers earn low incomes. To face these challenges, the government has taken strategic steps, including encouraging diversification of food consumption based on local resources through Presidential Regulation No. 22/2009. Modern agricultural technologies such as hydroponics are becoming increasingly important in increasing productivity [3][4]. Hydroponics allows farming on limited land with faster and high-quality yields. However, this technique requires a good control system, such as the use of a fuzzy logic controller (FLC) which is more adaptive than conventional PID control. FLC is also capable of handling uncertainties and variations that occur in the cultivation process.

This research aims to develop a water pH control system and environmental monitoring in hydroponic plants using fuzzy logic based on IoT. This system is expected to increase efficiency and yield, and contribute to food security through more independent and sustainable agriculture.

II. METHOD

This research on "Fuzzy Logic Sugeno Implementation in Decision Making on pH Addition and Nutrition of Iot-Based Hydroponic" is carried out using a number of tools and materials. This research will be carried out using the waterfall development method. In applying the waterfall method, the author will carry out several steps consisting of Requirements Analysis, Design, Implementation and coding, Testing, and maintenance. The process in this research is described in the following diagram.

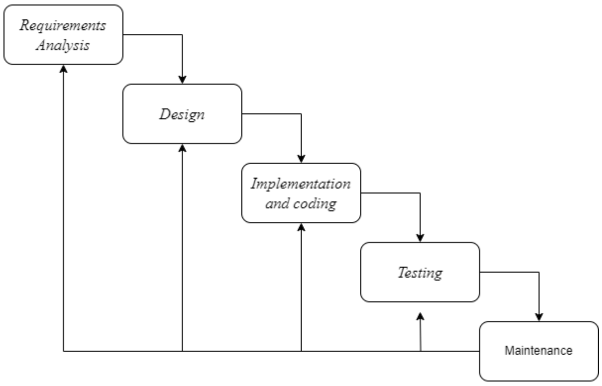

Fig 1. Waterfall graphic

A. Requirements Analysis

At the requirements analysis stage, the author will analyze needs such as analyzing the current system, analyzing problems and so on. Needs analysis is needed to find out whatis needed in building a system.

1. Ongoing System Analysis

Ongoing system analysis is defined as the decomposition of a complete system into component parts with the intention of defining and evaluating problems and obstacles that occur in the needs which can be expected to be proposed in the following figure.

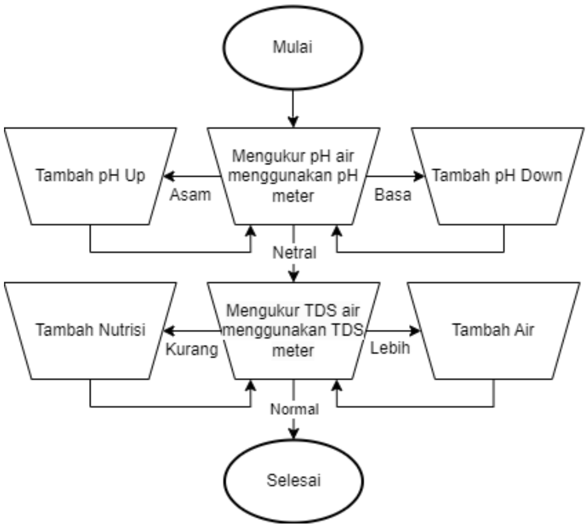

Fig 2. Ongoing System Analysis Diagram

From the analysis of the current system in the figure, measure the pH and water nutrients in hydroponics manually and add pH Up, pH Down, nutrients and water manually.

2. Problem Analysis

From the analysis of the current system in the figure, measure the pH and water nutrients in hydroponics manually and add pH Up, pH Down, nutrients and water manually.

3. Analysis of Proposed System

This analysis aims to create a new system to be automated so that it can be more effective and efficient. The needs analysis and flowchart are as follows.

a. Hardware Analysis

1) Arduino dan Esp32

In this process, the tool requires components that can process data from inputs that will be sent to the output. In this process, arduino and esp32 are used as the main controllers that will process data from the input to further regulate the course of the tool that will be sent to the output. The selection of arduino and esp32 as the main controller is due to the ease of access to input and output lines which are programmable.

2) DHT 22

DHT22 is a digital signal output temperature and humidity sensor. DHT22 has excellent long-term stability. DHT22's excellent quality, fast response, anti-interference capability and high cost advantage and performance of DHT22 on paper are better than DHT11.

3) PH-4502C Sensor

In a hydroponic environment, water plays a major role in plant growth therefore the regulation of dissolved pH in water can affect plants, a sensor is needed to be able to read the acidity or basicity of hydroponic water. The PH-4502C sensor was chosen because it can measure the level of acidity or basicity dissolved in water and can output analog data that is suitable for reading by a microcontroller.

4) TDS Sensor

TDS sensors are needed in a hydroponic environment to regulate the amount of dissolved nutrients in water. Plants are in dire need of nutrients to thrive but excess or lack of nutrients can adversely affect the plants therefore a TDS sensor is required in a hydroponic environment to measure the amount of dissolved nutrients in the water.

5) LED Lamp

Plants rely on heat to perform photosynthesis. LED lights are used to add heat to help plants perform photosynthesis.

6) Fan

Humidity levels can affect plant growth in hydroponic systems. For this reason, fans are used to insert and remove air to controlhumidity.

7) Relay

Relay is used as a switch to turn off the LED lights, fan, peristaltic pump by receiving commands from the Arduino.

8) Pompa peristaltik

This pump is used to add alkaline liquid or alkaline liquid and add nutrients to the water solution.

9) LCD

The use of LCD is functioned to display the condition of temperature, humidity, water pH and water ppm in the hydroponic environment at that time which is equipped with a display of the output value of the sensor. So that through the LCD can be known the condition of plants in the hydroponic environment offline.

10) Water Pump

The water pump acts as a water carrier for plants in a hydroponic system.

11) Aerator

The aerator acts as a dissolved oxygen enhancer in water to meet the dissolved oxygen needs of plants.

b. Software Analysis

1) Arduino IDE

Arduino in order to function a program is needed for that Arduino IDE is needed. Arduino IDE acts as a medium for writing program code anduploading to Arduino.

2) Flowchart

- The pH Meter sensor will read the pH parameter, the pH value read will be sent to Fuzzy logic for execution and will make a decision to turn on or turn off the pH Up andpH Down pumps.
- The TDS Meter sensor will read the TDS parameter, the TDS value read will be sent to Fuzzy logic for execution and will make a decision to turn on or turn off the nutrient pump.
- The TDS Meter sensor will read the TDS parameter, the TDS value read will be sent to Fuzzy logic for execution and will make a decision to turn on or turn off the nutrient pump.

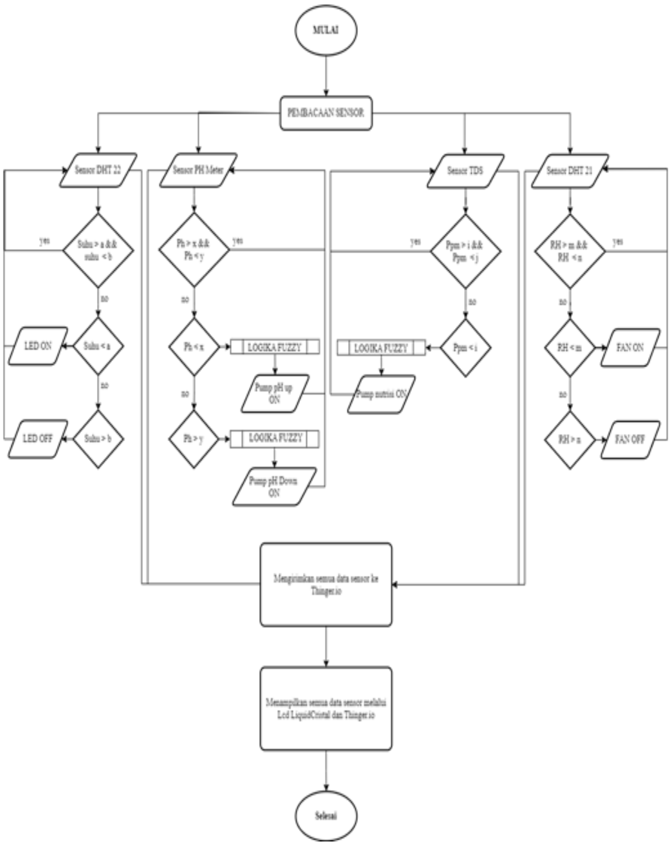

Fig 3. Flowchart

B. System Design

1. Fuzzy Logic Method

The application of fuzzy methods in this research involves three main processes, namely fuzzification, inference, and defuzzification. First, in the fuzzification process, the input data from the TDS sensor and PH Meter sensor are converted into membership values in the form of fuzzy sets. Each input data is given a membership label based on predefined rules. Second, in the inference process, fuzzy rules are used to generate logic rules which are then used to determine the output. Fuzzified input data is used as input to produce outputs in the form of on or off status of nutrient pumps and pH pumps. Third, in the defuzzification process, the output of the inference process is converted back into a firm value that can be understood by the system. The defuzzification method is used to convert the fuzzy set into a firm value that will be used as an instruction for the pump in controlling the nutrients and pH dissolved in water automatically. Through the application of fuzzy methods with fuzzification, inference, and defuzzification processes, this research is able to control the hydroponic system automatically based on input data measured by certain sensors.

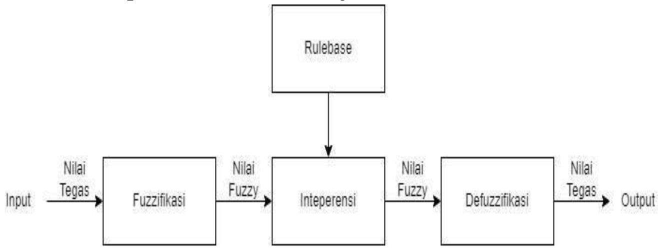

Fig 4. Sugeno Fuzzy Logic Flow

2. Hardware

a. Hydroponic System

The design of the hydroponic system uses the NFT system where the tool uses the basic material of a 2.5 inch PVC pipe with a length of 1 meter. The PVC pipe is given 10 holes measuring 5 cm which are used for netpot placement. In this hydroponic design, a water reservoir with a capacity of 60 liters is added.

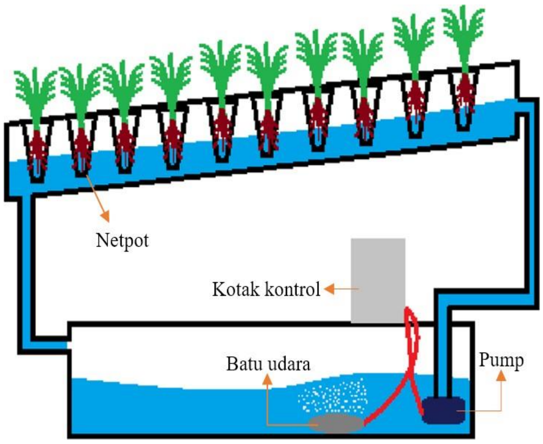

Fig 5. Hydroponic System Design

b. Control Box

The control box serves as the placement of the microcontroller and sensors. The control box uses a plastic box measuring 24 x 14 x 9.5 cm which is modified to fit the placement of the microcontroller and sensors.

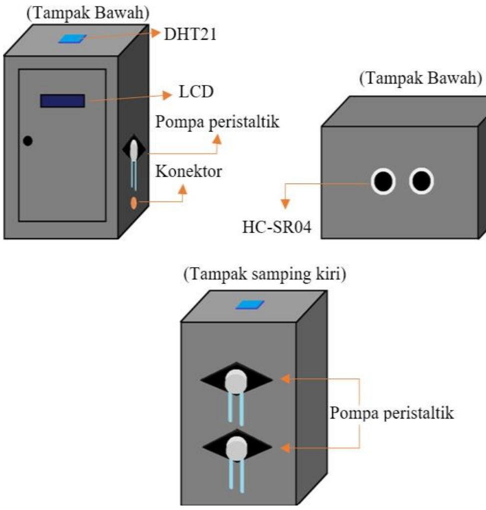

Fig 6. Control box design

c. Circuit Schematic

This scheme explains the relationship between components in this study. The following is a circuitscheme between components.

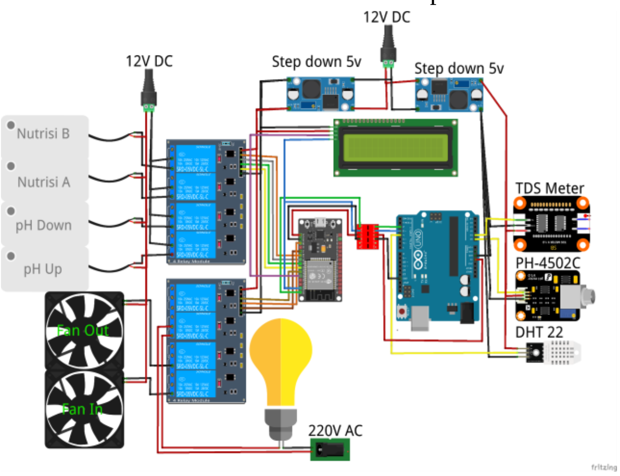

Fig 7. Circuit Schematic

3. Software

a. Dashboard Design

This section describes the display of the thinger.io platform connected to the esp32 device. Through this platform, users can view hydroponic environmental parameters in real time.

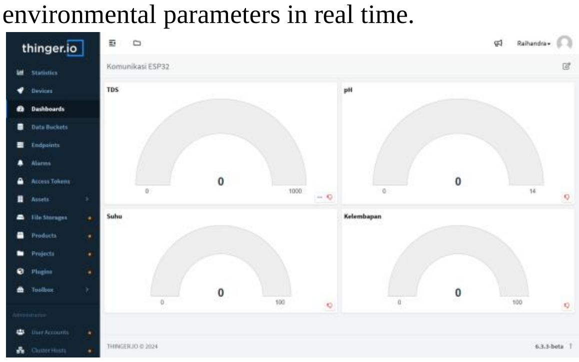

Fig 8. Dashboard Thinger.io

C. Implementation and Coding

In order to be understood by the microcontroller, the design that has been compiled previously must be converted into a format that the machine can understand. Therefore, a suitable programming language is needed to be understood by the machine. The arduino and esp32 microcontrollers use the C++ language in their programming. At this stage the programmer plays an important role to program the microcontroller so that they can connect to each other.

D. Testing

At the testing stage or testing the author uses the testing stage using white box testing manually. White-box testing allows testers to see and test parts in the source code that run on the Arduino and ESP32. Because the author is directly involved in the development of software and control logic on this IoT tool, this method gives the author the opportunity to understand in depth how each line of code operates. This is important to ensure that all logic flows, branching conditions, and hardware controls (such as relays and sensors) work as expected. The author as a tester will conduct Functional testing to ensure that all features and functions of the IoT tool work according to predetermined specifications.

III. RESULTS AND DISCUSSION

THE STEPS TO SOLVE A PROBLEM USING THE FUZZY METHOD ARE AS FOLLOWS:

A. Fuzzification

Fuzzification is the process of converting a strict value intoa membership function. the following membership degrees and their implementation.

$$\mu[x]\ Asam = \begin{cases} 1, & x < 0 \\ \dfrac{5{,}5 - y}{0 - 5{,}5}, & 0 < y < 5{,}5 \\ 0, & x < 5.5 \end{cases}$$

$$\mu[x]\ Netral = \begin{cases} 0, & x < 5.5\ atau\ x > 6.5 \\ \dfrac{y - 6}{6 - 5{,}5}, & 5.5 < y < 6 \\ \dfrac{y - 6{,}5}{6{,}5 - 6}, & 6 < y < 6{,}5 \end{cases}$$

$$\mu[x]\ Basa = \begin{cases} 1, & x > 14 \\ \dfrac{14 - y}{6.5 - 14}, & 6{,}5 < y < 14 \\ 0, & x < 6.5 \end{cases}$$

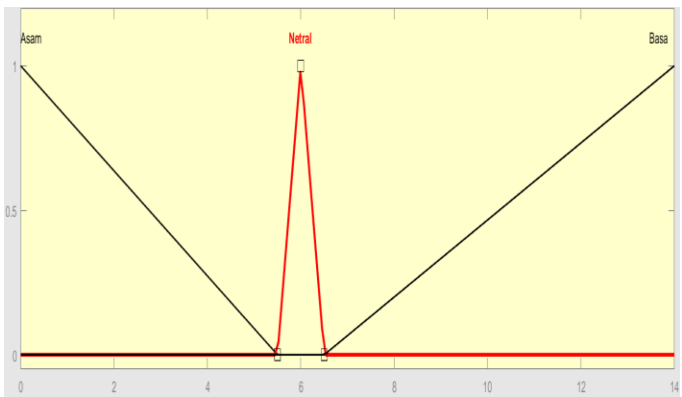

Fig 9. Degree of Membership pH

$$\mu[x]\ Sangat\ Sedikit = \begin{cases} 1, & x < 0 \\ \dfrac{700 - y}{0 - 700}, & 0 < y < 700 \\ 0, & x < 700 \end{cases}$$

$$\mu[x] Sedikit = \begin{cases} 0, & x < 700\ atau\ x > 900 \\ \dfrac{y - 800}{800 - 700}, & 700 < y < 800 \\ \dfrac{y - 900}{900 - 800}, & 800 < y < 900 \end{cases}$$

$$\mu[x]\ Normal = \begin{cases} 1, & x > 1000 \\ \dfrac{1000 - y}{900 - 1000}, & 900 < y < 1000 \\ 0, & x < 900 \end{cases}$$

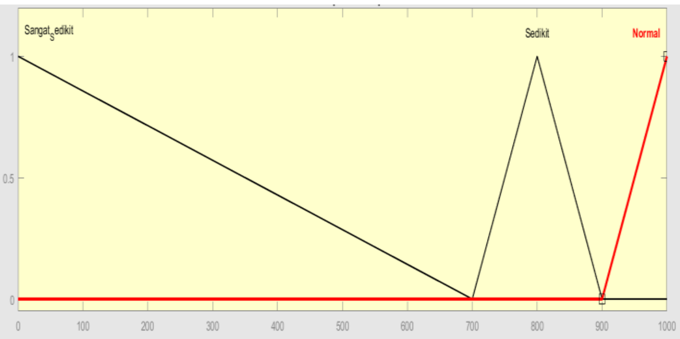

Fig 10. Degree of Membership TDS

In the Fig 11 is the membership degree and the fig 12 is the fuzzification form to restore the membership function

```
// deklarasi variabel untuk derajat keanggotaan pH
float KAsam[]       = { 0 , 0 , 5.5 };
float KNetral[]     = {5.5, 6 , 6.5 };
float KBasa[]       = {6.5,14 , 14  };

// deklarasi variabel untuk derajat keanggotaan TDS(Nutrisi)
float KSangatSedikit[]  = {0  , 0   , 700 };
float KSedikit[]        = {700, 800 , 900 };
float KNormal[]         = {900, 1000, 1000};
```

Fig 11. Implementation Degree of Membership pH and TDS

```
// deklarasi fungsi untuk mengembalikan nilai keanggotaan berdasarkan nilai pH
float fKAsam(){
  if (pHValue < KAsam[1]){
    return 1;
  }
  else if (pHValue >= KAsam[1] && pHValue <= KAsam[2]){
    return (KAsam[2] - pHValue) / (KAsam[2] - KAsam[1]);
  }
  else if (pHValue > KAsam[2]){
    return 0;
  }
}
```

Fig 12. Implementation Function Membership

b. Inference Machine

Inference Machine is an implication process that assesses input values to determine output values as a basis for decision making. Max Min reasoning is one of the frequently used reasoning models. In this reasoning, a min operation is first performed on the output signal from fuzzification, then followed by a max operation to determine the output value to be defuzzified. Figure 13 is the implementation of Inference Machine.

```
// fungsi untuk mengambil nilai terkecil dari 2 argumen
float Min(float a, float b)
{
  if (a < b){
    return a;
  }
  else if (b < a){
    return b;
  }
  else{
    return a;
  }
}
```

Fig 13. Implementation Inference Machine

c. Rule Based

The basic rules in fuzzy logic control are relational rules inthe form of “If-Then” as follows:

if x is A then y is B

Where A and B are linguistic values set in the range of variables X and Y. The statement “x is A” refers to the antecedent or premise, while the statement “y is B” refers to the consequent or conclusion. Figure 14 is the implementationof Rule Based.

```
void rule(){
  //jika ph asam dan TDS normal maka tambah ph up
  minr[1] = min(fKAsam(),fKNormal());
  Rule[1] = rule1;

  //jika ph asam dan TDS Sedikit maka tambah ph up dan Nutrisi
  minr[2] = min(fKAsam(),fKSedikit());
  Rule[2] = rule2;

  //jika ph asam dan TDS Sangat Sedikit maka tambah ph up dan Nutrisi
  minr[3] = min(fKAsam(),fKSangatSedikit());
  Rule[3] = rule3;

  //jika ph netral dan TDS normal maka tidak ada penambahan ph up/down dan nutrisi
  minr[4] = min(fKNetral(),fKNormal());
  Rule[4] = rule4;

  //jika ph netral dan TDS Sedikit maka tambah Nutrisi
  minr[5] = min(fKNetral(),fKSedikit());
  Rule[5] = rule5;

  //jika ph netral dan TDS sangat sedikit maka tambah Nutrisi
  minr[6] = min(fKNetral(),fKSangatSedikit());
  Rule[6] = rule6;
```

Fig 14. Implementation Rule bases

d. Defuzzification

The input of the defuzzification process is a fuzzy set resulting from the composition of fuzzy rules, while the output is a numerical value in the domain of the fuzzy set. Thus, if given a fuzzy set in a certain range, there must be a specific numerical value determination. Fig 15 is the implementation of Defuzzification

```
float defuzzyfikasi() {
    rule();
    A = 0;
    B = 0;
    for (int i = 1; i <= 9; i++) {
        A += Rule[i] * minr[i];
        B += minr[i];
    }
    if (B != 0) { // memastikan kalau nilai B tidak 0
        return A / B;
    } else {
        return 0;
    }
}
```

Fig 15. Implementation Defuzzification

IV. CONCLUSIONS

This research successfully designed and built a hydroponic system using Sugeno fuzzy logic. This system is equipped with a pH and nutrient control mechanism in hydroponics. The application of sugeno fuzzy logic plays an important role in controlling pH and nutrition. In addition, the application of the Internet of things is very helpful for users to monitor the condition of the hydroponic environment.

ACKNOWLEDGMENT

This research would not have been possible without the support of various parties. I would like to express my deepest gratitude to Mr. Ahmaddul Hadi, S.Pd, M.Kom. for his valuable guidance, especially in the preparation of this final project. Thank you also to Dr. Yeka Hendriyani, S.Kom., M.Kom and Dr. Sandi Rahmadika, M.T., M.Eng. for their advice and guidance in the preparation of this final project. Finally, the author would like to thank all parties who cannot be mentioned one by one who have helped in making this finalproject.

REFERENCES

[1] N. Muhamad, "Indonesia Impor Beras 567 Ribu Ton pada Maret 2024, Ini Pemasoknya," Databoks, Apr. 24, 2024. Accessed: May 19, 2024. [Online]. Available: https://databoks.katadata.co.id/datapublish/2024/04/24/in donesia-impor-beras-567-ribu-ton-pada-maret-2024-ini- pemasoknya

[2] Marwanti, "MENGGENJOT INDEKS PERTANAMAN PADI NASIONAL," tanamanpangan.pertanian.go.id, Sep. 05, 2022.

[3] https://tanamanpangan.pertanian.go.id/detil-konten/iptek

[4] /74 (accessed Aug. 16, 2022).

[5] L. Pamungkas, P. Rahardjo, and I. G. A. P. Raka Agung, "RANCANG BANGUN SISTEM MONITORING PADA HIDROPONIK NFT (NURTIENT FILM TEHCNIQUE) BERBASIS IOT," Jurnal SPEKTRUM, vol. 8, no. 2, p. 9, Jul. 2021, doi: 10.24843/spektrum.2021.v08.i02.p2.

[6] S. Susilawati, "DASAR-DASAR BERTANAM SECARA HIDROPONIK," Sriwijaya University Repository, 2019.

[7] http://repository.unsri.ac.id/id/eprint/26306 (accessed May 19, 2024).

[8] M. Banggu, M. D. Kalagison, A. Lestari, Salmawati, La Basri, and M. Saleh Refra, "Peningkatan Ketahanan Pangan Masyarakat Melalui Pelatihan Pembuatan Kembang Goyang Berbahan Dasar Sagu Di Kampung baingkete," Abdimas: Papua Journal of Community Service, vol. 5, no. 2, pp. 52–57, Jul. 2023, doi: 10.33506/pjcs.v5i2.2421.

[9] R. L. Alam and A. Nasuha, "Sistem Pengendali pH Air dan Pemantauan Lingkungan Tanaman Hidroponik menggunakan Fuzzy Logic berbasis IoT," Elinvo (Electronics, Informatics, and Vocational Education), vol. 5, no. 1, pp. 11–20, May 2020, doi: 10.21831/elinvo.v5i1.34587.

[10] G. Steven, "Chemical contents of hydroponic plants," International journal of chemical & material sciences, vol. 2, 2019, doi: 10.31295/ijcms.v2n1.83.

[11] J. Zhao et al., "Device design based on TDS water quality detection," Proceedings of International

[12] Conference on Artificial Life and Robotics, vol. 25, pp. 620–623, Jan. 2020, doi: 10.5954/icarob.2020.os9-2.

[13] Y. Yudhanto and A. Azis, Pengantar Teknologi Internet of Things (iot). UNSPress, 2019.

[14] M. Muafani, "PEMANFAATAN INTERNET OF THINGS (IOT) PADA DESAIN RUMAH TINGGAL," Jurnal Ilmiah Arsitektur, vol. 10, no. 2, pp. 61–66, Dec. 2020, doi: 10.32699/jiars.v10i2.1620.

[15] R. Doni and M. Rahman, "Sistem monitoring tanaman hidroponik berbasis iot (internet of thing) menggunakan nodemcu ESP8266," J-SAKTI (Jurnal Sains Komputer dan Informatika), vol. 4, no. 2, pp. 516–522, Sep. 2020, doi: 10.30645/j-sakti.v4i2.243.

[16] B. Wicaksana and Irfan, "Rancang Bangun Purwarupa Gerbang Otomatis Menggunakan bluetooth HC-05 dengan sensor Ultrasonic Berbasis Mikrokontroler Arduino Uno R3: Array," Jurnal Ilmiah Komputasi, vol. 18, no. 2, pp. 163–170, Jun. 2019.

[17] Ningsih, "Apa Yang Dimaksud Dengan Sensor? : Pengertian, Fungsi, Jenis-Jenis, Faktor dan Contoh Penerapan," IDMETAFORA, Aug. 31, 2022. https://idmetafora.com/id/blog/read/805/Apa-Yang-Dima ksud-Dengan-Sensor-Pengertian-Fungsi-Jenis-Jenis-Fakt or-dan-Contoh-Penerapan.html (accessed May 21, 2024).

[18] IDMETAFORA and Ketrina, "Jasa pembuatan website Yogyakarta - Web Developer Indonesia," IDMETAFORA, Jun. 28, 2023.

[19] https://idmetafora.com/id/blog/read/3611/Internet-of-Thi ngs-IoT-Membangun-Jaringan-Terhubung-di-Era-Digital

[20] .html (accessed Aug. 16, 2024).

[21] Vinsensia, D. (2021). Analisis Kinerja Pelayanan Kesehatan Dengan Pedekatan Logika Fuzzy Sugeno. Jurnal Media Informatika, 2(2), 62–73. https://doi.org/10.55338/jumin.v2i2.695