Article

Automatic Wastewater Control System for Soil Fertility use Fuzzy Logic and IoT-Based

Marianus Tiga[1], Puput Dani Prasetyo Adi[2*], Wahyu Dirgantara[3]

[1] Department of Electrical Engineering, University of Merdeka Malang; marianus.tiga@gmail.com;
[2] Department of Electrical Engineering, University of Merdeka Malang; puput.danny@gmail.com;
[3] Department of Electrical Engineering, University of Merdeka Malang; wahyu.dirgantara@unmer.ac.id

* Corresponding author: puput.danny@gmail.com

Citation: M.Tiga; P.D.P.Adi; W.Dirgantara, Automatic Wastewater Control System for Soil Fertility Using Fuzzy Logic Method and IoT-Based. *Iota*, **2021**, ISSN 2774-4353, Vol.01, 03. https://doi.org/10.31763/iota.v1i3.500

Academic Editor : Pranolo A.

Received : 25 July 2021

Accepted : 25 August 2021

Published : 15 September 2021

Abstract: The process of controlling the flow of waste in irrigation canals is one form of effort to support the sustainability of plant growth on garden beds. Farmers use many strategies or efforts to maintain fertility and plant growth to obtain more increased and productive yields. Based on research, clean water from rivers in irrigation canals that pass through residential areas to produce wastewater before it reaches plants. Moreover, a process, less healthy for plant growth than clean water irrigation channels with normal pH (Potential Hydrogen) required by plants. Setting pH and soil moisture according to plant needs, i.e., 6.5-7 for water pH and 50%-70% for soil moisture. This value is the best step in plant growth care; an irrigation canal is made that can measure water pH using sensor pH and soil moisture by using a soil moisture sensor and can normalize water pH and soil moisture according to plant needs. The pH down pump automatically pours acidic pH when the pH reading is alkaline and vice versa; the up pump automatically pours acid when the pH reading is acidic. To measure the water level in the reservoir, use an ultrasonic sensor to not seep out of the reservoir because it is full. This tool is equipped with a pump to channel water from the wastewater reservoir to the water pH measurement reservoir and proceed to the plants, where fuzzy logic works to regulate the speed of the plant watering pump with input obtained from soil moisture sensor readings and temperature sensors. Finally, control using the Esp32 MCU Node by being monitored using the Blynk application displayed on the android.

Keywords: Water pH, Soil Moisture, Temperature, Fuzzy Logic Control, Blynk IoT

1. Introduction

Many factors cause a decrease in the quality and quantity of production from agricultural land in Batu City; some of contributing factors are weather conditions, climate, and human factors such as converting agricultural land into settlements which causes reduced availability of agricultural land, poor treatment of agricultural crops in the presence of wastewater. Households, waste treatment, and so on affect rivers as irrigation canals in agricultural areas. Wastewater is caused because clean water flowing from rivers must pass through residential areas before flowing into the farmers' crops. The amount of chemicals and nitrogen from household waste mixed in irrigation canals causes clean water from rivers to become wastewater that can damage crops due to the abnormal pH of the water needed by plants, as one of the farmers' incomes in Batu City. From the research results of Stanislaus Yoseph and Puput Dani Prasetyo Adi on Implementation of Fuzzy Logic on Internet of Things-Based Greenhouse. Plants need a normal soil pH, 50-70% soil moisture, and a temperature of 0-50˚C in the room. Regarding water quality management and water pollution control which contains water quality criteria, it is stated in government regulation No. 82 of 2001. Therefore, in this case, we need a technology that can help farmers in monitoring and maintaining agricultural land in a practical, economical way (Green House) with supported by Wireless technology that can be applied to maintain and increase productivity and the quality of agricultural lands such as soil and water that supports plant growth and development.

Potential hydrogen or abbreviated pH is a measure to assess the level of acidity or alkalinity of a liquid. The scale is from 1 to 14. The onion itself has a pH content of 6.5-7, which is considered neutral because it has neither acidic nor alkaline qualities. If the pH is below 6.5, the water is said to be acidic. While water with a pH above seven means it is alkaline or alkaline. As an illustration, vinegar has a pH level of about two because it is very acidic, while the pH level of seawater is on average 8. One of the important roles of pH is that it can affect the growth of onion plants [16, 18, 21, 27, 28, 30]. For example, heavy metals found in water with a low pH tend to be more toxic to plants, and a high pH will help in lowering the concentration of these heavy metals. However, even water pH that is too high can damage plants.

Plants have their own size for the required soil moisture. The optimum humidity for the growth and development of shallot plants is 50-70%, with a tuber size of 1.5-1.8 cm for seedlings from the soil area in pots with a diameter of 60 cm. The soil below 50% is considered dry, and soil above 70% is considered moist. Soil that is too dry is bad for plants, and soil that is too moist is also not good for growth. Due to the lack of attention to the element of soil moisture in plants by farmers, it is caused by less fertile and productive plant growth.

Based on these problems, the researcher aims to make a prototype tool for controlling wastewater to be able to normalize the pH of the water according to the needs of shallot plants in IoT-based irrigation [46] channel that functions to monitor the work of the tool with Blynk application on an Android cellphone and use the fuzzy logic method to regulate the pump speed [49]. Flush from the soil moisture sensor readings used according to the required soil moisture. In this final project, the output is required to be used to answer the needs of the community not; only that, the final project also requires to produce a product that is used in real or real in the community; moreover, the final project is expected to be included in a simple patent or patent or become a Products that have copyright, in this study develop Wireless Technology and utilize the Internet of Things (IoT) technology to help the community, especially farmers.

In this study, Blynk Technology is combined with IoT [IoT [5, 13, 19, 37, 38, 53], which is used specifically to detect, monitor, monitor, and transmit data on the Blynk Web Server in real-time. Several factors studied in detail include soil moisture [44], the water level in the container, the speed of plant watering pumps, and water pH. The essence of this research is to increase the productivity of shallot plants by utilizing IoT technology. In several previous studies using Radio Frequency LoRa [1,2,3, 8, 9, 10, 11, 12, 15, 20, 22, 23, 31, 33, 34,] to transmit various sensors that are compatible for agriculture, and various types of analysis and other objects based on LoRa [40, 41, 42, 43, 47, 48, 50, 51, 54, 55].

2. Related Works

Oktarian Saputra, 2018, *Implementation of the Fuzzy Sugeno Method to Determine Fish Pond Water Quality in Aquaponics Systems*. Department of Computer Systems, Faculty of Computer Science, Sriwijaya University. The Sugeno fuzzy method has been implemented in the aquaponics system with crisp, fuzzy input in turbidity and water Ph [24, 25, 45, 52] parameters. The measurement of the value of the water turbidity parameter uses the A/D Turbidity Sensor, and the measurement of the pH parameter value of the water is measured using the Analog pH Sensor v.1.1. Sugeno fuzzy [32] system that is designed consists of a 24 Rule base. The output of the system is the lifetime of the water pump. From the results of experiments that have been carried out, the system has been able to run well. The error rate for measuring water turbidity levels using the A/D Turbidity Sensor was ±1.97%, and for pH measurements, an average error was ±4.8%. Based on the overall system test results, the designed system is able to reduce the pH value from 7.13 to 6.99, and it takes 18 minutes with an average error value of 0.14% for the pH parameter and 16.4% for the turbidity parameter.

Shidiq Mahfudz, Panca M Rahardjo, 2008, *Integrated Pond Water Temperature and pH Measurement with Data Logger*. Brawijaya University. Poor. (EECCIS Journal Vol. II, No. 1, June 2008). An integrated pond water temperature and pH meter with a data logger have been created. This tool is designed to be placed continuously in the field. The temperature meter uses an LM35 sensor, the pH meter uses a Hanna Instrument pH meter sensor, each of which has a measurement resolution of 1oC and 0.1. The data logger unit uses an ATMega 8535 microcontroller component with data transfer to a Personal Computer (PC) using USB. Using an external EEPROM with a capacity of 8K bytes, this tool can store data on sensor measurements, measurement time, and date data up to 8192 data. With this amount of data, then by setting the data storage at intervals of every 15 minutes in one day, the memory will be full approximately after seven days. By setting the data storage interval every 30 minutes in one day, the memory will be full after about 14 days. By setting data storage at intervals of every 1 hour in one day, the memory will be full after approximately 28 days.

Ningrum, Endah S., Paulus Susetyo W., Tomi Adi Putra, with a title of the research is a*pplication System for Water Acidity (pH) Sensors for Control Applications for Shrimp Pond Water Conditions*, Institut Teknologi Sepuluh Nopember (ITS). The result of shrimp ponds is a very profitable export commodity for Indonesia. Many factors affect the results of shrimp ponds, both in terms of quality and quantity, e.g., water conditions, types of shrimp, climate, or weather. One of the essential elements that must be maintained in managing shrimp pond water is controlling water acidity (pH). So far, pond farmers are still using conventional methods to monitor it, e.g., measuring the pH of pond water using a digital pH meter or litmus paper indicator. In this way, it isn't effortless to carry out measurements continuously over a long period.

Another problem that arises is that pH measurement is strongly influenced by the temperature conditions of the liquid itself. Therefore, in this study, a water acidity (pH) sensor system was created that can be interfaced or used as input by a controller and data processor. In principle, the sensor system made consists of a pH electrode which is used to detect the number of H+ ions from a liquid, a temperature sensor as a pH measurement parameter, a microcontroller as a data processor, and a visual aid (display), to reduce the effect of temperature on pH measurements, a partial line equation method is used which is implemented in software on the microcontroller. This method is able to reduce the error of reading the acidity of the water (pH) up to 0.57%. This pH sensor system is expected to be one part (input system) of an adaptive control system for automatically managing pond water quality of shrimp ponds.

Mardika, Ardeana Galih, and Rikie Kartadie. "*Adjusting soil moisture using an Arduino-based YL-69 soil moisture sensor on agarwood tree planting media*." JoEICT (Journal of Education And ICT) 3, no. 2 (2019). Soil moisture is the amount of water stored between the soil pores, which is dynamic. High soil moisture levels can cause problems and soil conditions that are too moist to make it difficult to carry out permanent agricultural or forestry activities that use mechanical tools. Gaharu is a non-timber forest product (NTFP) commodity that is quite reliable; the high selling value of this agarwood encourages people to use it. The research method is to observe and study literature in order to obtain information that is used as initial data for the basis for determining the need for hardware and component design to carry out the design. Then, make a software design after designing the software and calibrating the sensor. The sensor has not been calibrated, then it returns to software design, and the sensor is calibrated, then proceed to data collection, and then data analysis is complete. The research results, the soil moisture regulator for gaharu tree planting using the YL-69 soil moisture sensor and Arduino Mega 2560 were programmed. The soil moisture sensor will detect the level of soil moisture in the agarwood tree soil media. If the soil moisture is >80%, Arduino Mega will order the water pump to turn on and drain the water to water the plants. If the soil moisture condition is <= 80% according to what plants need, the water pump will die, and the water will not flow. So the conclusion from the YL-69 soil moisture sensor can be said to have an accuracy value of 88.76%.

Anggher Dea Pangestu, Feby Ardianto, Bengawan Alfaresi, with the research title, is *an Electric Load Monitoring System Based on Arduino Nodemcu ESP826*" Electrical Study Program, Faculty of Engineering, University of Muhammadiyah Palembang Journal Ampere Vol 4 No 1, June 2019. So far, the use of electrical power in households can only be seen through the kWh meter distributed by PLN. These tools don't provide information about how much electric power is used in real-time. kWh meter only shows the amount of cumulative power used. Therefore, a tool is needed that can show the use of electric power in real-time, making it easier for users to monitor electrical energy consumption. This research aims to monitor household electrical load using Arduino NodeMCU ESP8266 [4, 26] in real-time. The method used in this research consists of 4 stages, namely: 1). Selection of software and hardware equipment, 2). System design, 3). Programming, and 4). Tool testing. The results of testing the tool using an inductive load in the form of 2 15 Watt LED lights and a resistive load in the form of an electric iron that is set at the maximum hot point, the tool works well and can read the amount of current and power used when conditioning ON to inductive loads and loads. Resistive, the tool's accuracy in reading ranges from 96-98%.

3. Literature Review

3.1. ESP32 for Microcontroller and IoT devices

ESP32 is a microcontroller introduced by the Espressif System, the successor of the ESP8266 microcontroller. There is already a WiFi module in the chip in this microcontroller, so it supports making the Internet of Things application systems. ESP32 itself is not much different from the familiar ESP8266 on the market; it's just that ESP32 is more complex than ESP8266, perfect for friends with large projects.

Table 1. Specifications of NodeMCU ESP32

Attribute	**Detail**
CPU	Tensilica Xtensa LX6 32 bit Dual Core at 160/240 Mhz
SRAM	520 KB
FLASH	2MB (MAX 64MB)
Voltage	2.2 V to 3.6 V
Working Flow	Average 80 mA
Programmable	Yes (C,C++ Python, Lua, etc.)

Attribute	Detail
Open Source	Yes
Connectivity	
Wi-Fi	802,11 b/g/n
Bluetooth	4,2 BR/EDR and BLE
UART	3
I/O	
GPIO	32
SPI	4
12C	2
PWM	8
ADS	18 (12-Bit)
DAC	2 (8-bit)

- Processor: Xtensa dual-core (or single-core) 32-bit LX6 microprocessor, operating at 160 or 240 MHz.
- Memory: 520 KB of SRAM.
- Wireless connectivity: WiFi 802.11 b/g/n, Bluetooth v4.2 BR/EDR, and BLE (shares the radio with WiFi).
- Peripheral I/O: 12-bit SAR ADC (up to 18 channels), 2x 8-bit DACs, 10x touch sensors (capacitive sensing GPIOs), 4x SPI, 2x I2S interfaces, 2x I2C interfaces, 3x UART, SD/SDIO /CE-ATA/MMC/eMMC host controller, SDIO/SPI slave controller, Ethernet MAC interface, CAN bus 2.0, infrared remote controller (TX/RX, up to 8 channels), PWM motor, LED PWM (up to 16 channels) , Hall effect sensor, ultra-low power analog pre-amplifier.
- Security: IEEE 802.11 standard security, secure boot, flash, encryption, 1024-bit, OTP (up to 768-bit for customers), cryptographic hardware acceleration (AES, SHA-2, RSA, ECC), random number generator (RNG)).

This ESP32 microcontroller can be programmed using C++, C, Python, Lua, etc. To run the ESP32 microcontroller program requires programming software; the following is an example of the software to run the ESP32 microcontroller program, including the following: Arduino Pro Mini, Arduino [6, 7, 17, 29, 39] IDE, Ubuntu 14.04 LTS, ESP-IDF Visual Studio Code Extension, Expressive IoT Development Framework.

The ESP32 microcontroller is widely used and supportive for making the Internet of Things (IoT) application systems. The following is an example of its use, as follows:

- Smart Security, One of the most common smart security devices is a house key that uses biometrics such as fingerprints or authentication codes. These tools reduce burglaries and home burglaries and tighten home security from people who want to do evil. In addition, to overcome some minor 'accidents' such as losing keys, access to the house by guests, and access to rooms that require special authorization, such as parents' rooms.

- Smart City, On a broader scale, IoT technology also touches on urban planning. The use of this smart city is to integrate all city problems into one. Examples include CCTV traffic lights and the integration of transportation systems in the city. Everything can be accessed directly via a smartphone connected to the internet. The appearance of the Schematic of ESP8266 NodeMCU and LCD Connectivity can be shown in Figure 1.

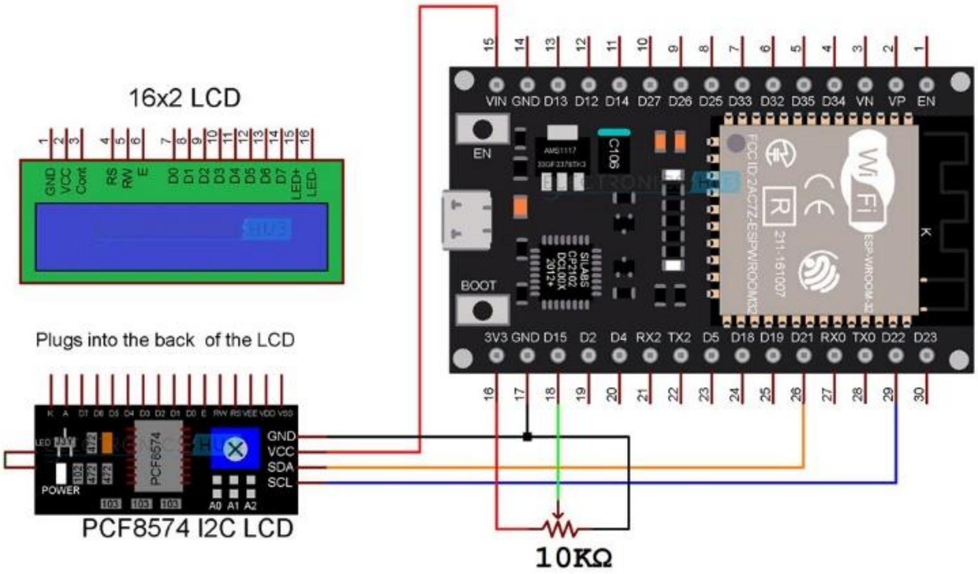


Figure 1. ESP32 and PCF8574 I2C LCD (source: https://www.electronicshub.org/)

3.2. Water pH sensor

PH stands for the power of hydrogen, which is a measurement of the concentration of hydrogen ions in the body. The total pH scale ranges from 1 to 14, with seven being considered neutral. A pH less than seven is said to be acidic, and a solution with a pH greater than 7 is basic or alkaline. This tool can measure water quality and other affordable parameters. It is also Arduino compatible, especially designed for Arduino controllers to easily interface sensors with practical connectors. This will allow expanding your project to bio-robotics. It has a working LED as a Power Indicator, BNC connector, and pH 2.0 interface sensor. To use it, just connect the pH sensor with the BND connector, and plug the pH 2.0 interface into the analog input port of any Arduino controller. If it is pre-programmed, you will get the pH value easily.

pH is the degree of acidity used to express the level of acidity or alkalinity of a solution. It is defined as the cologarithm of the dissolved hydrogen ion (H+) activity. The hydrogen ion activity coefficient cannot be measured experimentally, so its value is based on theoretical calculations. The pH scale is not an absolute scale. pH is the level of acidity or alkalinity of an object measured using a pH scale between 0 to 14. Acidity has a pH between 0 to 7, and alkaline has a pH value of 7 to 14. For example, orange juice and battery water have a pH between 0 to 7, while seawater and bleach have alkaline properties (also called alkaline) with a pH value of 7-14. Pure water ('*aquades*') is neutral or has a pH value of 7. PH Meter is an electronic device used to measure pH (acidity or alkalinity) or alkalinity of a solution (though special probes are sometimes used to measure the pH of semisolids). A typical pH meter consists of a pH measuring probe (glass electrode) connected to a reading meter that measures and displays the measured pH.

The working principle of this tool is that the more electrons in the sample, the more acidic it will be and vice versa, because the bar on the pH meter contains a weak electrolyte solution. There are digital and analog tools. pH meters are widely used in quantitative chemical analysis. The pH probe measures the pH as well as the activity of the hydrogen ions surrounding a thin-walled glass bulb at the end. (approximately 0.06 volts per pH unit) which is measured and displayed as a reading of the pH value Acids have a pH between 0 and 7, and alkaline properties have a pH value of 7 to 14. For samples of orange juice and battery, water has a pH between 0 to 7, while seawater and bleach have alkaline properties (also called alkaline); the series of measurements is no more than a voltmeter which displays measurements in pH other than volts. Figure 2 is a Water pH sensor and the components that work in it.

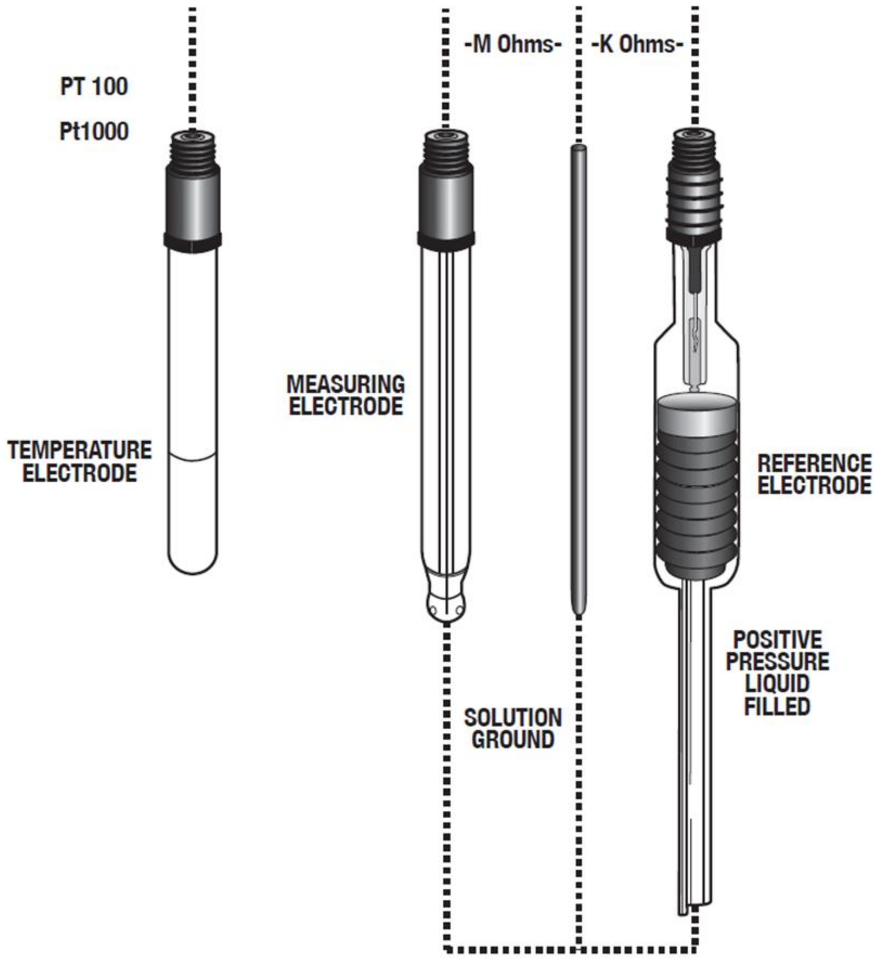


Figure 2. Water pH sensor (https://web-material3.yokogawa.com/)

The input impedance measurement must be very high due to the presence of high resistance (about 20 to 1000 MΩ) on the probe electrode, which is commonly used with pH meters. The pH meter circuit usually consists of an operational amplifier having an inverting configuration, with a total voltage of approximately -17. The amplifier converts the low voltage generated by the probe (+0.059 volts/pH) in pH units, which is then compared to the reference voltage to give a reading on the pH scale. The pH meter must be calibrated before and after each measurement for very precise and precise measurements. For normal use, calibration should be carried out daily. The reason for doing this is that the glass electrode probe is not manufactured e.m.f. for a long period of time.Calibration must be carried out with at least two kinds of standard buffer fluids that correspond to the range of pH values to be measured.For general use buffers pH 4 and pH ten are allowed. The pH meter has a first controller (calibration) to set the measurement reading equal to the value of the first standard buffer and a second controller (slope) used to set the meter reading to the value of the second buffer. The third controller sets the temperature. The instruments used in the pH meter can be analog or digital. As with other tools, to get good measurement results, it is necessary to maintain and calibrate the pH meter. When using a pH meter, the calibration of the instrument must be considered before taking measurements. As is known, the main principle of a pH meter is the measurement of the electric current recorded on the pH sensor due to the ionic atmosphere in the solution. The stability of the sensor must always be maintained, and the way is to calibrate the instrument. Calibration of the pH meter is carried out with: Standard buffer solution: pH = 4.01; 7.00 ; 10.0.

4. Method

4.1 Flowchart System and Hardware Connectivity

The workings of each of the block diagrams or Figure 3 are as follows:

- Android: A mobile phone that will access data from the ESP32 server using the Blynk application.
- Blynk: As an application that accesses data from the microcontroller used and monitors and controls the incoming data.
- NodeMCU ESP32: As the main server that real-time [14, 35, 36] retrieves data from the microcontroller and makes Blynk applications that can be accessed on the android glass screen.
- The pH sensor here functions as a device that reads the acid and alkaline levels of water. Soil Moisture Sensor: Soil moisture reading device for onion plants.
- Ultrasonic Sensor: Device for reading the water level distance in the container
- DHT11 sensor: temperature reading device in the garden.
- Mosfet Driver here functions as an Amplifier circuit to control the PWM DC motor, i.e., acid PH, alkaline pH, and flush pump.
- Relay: Breakers and voltage connectors to AC1 pumps, AC2 pumps, and AC3 Pumps.

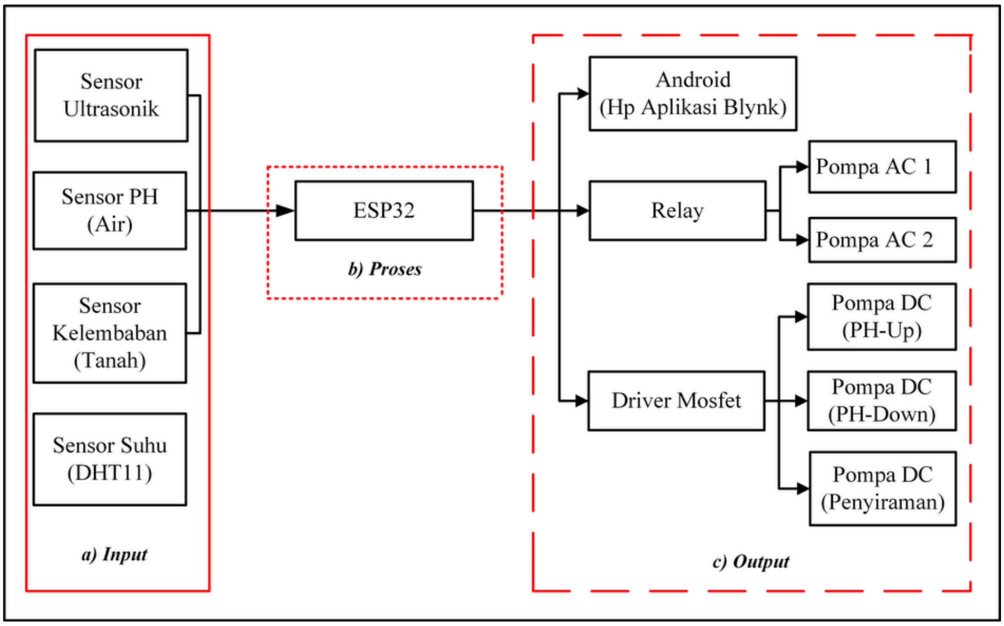


Figure 3. Connectivity of ESP32 and the I/O Devices

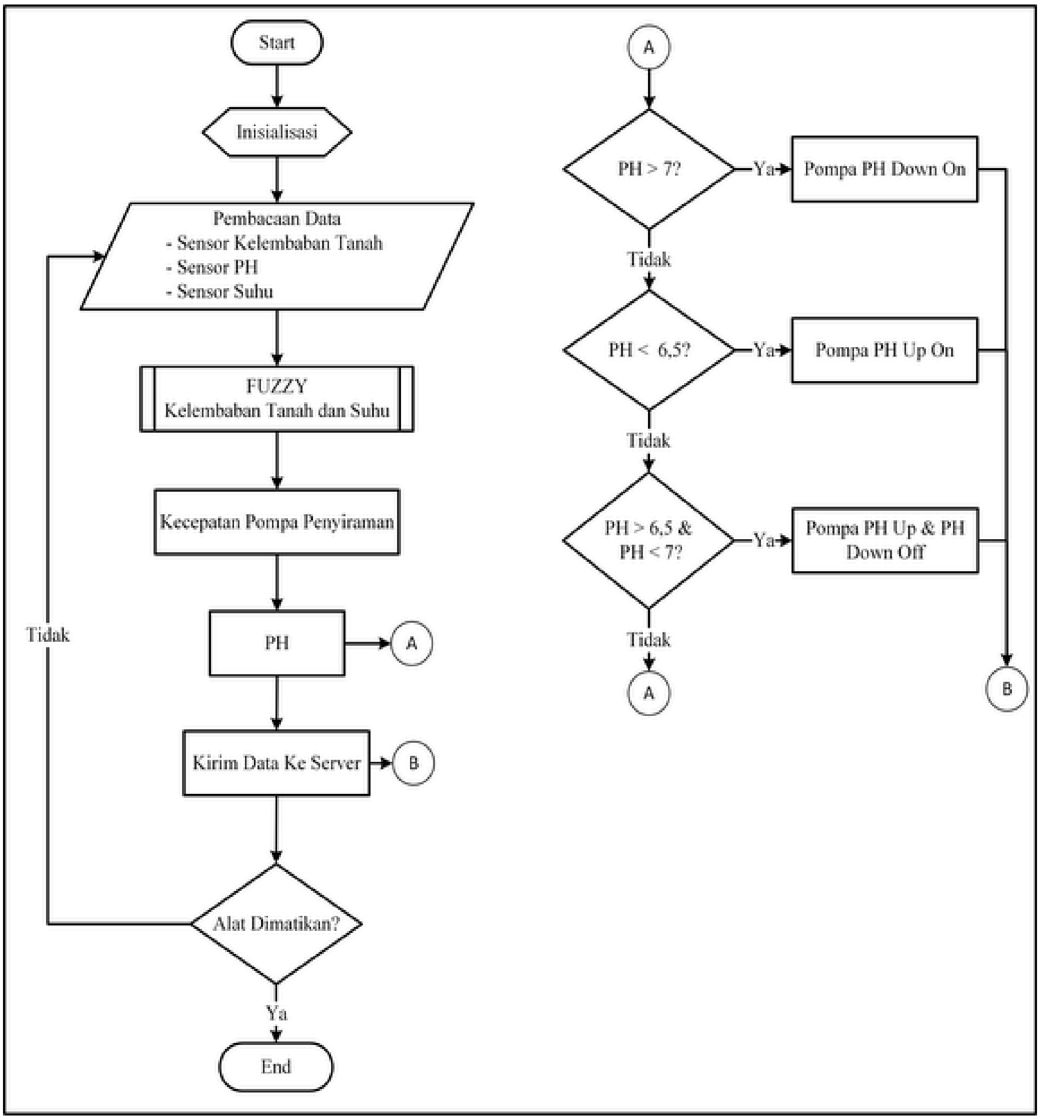
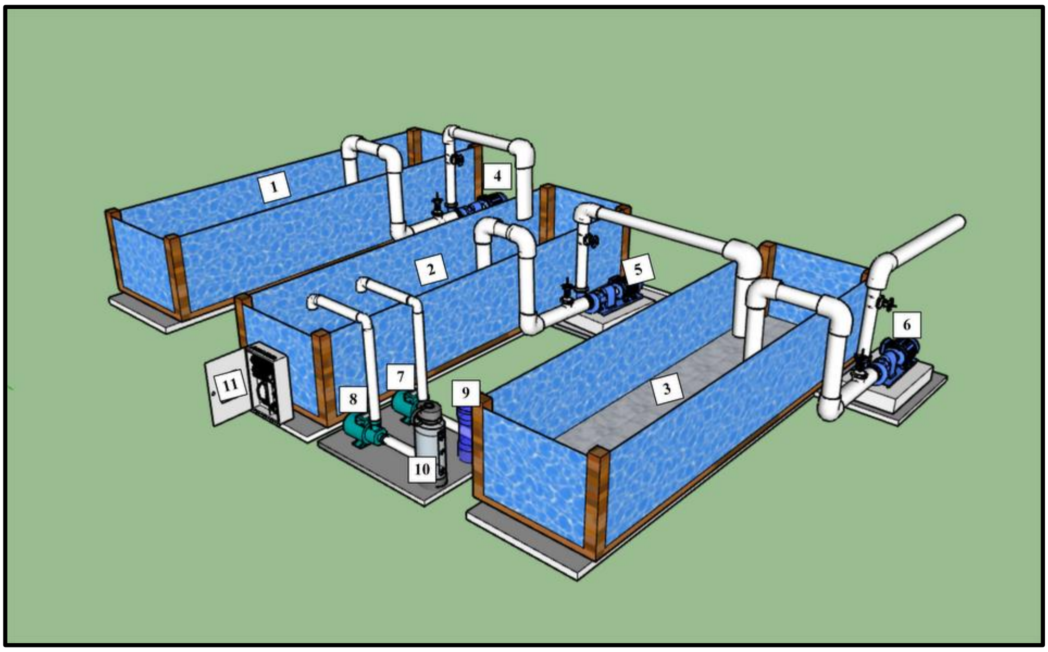


Figure 4. Flowchart of how this research works

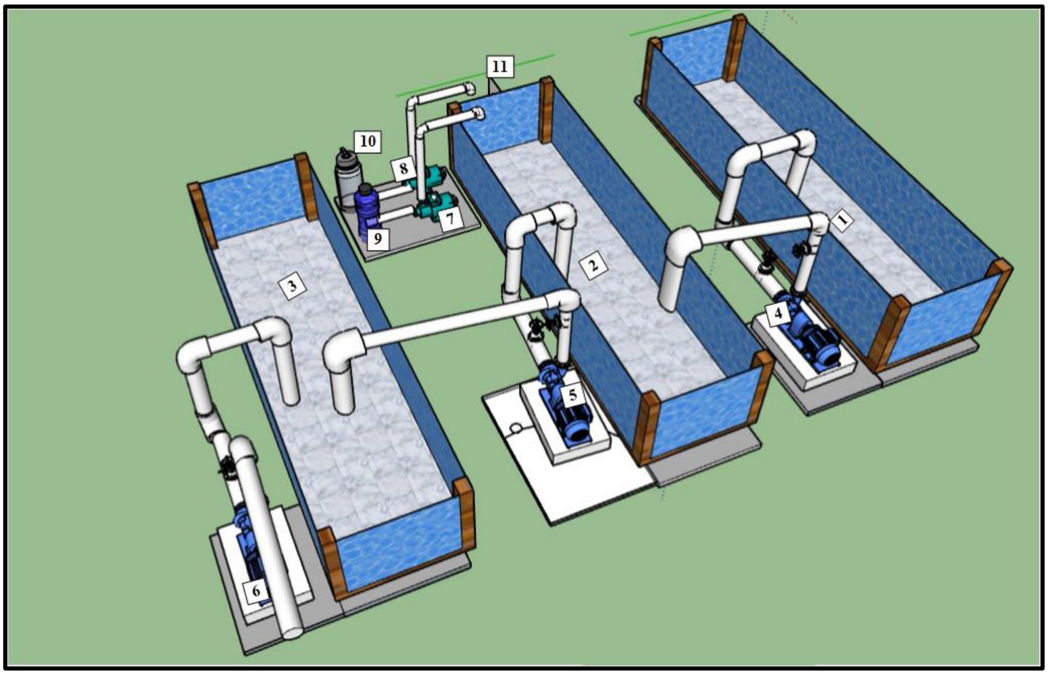
In figure 4, the software flowchart starts from initialization checks soil moisture sensors, pH sensors, and temperature sensors to read soil moisture values, pH values, and temperature values in soil moisture and temperature fuzzification plants to adjust the speed of the watering pump. Followed by the pH value, if the pH value is more than 7, then the pH down pump automatically turns on, if the pH value is less than 6.5, then the pH up pump automatically turns on, and if the pH value is more than 7 and less than 6.5 then the pump is down and pump up dead by sending data to the server. If it has not been turned off, it will return to checking the soil moisture sensor, ph sensor, and temperature sensor; if it has been turned off, it is finished.

4.2 Tool design in 3D design

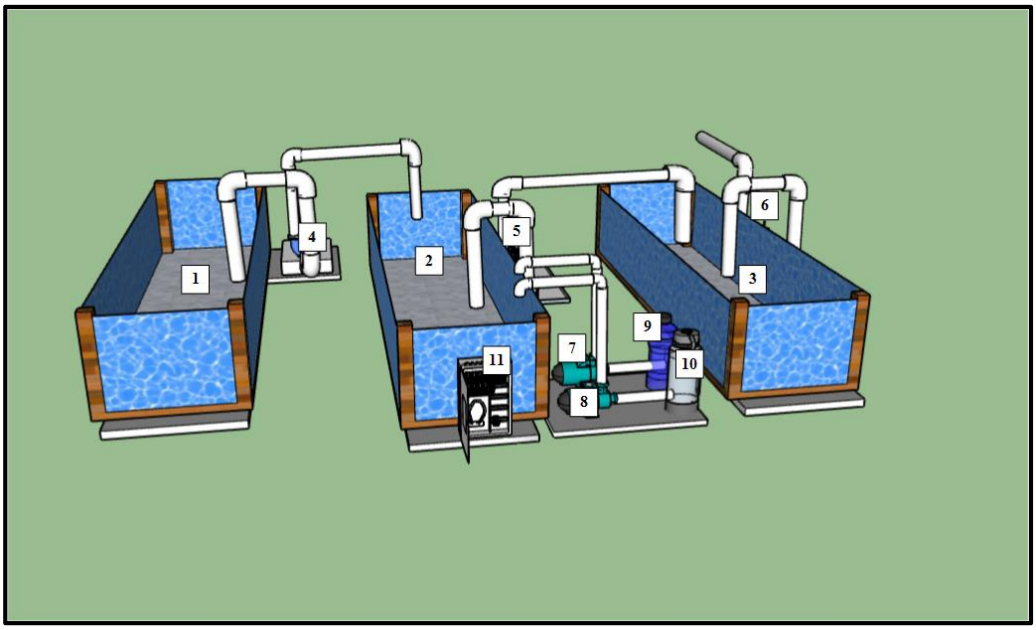
The mechanical design of the " *Automatic Wastewater Control System for Soil Fertility use Fuzzy Logic and IoT-Based*" will be made in the form of a prototype tool. The mechanical design will be shown in Figure 5.



(a) 3D design view of IoT based automatic filtering container: Side view



(b) 3D design view of IoT based automatic filtering container: Top view



(c) 3D design view of IoT based automatic filtering container: Front view

Figure 5. 3D design view of IoT based automatic filtering container

The sections in Figure 5 are explained specifically at the following points:

1. Water Container 1 cloudy wastewater
2. Water Container 2
3. Water Container
4. AC Pump 1
5. AC Pump
6. Watering DC Pump
7. DC Motor Pump pH Down
8. Motor Pump dc pH Up
9. Substance pH Down
10. Substance pH Up
11. Control component panel

The pH sensor is in water container 2, the ultrasonic sensor 1 is in water container 2, the ultrasonic sensor 2 is in water container 3, the soil moisture sensor and the temperature sensor are on the plant.

The functions of the parts of the device used in Figure 5 are as follows:

1. AC pump 1 which functions to pump water from water container 1 to water container 2
2. The pH sensor in container 2 is useful for checking the pH of the water
3. Water container 2 is useful for accommodating normal water, namely pH 6.5 – pH 7
4. AC pump 2 functions to pump water in container 2, which is channeled through a pipe to a 3 . water container
5. Watering DC pump serves to pump water from water containers 3 to the destination (garden or plants)

6. pH down DC motor pump is useful for pumping alkaline levels from alkaline pH bottles to 2 . water containers
7. DC up motor pump is useful for pumping acid levels from acid pH bottles to 2 . water containers
8. Ultrasonic Sensor 1 serves to read the water level in a 2 . water container
9. Ultrasonic Sensor 2 serves to read the water level in a 3 . water container
10. Soil Moisture Sensor (soil moisture v2.0) serves to read soil moisture on plants
11. Temperature sensor DHT11 serves to read the temperature around the plant
12. The control component panel is useful for holding all the devices needed by the tool.

5. Result and Analyzes

In this chapter, we will discuss testing and analyzing the results of system work data with designs that have been made. The testing and discussion are carried out by functionally testing each component, testing the program using simulation, and testing as a whole. The results of testing the tool and taking data are expected to get valid data, and the tool works according to its functions and objectives as expected. Tabel 1 is a specific test result of Water pH.

Tabel 1. Water pH Test

No	pH Condition	ADC (volt)	pH Measuring Instrument	pH Sensor value	Error (%)
1.	Acid/Down	560	4.0	4.0	0
2.	Acid/Down	549	3,9	0	0
3.	Acid/Down	420	2,6	0	0
4.	Acid/Down	840	4,4	4,44	0,90
5.	Acid/Down	980	4,6	4,63	0,65
6.	Acid/Down	1.118	4,8	4,83	0,62
7.	Acid/Down	1.322	5,1	5,10	0
8.	Acid/Down	1.730	5,7	5,72	0,35
9.	Acid/Down	1.866	5,9	5,91	0,16
10.	Neutral	2.002	6,1	6,14	0,65
11.	Neutral	2.225	6,4	6,42	0,31
12.	Neutral	2.294	6,5	6,51	0,15
13.	Neutral	2.363	6,6	6,64	0,60
14.	Neutral	2493	6,8	6,82	0,29
15.	Neutral	2.623	7.0	7,04	0,57
16.	Alkali/Up	2.818	7,3	7,34	0,54
17.	Alkali/Up	2.948	7,5	7,52	0,26
18.	Alkali/Up	3.013	7,6	7,67	0,92
19.	Alkali/Up	3.225	7,9	7,93	0,37
20.	Alkali/Up	3,334	8,2	8,21	0,12
21.	Alkali/Up	3.602	8,6	8,66	0,69
22.	Alkali/Up	3.803	8.9	8,93	0,33
		Average			0,38

Tabel 2. Soil Moisture Sensor Test

Soil Moisture Sensor	Soil Condition (%)	ADC value (volts)
SKT	0	4095
SKT	100	1390

Based on table 2, the ADC (Analog to Digital Converter) value is 4095 for 0% dry soil on the soil moisture sensor, while the value is 1390 for 100% wet soil on the soil moisture sensor.

Figure 6. Comparison of soil moisture measurement using a soil moisture meter and a soil moisture sensor

Table 3. Soil Moisture comparison and test Performance

No	Soil Condition	Soil Moisture Meter (%)	Soil Moisture Sensor (%)	Error (%)
1.	Dry	10	10,05	0,5
2.	Dry	21	21,03	0,14
3.	Dry	33	33,02	0,06
4.	Dry	38	38,03	0,07
5.	Dry	43	43,02	0,04
6.	Dry	49	49,01	0,02
7.	Normal	51	51,03	0,05
8.	Normal	55	55,04	0,07
9.	Normal	63	63,01	0,01
10.	Normal	68	68,05	0,07
11.	Wet	72	72,06	0,08
12.	Wet	76	76,05	0,65

No	Soil Condition	Soil Moisture Meter (%)	Soil Moisture Sensor (%)	Error (%)
13.	Wet	80	80,12	0,12
14.	Wet	83	83,07	0,08
15.	Wet	87	87,06	0,06
16.	Wet	91	91,02	0,02
		Average		0,12%

Figure 7. AC pump testing Performance

Table 4. Pin ESP32, Relay, and AC Pump Condition Comparison

No	Pin Logic		Relay		AC Pump (220 Volt)		
	D22	**D23**	**1**	**2**	**1**	**2**	**3**
1.	0	0	ON	ON	ON	ON	ON
2.	0	1	ON	OFF	ON	OFF	ON
3.	1	0	OFF	ON	OFF	ON	ON
4.	1	1	OFF	OFF	OFF	OFF	ON

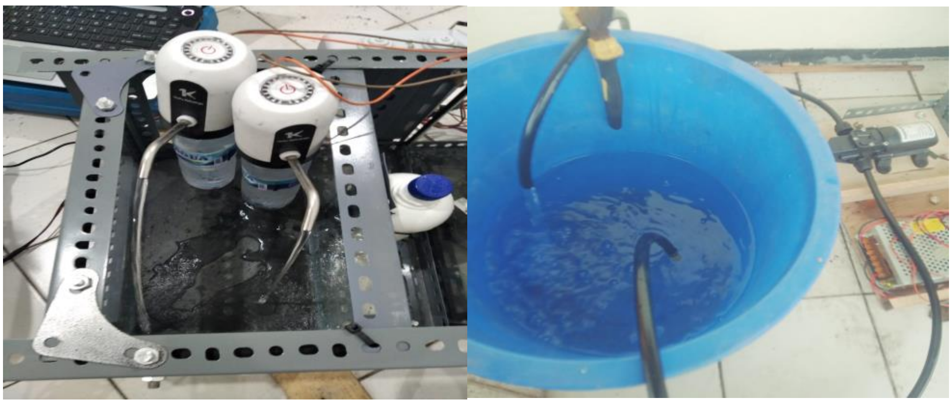


Figure 8. DC pump testing Performance

Table 5. DC Pump, Mosfet, and Digital Pin Address and condition

No	Pin Logic			Mosfet			DC Pump		
	D13	D12	D14	1	2	3	Acid pH	Alkali pH	Flush
1.	0	0	0	OFF	OFF	OFF	OFF	OFF	OFF
2.	0	0	1	OFF	OFF	ON	OFF	OFF	ON
3.	0	1	1	OFF	ON	ON	OFF	ON	ON
4.	1	0	0	ON	OFF	OFF	ON	OFF	OFF
5.	1	1	0	ON	ON	OFF	ON	ON	OFF
6.	1	1	1	ON	ON	ON	ON	ON	ON
7.	0	1	0	OFF	ON	OFF	OFF	ON	OFF
8.	1	0	1	ON	OFF	ON	ON	OFF	ON

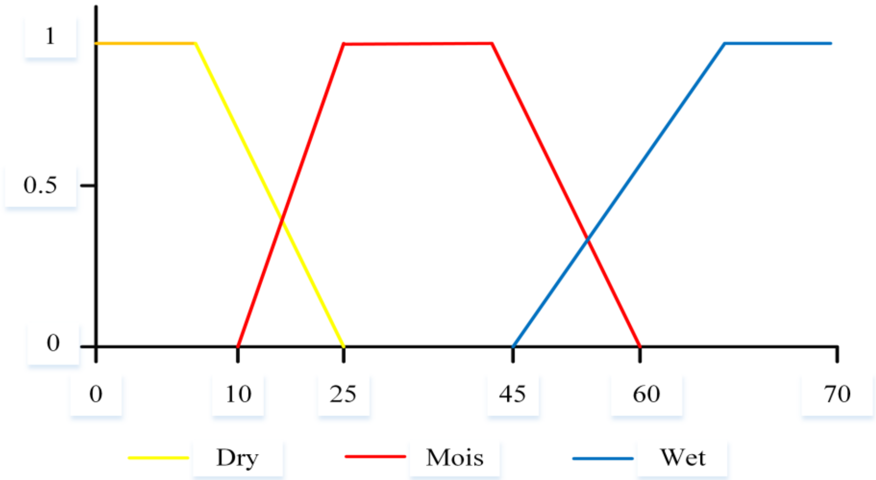


Figure 9. Soil Moisture Sensor Input Membership Function

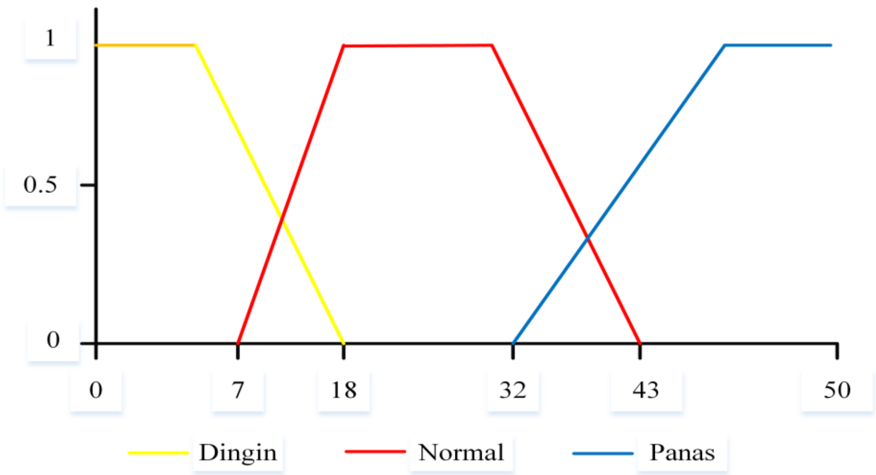


Figure 10. Temperature Input Membership Function

Based on Figure 9. range 0-70 by dividing the trapezoidal membership function for the soil moisture sensor 1 where Dry is worth [0-25], Mois is worth [10-60], and Wet is worth

[45-70]. Furthermore, Soil moisture range domain display can be shown in table 6. Table 7 is a Temperature Range Domain Display, Table 8 is a Pump Output Range Domain Display, and Table 9 is a Test Results on Blynk Applications and MATLAB Applications. And Finally, Figure 10 is a display from Blynk which can dynamically control all devices on the Digital Input and Digital Output ESP32.

Table 6. Soil Moisture Range Domain Display

No.	Input Membership Function	Soil Moisture Range
1.	Dry	[0 - 25]
2.	Mois	[10 - 60]
3.	Wet	[45 - 70]

Table 7. Temperature Range Domain Display

No.	Input Membership Function	Range (Temperature)
1.	Cold	[0 - 18]
2.	Normal	[7 - 43]
3.	Hot	[32 - 50]

Table 8. Pump Output Range Domain Display

No.	Input Membership Function	Range (PWM)
1.	Low	[0]
2.	Medium	[127]
3.	High	[255]

Table 9. Test Results on Blynk Applications and MATLAB Applications

No	Blynk app			MATLAB App			Error %
	SKT	Temperature	PWM Pompa	SKT	Temperature	PWM Pompa	
1.	69,54	35,1	0	69,54	35,1	0	0
2.	70	45,3	0	70	45,3	0	0
3.	54,64	42,6	92,07	54,64	42,6	92,07	0
4.	56,78	25,8	56,57	56,78	25,8	56,57	0
5.	51,61	15,8	192,46	51,61	15,8	192,46	0
6.	44,25	26,3	152,06	44,25	26,3	152,06	0

No	Blynk app			MATLAB App			Error %
	SKT	Temperature	PWM Pompa	SKT	Temperature	PWM Pompa	
7.	57,71	28	41,26	57,71	28	41,26	0
8.	50,35	22,97	163,08	50,35	22,97	163,08	0
9.	51,98	49,3	136,15	51,98	49,3	136,15	0
10.	54,97	39,9	86,56	54,97	39,9	86,56	0
11.	57,82	41,8	39,43	57,82	41,8	39,43	0
12.	61,37	28,2	11,88	61,37	28,2	11,88	0
13.	57,34	30	47,39	57,34	30	47,39	0
14.	61,29	35,9	45,55	61,29	35,9	45,55	0
15.	26,65	25,5	255	26,65	25,5	255	0
16.	33,49	25,8	255	33,49	25,8	255	0
17.	43,14	25,8	223,07	43,14	25,8	223,07	0
18.	47,95	26,9	202,87	47,95	26,9	202,87	0
19.	45,58	21,53	242,05	45,58	21,53	242,05	0
20.	48,1	22,5	211,44	48,1	22,5	211,5	0

1 2 3

Figure 10. Soil Moisture, Temperature and PWM Readings of the Blynk Application Pump

6. Conclusions and Suggestion

Based on testing and analysis, several conclusions are drawn. The tool can neutralize the pH of wastewater in irrigation canals with acidic pH substances and alkaline pH substances. The results of the pH sensor readings are processed by Esp32 to regulate the work of the acid pH pump and alkaline pH pump to obtain a neutral pH value. Furthermore, Automatic control of the device in regulating soil moisture with soil moisture sensor readings (soil moisture v2.0) processed by Esp 32 to run a DC pump for watering shallots. The tool is able to implement the fuzzy logic method in the wastewater control system in irrigation canals by adjusting the PWM speed of the shallot plant watering pump. The process starts from the readings from the two soil moisture sensors as input, and then it is fuzzy to adjust the pump speed so that the soil moisture is adjusted to the needs of the shallot plant., and Monitoring water pH and soil moisture remotely using the Blynk IoT application on an android phone. The process starts from the readings from the pH sensor and soil moisture sensor, which Esp32 then processes as the main server with a WiFi feature. The data obtained is forwarded to the Blynk IoT application to be able to display it on an android phone.

Based on the testing and analysis, several shortcomings in this system were drawn, which were used as suggestions for the next research; wastewater is collected and filtered to be cleaner and more sterile so that it can be used for other crops besides irrigation for watering shallots.The source of electricity for the equipment can be made a separate source by making a mini power plant adjacent to the storage area for the irrigation canal. And The use and manufacture of irrigation canal equipment are not in the form of a prototype but a tool that is able to provide a much greater impact for farmers.

Author Contributions: Conceptualization; Marianus Tiga [MT], Puput Dani Prasetyo Adi [PDPA], Wahyu Dirgantara [WD], methodology; [MT],[PDPA],[WD] software; [MT],[PDPA],[WD], validation; [PDPA],[WD], formal analysis; [MT],[PDPA],[WD], investigation; [MT],[PDPA],[WD], data curation; [MT],[PDPA],[WD], writing—original draft preparation; [MT],[PDPA],[WD], writing—review and editing; [MT],[PDPA], visualization; [MT],[PDPA],[WD], supervision; [PDPA],[WD], project administration; [MT],[PDPA], funding acquisition; [MT],[PDPA], have read and agreed to the published version of the manuscript.

Acknowledgments: The authors would like to thank the Department of Electrical Engineering, University of Merdeka Malang, and the research team members. Therefore, this research can be completed properly.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. A. Gehani, S. Harsha Shatagopam, R. Raghav, M. Sarkar and C. Paolini, "Application of 915 MHz Band LoRa for Agro-Informatics," 2021 Wireless Telecommunications Symposium (WTS), 2021, pp. 1-4, doi: 10.1109/WTS51064.2021.9433712.
2. A. K. Junejo, F. Benkhelifa, B. Wong and J. A. McCann, "LoRa-LiSK: A Lightweight Shared Secret Key Generation Scheme for LoRa Networks," in IEEE Internet of Things Journal, doi: 10.1109/JIOT.2021.3103009.
3. A. Marquet, N. Montavont and G. Z. Papadopoulos, "Investigating Theoretical Performance and Demodulation Techniques for LoRa," 2019 IEEE 20th International Symposium on "A World of Wireless, Mobile and Multimedia Networks" (WoWMoM), 2019, pp. 1-6, doi: 10.1109/WoWMoM.2019.8793014.
4. Achmad Fachri, Jihan Fairuz Muslim, Rancang Bangun Prototype Sistem Monitoring Kanal Air Berbasis Node MCU dan ESP32 CAM melalui Aplikasi Blynk, https://repository.pnj.ac.id/id/eprint/1273/1/4617030004_Jihan%20Fairuz%20Muslim_Judul,%20Bab%20I%20dan%20Bab%20V.pdf
5. Aldiaz Rasyid Ardiliansyah, Mariana Diah Puspitasari, and Teguh Arifianto, "Rancang Bangun Prototipe Pompa Otomatis Dengan Fitur Monitoring Berbasis IoT Menggunakan Sensor Flow Meter dan Ultrasonik", EXPLORIT, vol. 13, no. 2, pp. 59-67, Dec. 2021.
6. Andhika Yodi Pratama, Elfizon Elfizon, Sistem Pengontrolan Air Conditioner Berbasis Arduino, Vol 2 No 2 (2021): JTEIN: Jurnal Teknik Elektro Indonesia, Nov 5, 2021, https://doi.org/10.24036/jtein.v2i2.168
7. BARETA, Bintara Putra Candra; HARIJANTO, Alex; MARYANI, Maryani. RANCANG BANGUN ALAT UKUR SISTEM MONITORING pH, TEMPERATUR, DAN KELEMBAPAN AKUARIUM IKAN HIAS BERBASIS ARDUINO UNO. JURNAL PEMBELAJARAN FISIKA, [S.l.], v. 10, n. 1, p. 1-7, mar. 2021. ISSN 2301-9794. Available at: <https://jurnal.unej.ac.id/index.php/JPF/article/view/21900>. Date accessed: 13 feb. 2022. doi: https://doi.org/10.19184/jpf.v10i1.21900.
8. C.Baydur, S.Sahin, "ARM-Based Smart Water Meter with LoRa for Soilless Agriculture Application", European Journal of Science and Technology, June 2021, doi: 10.31590/ejosat.957639.
9. D.Sumanth, "LoRa based Wireless Weather Station", International Journal for Research in Applied Science and Engineering Technology (IJRASET), June 2021, doi: 10.22214/ijraset.2021.35289.
10. E. Kökten, B. C. Çalışkan, S. Karamzadeh and E. G. Soyak, "Low-Powered Agriculture IoT Systems with LoRa," 2020 IEEE Microwave Theory and Techniques in Wireless Communications (MTTW), 2020, pp. 178-183, doi: 10.1109/MTTW51045.2020.9244927.
11. FU.Khan, A.N.Mian, M.T.Mushtaq, "Experimental testbed evaluation of cell level indoor localization algorithm using WiFi and LoRa protocols", Ad Hoc Networks, Vol.125, 1 February 2022, 102732, doi: 10.1016/j.adhoc.2021.102732.
12. F.Zhang, Z.Chang, J.Xiong, D.Zhang, "Exploring LoRa for Sensing", GetMobile: Mobile Computing and Communications, Volume 25, Issue 2, June 2021, pp 33–37, doi: 10.1145/3486880.3486890.
13. Febry Purnomo Aji, Solehudin, A., & Rozikin, C. (2021). Implementasi Sensor Ultrasonik Dalam Mendeteksi Volume Limbah B3 Pada Tempat Sampah Berbasis Internet of Things. Jurnal Ilmiah Informatika, 6(2), 117-126. https://doi.org/10.35316/jimi.v6i2.1306
14. Fransiska Sisilia Mukti, Puput Dani Prasetyo Adi, Dwi Arman Prasetya, Volvo Sihombing, Nicodemus Rahanra, Kristia Yuliawan and Julianto Simatupang, "Integrating Cost-231 Multiwall Propagation and Adaptive Data Rate Method for Access Point Placement Recommendation" *International Journal of Advanced Computer Science and Applications(IJACSA),* 12(4), 2021. http://dx.doi.org/10.14569/IJACSA.2021.0120494
15. H.Kasral, M.Taufik, R.H.Y.Perdana, A.E.Rakhmania, "Digital centralized water meter using 433 MHz LoRa", Bulletin of Electrical Engineering and Informatics 10(4): August 2021, doi: 10.11591/eei.v10i4.2950.

16. Hani Fidiyanti, Respon Pertumbuhan dan Produksi Tanaman Bawang Merah (Allium ascalonicum L.) Pada Berbagai Media Tanam dan Pupuk Hayati di Polybag, http://repository.um-palembang.ac.id/id/eprint/18277/
17. Heri Purwanto , Anggi Algifary Salim, Teknologi Penghitung Jumlah Objek Otomatis Menggunakan Sensor Ultrasonik dan Mikrokontroler Arduino Uno, VOL 14 NO 2 (2021): JURNAL KOMPUTER BISNIS, JAN 6, 2022, http://jurnal.lpkia.ac.id/index.php/jkb/article/view/379
18. Imelda Pratiwi Putri, Bustanul Arifin, Ktut Murniati, Analisis Pendapatan Dan Efisiensi Teknis Usahatani Bawang Merah Di Kecamatan Gunung Alip Kabupaten Tanggamus Provinsi Lampung, https://jurnal.fp.unila.ac.id/index.php/JIA/article/download/4820/3415, DOI:10.23960/JIIA.V9I1.4820
19. J.Wang, Y.Liu, Z.Lei, K.Wu, X.Zhao, C.Feng, H.Liu, X.Shuai, Z.Tang, L.Wu, S.Long, J.Wu, "Smart Water Lora IoT System", ICCET '18: Proceedings of the 2018 International Conference on Communication Engineering and Technology, February 2018, pp 48–51, doi:10.1145/3194244.3194260.
20. J.Gresl, S.Fazackerley, R.Lawrence, "Practical Precision Agriculture with LoRa based Wireless Sensor Networks", Special Session on Wireless Sensor Networks for Precise Agriculture, January 2021, doi: 10.5220/0010394401310140.
21. Jamaludin Jamaludin, Krisnarini Krisnarini, Rakhmiati Rakhmiati, Pertumbuhan dan Hasil Bawang Merah (Allium ascalonicum L.) dalam Polybag Akibat Pemberian Pupuk KNO3 Berbagai Dosis, Jurnal Tanaman Pangan dan Hortikultura, Planta Simbiosa, Vol 3 No 2 (2021), e-issn: 2685-4627, https://jurnal.polinela.ac.id/JPS/article/view/225
22. L.Tu, A.Bradai, Y.Pousset, A.I. Aravanis. "Energy Efficiency Analysis of LoRa Networks. IEEE Wireless Communications Letters", IEEE comsoc, 2021, doi:10.1109/LWC.2021.3084996.
23. M.El-Aasser, P.Edward, M.Mandour, M.Ashour, T.Elshabrawy, "A comprehensive hybrid bit-level and packet-level LoRa-LPWAN simulation model", Internet of Things, vol.14, 2021, doi: 10.1016/j.iot.2021.100386.2021.
24. M.S.A.Muthanna, A.Muthanna, A.Rafiq, M. Hammoudeh, R.Alkanhel, S.Lynch, A.A.A. El-Latif, "Deep reinforcement learning based transmission policy enforcement and multi-hop routing in QoS aware LoRa IoT networks", Computer Communications, vol.183, pp.33-50, 2022, doi: 10.1016/j.comcom.2021.11.010. 2022.
25. M.Ghadafi, "Water Analysis (pH, Water Level, and Total Nitrogen) of the Downstream Tokachi River Basin", PARE - Hokkaido Summer Institute, August 2018, doi: 10.13140/RG.2.2.27140.96647.
26. Marina Artiyasa, Aidah Nita Rostini, Edwinanto, Anggy Pradifta Junfithrana, Aplikasi Smart Home Node MCU IoT Untuk BLYNK, Jurnal Rekayasa Teknologi Nusa Putra. Vol. 7, No. 1, September 2020: Hal 1- 7, https://rekayasa.nusaputra.ac.id/article/download/59/47
27. Manurung, Arih Yos Brando, Rancang Bangun Pengontrol Suhu dan Kelembapan pada Tanaman Palawija Berbasis Nodemcu dengan Aplikasi Telegram, Repositori Institusi Universitas Sumatera Utara, https://repositori.usu.ac.id/handle/123456789/43972
28. M. K. Novan Pratama dan G. Setiawan, “Rancang Bangun Sistem Pengontrol Kelembaban Tanah Pertanian Sayur Pakcoy dan Sawi”, JOKI, vol. 13, no. 2, hlm. 101-108, Okt 2021.
29. Muhamad Fauzan Zarkashie, Rancang Bangun Sistem Pengukuran Kualitas Air Untuk Keperluan Higiene Sanitasi Berbasis Arduino Uno, Institutional Repository UIN Syarif Hidayatullah Jakarta, 2021, https://repository.uinjkt.ac.id/dspace/bitstream/123456789/56325/1/MUHAAMAD%20FAUZAN%20ZARKASHIE-FST.pdf
30. Mohammad Iqbal Salim, Simulasi Logika Fuzzy Pada Pengatur Sensor Suhu dan Kelembapan Tanah Tanaman, Seminar Nasional Fortei Regional 7, SinarFe7, http://journal.fortei7.org/index.php/sinarFe7/article/download/38/26
31. N.Hashim, "Location tracking using LoRa", International Journal of Electrical and Computer Engineering, vol.11 no.4, August 2021, doi: 10.11591/ijece.v11i4. pp. 3123-3128.
32. Nasron Nasron, Suroso Suroso, Astriana Rahma Putri, Perancangan Logika Fuzzy Untuk Sistem Pengendali Kelembaban Tanah dan Suhu Tanaman, Jurnal Media Informatika Budidarma (MIB) STMIK Budi Darma, DOI: 10.30865/mib.v3i4.1245
33. P.D.P.Adi, A.Kitagawa, "A performance of radio frequency and signal strength of LoRa with BME280 sensor", *TELKOMNIKA Indonesian Journal of Electrical Engineering,* vol.18, no.2, pp.649-660, April 2020, doi: 10.12928/telkomnika.v18i2.

34. P.D.P.Adi, A.Kitagawa, "Performance Evaluation of LoRa ES920LR 920 MHz on the Development Board", *International Journal of Advanced Computer Science and Applications,* vol.11, no.6, January 2020. doi:10.14569/IJACSA.2020.0110602.
35. P. D. P. Adi and A. Kitagawa, "A Review of the Blockly Programming on M5Stack Board and MQTT Based for Programming Education," *2019 IEEE 11th International Conference on Engineering Education (ICEED)*, 2019, pp. 102-107, doi: 10.1109/ICEED47294.2019.8994922.
36. P. D. P. Adi, A. Kitagawa and J. Akita, "Finger Robotic control use M5Stack board and MQTT Protocol based," *2020 7th International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE)*, pp.1-6, 2020, doi: 10.1109/ICITACEE50144.2020.9239170.
37. P. D. P. Adi, R. Arifuddin, "Design of Tsunami Detector based Sort Message Service using arduino and sim900a to GSM/GPRS module", *jeemecs (Journal of Electrical Engineering Mechatronic and Computer Science)*, vol.1, no.1, July 2018, doi: 10.26905/jeemecs.v1i1.1982.
38. P. D. P. Adi et al., "A Performance Evaluation of ZigBee Mesh Communication on the Internet of Things (IoT)," 2021 *3rd East Indonesia Conference on Computer and Information Technology (EIConCIT),* 2021, pp. 7-13, doi: 10.1109/EIConCIT50028.2021.9431875.
39. P D P Adi, A Kitagawa, V Sihombing, G J Silaen, N E Mustamu, V M M Siregar, F A Sianturi, W Purba, "A Study of Programmable System on Chip (PSoC) Technology for Engineering Education", *Journal of Physics: Conference Series*, WEAST 2020, 1899 (2021) 012163, doi:10.1088/1742-6596/1899/1/012163.
40. P. D. P. Adi and A. Kitagawa, "Performance Evaluation of Low Power Wide Area (LPWA) LoRa 920 MHz Sensor Node to Medical Monitoring IoT Based," *2020 10th Electrical Power, Electronics, Communications, Controls and Informatics Seminar (EECCIS), 2020*, pp. 278-283, doi: 10.1109/EECCIS49483.2020.9263418.
41. P. D. P. Adi, A. Kitagawa, D. A. Prasetya and A. B. Setiawan, "A Performance of ES920LR LoRa for the Internet of Things: A Technology Review," *2021 3rd East Indonesia Conference on Computer and Information Technology (EIConCIT),* 2021, pp. 1-7, doi: 10.1109/EIConCIT50028.2021.9431912.
42. P.Branch, "Propagation Measurements and Models of 915 MHz LoRa Radio in a Block Cave Gold Mine", 2021 International Conference on Information Networking (ICOIN), January 2021. doi: 10.1109/ICOIN50884.2021.9333935.
43. R.Hamdi, E.Baccour, A.Erbad, M.Qaraqe, M.Hamdi "LoRa-RL: Deep Reinforcement Learning for Resource Management in Hybrid Energy LoRa Wireless Networks", IEEE Internet of Things Journal PP(99), September 2021, doi: 10.1109/JIOT.2021.3110996.
44. Rigoberto Martínez Ramírez, C Miguel Rodríguez-Orozco, C Ii, Yoel Betancourt, Omar González Cueto, Ing Sergio Ii, Guillén-Sosa, C Luciano Vidal-Díaz, Sugarcane Harvesting in High Moisture Soil, Revista Ingeniería Agrícola, ISSN-2306-1545, E-ISSN-2227-8761, Vol. 11, No. 4 (octubre-noviembre-diciembre, pp. 68-74), 2021
45. S. Mondal, S. Karuppuswami and P. Chahal, "ID Integrated Batteryless Wireless Digital pH Sensor," in IEEE Sensors Journal, vol. 19, no. 24, pp. 12079-12086, Dec.15, 2019, doi: 10.1109/JSEN.2019.2939926.
46. Sevira Rambanisa Hamzah, Chairul G Irianto, Ishak Kasim, Sistem PLTS Untuk Pompa Air Irigasi Pertanian di Kota Depok, Jetri:Jurnal Ilmiah Teknik Elektro, Vol.17, No.1., Agustus 2019, https://trijurnal.lemlit.trisakti.ac.id/jetri/article/view/4788
47. T.Karunathilake, A.Udugama, A.Förster, "LoRa-DuCy: Duty Cycling for LoRa-Enabled Internet of Things Devices", 2021 Twelfth International Conference on Ubiquitous and Future Networks (ICUFN), August 2021, doi: 10.1109/ICUFN49451.2021.9528805.
48. T.Osmëni, M.Ali, "LoRa IoT WSN for E-Agriculture", 4th International Conference on Emerging Technologies in Computing 2021 (iCETiC'21) UK, August 2021.
49. Tafrikhatin, A., Kurniawan, E., Muslihin, R., & Kusworo, S. (2021). Perancangan Sistem Otomatis Pompa Air Menggunakan Frekwensi Radio 27 MHz. JASATEC : Journal of Students of Automotive, Electronic and Computer, 1(2), 54-61. https://doi.org/10.37339/jasatec.v1i2.738

50. V.M.Fialho, "Integer N Synthesizer Design for LoRa Transceivers", International Journal of Innovative Technology and Exploring Engineering, vol.10 no.10, pp.101-106, August 2021, doi: 10.35940/ijitee.J9447.08101021.
51. W.Xiao, N.E.Rachkidy, A.Guitton, "Recovering Colliding LoRa Frames from Uncertainties Using LoRa Coding", IEEE 46th Conference on Local Computer Networks (LCN), October 2021, doi: 10.1109/LCN52139.2021.9524949.
52. Wahyuni Eka Sari, Eko Junirianto, Geofani Fatur Perdana, System of Measuring PH, Humidity, and Temperature Based on Internet of Things (IoT), January 2021, Buletin Ilmiah Sarjana Teknik Elektro 3(1):72, DOI: 10.12928/biste.v3i1.3214
53. Wiksandiyo, A., "Pengembangan Internet of Things (IoT) Untuk Aplikasi Penyemprotan Pestisida Otomatis", Jurnal Teknik Elektro, Program Studi Teknik Elektro, Fakultas Teknik – Universitas Pakuan, https://jom.unpak.ac.id/index.php/teknikelektro/article/view/1816
54. Y. A. Liani et al., "The Broiler Chicken Coop Temperature Monitoring Use Fuzzy Logic and LoRAWAN," *2021 3rd International Conference on Electronics Representation and Algorithm (ICERA),* 2021, pp. 161-166, doi: 10.1109/ICERA53111.2021.9538771.
55. Y. Ye, Y. Yang, L. Zhu, J. Wang and D. Rao, "A LoRa-based Low-power Smart Water Metering System," 2021 IEEE International Conference on Consumer Electronics and Computer Engineering (ICCECE), pp. 301-305, 2021, doi: 10.1109/ICCECE51280.2021.9342327.