Design and Implementation of an IoT System for Smart Irrigation

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Abstract

Irrigation is the process of spread on controlled amounts of water to plants. Irrigation is also the important factor for increasing agricultural production. Farmer is sill doing irrigation activities by manual that require time and extra effort. This can be made easier by creating a smart system can help farmer using microcontroller, irrigation can be done automatically. The objective of the research is to build a smart irrigation system based on the Internet of things where irrigation system control and monitoring can be done online using the groundwater content sensor YL-69 and NodeMCU ESP 8266 as a microcontroller. The sensor readings of analog signal are converted into a water content value in the form of a percent (%) and displayed in the Blynk App as the IoT platform. The moisture sensor sends water content data to the microcontroller and becomes reference for automatically opening and closing the solenoid valve which as an actuator. In this study, irrigation occurred at exactly the time of level water is at a value of 25%. During calibration test, four sensors used to ascertain the actual moisture content value being compared with the gravimetric test. The result show R2 value obtained were 0.9998, 0.9998, 0.9993, 0.9996 respectively for each sensor. The regression analysis was obtained by comparing the results of the sensor with gravimetric test results obtained an average result linear regression, the R2 value of control system I is 0.8533 with the RMSE value (Root Mean Square Error) 0.02 and control system II has a value of R2 0.8739 with an RMSE (Root Mean Square Error) value of 0.02. Result Plant observations made for 15 days were obtained on average Plant height is 7 cm and the average number of leaves is 8 leaves. The irrigation system built can save water as much as 58.2%.

Keywords: Irrigation; Internet of Things, Smart Irrigation; Groundwater Content; Control System.

1. Introduction

Irrigation is one of the important factors to increase agricultural production in an effort to supply increasing needs. Basically, irrigation is the activity of channeling water from water sources to agricultural land in order to meet crop water needs. Siebert and Döll (2010) estimate that the average yield of grain crops with an irrigation system is 4.4 tonnes / ha, whereas with a rainfed system it is 2.7 tonnes / ha. As much as 42% of the production of cereal crops generally comes from irrigated land and without an irrigation system the production will decrease by 20%. This proves that irrigation has a significant role in increasing agricultural production.

Irrigation in Indonesia is generally still done manually by channeling water to lands. This irrigation activity is carried out based on observations and estimates so that it allows inaccurate irrigation water provision. Without good irrigation management, excess and lack of water in the irrigation process can occur. Excessive irrigation also increases the likelihood of crop mortality, surface erosion and most importantly, over-irrigation will reduce resistance during the dry season. On the other hand, irrigation that is less than demand should cause a decrease in the production of agricultural commodities.

Technological advances make it easy to monitor and control a system using the Internet of Things. Internet of Things is a concept for connecting one device or several devices with other devices by connecting it to the internet and these objects or tools can work automatically with the ability to transfer data via the internet network without requiring much human intervention (Kurniawan et al, 2018). By using the Internet of Things we can monitor the condition of plants and also manage water distribution through irrigation. By using the ESP 8266 NodeMCU Board as a microcontroller that can be connected to the internet and also using the Blynk application as an application that can display the results of observations made by sensors and also control the drip irrigation system in plants.

The results read from the sensor will be displayed on the Blynk application. By connecting the NodeMCU ESP8266 with the Blynk application. This is called the Internet of Things (IoT) where monitoring and control of the system can be done automatically and connected to the internet so that monitoring and control can be done remotely using a smartphone.

2. Material and Methods

The tools used in this research are as follows: scissors, cutters, screwdrivers, glue, saws, drills, measuring instruments, water reservoirs, hammers and stopwatches. The materials needed are as follows: ESP8266 MCU Node, Blynk Application, Soil Moisture Sensor YL-69, Relay, Lipo Battery, Battery Charger, Acrylic, Jumper Cables, Dripper, Polybag, Hose, Connector, Kale Plant.

2.1 Methods

The method used in this research is an experimental method. This research was carried out in several stages as follows: 1) carrying out functional and structural design for the control system of the irrigation system based on the Internet of Things using a groundwater level reader sensor for water supply using drip irrigation with the help of a NodeMCU ESP 8266 microcontroller, 2) making manufacturing and control system testing, 3) observing the work results of the IoT-based irrigation system control system.

2.2 Design

The design in this study is divided into irrigation system design and control system design

2.2.1 Irrigation System Design

The design of the Irrigation System is used to carry out the function of the components according to their duties to determine the soil water content and maintain groundwater conditions at the desired limit. An overview of the system can be seen in Figure 1 below, including the following:

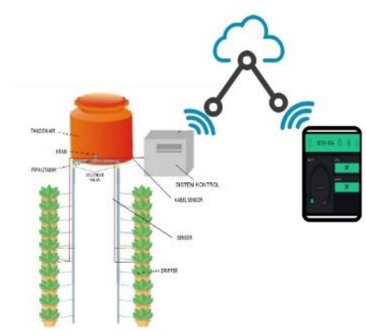
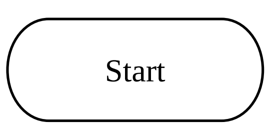


Figure 1 Overview of the System

2.2.2 Control System Design

The control system design is based on a predetermined mechanism. The control system flow chart can be seen in Figure 2 below:



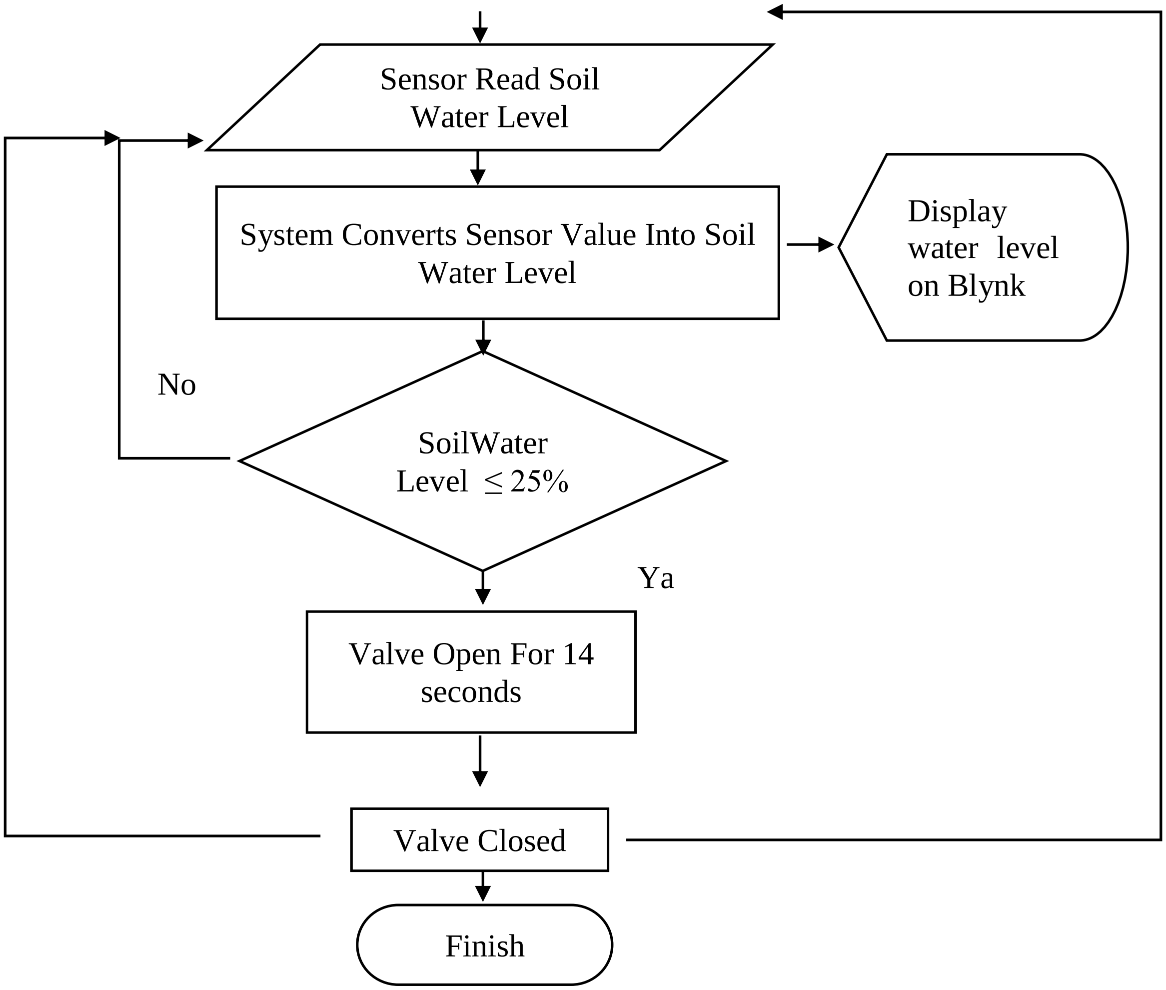


Figure 2 Control System Flow Chart

2.3 Preparation of Irrigation Installation and Control System Testing

Making installation and testing of control systems consisting of 1) plant preparation, 2) calculating system power requirements, 3) determining the level of soil moisture conditions, 4) determining the set point value, 5) calibrating the sensor to the set point value, 6) connecting the microcontroller to the Blynk App

2.4 Preparation of Plants

In this research, Kangkung (Ipomoea Reptans Poir) was planted in 30 polybags measuring 14.5 cm x 22 cm as a container for planting. Polybags are filled with humus soil as a planting medium and planted with kale seeds. The cropping pattern is made into 2 rows of plants with 15 polybags in each row.

2.5 Calculating System Power Requirements

Determining the total electrical power required in the system is needed to determine how much power is needed to run the control system. To determine electric power, Equation 5 can be used.

$$P = V \times I$$

Information :

P = Electricity (watts)

V = Voltage (Volt)

I = Current (Ampere)

2.6 Level Determination of Soil Moisture Conditions

The input voltage received by the sensor from nodeMCU is 0 volts to 5 volts. This shows the analog value 0 as a representation of the lowest resistance value and the analog value 1023 representing the highest resistance value. This condition helps explain the condition of the moisture content in the soil because water will help flow current from one probe to another on the sensor.

2.7 Determination of Set Point Value

The determination of the set point value will provide a working limit of the system, namely the maximum value in the Field Capacity condition and the minimum value at the permanent wilt point condition. However, letting the plant reach a permanent wilting point is not something that is expected in cultivation activities because it will have an impact on the condition of the plant itself. Therefore, the minimum set point value is positioned slightly above the permanent wilt point, which is at the maximum water loss or MAD.

2.8 Connection to the Blynk App

After the sensor has been properly calibrated, then the results of the sensor readings must be displayed in the Blynk application as an IoT platform by entering the auth token code provided by the Blynk application when you first log in to making this IoT project. The auth token code is copied and entered into the code that is input into the microcontroller.

2.9 Observations

The observations made in this study are; 1) Groundwater content, 2) Accuracy of sensor readings, 3) Irrigation water requirements, 4) Water discharge 5) Selenoid valve life time, 6) Irrigation water pressure 7). Plant Observation.

2.10 Ground Water Content

The groundwater content is expressed in volume percent, namely the percentage ratio between the volume of water and the volume of the sample. The determination of the soil water content was carried out using the gravimetric method. To find the value of groundwater content using equation 8.

Moisture Content = (BA-BK) / BA x 100%

2.11 Sensor Readings Accuracy

The accuracy of the sensor readings is seen from the similarity in value between the sensor readings and the value of the groundwater content that has been determined by the value. The sensor reading value is expected to be close to the predetermined groundwater content value based on the percent value of the ratio of soil volume to water volume. To test the accuracy of the sensor readings, validation was carried out by looking for linear regression between the value of groundwater content using the gravimetric method and the groundwater content data read by the sensor. If the R2 value obtained is closer to 1, the reading of the groundwater content by the sensor is accurate.

2.12 Need for Irrigation Water

The RAW value of the soil will determine the amount of water to be irrigated. By knowing the RAW value, the required volume of water can be calculated by calculating the RAW for the entire area to be irrigated using equation 8

V = RAW x A

Information :

V = Volume of Water Required (m ^ 3)

RAW = Immediately Available Water (m)

A = Irrigation Area (m ^ 2)

Meanwhile, to find the previous RAW value, we must know the value of the field capacity, the permanent wilt point and the depth of the roots so that water is available.

2.13 Water discharge

In a drip irrigation system, a low flow rate is required but with a high frequency of water dropping from the emitter, and it is obtained by measuring the output of the irrigation system per unit time. The flow rate can be calculated using equation 9.

$$Q = V / t$$

Information :

Q = Flow Rate (m ^ 3 / sec)

V = Volume of Water (m ^ 3)

t = Time (seconds)

2.14 Selenoid Valve Life Time

The solenoid valve will turn on when the ground water level is at a lower threshold. The lifetime of the solenoid valve will determine the amount of water that is drained into the soil. Taking into account the volume of water required for irrigation and the flow rate in the system, the pump life time can be calculated using equation 10.

$$t = V / Q$$

Information :

t = Pump Start Time (seconds)

V = Volume of Water Required (m ^ 3)

Q = Flow Rate (m ^ 3 / sec)

2.15 Irrigation Water Pressure

In the drip irrigation system, the height of the reservoir as a water reservoir has an effect on the pressure generated, because the higher the location of the water reservoir, when the water flows down the resulting pressure is also greater. Water pressure can be calculated using equation 11.

$$P = \rho g h$$

Information :

P = Pressure

ρ = Density of water in Kg / m3

g = Constant Gravity Acceleration

h = water level

2.16 Plant Observation

Plant observations are carried out as a reference for the results of an automatic irrigation system based on the Internet of Thing designed for kale plants by taking into account the height of the plants and the number of leaves on the 3rd, 6th, 9th, 12th, and 15th days.

3. Result

In this study, a drip irrigation system was used as a mechanism for providing irrigation water to plants with a driper as an emitter from which irrigation water was issued. In this design, a water reservoir with a capacity of 200 liters and a height of 1 meter is used, the reservoir is placed on an iron stand. The position of the water reservoir can be seen in Fig.

Figure 3 Results of Irrigation System Design

In this irrigation system design uses a main pipe with a size of 1 "and then forwarded to a 1" divider pipe to the selenoid valve as the opening and automatic closing then connected to a lateral pipe measuring 0.5 "and given a hole measuring 5 mm to be connected with PE hose measuring 5 mm as the connection to the emiter, in this research using a driper stick as the emitter.

The control system is a major component in this automatic irrigation system based on the Internet of Things. This system will manage all existing components. The control system consists of several main components, including:

1. ESP 8266 NodeMCU microcontroller;
2. Ground Water Content Sensor (YL-69);
3. *Relay;*
4. *Smartphone;*

5. *Breadboard.*

These components work to form a control system for the condition of the soil water content in the land to be irrigated. The sensor component will read the value of the ground water content and then input information on the microcontroller. This information input is then processed on the microcontroller which will then provide output to the Blynk application and commands to the relay. When the groundwater content is in a condition where irrigation must be carried out, the microcontroller will give a command to the relay to turn on. The results of the control system design development can be seen in Figure 4.

Figure 4 Control System Design

3.1 Manufacture of Control System Installation and Testing

3.1.1 System Power Requirements

The main components that require electrical power in the system are NodeMCU ESP 8266 and Selenoid valve. NodeMCU ESP 8266 has an input voltage limit of 3.3 volts to 5 volts. Each input and output pin requires a current of 40 mA. The total number of digital pins used is 5 pins and 1 pin analogue which is connected to a voltage of 3.3 volts so that the power required can be calculated using Equation 5.

$$Daya\ = 3{,}3\ volt\ x\ (0{,}04\ mA\ x4) = 3{,}3\ \ volt\ x\ 0{,}24\ A = 0{,}53\ watt$$

Selenoid valve requires 12 volts and a current of 0.4 amperes to turn on and in this design I use 2 Selenoid valves so that the power required can be calculated using Equation 5.

$$Daya\ = 12\ volt\ x\ (0{,}4\ Ampere\ )\ 2 = 9{,}6\ watt$$

The total power required when the total system is on is 10.13 watts. With the need for electric power of that size, I use a source of electricity from PLN by connecting the control system to the socket so that the electricity supply is maintained stable.

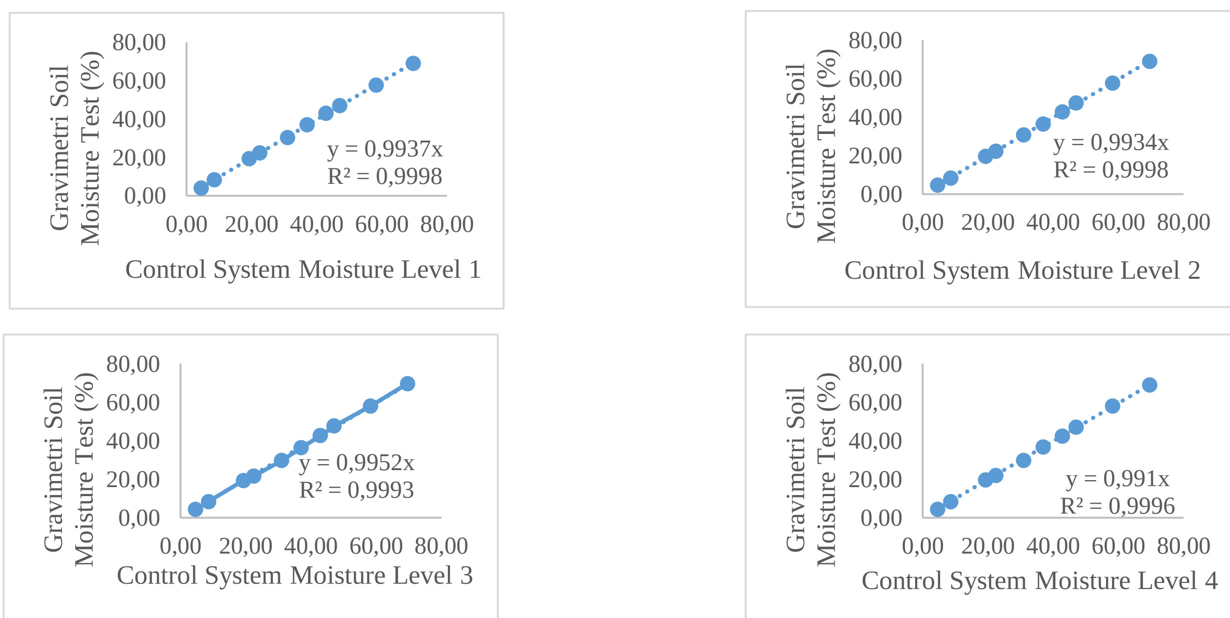
3.1.2 Sensor Calibration

The sensor readings are in the form of analog (0-1024), to change the analog value into a water percentage value, when programming on the Arduino IDE we use the map function. The map function on the Arduino IDE will convert a number in a range to another number range, in this research the map function is used to convert the sensor value into a water percentage value (Equation 6). The commands that are input on the Arduino IDE can be seen in Figure 25.

```
Blynk.run();
//Sensor 1
Serial.println("Sensor y0  ");
inputMultiplekser(0);
nilaiInput0 = analogRead(analogPin);
Serial.println(nilaiInput0);
int persentase0 = map (nilaiInput0,1024,0,0,100);
Serial.println(persentase0);
Blynk.virtualWrite (V0, persentase0);
if (persentase0 <= 25) {
  digitalWrite(relay1, HIGH);
```

Figure 5 MAP Command Program

Then the sensor calibration is carried out to ensure that the water content value read by the sensor is in accordance with the actual moisture content value carried out from laboratory tests (gravimetric test). The sensor calibration uses 10 types of variations in moisture content



Based on the results of sensor calibration data processing after testing on 10 soil samples with different moisture content can be seen in Figure 25, the results of the R^2 value are 0.9998, 0.9998, 0.9993, 0.9996, which means the comparison of the reading values by 4 sensors with measurement of levels. groundwater using the gravimetric method can be said to be accurate because it is almost close to number 1 which can be concluded that the sensor is working properly and optimally.

3.1.3 Connection to the Blynk App

NodeMCU ESP 8266 is an open source based application which can be accessed easily as an IoT platform which can be downloaded on the Google Play Store and also the App Store. After the application has been installed, we can open the Blynk App, first we have to register our account using email, this is so that Blynk can send authtoken codes and can send reading data results via email.

The first step is to connect the Blynk application using the auth token as a code to match the server used by the two components. The auth token is obtained when we sign in at the beginning of entering the Blynk application, by entering an email, Blynk will automatically send the auth token code to the email that we input which will be entered in the coding on the Arduino IDE. In addition to the auth token code, to make a connection between the microcontroller and Blynk, a WiFi connection is also needed in an area that is covered by the microcontroller. By entering the SSID and WiFi password into the coding program, the microcontroller and the Blynk app are connected with the coding as follows:

```
char auth[] = "amA0XNzZZB3O9N4vJaJ6Bw6IZS-Z01DO";
char ssid[] = "Wifi.id";
char pass[] = "MAGNUMMILD";
```

Figure 6 Connect to Wifi

After the Blynk application is connected to the Microcontroller, we have to design the user interface of the application to make it easier for the control and monitoring carried out by the Blynk application, by clicking the plus sign which functions to add a widget.The Blynk application has many control and monitoring functions that can be accessed easily, just by Drag and drop, we can determine the control and monitoring functions that you want to use. After connecting, the sensor readings will be displayed in the Blynk application, which we have previously set with the widgets that you want to use according to their respective functions. The user interface display can be seen in Figure 6

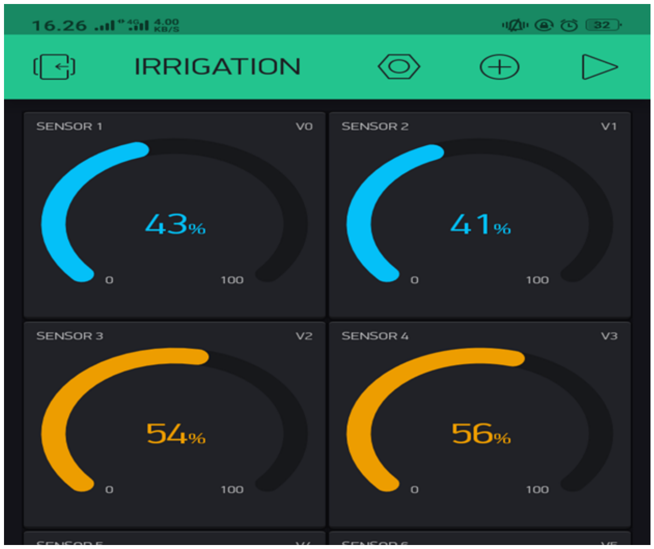
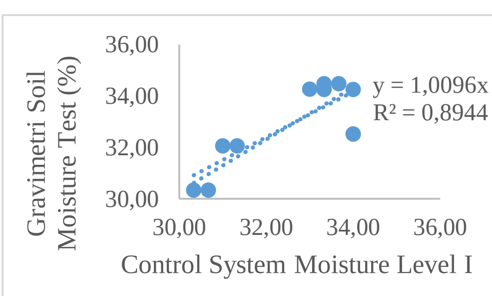


Figure 7 The Blynk App User Interface

3.1.4 Sensor Readings Accuracy

The control system is divided into two parts of the pipe, each pipe has 1 actuator, namely Selenoid valve and 2 sensors of ground water content. In each pipe, 2 sensors are installed, 1 sensor as a control reference for the automatic opening and closing of the Selenoid valve and the remaining sensors as a check unit to ensure the sensor reading value. The test of the control system was carried out for 15 days with observations every 3 days by looking at and comparing the water content data from the four sensors with groundwater content testing using the gravimetric method which was carried out in the laboratory every 3 day interval.

Soil samples were taken to be tested using the gravimetric method at 10.00 WIB when the soil was still relatively moist and not too wet, soil samples weighing 7 grams were tested using the gravimetric method to see how much water the soil contained and compared with the sensor reading data at the same time. The first observations were made on the 3rd day after the beginning of planting by looking at and comparing the soil water content data from sensor readings and groundwater content data using the gravimetric test with the following graphical results:



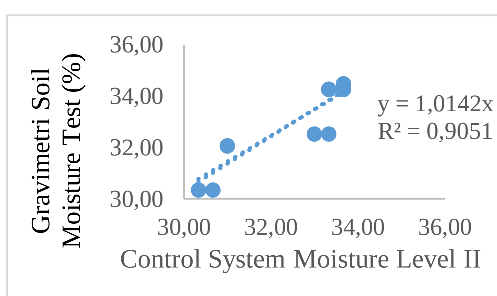


Figure 8 Graph of Comparison of Ground Water Content on Day 3

Observations made on day 3 were obtained linearly with the R^2 value in control system I and control system II being 0.8944, 0.9051 which indicates that the sensor reading data can still be said to be accurate because it is still close to 1. Further observations are made on day 6 by looking and comparing Soil water content data from sensor readings and groundwater content data using the gravimetric test with the following graphical results:

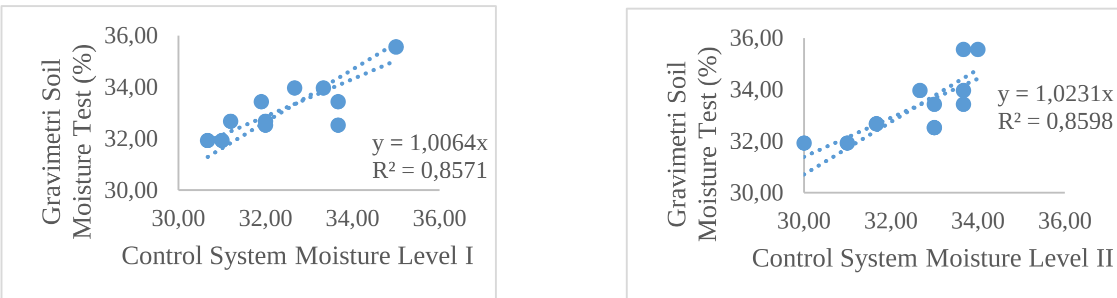


Figure 9 Graph of Comparison of Ground Water Content on Day 6

Observations made on day 6 were obtained linearly with the R^2 value in control system I and control system II being 0.8571, 0.8598 which indicates that the sensor reading data can still be said to be accurate because it is still close to 1. Further observations are made on day 9 by looking and comparing Soil water content data from sensor readings and groundwater content data using the gravimetric test with the following graphical results:

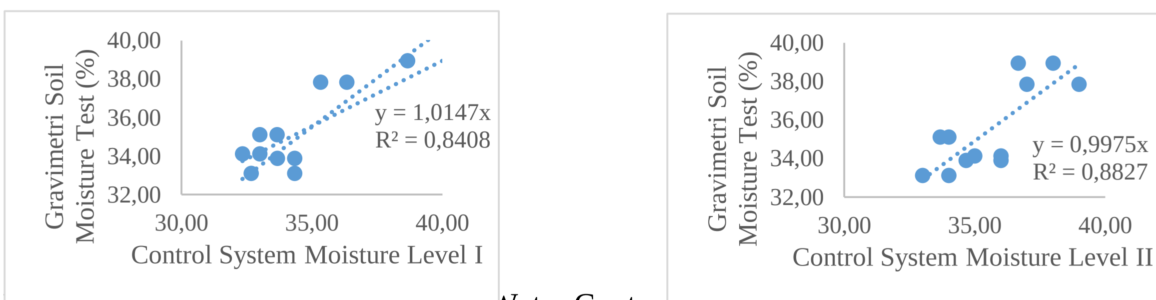
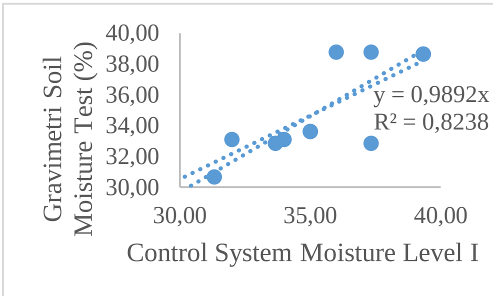


Figure 10 Comparison Graph of Soil Water Content on Day 9

The observations made on day 9 were obtained linearly with the R^2 value in control system I and control system II being 0.8408, 0.8827 which indicates that the sensor reading data can still be said to be accurate because it is still close to 1. Further observations are made on day 12 by looking and comparing Soil water content data from sensor readings and groundwater content data using the gravimetric test with the following graphical results:



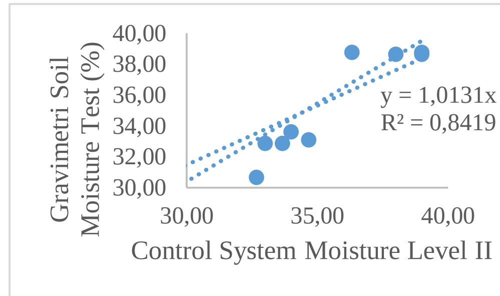
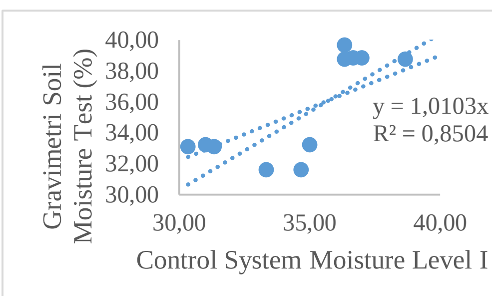


Figure 11 Comparison Graph of Soil Water Content on Day 12

The observations made on day 12 were obtained linearly with the R^2 value in control system I and control system II being 0.8238, 0.8419 which indicates that the sensor reading data can still be said to be accurate because it is still close to 1. Further observations are made on day 15 by looking and comparing Soil water content data from sensor readings and soil level data using the gravimetric test with the following graphical results:



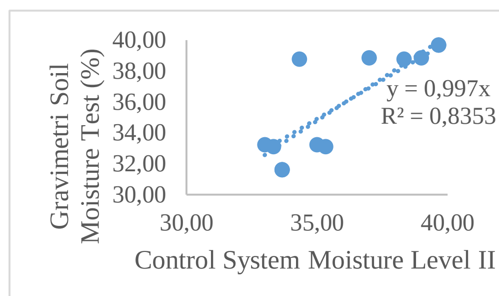


Figure 12 Comparison Graph of Soil Water Content on Day 15

The observations made on the 15th day were obtained linearly with the R^2 value in control system I and control system II being 0.8504, 0.8353 which indicates that the sensor reading data can still be said to be accurate because it is still close to 1.Based on the observations that have been made in this research, the test results regression analysis of gravimetric soil water content, the average linear regression of R2 value from control system I was 0.8533. The RMSE (Root Mean Square) test yields a value of 0.02, which means an average error value of 2%. The results of the regression analysis of the gravimetric soil water content obtained the average linear regression R2 value from control system II of 0.8739. The RMSE (Root Mean Square) test yields a value of 0.02, which means an average error value of 2%. The value of R2 is still close to number 1 which means that in the observations made for 15 days, the sensor is still working according to the codding ordered. This can be seen from the difference in the ratio of the water content value of the sensor readings with the water content value of the gravimetric test carried out in the laboratory.

In previous research, Agus Putu (2018) received an average value of R2 of 0.9121. This value is not much different from the average R2 value obtained, which means that in this study the sensor that was run for 15 days can still be said to be accurate.

3.1.5 Need for Irrigation Water

In drip irrigation, evaporation is kept as small as possible, the maximum evapotranspiration value of Padang city is 6.01 mm / day according to Andriani's (2008) research. Water content testing in the laboratory was carried out on 75 ml of soil samples in field capacity conditions and obtained an average volume-based water content of 27.34%. The water content of the permanent wilting point is taken based on the assumption that it is at 17% because the soil sample used has a sandy texture and can form soil clumps that are easily destroyed. Sandy soils have a soil water content at conditions of field capacity and permanent wilting point of 27% and 17% by volume, respectively (Schwab, 1992). Root depth is needed as a limitation for observation because irrigation orientation is limited to the depth where plant roots can absorb groundwater. In this study, it was used into the roots at 5 cm. A depth of 5 cm is considered based on plant conditions in the field.

With the known value of field capacity, permanent wilt point and root depth, the available water can be calculated based on equation 1.

$$Available\ Water = (27 - 17)/100\ x\ 0{,}05\ m = 0{,}005\ m$$

In every 0.05 meters of soil depth there is 0.005 meters or 5 mm of water available. The MAD value for kale plants is 0.3 (Saleh et al. 2017). To get the value of immediately available water (RAW) or water that must be irrigated every time irrigation takes place, it can be calculated using equation 4.

$$Readily\ Available\ Water = 0{,}3\ x\ 0{,}005\ meter = 0{,}0015\ meter$$

Immediately available water at any depth of 0.05 meters is 0.0015 meters. The land used in this study has 30 polybags with a diameter of 15 cm, if one polybag has an area of 0.0176 m2 then if 30 polybags have a total polybag area of 0.528 m2. So for all land which has an area of 0.528, the volume of water is immediately available based on equation 8.m^2

$$Irrigation\ Water\ Volume = 0{,}0015\ m\ x\ 0{,}528 = 0.00079\ m^2 m^3$$

The total volume of water available for plants during one irrigation activity is 0.00079 or 0.79 liters.m^3

3.1.6 Flow Rate

The system uses a head that comes from a reservoir that is placed at a height of 2 meters from the end of the tap. The tip of the tap is capable of dispensing 1 liter of water in 18 seconds so that the flow rate can be calculated using Equation 9.

$$Flow\ Rate = \frac{1\ liter}{9\ Sec} = 0{,}0555\ liter\ per\ Sec$$

From the above calculations, the irrigation water flow rate is 0.0555 liters in 1 second. The flow rate is needed to calculate the solenoid valve life time.

3.1.7 Selenoid Valve Life Time

The life time of the solenoid valve can be divided into two criteria, namely how long the solenoid valve should live and when the solenoid valve should be on. How long the solenoid valve will live will determine the volume of water that is channeled into the land and when the solenoid is alive determines the accuracy of the irrigation schedule. The lifespan of the solenoid valve can be seen in Table 1.

Table 1 Solenoid Valve Life Time Calculation

IrrigationVolume (Liter)	Time1 liter (Seconds)	Irrigation flow rate (L / Second)	TotalTime (seconds)
0.79	18	0.0555	14.3

Based on the table above, it can be determined that every time the irrigation is done, the solenoid valve will live for 14.3 seconds. The command setting in the program is needed so that the solenoid valve can open at the desired water content and can be open for 14.3 seconds.

When the solenoid valve should turn on is determined taking into account the lower limit of water content as the lower limit of the control system operation. Based on the MAD value, the lower limit of the system's work in percent value is obtained through the following equation:

$$Lower\ Limit = FC - \left((FC - PWP)\ 0{,}3\right)$$

$$= 28\% - \left((28\% - 18\%)0{,}3\right)$$

$$= 28\% - 3\%$$

$$= 25\ \%$$

The lower limit is used to determine the start of the system per period. If the groundwater condition reaches 25% or 452 in the form of an analog signal, the system is instructed to turn on the selenoid valve so that irrigation can occur. The command added to Arduino can be seen in Figure 13.

```
if ((analogRead(A3) > 452) & (pirState == LOW)) {
  digitalWrite(relayPin, LOW);
  startMillis = millis();
  pirState = HIGH;

}
```

Figure 13 ESP 8266 NodeMCU Program

3.1.8 Irrigation Water Pressure

The drip irrigation system does not require too much pressure, this time the irrigation system utilizes hydrostatic pressure as a source of water pressure by utilizing the position of the water reservoir that is above its seat as high as one meter, and the height of the water reservoir is also 1 meter high. If the water reservoir is full, the water will be 2 meters above the ground. The total water pressure can be calculated using the equation.

P = 1000 kg / m3 x 9.8 m / s2 x 2m

= 19,600 pascals

= 2.84 psi

3.1.9 Plant Observation

Plant observations were carried out at intervals of 3 days once every 15 days to see the growth in height and number of kale leaves planted in polybags, the average yield value can be seen in Figure 14 and Figure 15.

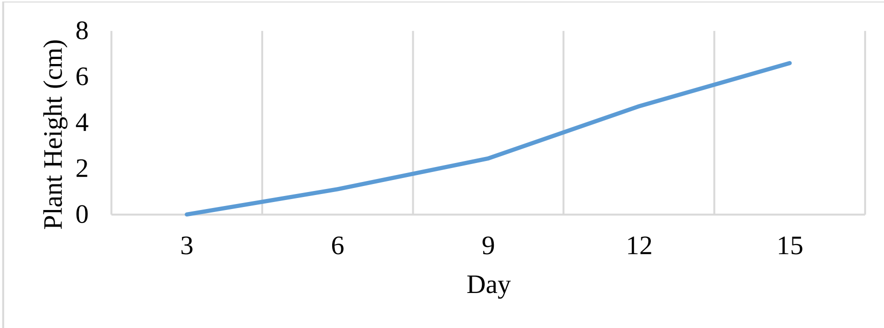


Figure 14 Graph of Observation of Plant Height Average Value

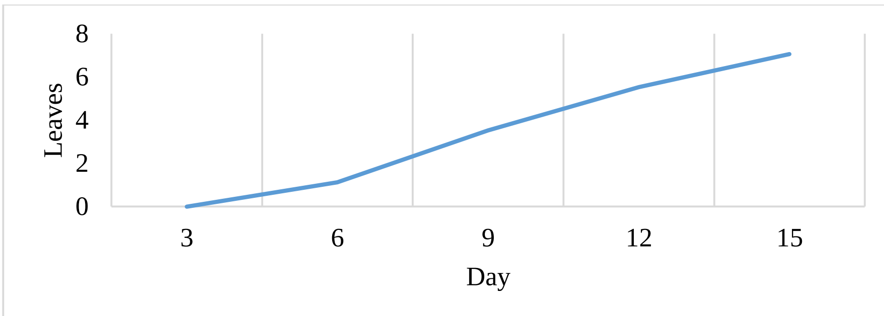


Figure 15 Graph of Observation of Plant Height Average Value

In previous research, Bejo Suroso (2015) found an average plant height growth value of 8 cm and an average number of leaves of 7 leaves for 15 days. In this research, it was found that the average plant height value on the 15th day was 7 cm high and the average number value in the plant was 8 leaves. This shows that there is a normal growth of water spinach because there is no significant difference. So it can be concluded that the automatic irrigation system used does not interfere with plant growth.

4. Conclusions And Suggestions

4.1 Conclusion

Based on the research that has been done, it can be concluded that:

1. The sensor readings are close to the real value with an average error value of less than 2%;
2. The irrigation system is live when the water content is at 25%;
3. The Internet of Things-based automatic drip irrigation system can perform irrigation based on groundwater conditions;

4. Monitoring and control of the irrigation system can be carried out using a smartphone connected to the internet so that monitoring can be done online;
5. The irrigation system built does not interfere with plant growth;

4.2 Suggestion

In order to develop the research that has been done, the authors suggest:

1. Adding other sensor components so that irrigation can be done more optimally;
2. Paying attention to the state of the sensor by regularly checking its condition periodically so that the sensor readings remain accurate;
3. Paying attention to plant conditions by estimating all aspects of agricultural activities so that plants can grow more optimally;
4. The use of drip irrigation can be done in conjunction with fertilization so that crop yields are more optimal;

5. Refference

[1] Aiswarya, L. 2019. *Estimation of Actual Crop Evapotranspiration of Green Chilli in Semi-Arid Region under Different Atmospheric Condition.* Agricultural Engineering College and Research Institute. India

[2] Agus, Putu. 2018. *Perancangan Sistem Irigasi Automatis dengan Sensor Resistif Berbasis Kadar Air Tanah pada Tanaman Rukola (Eruca sativa).* Program Studi Teknik Pertanian. Fakultas Teknologi Pertanian. UNUD. Bali

[3] Anonim. 2011. *Watering With Soil Moisture Sensors.* Baseline Inc

[4] Budiharto, Widodo. 2005. *Perancangan Sistem dan Aplikasi Mikrokontroler*. Jakarta. Media Komputindo.

[5] Baseline Inc. 2011. *Tekstur Tanah.* http://www.geologinesia.com (di akses 25 Februaru 2020)

[6] Dadang, Ridwa. 2013. *Model Jaringan Irigasi Tetes Berbasis Bahan Lokal Untuk Pertanian Lahan Sempit.* Balai Irigasi. Jakarta

[7] Few, Stephen. 2006. *Information Dashboard Design*. O’Reily;ISBN:0-59610016-7.

[8] IEEE. 2014. *Internet Of Things* (IoT). Technology and Field

[9] Indo ware., 2015, *Soil Moisture sensor*, http://indo-ware.com/produk-284moisture-sensor-.html , diakses pada 25 Februari 2020

[10] James, Larry G. 1988. *Principles Of Farm Irrigation System Design*. Washington State University. United State

[11] Kartasapoetra, A. G dan Sutedjo, M. M. 1994. *Teknologi Pengairan Pertanian (Irigasi).* Jakarta. Bumi Aksara.

[12] Kurniawan, Doni. 2018. *Implementasi Internet of Things pada Sistem Irigasi Tetes dalam Membantu Pemanfaatan Urban Farming.* Universitas Trilogi Jakarta

[13] Malik, Shadan. 2005. *Enterprise Dashboards – Design and Best Practices for IT*. John Wiley & Sons, Inc

[14] Muhammad, Reza. 2019. *Prototype Pintu Air Irigasi Otomatis Berdasarkan Level Kadar Air Tanah Berbasis Mikrokontroler*. Universitas Andalas. Padang.

[15] Rajeev Piyare, Seong Ro Lee. 2013. *Board NodeMCU*. Jakarta

[16] RanjaniP. Roopa & Gvnsk Sravya. 2018. *IOT Based Smart Irrigation System*. Institute of Technology and Science. Hyderabad

[17] Ridwan, Dadang. 2013. *Model Jaringan Irigasi Tetes Berbasis Bahan Lokal Untuk Pertanian Lahan Sempit.* Balai Irigasi, Jakarta

[18] Saleh,T., Sumon, D., Jacob, S. 2017. *Understanding Soil Water Content and Thresholds for Irrigation Management.* Oklahoma State University. Amerika Serikat.

[19] Santoso, Digdio. 2010. *Sensor Kapasitif* di www.academia.edu. (diakses 22 Februari 2020)

[20] Sapei, Asep. 2006. *Irigasi Tetes.* IPB. Bogor

[21] Schwab, Glenn O. 1992. Soil and Water Conservation Engineering. Wiley, Inc. Kanada

[22] Siebert, S., & Döll, P. 2010. *Quantifying blue and green virtual water contents in global crop production as well as potential production losses without irrigation.* Journal of Hydrology, 384(3), 198–217.

[23] Sirait, Sudirman, Maryati, Sri. 2018. *Sistem Kontrol Irigasi Sprinkler Otomatis Bertenaga Surya di Kelompok Tani Kecamatan Meureubo Kabupaten Aceh Barat.* Aceh. Jurnal Irigasi PU, 13(1), 55-56.

[24]Teknik Elektronika., 2015, *Pengertian dan Fungsi Relay*,http://teknikelektronika.com/pengertian-Relay-fungsi-Relay/, diakses pada 20 Februari 2020