Soil Moisture Monitoring System Applied to the Internet of Things (IoT) Based Automatic Watering Equipment in Papaya Fields

Lola Adetia*, Sri Wahyu Suciyati, Amir Supriyanto, and Gurum Ahmad Pauzi

Department of Physics, University of Lampung, Bandar Lampung, Indonesia, 35141

Article Information	Abstract
	In this research, the design of an automatic plant watering device and a real-time soil moisture monitoring system was realized in an internet of things (IoT) based papaya farm. The design of this automatic plant watering device aims to create an automatic plant watering system using the FC-28 sensor and a monitoring system using the Blynk application on papaya fields. In the system, the microcontroller used is an Arduino UNO with outputs, namely a dc pump, 16X2 LCD, and Blynk application. Based on the android interface app, the Blynk app can monitor the soil moisture value in real-time every 1 second. Data collection was done by measuring the moisture value in 3 papaya farms with different crop ages, and the tool will water when the soil moisture value read by the sensor is> 350 or <65%. Based on the study results, the device can run well, as shown by the pump can water when the soil moisture value is> 350 or <65 %, and the pump will stop when the soil moisture value is <350 or > 65%.

Informasi Artikel	Abstrak
	Pada penelitian ini telah direalisasikan rancang bangun alat penyiraman tanaman otomatis dan sistem monitoring kelembaban tanah secara real time pada lahan pepaya berbasis internet of things (IoT). Rancang bangun alat penyiraman tanaman otomatis ini bertujuan untuk membuat sistem peyiraman tanaman otomatis menggunakan sensor FC-28 dan sistem monitoring menggunakan aplikasi blynk pada lahan pepaya. Pada sistem, mikrokontroler yang digunakan yaitu arduino UNO dengan output yaitu pompa dc, LCD 16X2 dan aplikasi blynk. Pengambilan data dilakukan dengan mengukur nilai kelembaban pada 3 lahan pepaya yang berbeda usia tanam, alat akan melakukan penyiraman ketika nilai kelembaban tanah yang terbaca oleh sensor sebesar >350 atau <65%. Berdasarkan hasil penelitian, alat dapat berjalan dengan baik ditunjukkan dengan pompa dapat menyiram ketika nilai kelembaban tanah >350 atau <65% dan pompa akan berhenti ketika nilai kelembaban tanah <350 atau >65%. Berdasarkan aplikasi antarmuka android, aplikasi blynk dapat melakukan monitoring nilai kelembaban tanah secara real time tiap 1 detik.

1. Introduction

Papaya is a plant that comes from Southern Mexico. Papaya plants are easy to cultivate, so they are widely found in various countries such as Central and South America, North Africa, Hawaii, India, Indonesia, Malaysia, Thailand, and Sri Lanka (Sujiprihati & Suketi, 2019). Papaya plants consist of several types including Bangkok papaya, F1 solo papaya, Calina papaya (California), mountain papaya, and ornamental papaya (Sofiana, 2016) . The manufacture of papaya requires superior varieties and quality seeds, such as the Calina IPB 9 papaya or California papaya (Ardiansyah, 2020). Papaya plants can grow in the tropics, lowlands, and highlands, namely at an altitude of 1000 m above sea level and have a temperature of 24°C to 25°C, with a soil pH of 6.0 for dry soil irradiated by direct sunlight. (Sugito and Edy, 2017).

----
* Corresponding author.
E-mail address: lolaadetia2@gmail.com

64

Adetia et al., 2022/ *J. Energy Mater. Instrum. Technol. Vol. 3 No. 2, 2022*

With where to grow papaya plants, it is necessary to know the characteristics of the soil to improve the quality of papaya plants. The high level of soil fertility is indicated by the quality of the soil and the availability of sufficient water so that an increase in plant productivity can be realized. In addition to supporting plant growth, good soil quality can also regulate and distribute water flow equality and protect the environment (Juarti, 2016). Soil moisture is vital in the plant growth process, with a soil moisture range of 300% - 700% (Fahrurrozi & Nuraharjo, 2020). Soil moisture below this value causes plants to wither and even die from drought (Yahwe et al., 2016).

One of the factors that affect soil moisture is the water content in the soil. The watering process can meet these factors. Watering is one of the treatment processes for plants to maintain water content in the soil as a source of food for plants. Manually watering plants is less efficient for farmers in terms of time and energy for large-scale agriculture, so this study seeks to minimize it by monitoring soil moisture as an indicator for automatic watering. This system is equipped with Internet of Things (IoT) technology to monitor soil moisture conditions as the basis for activating the watering pump. The process of watering plants is carried out automatically based on information from the input voltage that has been converted to the value of soil moisture.

This research will create an automatic plant watering device and a soil moisture monitoring system based on the explanation above. The input section consists of an FC-28 sensor that detects soil moisture value. The input from the sensor will then be processed by Arduino Uno to be communicated serially with the ESP8266 Wifi module so that it produces output in the form of a visual display on a 16X2 LCD, relay, and pump. Then Arduino will send data via the internet or Wifi to the Blynk application.

2. Research methods

The tools and materials used in this research are a laptop, Arduino uno, 12V 5A adapter, ESP8266, 16X2 LCD, soil moisture sensor FC-28, relay, water pump, USB type B standard cable, jumper, bucket, PVC, Arduino IDE, Blynk, fritzing and Android.

2.1 Overall Tool Design

The tool's design consists of 3 parts, namely input, process, and output. The input section contains an FC-28 soil moisture sensor that detects soil moisture. The process section, Arduino UNO, works as an input data processor and produces output data directed to a relay to drive the pump, a 16x2 LCD for data display in the toolbox, and an ESP8266 Wifi module to send data to the Blynk application. System planning block diagram in **Figure 1**.
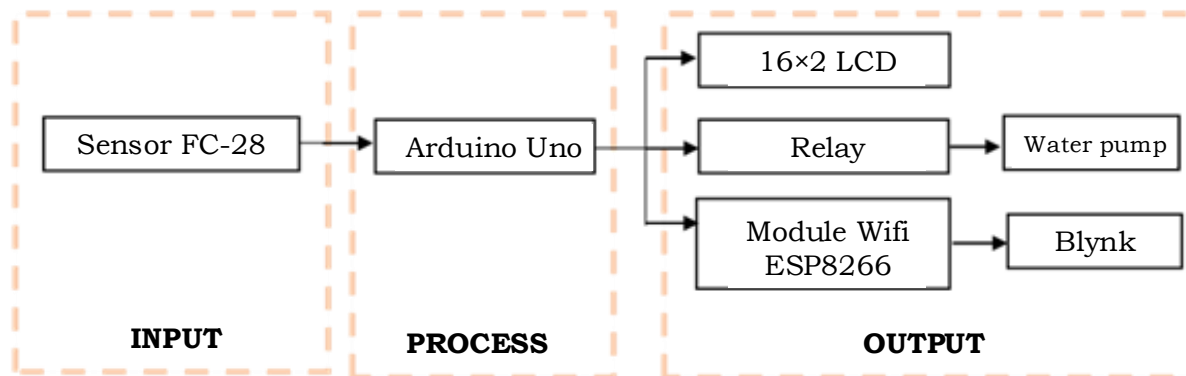

Figure 1. System planning block diagram

The working principle of the tool is based on information on the detection of soil moisture sensor FC-28 which is plugged into the soil around the papaya plant. The sensor detection data is then sent to Arduino via cable media to be read and processed for conversion and displayed on the Arduino IDE serial monitor. This data process is divided into two categories. First, when the FC-28 soil moisture sensor value is >350 or <65% or the soil is dry, the relay will drive the pump, and watering occurs. Second, the pump will stop watering when the sensor value is <350 or >65% or the soil is moist. In addition to driving the relay, the output of this sensor also displays the humidity value on the 16x2 LCD. It displays the sensor value data that is read to the Blynk application in real-time via the internet/Wifi. The Blynk application monitors the soil moisture value system on papaya land through Android. The complete series of watering tools can be seen in **Figure 2, which was made using the** fritzing device application.
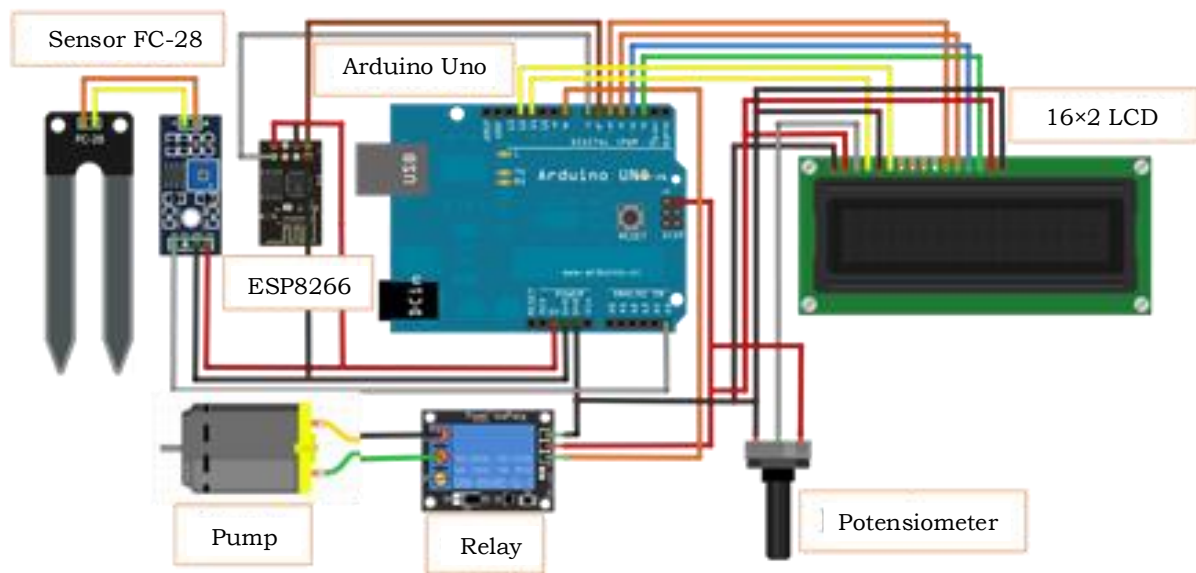
Figure 2. The whole series of tools.

Based on the circuit in **Figure 2,** the Arduino microcontroller uses nine digital pins, one analog pin, 2 VCC, and 2 GND. The FC-28 sensor is connected to pins A0, VCC, and GND. The ESP8266 wifi module is connected to VCC, GND, TX (D6), RX (D7), and pins 5 and 7 on the ESP8266 are connected. Then the relay is connected to pin D(8), VCC, and GND, then NO is connected to the negative of the pump, and COM is connected to the negative of the adapter. The positive part of the pump is connected to the positive of the adapter, and the negative of the pump is connected to the NO relay. Then connect the 16-pin LCD with Arduino and potentiometer, pin rs with D(12), pin en with D(11), pin d4 with D(5), pin d5 with D(4), pin d6 with D(3), pin d7 to D(2). GND, E, and cathode are connected to Arduino GND, then VCC and anode are connected to Arduino VCC, and VEE is connected to pin 2 of the potentiometer. The design of the automatic plant watering device is shown in **Figure 3.**
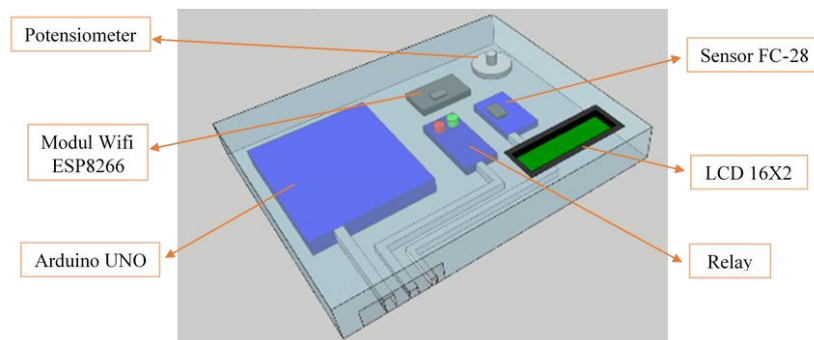

Figure 3. Tool design design

Based on **Figure 3,** the box used is 19 cm x 13.5 cm x 13.5 cm and made of acrylic. At the top of the box, there is a 16X2 LCD that functions to display the soil moisture value. Inside the box are an Arduino UNO and an ESP8266 Wifi module that functions as a processor. Then the relay functions as a switch to turn on the pump. Furthermore, the soil moisture sensor functions to read the soil moisture value.

3. Results and Discussions

3.1 System Design Implementation

The instrumentation system for watering plants and a monitoring system for soil moisture in papaya fields have been realized with the results shown in **Figure 4.** The components contained in this tool include Arduino UNO, ESP8266 Wifi module, FC-28 soil moisture sensor, 16X2 LCD, and potentiometer. The box used in this tool has 19 cm x 13.5 cm x 13.5 cm and is acrylic. Before this tool is realized, first, the characterization of the FC-28 sensor is carried out. This characterization is carried out to ensure the sensor works well in terms of linearization, accuracy, and precision.

66

Adetia et al., 2022/ *J. Energy Mater. Instrum. Technol. Vol. 3 No. 2, 2022*
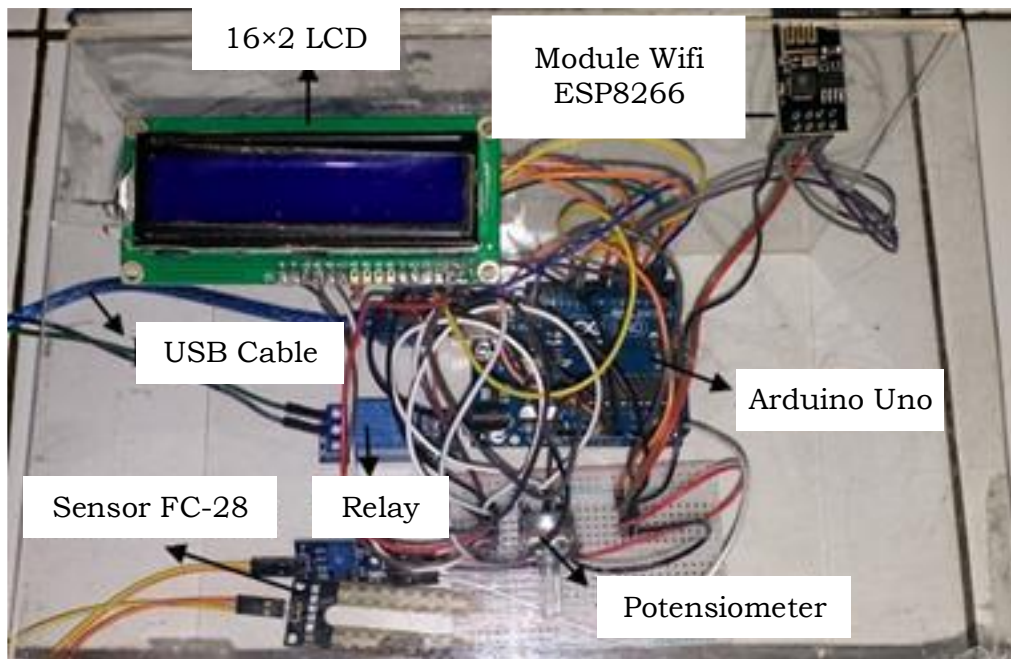
Figure 4. Realization of plant watering tools

In this study, the principle of a closed-loop control system is applied with the output signal affecting the control process (Andrizal & Yendri, 2017). The closed-loop control system consists of input, controller, plant, feedback, and output parts. **Figure 5** shows the block diagram of a closed-loop control system.

.
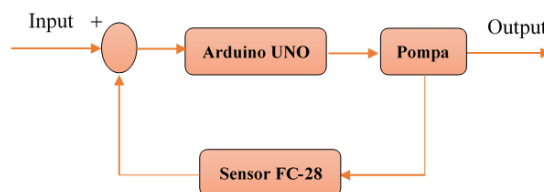
Figure 5. Block diagram of a closed-loop control system (Erinofiardi et al., 2012).

In this closed-loop system, there is an input of soil moisture value, Arduino UNO as controller, pump as plant, with feedback, namely FC-28 sensor, and produces soil moisture value output. The soil moisture output value is used to determine the input to the pump or plant.

3.2 FC-28. Soil Moisture Sensor Testing

The FC-28 sensor has an analog output, so it needs to be converted by Arduino Uno. The characterization of the FC-28 sensor was carried out using a calibrated soil moisture meter (HTC-2). The testing process was carried out in papaya fields by comparing the value read by the FC-28 sensor with the value of the soil moisture meter, as shown in **Figure 6.**
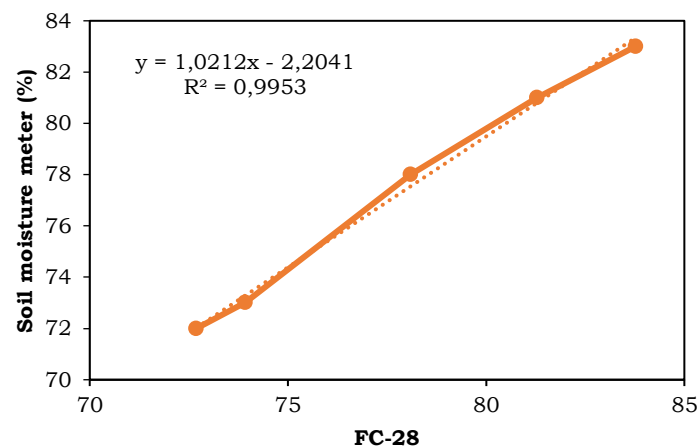

Figure 6. Testing soil moisture on the FC-28. sensor

The mechanism for testing the FC-28 sensor is by plugging the sensor into the soil, and there is already a comparison measuring instrument (HTC-2) used to measure the value of soil moisture. The test was carried out on five different papaya tree fields. This measurement was repeated five times so that the results of the FC-28 sensor soil moisture measurement on the measuring instrument were shown in **Table 1.**

Table 1. The results of measuring soil moisture from the FC-28 sensor on measuring instruments

No	Measuring instrument	FC-28. Sensor					average	Accuracy (%)	Precision (%)
		1	2	3	4	5			
1.	72	72.83	72.92	72.73	72.53	72.43	72.69	99.04	100.00
2.	73	73.12	73.8	74.1	74.19	74.39	73.92	98.74	100.00
3.	78	77.52	77.91	78.1	78.98	78.01	78.1	99.57	99.99
4.	81	81.82	81.23	81.33	81.04	81.04	81.29	99.64	100.00
5.	83	83.77	84.16	83.77	83.58	83.58	83.77	99.07	100.00
AVERAGE								99.21	100.00

Based on the data obtained, a graph of the results of the FC-28 sensor characterization was made on the soil moisture measuring instrument, which is shown in **Figure 7.**

Figure 7. Graph of soil moisture measurement on the FC-28 sensor against the HTC-2. measuring instrument

The results of soil moisture measurement using the FC-28 sensor on the soil moisture measuring instrument shown in **Figure 7** show a very linear value with R2 of 0.9953 and a gradient value close to one. These values indicate a strong relationship between the FC-28 and the HTC-2 gauge. Based on the data obtained from the test results, calculate the percentage value of error (error), accuracy, and precision using **Equation 1, Equation 2, and Equation 3** where Y = reference parameter value, X_n = nth measured parameter value, $\overline{X_n}$ = average parameter value measured nth.

$$\text{Errors} = \left| \frac{Y - X_n}{Y} \right| \times 100\% \tag{1}$$

$$\text{Accuracy} = \left[1 - \left| \frac{Y - X_n}{Y} \right| \times 100\% \right] \tag{2}$$

$$\text{Precision} = \left[1 - \left| \frac{X_n - \overline{X_n}}{X_n} \right| \times 100\% \right] \tag{3}$$

Based on the calculations, the average accuracy value for the soil moisture sensor (FC-28) is 99.21%, the average precision value is 100%, and the average error value is 0.78%. This shows that the soil moisture sensor (FC-28) has a high accuracy level, so it can be applied to calculate soil moisture value in papaya fields.

3.3 Android Interface Application Testing

The android interface application used is the Blynk application. Blynk monitors sensor readings or soil moisture values of papaya land. The Blynk application can be downloaded via the play store. The Blynk application can run

68

Adetia et al., 2022/ *J. Energy Mater. Instrum. Technol. Vol. 3 No. 2, 2022*

if there is an internet connection (mobile hotspot) or Wifi. In programming, enter the auth token sent by Blynk via email, then enter the Wifi name and password. When Arduino UNO is connected to Wifi, Arduino UNO can directly send data to the Blynk application. The monitoring system created can be accessed using other androids by scanning the barcode on the Blynk application.

Testing the Blynk application is carried out to determine whether the Internet of Things (IoT) system that has been created can run well and receive data in real-time. Testing the data transmission rate to the Blynk application is also carried out by comparing the time indicated on the super-chart in the Blynk application with the time in the Digital Clock application, as shown in **Figure 8.**
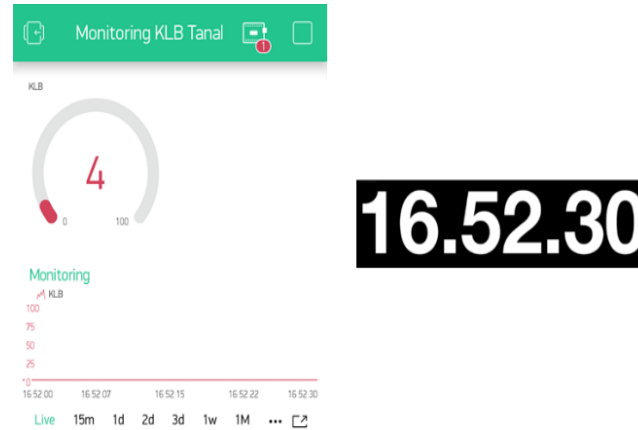

Figure 8. Display of Blynk application and application Digital Clock

In the display of the blynk application using the Widget Gauge and superchart, which can be purchased on the Widget Box menu. Figure 8 shows the blynk application and the Digital Clock application display. Based on **Figure 8,** the time shown by the superchart on the blynk application is 16.52.30, and the time displayed by the digital clock application is 16.52.30. So that the data obtained for five repetitions is shown in **Table 1.**

Table 2 Table of time testing of the Blynk application against the Digital Clock application

Digital Clock	Blynk
16:52:30	16:52:30
16:52:31	16:52:31
16:52:32	16:52:32
16:52:33	16:52:33
16:52:34	16:52:34

Based on the data obtained, a graph of the results of testing the Blynk application against the Digital clock application is made, shown in **Figure 9.**
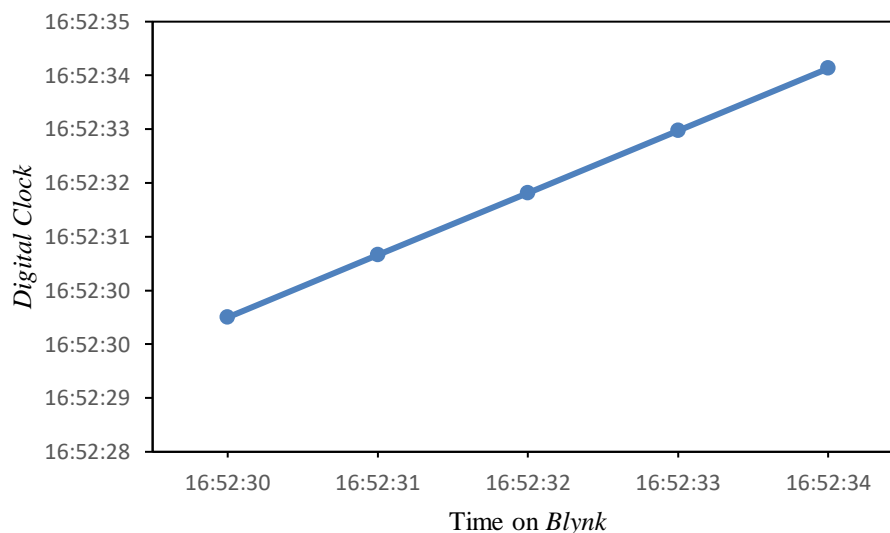
Figure 9. Graph of time testing on the Blynk application against the digital clock application

Based on the graph, it can be seen that the time listed on the Blynk application corresponds to the time stated on the Digital Clock application so the Blynk application can be used for a monitoring system for soil moisture values in papaya fields in real-time.

3.4 Data Collection and Analysis

Data collection for implementing the tool is carried out in papaya fields by placing the hardware system in the specified place. In general, the data collection is shown in **Figure 10.**

Figure 10. System implementation on papaya land

The soil moisture needed for papaya plants is 66% (Muktiani, 2011), and the lack of moisture in the soil makes the plants wilt and even die (Yahwe et al., 2016). This humidity value becomes the basis for setting the sensor and relay performance limits to activate the pump. When the sensor reads the soil moisture value >350 or <65%, the relay automatically turns on the pump, and when the soil moisture value is <350 or >65%, the relay automatically turns off the pump.

Figure 10 also shows an automatic plant watering system, and watering is carried out using a 12V 3A dc pump connected to a 12V 3A adapter as a voltage source. The water used is in a bucket and will be channeled through a PVC with a length of 190 cm and 130 cm, which has been perforated in 4 equal parts with a distance to the sensor of 60 cm for trees one and tree 2 and 50 cm for tree 3. measuring the soil moisture of papaya land on three trees with different growth periods, namely, newly planted trees, trees leading to fruiting and trees that are already fruiting. The papaya land used has an area of 200 x 200 cm.

The sensor will send data in the form of a 16X2 LCD for the monitoring system and send data to the interface application, namely the Blynk application, in real-time. The following is a program used to display data to a 16X2 LCD.

```
#include <LiquidCrystal.h>

const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

lcd.setCursor(0, 0);
lcd.print("KLB : ");
lcd.print(klbtanah);
lcd.print(" % ");
delay (1000);
```

The above program is used to initialize the 16X2 LCD to be able to receive sensor data. The programming explains that the 16X2 LCD pins are connected to the Arduino UNO pins, namely const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2; then display the value on the 16X2 LCD with the command lcd.print("KLB : "); with a repetition interval of 1000 ms. Based on the program that has been made, the results of soil moisture measurements on a 16X2 LCD are displayed, as shown in **Figure 11.**

70

Adetia et al., 2022/ *J. Energy Mater. Instrum. Technol. Vol. 3 No. 2, 2022*

Figure 11. Display of soil moisture value on LCD

Based on the value seen on the LCD, the soil moisture value is 62%. The data sent to the LCD will be updated with an interval of 1 second during the data retrieval process. It can also see the program used to send data to the Blynk application.

```
#define BLYNK_PRINT Serial
#include <ESP8266_Lib.h>
#include <BlynkSimpleShieldEsp8266.h>

char auth[] = "MEOXCJ5AInx9tbIVFk5IFUALdYVFMhFQ";
char ssid[] = "Lola";
char pass[] = "adetiaaa";

#include <SoftwareSerial.h>
SoftwareSerial EspSerial(7, 6 ); // RX, TX
#define ESP8266_BAUD 9600
ESP8266 wifi(&EspSerial);
BlynkTimer timer;

void setup(){
 Serial.begin(115200);
 delay(1000); EspSerial.begin(ESP8266_BAUD);
Blynk.begin(auth, wifi, ssid, pass);
timer.setInterval(1000L, myTimerEvent);
}

void loop()
{
 Blynk.run();
 timer.run();
}
void myTimerEvent()
{
 int klb = random(0,100);
 Blynk.virtualWrite(V1, klb);
}
```

The above program initializes the Blynk application as an interface to receive data based on random values. In programming, enter the auth token sent by Blynk via email, then enter the wifi name and password. The RX TX pins are connected to pins D(7) and D(6) and use a baud rate of 115200. The process of sending data to the Blynk application with a repetition interval of 1000ms. The results of monitoring soil moisture values in the Blynk application can be seen in **Figure 12.**
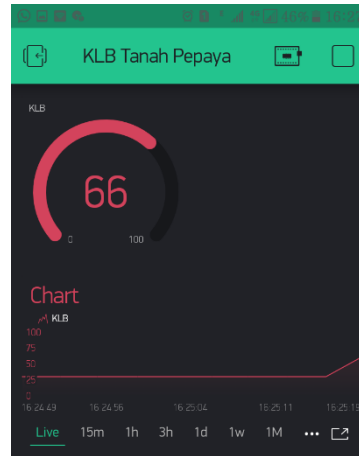

Figure 12. Display of soil moisture value in the Blynk application.

Figure 12 is a display of soil moisture values in the Blynk application. The display on the Blynk application contains Gauge and Super-chart with a value range of 1-100. The data retrieval process shows that the Blynk application can receive data every 1 second, and on the graph, it is displayed every 8 seconds. Based on the monitoring results, the data obtained from monitoring soil moisture are shown in **Table 3.**
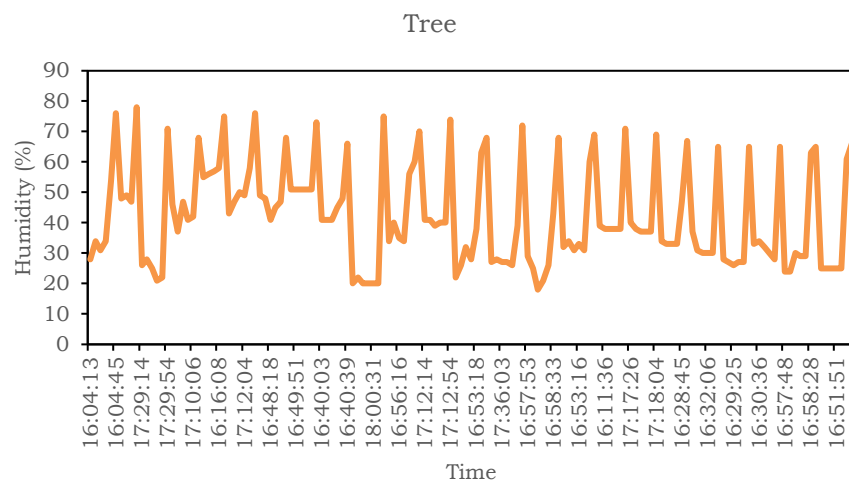
Table 3. Results of monitoring tree soil moisture 1

| Time	Humidity (%)	Pump
27-09-21 15:53:55	40	ON
27-09-21 15:54:03	36	ON
27-09-21 15:54:05	42	ON
27-09-21 15:54:11	46	ON
27-09-21 15:54:27	73	OFF
27-09-21 15:54:28	76	OFF

The data in **Table 3** results from monitoring the soil moisture value of tree one on September 27, 2021. The data collection process was carried out in Air Kubang Village, Airnaningan District, Tanggamus Regency, for 30 days from September 27, 2021, to October 26, 2021, and was carried out every afternoon with an interval of 1 second until the watering was process stops. Data collection was carried out by measuring the soil moisture of papaya land on three trees with different growth periods: newly planted trees, trees leading to fruiting, and trees that were already fruiting. Based on the data obtained, a graph of the soil moisture value against time is made, as shown in **Figure 13, Figure 14,** and **Figure 15.**

72

Adetia et al., 2022/ *J. Energy Mater. Instrum. Technol. Vol. 3 No. 2, 2022*

Tree Soil Moisture 1
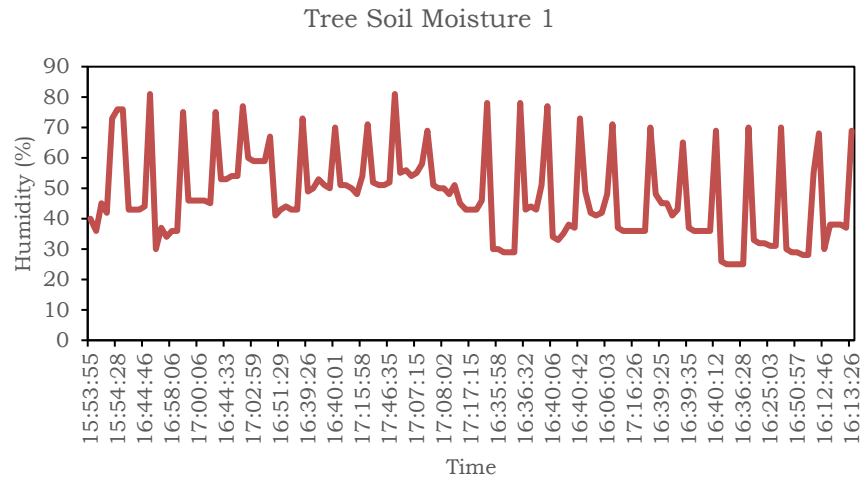
Figure 13. Graph of Soil Moisture with Time on Tree 1

Tree

Figure 14. Graph of Soil Moisture with Time on Tree 2

Tree Soil Moisture 3
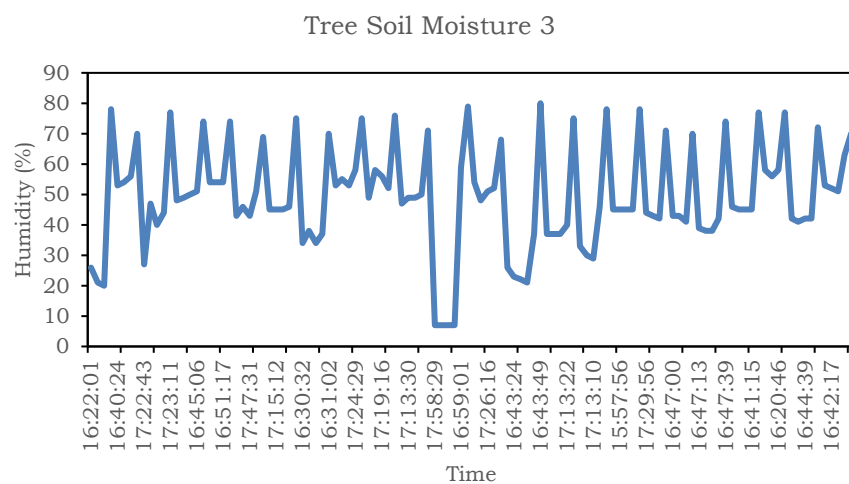
Figure 15. Graph of Soil Moisture against Time on a 3 Tree

In **Figure 13, Figure 14,** and **Figure 15,** the soil moisture value of papaya land can is seen against time. In **Figure 13,** or tree soil moisture, the value of soil moisture at the initial watering condition for one month ranges from 25%-58% with the pump OFF condition. Soil moisture with the driest initial conditions is on October 25, 2021,

which is 25%. For the value of soil moisture in a wet state, which is 65%-81% with the pump ON condition. The length of watering time ranges from 27 seconds to 42 seconds on the pump with the ON condition.

In **Figure 14,** the initial watering conditions for one month have soil moisture values for pump OFF conditions ranging from 18%-55%. On October 13, 2021, the soil moisture value in the driest condition was 18%. The value of wet soil moisture for pump OFF conditions is in the range of 65%-78%. In tree 2, the pump is in the ON condition, with the watering time ranging from 28 to 44 seconds.

In **Figure 15,** the watering process for one month has the initial conditions of soil moisture values ranging from 7%-58% for the pump in the OFF condition. In a wet state for one month, the humidity value ranges from 68%-80 % for the pump in the ON condition. In tree 3, there is a soil condition with the driest moisture value on October 10, 2021, with a value of 7%. Because, on that date, the farmer was plowing the papaya land, a new tree was planted, namely on these three trees. On the same day, the weather conditions were hot, so the ground was in a dry condition, different from the conditions above. However, after the watering process, the soil conditions on tree 3 are normal because, in tree 3, the soil is more friable than the soil conditions for tree one and tree 2. The length of time for watering for one month for tree 3 with the pump in the ON condition ranges from 21 to 36 seconds.

Based on the results obtained from the hardware and software system that has been made, it can maintain soil conditions on papaya land so that it does not dry out, and the value of soil moisture can be known through monitoring applications in real-time. The three types of papaya soil used for the watering process and data collection had different soil conditions. Trees 1 and 2 have large trees and roots, so they need a longer watering time, while tree 3, trees and roots are still small, so watering is not too long, and the soil is loose because farmers still often do plowing. Loose soil conditions facilitate the spread of water in the soil. Usually, soil moisture is still within the allowed limits.

4. Conclusions

Based on the hardware and software system that has been created, it can make it easier for farmers or papaya land owners to carry out the process of watering plants automatically and monitoring the value of soil moisture in papaya fields. The realization of the design of an automatic plant watering device and a real-time soil moisture monitoring system in papaya land based on the Internet of Things (IoT) can run well, as indicated by the pump flushing when the soil moisture value is >350 or <65% and the pump stops when the soil moisture <350 or >65%. Based on the interface application for the soil moisture monitoring system in papaya fields, the data soil moisture sensor sends data to the Blynk application in real-time every 1 second. Based on the test results of the FC-28 soil moisture sensor, the average error value is 0.78%, the average accuracy is 99.21%, and the average precision is 100%, so it can be applied to measure the soil moisture value in papaya fields.

5. Bibliography

Andrizal, & Yendri, D. (2017). Pengendali Pompa Pengisi Galon Air Berbasis Sensor Waterflow dan Mini PC. *Jurnal Resti, 1*(2), 106–113.

Ardiansyah, M. (2020). Keuntungan Usaha Budidaya Pepaya Calina IPB 9 di Kecamatan Penyambungan Barat Kabupaten Maindailing Natal Provinsi Sumatera Utara. *Jurnal Inovasi Penelitian, 1*(4), 779–812.

Erinofiardi, Supriandi, N. I., & Redi. (2012). Penggunaan PLC dalam Pengontrolan Temperatur Sumulasi pada Prototype Ruangan. *Jurnal Mekanikal, 2*(2), 261–268.

Fahrurrozi, M., & Nuraharjo, E. (2020). Automonitoring Kelembaban Media Tanam. *Jurnal Dinamika Informatika, 12*(2), 60–67.

Juarti. (2016). Analisis Indeks Kualitas Tanah Andisol pada Berbagai Penggunaan Lahan di Desa Sumber Brantas Kota Batu. *Jurnal Pendidikan Geografi, 2*, 58–71.

Muktiani. (2011). *Bertanam Varietas Unggul Pepaya Callifornia.* Pustaka Baru Press.

Sofiana, N. (2016). *Faktor Faktor yang Mempengaruhi Permintaan Buah Pepaya di Kota Medan.* Universitas Medan Area.

Sugito dan Edy Suwandi. (2017). Efektifitas Ekstrak Ethanol Daun Pepaya (Carica Papaya L) Terhadap Pertumbuhan Bakteri Escherichia Coli dengan Metode Difusi. *Jurnal Laboratorium Khatulistiwa, 1*(1), 21–25.

Sujiprihati, S., dan Suketi, K. (2019). *Budidaya Pepaya Unggul.* Penebar Swadaya.

Yahwe, C. P., Isnawaty, & Aksara, L. . F. (2016). Rancang Bangun Prototype System Monitoring Kelembaban Tanah Melalui SMS Berdasarkan Hasil Penyiraman Tanaman "Studi Kasus Tanaman Cabai dan Tomat." *SemanTIK, 2*(1), 97–110.