

Design and Construction of an Internet of Things-Based Automatic Irrigation System for Dry Land

Muhamad Hidayat Ramli¹, Almido H. Ginting², Don E.D.G. Pollo³

^{1, 2, 3} Department of Electrical Engineering, Faculty of Science and Engineering, University of Nusa Cendana, Kupang, Indonesia

¹ email: hdytmvlog@gmail.com

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ABSTRACT: This research aims to design and develop an automatic irrigation system for dry land based on the Internet of Things (IoT) to address limited water availability and improve irrigation efficiency. The system utilizes three ESP8266 microcontrollers—one as the master and two as slave nodes. The slave nodes are responsible for reading soil moisture levels using YL-69 sensors, while the master receives data from both nodes, controls the water pump based on water level data from an ultrasonic sensor, and sends commands to solenoid valves via the slave nodes. The system is connected to the Blynk application for real-time monitoring and control and also displays moisture data on an LCD. Test results show that the system functions as intended, with adequate sensor accuracy and the ability to regulate irrigation automatically based on soil moisture thresholds of 70% and 80%. This system is expected to serve as an efficient solution for sustainable dry land management.

KEYWORDS: Internet of Things, ESP8266, soil moisture, automatic irrigation, blynk, dry land.

I. INTRODUCTION

Dry land is one of the factors that affect human life. Dry land occurs as a result of low rainfall, so that the availability of water is minimal, causing the soil to become less fertile. Unpredictable seasonal changes in Indonesia make land management difficult. Drylands in NTT also have a dry climate with uneven and erratic rainfall distribution and intensity, often resulting in crop failure due to limited water availability. Indonesia's dryland potential reaches 148 million hectares. According to data released by the East Nusa Tenggara Provincial Statistics Agency, as of 2019, the area of dry land was 3,852,726 ha, with Kupang City having the smallest area of dry land at 7,284 ha. The climate types are D3 (3-4 rainy seasons and 4-6 dry seasons), D4 (3-4 rainy seasons and >6 dry seasons), and E3 (6 dry seasons). (Oldeman, 1981). The distribution and intensity of rainfall in the drylands of NTT are uneven, irregular, and unpredictable, often leading to crop failures due to limited water availability. Water surpluses only occur during the wet months (December, January/February), while the rest of the year experiences water shortages. [1].

Problems that often arise in the field include irrigation management systems that are still dominated by conventional technology, with everything still being done manually by human labor (officials), such as opening and closing water channels, determining availability, and distributing water to agricultural land in a suboptimal manner. The size of the land and the different types of crops grown in each agricultural area affect the water requirements that must be met[2].

Previous research conducted by Wilanda and colleagues in 2021[3], they designed a device that uses an automatic watering system to maintain soil moisture at the desired percentage and can be operated remotely using a Telegram application integrated with a smartphone. The results obtained were that the power supply test yielded a result of 12.24 V. From the LM2596 test results, we can see that when the is ON, the voltage obtained is 4.92 V, while when it is OFF, the voltage obtained is 0 V. From the test results on the NodeMCU ESP8266 connected to the relay, measurements were taken in two stages: first, when the relay was ON, the voltage was 0.02 V, and second, when the relay was OFF, the voltage was 4.96 V.

This study aims to combine the advantages of previous studies by adding two ESP8266 microcontrollers to different plots of land, controlled by a master ESP8266 that functions as the parent controller. These ESP8266s will be connected wirelessly to each other and to Blynk, enabling quick and easy provision of information about the control of dry land.

II. LITERATURE REVIEW

A. DRY LAND

Dry land is a landscape that is not flooded for long periods of time or all the time. Dry land is often referred to as upland, dryland, or unirrigated land. Rainfed systems are agricultural land use systems that rely on rain as a water source or guarantee water availability. These systems are used for dry land use on dryland or unirrigated land. Upland is land located in highlands or geographically an area located at > 700 meters above sea level (Notohadinegoro, 2000).

Dry land is an area of land where water does not experience flooding for a long period of time in a year (Adimiharja and Agus, 2000). Dry land can be defined as cultivation/management activities other than rice fields that are carried out in the upper reaches of a watershed or upland areas located in dry (water-limited) areas and using rainwater harvesting systems as a source of water availability (Manuwoto, 1991, Satari et al. 1977). Land use in these areas is adjusted to the capacity of the land to avoid soil degradation or erosion. Upland management can apply soil and water conservation principles to maintain the sustainability of natural resources. In the community, the definition of dry land is land management/cultivation that relies entirely on rainwater for crop cultivation and does not experience prolonged waterlogging (Notohadiparwiro, 1989). The use of dry land by the community in general in the field of agriculture (BPS. 2010) is grouped into production and biotic environmental functions. The production function serves as the basis or support for production to provide food, animal feed, other biotic materials, and so on, such as yards, fields/farms, and plantation land, with a total area of 63.4 million hectares (33.7%) of Indonesia's total area ([4]).

B. ARDUINO IDE SOFTWARE

Arduino IDE (Integrated Development Environment) is software used to program Arduino microcontrollers. In other words, Arduino IDE is a medium for programming Arduino boards. This software is useful as a text editor for creating, editing, and validating program code. Arduino IDE is made from the JAVA programming language, equipped with a C/C++ (wiring) library, which makes input/output operations easier[5].

C. NODEMCU ESP8266

NodeMCU is an open-source IoT platform. It consists of hardware in the form of the ESP8266 System On Chip from Espressif System, as well as the firmware used, which uses the Lua scripting programming language. By default, NodeMCU actually refers to the firmware used rather than the development kit hardware. NodeMCU can be analogized as the Arduino board of ESP8266[6].

D. SOIL MOISTURE SENSOR (SOIL MOISTURE SENSOR YL-69)

The Soil Moisture Sensor is a moisture sensor that can measure and detect temperature in the soil. There are two probes in this sensor to measure current. When the soil is wet, the output voltage will decrease, while when the soil is dry, the output voltage will increase. The analog output value will change according to the water content in the soil[7].

E. ULTRASONIC SENSOR HC-SR04

An ultrasonic sensor is a sensor that uses ultrasonic waves. Ultrasonic waves are commonly used to detect the presence of an object by estimating the distance between the sensor and the object. To detect the water level in a tank, this system uses an ultrasonic sensor. The sensor can be installed above the tank and emits ultrasonic waves to the water surface. This sensor uses the principle of ultrasonic wave reflection. When ultrasonic waves are emitted by this sensor and there is an object that causes the waves to reflect, the sensor will send data to the microcontroller. This sensor will work when triggered using a pulse with a period of 10 us. Immediately, the sensor will emit 8 cycles of ultrasonic waves with a frequency of 40 KHz. When the waves are reflected, the receiver on the sensor will send a pulse signal to the microcontroller[8].

F. INTERNET OF THINGS (IOT)

The Internet of Things is a concept in which objects are embedded with technologies such as sensors and software for the purpose of communicating, controlling, connecting, and exchanging data through other devices while connected to the internet. This concept, which connects the digital world with human activities, greatly facilitates human activities. In the future, computers will be able to dominate human work and surpass human computing capabilities, such as controlling electronic equipment remotely using the internet. It is speculated that in the near future, computers and electronic equipment will be able to exchange information between themselves, thereby reducing human interaction. This will also increase the number of internet users with various internet facilities and services[9].

G. SOLENOID WATER VALVE

A solenoid water valve is a type of valve that uses a solenoid (an electromagnetic device) to control water flow. When an electric current is applied to the solenoid, it creates a magnetic field that attracts the valve part, opening or closing the water flow as needed. One of the most common forms of solenoid water valves is used to automate water systems, such as in automatic irrigation systems, washing machines, and watering systems. Solenoid water valves are very useful in applications where water flow needs to be controlled automatically and quickly.

H. RELAY MODUL

A relay module is a device that operates based on the electromagnetic principle to move a contactor to switch from the ON to OFF position or vice versa using electrical power. The closing and opening of this contactor occurs due to the magnetic induction

effect generated by the electric induction coil. Figure 2.9 shows the form of a 1-channel relay module. The most fundamental difference between a relay and a switch is when moving from the ON to OFF position. Basically, the function of a relay module is as an electric switch. It will work automatically based on the logic command given. Mostly, 5-volt DC relays are used to make projects where one of the components requires high voltage or is AC (Alternating Current)[10].

I. LCD (LIQUID CRYSTAL DISPLAY)

This component is an electronic component that functions as a display for data, whether characters, letters, or graphics. Liquid Crystal Display (LCD) is a type of electronic display made with CMOS logic technology that works by not producing light but reflecting the light around it onto the front-lit or transmitting light from the back-lit. This LCD is a layer of organic mixture between a clear glass layer with a transparent indium oxide electrode in the form of a seven-segment display and an electrode layer on the back glass. The way LCD works is that when the electrodes are activated by an electric field (voltage), the long, cylindrical organic molecules adjust themselves to the electrodes of the segments. The sandwich layer has a front vertical light polarizer and a rear horizontal light polarizer, followed by a reflector layer. The reflected light cannot pass through the aligned molecules, and the activated segments appear dark, forming the desired data characters. Thus, the information obtained is in the form of text ([11]).

J. BLYNK

Blynk is a server service used to support Internet of Things projects. This server service has a mobile user environment for both Android and iOS. The Blynk application, which supports IoT, can be downloaded via Google Play for Android users and via the App Store for iOS users. Blynk supports a wide range of hardware that can be used for Internet of Things projects. Blynk is a digital dashboard with a graphical interface for project creation[12].

III. METODE PENELITIAN

The research methods used in this project are qualitative research and experimental methods, which produce descriptive data through facts and natural conditions during data collection and as a direct source with the research instruments themselves. Data is also obtained through testing and experimentation with the tools that have been created, methods of collecting data about the project, and comparing the actual data obtained with sensor reading data.

A. SYSTEM BLOCK DIAGRAM

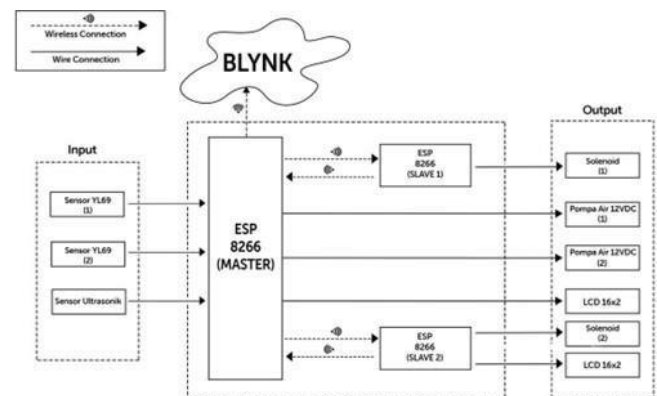


Fig. 1 Hardware Design Block Diagram

B. SLAVE TO MASTER ALGORITHM

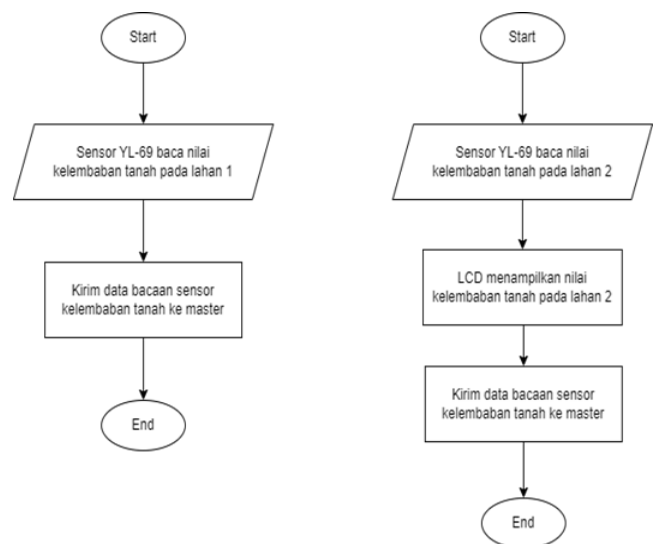


Fig. 2 Slave-to-Master Algorithm Diagram

C. MASTER ALGORITHM

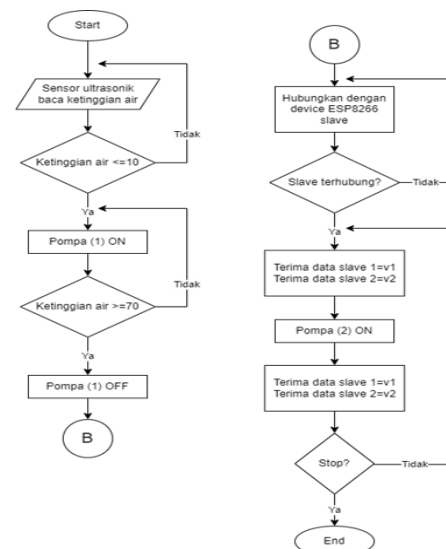


Fig. 3 Image Master Algorithm

D. MASTER TO SLAVE ALGORITHM

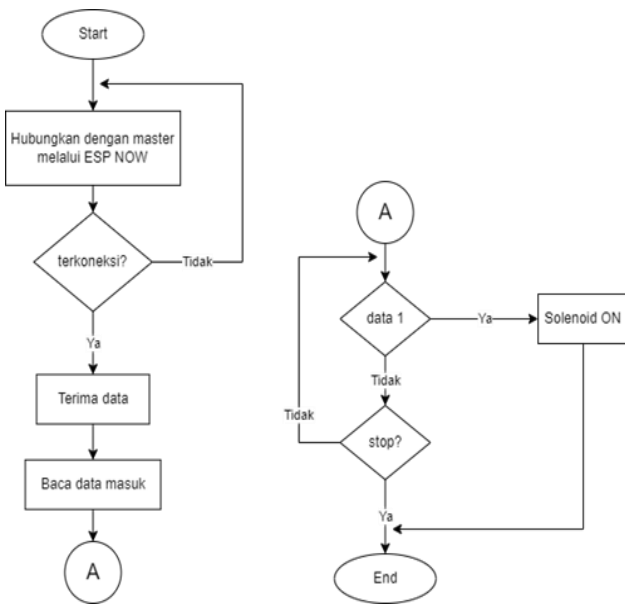


Fig. 4 Master to Slave Algorithm

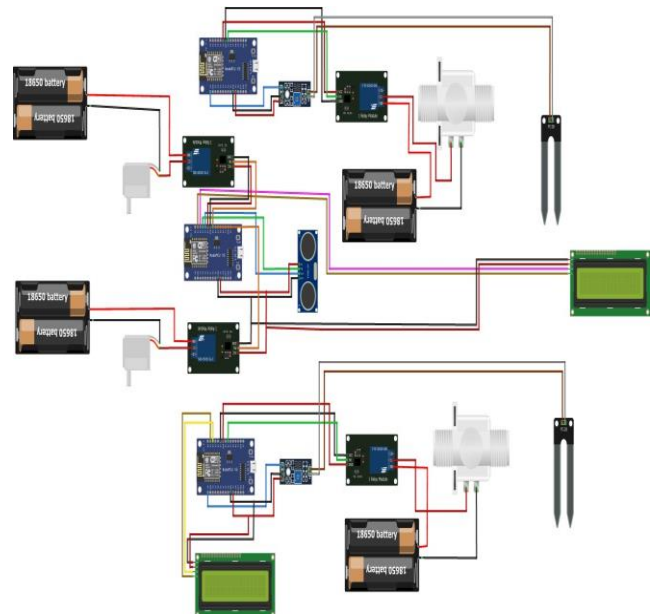


Fig. 5 Schematic Diagram of Automatic Watering Device Circuit

IV. RESULTS AND DISCUSSION

A. CREATION OF AN AUTOMATIC WATERING DEVICE

There are several materials that will support the operation of the device so that the automatic plant watering device can work properly. The components used as the main materials, there are also several other components that can be seen in Table 1.

Tbl. 1 Components used

No	Component Name	Quantity	Purpose
1	ESP8266	3	To manage and control all components that will be used.
2	Arduino IDE	1	As software
3	HC-SR04 Ultrasonic Sensor	1	To detect water level in a tank
4	Soil Moisture Sensor YL-69	2	To detect soil moisture
5	Water Solenoid Valve	2	To open and close the water valve
6	Relay Module	4	To turn the water pump and solenoid on or off
7	12V DC Water Pump	2	For water distribution
8	12V DC adapter	2	Solenoid power source
9	18650 battery	12	Component power source except solenoid
10	LCD	2	Displays the soil moisture percentage value along with the ADC value

All components are connected by connecting the pins on each module used to the ESP8266 pins. Once all the modules used are connected, the next step is to give commands to each module in C language on the Arduino software so that the automatic watering device designed can run as it should.

B. TESTING THE AUTOMATIC WATERING DEVICE THROUGH THE BLYNK APPLICATION

The purpose of testing the Blynk application is to ensure that the Blynk application can display real-time soil moisture data from sensors and show the status of the solenoid valve (ON/OFF). The testing was conducted by turning on the automatic irrigation system and inserting soil moisture sensors into growing media with varying water content. The Blynk application was connected to the ESP8266 via an internet connection (Wi-Fi). Any changes in moisture values were monitored through the Blynk application, and the solenoid status was also monitored through the Blynk application. The Blynk application display can be seen in Figure 6, and the results of the Blynk application testing can be seen in Tables 2 and 3.



Fig. 6 Blynk App Display When Solenoid is ON and OFF

Tb1. 2 Blynk App Test Results for 80% Soil Humidity

No	Humidity (%)	Blynk Display	Solenoid Status
1	25	25	ON
2	50	50	ON
3	65	65	ON
4	80	80	OFF
5	82	82	OFF

Tb1. 3 Results of Blynk Application Testing for Soil Moisture 70%

No	Moisture (%)	Blynk Display	Solenoid Status
1	15	15	ON
2	35	35	ON
3	60	60	ON
4	70	70	OFF
5	73	73	OFF

Based on the test results shown in Table 2 and Table 3, the *Blynk* application is capable of displaying data from the ESP8266 in *real-time* and accurately. *Blynk* displays data in *real-time* with a delay of approximately 1-5 seconds. The solenoid status is *updated* accurately according to the system logic.

C. SENSOR TESTING RESULTS

The sensor testing experiment for this device comprehensively shows various conditions and output results from the sensor for this device, which will be displayed on the *Blynk* application. The sensor testing can be seen in Table 4.

Tb1. 4 Sensor Testing

No	Component Name	Test Conditions	Test Results
1	Ultrasonic Sensor HC-SR04	Water Level in Tank 10%	Pump 1 ON
		Water Level in Tank 100%	Pump 1 OFF
2	Soil Moisture Sensor YL-69 (1)	Soil Moisture $\leq 60\%$	Solenoid 1 ON
		Soil Moisture $\geq 80\%$	Solenoid 1 OFF
3	Soil Moisture Sensor YL-69 (2)	Soil Moisture $\leq 60\%$	Solenoid 2 ON
		Soil Moisture $\geq 70\%$	Solenoid 2 OFF

D. TEST RESULTS OF THE OUTPUT

The overall output testing has been conducted in accordance with the objectives and problem constraints specified, and the device that has been developed is capable of operating as expected. The

overall output testing results can be seen in Table 5.

Tb1. 5. Output Test Results

No	Test Name	Test Input	Expected Result	Test Results
1	Solenoid (1)	Soil Moisture Sensor YL-69 (1) $\leq 60\%$	Pump (2) ON and Display on Blynk App ON	As Expected
		Soil Moisture Sensor YL-69 (1) $\geq 80\%$	Pump (2) OFF and Display on Blynk App OFF	As Expected
2	Solenoid (2)	Soil Moisture Sensor YL-69 (2) $\leq 60\%$	Pump (2) ON and Display on Blynk App ON	As Expected
		Soil Moisture Sensor YL-69 (2) $\geq 70\%$	Pump (2) OFF and Display on Blynk App OFF	As Expected
3	LCD Display (1)	Soil Moisture Sensor YL-69 (1) & Soil Moisture Sensor YL-69 (2) Detects Soil Moisture	The LCD will display the percentage value and ADC value from the YL-69 soil moisture sensor	As Expected
4	LCD Display (2)	Soil Moisture Sensor YL-69 (2) Detects Soil Moisture	The LCD will display the percentage value and ADC value from the YL-69 soil moisture sensor	As Expected
5	Blynk App Display	- The ultrasonic sensor detects water level - Soil Moisture Sensor detects soil moisture	The Blynk application will display the percentage of water tank level and the percentage of soil moisture	As Expected

E. SOIL MOISTURE SENSOR CALIBRATION

Calibration is performed to ensure that the *soil moisture* sensor provides measurement results that are close to the actual soil moisture value. Table 6 compares the moisture values obtained from the standard device with the ADC values produced by the *soil moisture* sensor.

Tbl. 6 Calibration of Soil Moisture Sensor with Standard Instrument

Soil Conditions	Standard Instrument (%)	Sensor (ADC)
Dry	25	880
Slightly Dry	36	805
Low Moisture	40	710
Moderate humidity	54	658
High humidity	66	525
Wet	76	470
Very wet	93	410

Table 6 shows that there is a linear relationship between soil moisture values and ADC values. The higher the soil moisture, the lower the ADC value read by the sensor. Conversely, the drier the soil, the higher the ADC value. The calibration results graph can be seen in Figure 7.

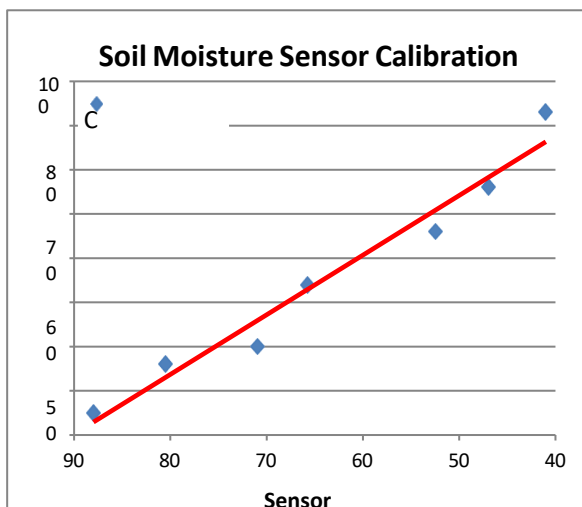


Fig. 7 Calibration Results Graph for Soil Moisture Sensor

Figure 7 shows the calibration data modeling results in graph form. This graph shows the relationship between ADC values and soil moisture (%). The red line on the graph is a *trend line* formed from the results of linear regression on the measurement data. Equation 1 is the regression line equation obtained as follows:

$$y = -0.134x + 141.6 \dots \dots \dots (1)$$

Where:

x is the ADC value from the sensor reading.

y is the estimated soil moisture in percent (%).

This equation shows that the relationship between ADC values and soil moisture is linearly decreasing. With this equation, ADC readings from the sensor can be automatically converted into moisture values in percent on the microcontroller. This is very useful in the application of microcontroller-based automatic irrigation systems because it allows the device to determine the irrigation time based on accurate moisture values.

F. COMPARISON TEST RESULTS

The *prototype* device was tested in comparison with a standard soil moisture detector. The comparison test results can be seen in Table 7 and Figure 8 for the comparison test of soil moisture values on Plot 1, which is 80%:

Tbl. 7 Comparative Testing of Soil Moisture Values on Plot 1

Number of Tests	Soil Moisture Value 80%	
	Prototype Device	Standard Device
Test 1	81	83
Test 2	80	83%
Test 3	80	83%
Test 4	82%	84%
Test 5	81%	84%
Test 6	81	84%
Test 7	80	82%
Test 8	82	83
Test 9	80	83%
Test 10	81	84

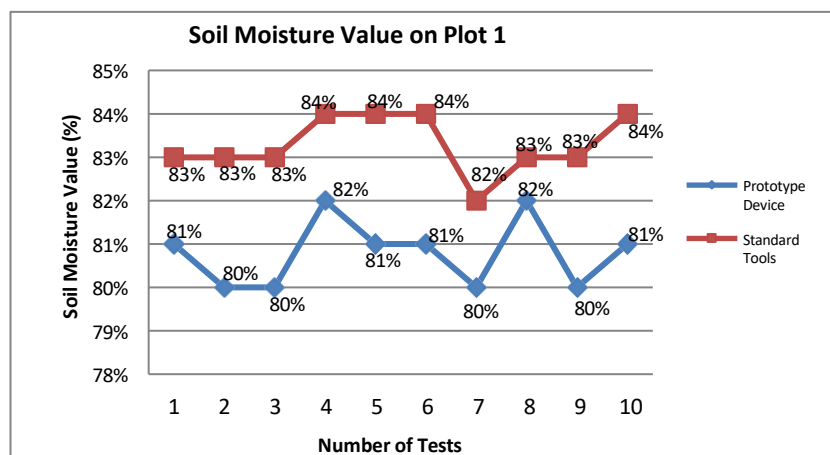


Fig. 8 Graph Comparing Soil Moisture Values on Plot 1

Meanwhile, Table 8 and Figure 9 show the comparison test of soil moisture values on land 2, which is 70%.

Tbl. 8 Comparison of Soil Moisture Values on Plot 2

Number of Tests	Soil Moisture Value 70%	
	Prototype Device	Standard Device
Test 1	71	74
Test 2	73	74%
Test 3	70	73
Test 4	70	73
Test 5	72	74
Test 6	73	74
Test 7	71	72
Test 8	70	73
Test 9	72	74
Test 10	73	74

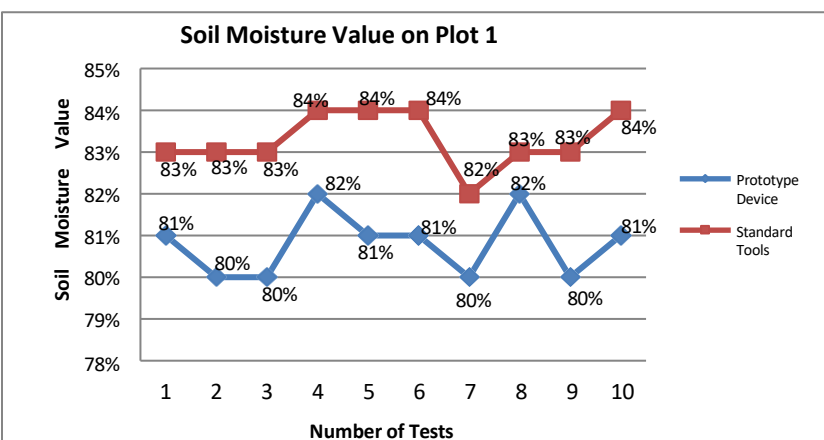


Fig. 9 Graph Comparing Soil Moisture Values on Plot 2

V. CONCLUSION

Based on the overall test results, it can be concluded that the Internet of Things-based automatic irrigation system for dry land works as expected, where the ultrasonic sensor in the water tank can detect water levels with a percentage of 10% - 100%, the YL-69 soil moisture sensor can detect soil moisture with a percentage of 80% for slave 1 and 70% for slave 2, and the solenoid can open and close the water valve. Each process performed will be monitored by the LCD and the Blynk application.

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AUTHOR BIOGRAPHY AND CONTRIBUTIONS



Muhamad Hidayat Ramli, born in Waikabubak on April 4, 2001, is currently pursuing a bachelor's degree in Electrical Engineering, Nusa Cendana University, with his research focus being Computer Control Engineering.