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IOT-based Soil Moisture Monitoring and Water Pump Control System for Ornamental Plants

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Abstract

Ornamental plant cultivation is a rapidly growing and potentially profitable type of plant cultivation in Indonesia. In Bogor Regency, many farmers have begun cultivating ornamental plants since the pandemic. Their unique tropical patterns have led to a surge in market demand, one of which is the Syngonium species. Indonesia's tropical climate results in high rainfall and unpredictable heat. Several types of plants are highly sensitive to soil pH or acidity during their growth. Intensification is one solution to address these issues. This research aims to create a water pump **monitoring** and control system that provides direct information on **soil moisture** and regular irrigation. The system uses a soil moisture sensor as input for three soil conditions: dry, moist, and wet. Data is then sent by **NodeMCU** into the database to be displayed on a website of an application, all connected to the **Arduino cloud**, and received by the water pump for regular irrigation, which will follow the steps of the hardware programming method. The result of this research is a prototype of a soil moisture monitoring system and water pump controller for IoT-based ornamental plants which is expected to help farmers in producing good planting media as well as good irrigation during the plant care phase.

Keywords: *Ornamental Plants, Monitoring, Soil Moisture, nodemcu , Arduino cloud*

1. Introduction

Agriculture is the activity utilizing nature resources, carried out by humans to produce food, industrial raw materials, or energy sources, as well as to manage their environment itself. In Indonesia itself, the majority of people make their living as farmers. As of May 2023, 38.7 million people worked in the agricultural sector (Indonesian Central Bureau of Statistics, 2023). Fertile soil and yields abundant nature, give chance for farmer to start a *Horticulture* (cultivation plants). Starting from *Fruticulture* (fruiting), *Olericulture* (vegetables planting), *Biopharmaceuticals* (medicinal planting), and also *Floriculture* (Decorating / Ornamental Plants).

The height request for decorative plant turns out to be the effect of the increasing productivity from perpetrator plant decoration themselves, balancing the market with high demand. In the Bogor regency area itself lots of farmers who start develop decorative plant business started after the Pandemic Era, this happens because of restrictions mobility or channeling hobby to remove boredom and filling time. Data from the Ministry of Agriculture shows total production for Decorative plant reached 616 million stalk with rate growth by 26 % each the year, when international market preferences start changed into direction decorative tropical plants [6]. Therefore, prospect of development business for decorative plants open wide for farmers in this modern era. Even if challenges in cultivation plant come from the environment itself . Taken from [3] Changes climate and patterns rainfall rain that can influence productivity plant plantations . Among them is season of long rain , less sunshine efficient , and attacks from pests . There are several type plants that are very sensitive in their growth process on soil pH or level acidity land . One of the solution handling fthe problem factor above is with to apply *Intensification* .

Based on [8] a good irrigation quality is one of the factor that increase productivity results in harvesting . artificial water source from farmer need quite a long time in order to see the result, because in this process the farmer need carry out manual controlling and monitoring. At the same time convenience and efficiency time as well as Man power become consideration for farmer doing Ornamental plants cultivation.In the

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previously device tool faqihan use submersible pump as a tool to drain water from water source into the rice fields. A *soil moisture sensor*, *water level sensor*, *Arduino UNO, and GSM (Global System for Mobile Communications)* module as monitoring and controlling.

Seeing from the problems and background that were existing , namely a necessity to a monitoring and a controlling systems, hoping to help the farmers to get a good planting medium, in this matter are in cultivation for the Ornamental and decorative plant. This research aims to create a prototype system, then a study to make a monitoring and controlling system in an automatic way, with an objective to make a system that can create convenience, time efficiency, and improvement quality irrigation so that productivity results harvest increased. Ornamental Plants that were used is 2 Syngonium ornamental plant seeds called *White Butterfly*.The researcher considered the main parameters and limitations of previous studies, such as recorded by [8] using the GSM (Global System for Mobile Communications) module for monitoring and controlling, and also the use of server and database recorded by [12]. On this prototype system it will be using A *Capacitive Soil / Hygrometer Moisture Sensor , NodeMCU V3 ESP8266*, and *Arduino Cloud IoT Application* as a base of the prototype IOT-based Soil Moisture Monitoring and Water Pump Control System for the ornamental plants.

2. Methods

This research involves hardware programming, integrating sensors, microcontrollers, and IoT interfaces with the help of Cloud database of Arduino. The researcher is making a prototype of an IoT-based soil moisture monitoring system and water pump control for ornamental plants. Readings of soil moisture are carried out by capacitive soil / soil moisture sensors as initial input which will later be processed in the NodeMCU V3 ESP8266 microcontroller, then followed by output in the form of analog voltage. Sensor and method selection was based on a careful assessment of the pros and cons, including the need for precise reading and flexibility controling media, to ensure robust data collection and analysis.

2.1. Hardware Programming Method

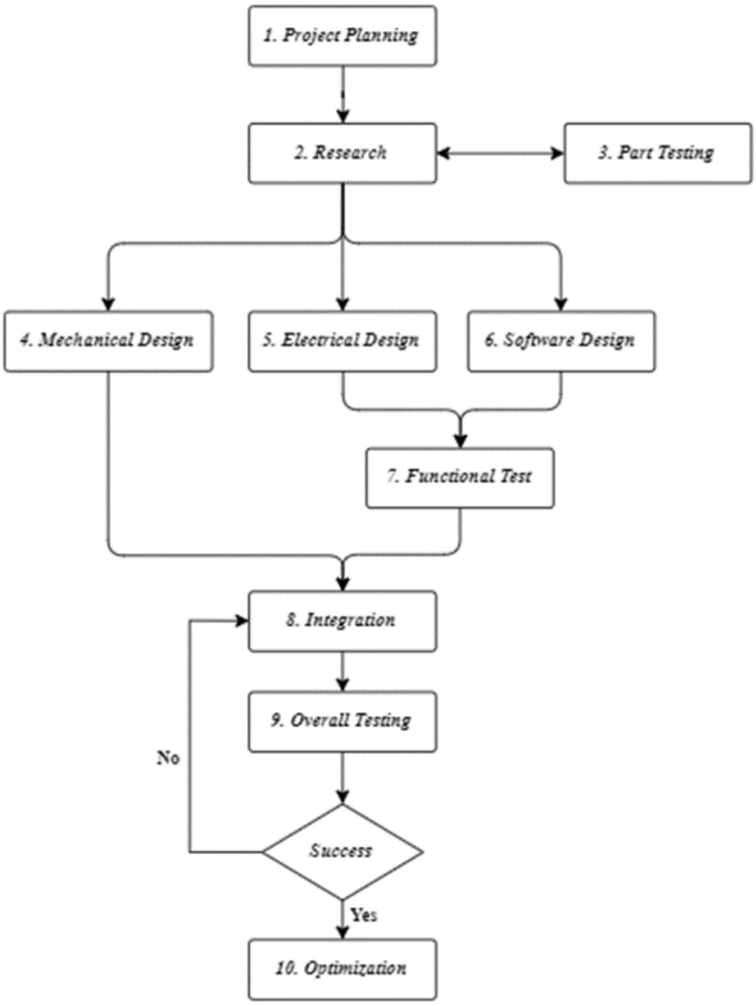


Figure 1. Hardware Programming Method

The stages used in this study are the *hardware programming research method* which is taken through 10 stages. The research stages are shown in **Figure 1.**

A. Planning Project Study

At this stage done by planning about the tool that will built, as well as define goals and needs tools. There are a number of things to do determined and considered in research , between other :

1) Preliminary Research
2) Need tools and materials
3) system device software Design
4) Budget Estimation

B. Research

After the planning stage has done , it continued with studying stages, beginning from the tool that will be made, from the selection components , up to testing components (tools) and material

C. Components Testing (*Part Testing*)

This test aims to figure the results of the selected components, determine if there is a damage or an error to a component that were needed for the *device prototype*.

Mechanical Design

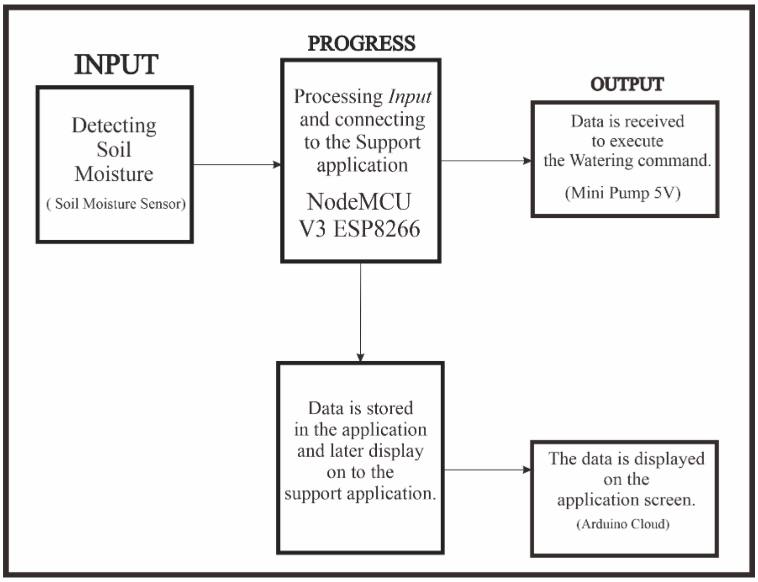


Figure 2. Mechanical System Design

Designing hardware device, Mechanical design is things to considered, determining if the channel work in the overall system. *Input* is the process where the sensor reads data, then it continue to processing the data, and finally the *Output* is the result of data processing in the form of action to the pump and data attachment to the monitor as in **Figure 2**. In general, the need to applying Mechanical design among others is.

1) Shape and size
2) Durability and flexibility to environment
3) Placement electronic modules
4) Testing mechanical system designed

D. Electrical Design

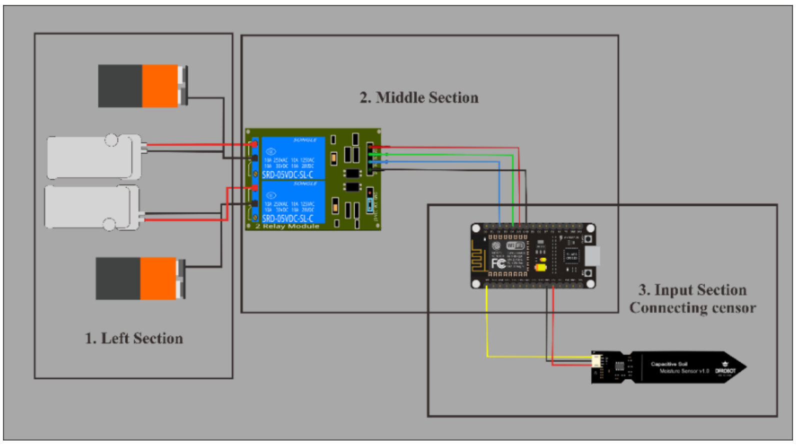


Figure 3. Electrical Design

Electrical system design, is the stage when connecting one component with the others, that will united with microcontroller, left section it's a place where it store the Battery and the Pump, Middle Section are the main component for the system to be working consisting of Microcontroller, lastly the Input

Section consisting Soil Moisture Sensor as in **Figure 3.** In designing Electrical system there is a number of things to note, between them:

1) Microcontroller used
2) Driver design to Suppor the application
3) Control System design that will applied
4) Electricity system Testing that has been designed .

E. Software Design

To program a prototype device runs as desired, software are needed. Software is needed for hardware programing, software for the systems control, and software for the interface systems within the computers. In standalone applications that do not require any control with a computer, only software is needed for control in the tool.

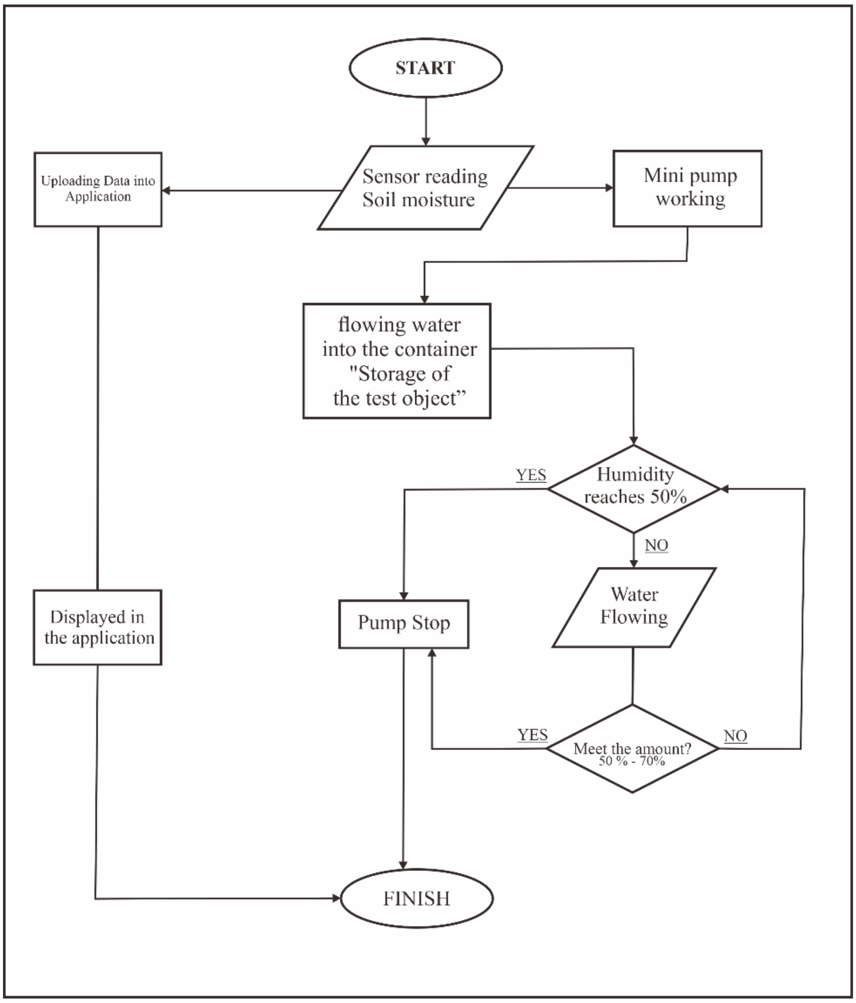


Figure 4 . System Design Electric

The flowchart above illustrates how the system works, which will be applied to the final project. The Soil moisture sensor initially provides input regarding the humidity value to the NodeMCU 8266 after the power is turned on. The sensor will begin reading (working) after the water is poured into the "Storage of the tested object" container. If the water/soil has reached the written humidity value, the microcontroller will initiate data processing, where the tank will stop pumping water into the container. The value of 40%-80% is taken from reference books and previous research, which will be used to measure the level of soil moisture shown in **Figure 4.**

F. Functional Test

Functionality test is done by testing system electricity and the *software*, whom has been designed . This test is done to increase performance from software to control electrical part and eliminate *error* in the designated device .

G. Integration or Assembly (*Integration*)

Electrical module has been integrated with *software* in the the controller , integrated to the mechanic structure who have designed . Then carried out by functional testing to overall system .

H. Overall Testing

Functional test to the overall system, this testing conducted from overall system study .

I. Optimization

Optimization is stages which the Device is already assembled in accordance provisions and will be maximized its performance in this stages.

3. Results and Discussion

3.1. Results

The device has been built so that become one unity component and making a soil moisture monitoring system and plant water pump control. The result of this study is a sytem of IOT-based Soil Moisture Monitoring and Water Pump Control System for Ornamental Plants, it’s a prototype tool that has been completed so that it becomes a single component. The advantage of this prototype tool is in the monitoring section which is integrated with the website and in the irrigation system which is carried out automatically, whereas in the current system or more precisely the majority, the monitoring carried out by ornamental plant farmers is still done manually and traditionally, recording Watering data is still done by manual typing, and watering is done byguesswork. The container used is made of wood which has been shaped in such a way that the plants can grow during the treatment period.

Figure 5. The series of tools that have been tested

The upper level is used for storing the circuit and the lower level is used for testing objects which have 2 containers, namely Container A as a soil simulation without a prototype system and Container B as a simulation using a prototype system prototype in **Figure 5.**

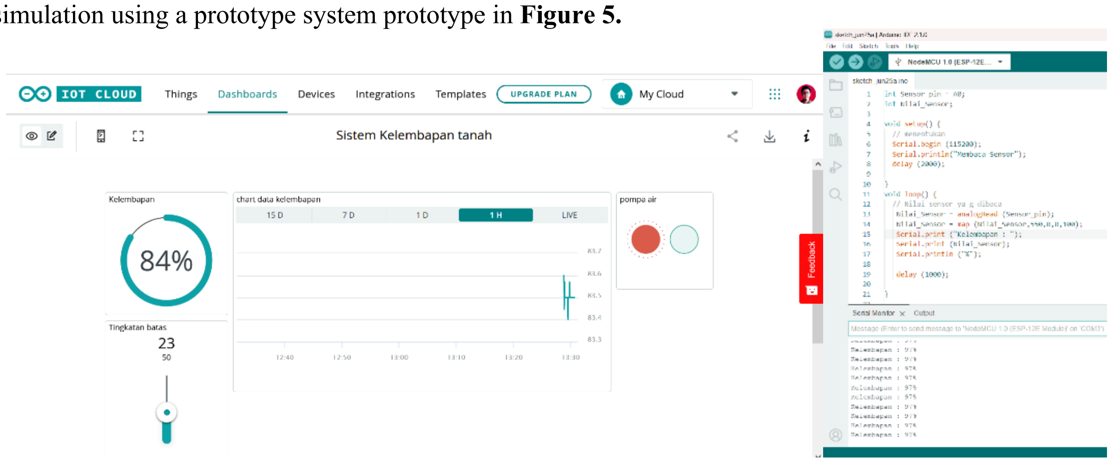


Figure 6 . View page *website*

Trials validation are done to determine if data has been inputed into the system. And testing the similarity of a data that were sent into the *database* with that displayed by the Arduino Serial Monitor so that it doesn't happen mistake among them , this validation can be seen inside appearance page *Website* in **Figure 6.**

Testing the *website* done as many as 10 times with conditions and actions from different sensor readings with hope system can displayed in a constant and continuous way. Results testing provided in form of **Table 1.**

Table 1. Validation Trial

Test Condition	Reading land (Percentage(%) 1	2	3	Arduino Serial Monitor View	Relay (Mini Pump Action)	Delivery to *Cloud*	Appearance on *website*
Dry	-10	-12	11	Featured	Life	Sent	Succeed
Dry	18	21	31	Featured	Life	Sent	Succeed

Dry	33	32	33	Featured	Life	Sent	Succeed
Moist	55	49	78	Featured	Dead	Sent	Succeed
Moist	60	56	67	Featured	Dead	Sent	Succeed
Moist	75	76	60	Featured	Dead	Sent	Succeed
Moist	78	75	77	Featured	Dead	Sent	Succeed
Wet	88	79	91	Featured	Dead	Sent	Succeed
Wet	89	89	89	Featured	Dead	Sent	Succeed
Wet	91	90	92	Featured	Dead	Sent	Succeed

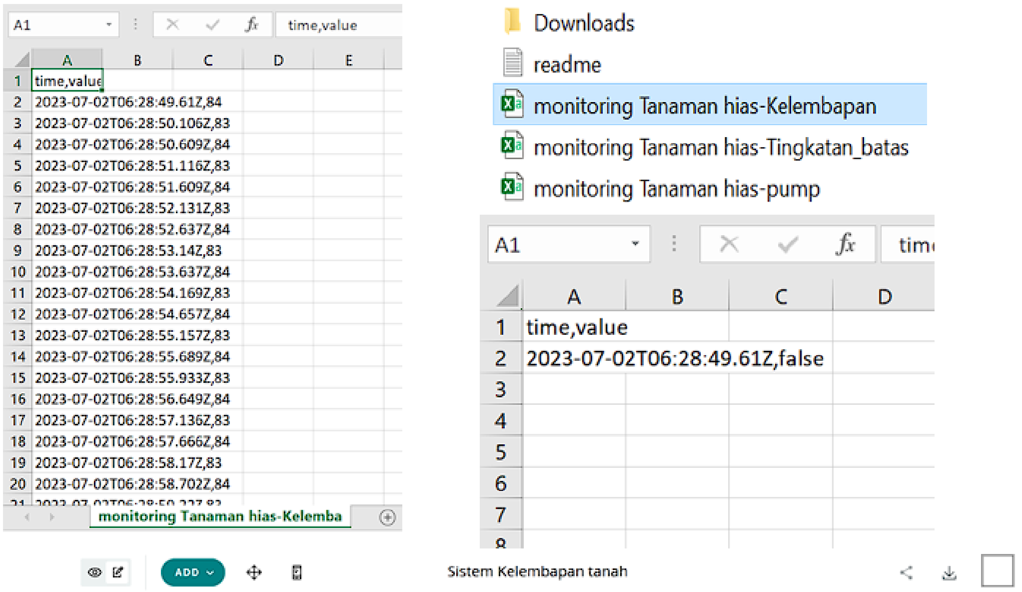


Figure 7. Reporting Results Table Downloaded by system in *Arduino Cloud*

Validation test done in a number of stage , namely validation test, Validating the tool with a land condition, determining wether the land is dry or in a wet condition . The data that has been input by the Node MCU will enter into the *Arduino Cloud* . Then through Coding process, data from *Cloud* will displayed on the page *Arduino IDE* website, can be seen in **Figure 7.**

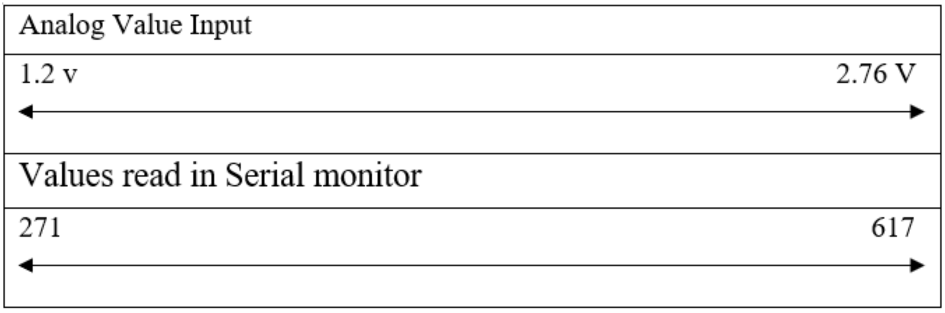
3.2. Discussion

After the results from *hardware* and *software* obtained , then we will discussed about the overall system work, starting from the *input* which will be processed to produce main *output* in the form of humidity calculation . System will start working when given voltages as much as 5V, there are 2 ways giving voltage For the series, namely :

A. USB cable connected with one of the computer ports or laptop.

B. Using a 5v adapter connected to microcontroller .

After the Device has given power , *Capacitive Soil sensor* , *pump* , and *Arduino Cloud* will work in a automatic way, because previously the program has saved in the microcontroller . The sensor that will used in Soil Moisture Monitoring System and Plant Water Pump Control Decorate Based on IoT has been calibratied using an appropriate tool to measure the desired parameters . The Device *prototype* has 2 levels structure with the overall size ranging from Length x width x height namely 35cm x 22cm x 23/24 cm. The upper levels used as a storage for hardware system and the lower levels were used to store a test subject, it has 2 containers , namely Container A as a simulation of a soil condition without using the *prototype* system and Container B as a simulation of a soil condition using the *prototype* system. Containers A and B had the same size, such as length x width x height namely 18 x 14 x 12 cm, this container will filled with fertilizer compost (*aerobic*) and a decorative plant (*Object*) age between 2 up to 5 weeks, sizing 5 – 12 cm in height, with 10 – 13 stalks and shoots leaves . Drying time for the object start at 9:00 am going up to 12:00 pm, 2 hours a day it will watering it self with vitamin B1 in the tank .



$$\text{Value (\%)} = \frac{Highest\ Sensor\ Value\ (617) - Lowest\ Sensor\ Value\ (271)}{100}$$

Figure 8 . Analog to Digital Value Conversion

Because the results of *Capacitive Soil sensor* are in a form of analog value , then sensor calibration is needed to required conversion mark and results read of the humidity sensor. this conversion is needed so it easier to read and mark the humidity levels of the soil. The highest analog value which is 617 is subtracted with the lowest mark data which is 217. From that, worth 346 points this will be divided by 100, where We will get a value 3.46 which we can assume as the lowest mark percentage . Example of this conversion can seen in **Figure 8** .

3.3. Test Table

Readings will be done by the sensor with mark time and percentage as a reference value used to make plants irrigation system .The first conditions of a pump is at “LOW” state, equal Off, not to cause overflowing for the irrigation, trigger (*trigger*) level value of pump can changed in accordance with the input value from the sensor. There are 3 levels of humidity status and each of its levels there is actions performed by the *Capacitive Soil sensor*, giving mark for the Relay which will trigger the pump sending water into the container .First condition of the container is " *Dry* " (land moisture < 40%), the second is *“ Humid ”* (land moisture are between 40-80%) and *" Wet "* (Humidity > 90%). Every 1 seconds of data from the *Capacitive Soil* sensor will displayed on the *Arduino serial monitor* which also automatically uploaded to the *Cloud*, later will be displayed in a *website* page, which is useful as a media to monitoring and reporting, also evaluated by the farmers to create a better planting medium. As for the data from each *Level Soil Moisture Prototype* it can seen in **Table 2.** under This .

Table 2. *Level* Prototype Tool Soil Moisture

No.	Test Object Container	Sensor Reading Mark		Time
1	Container B	< 40 %	(Dry)	12:00 WIB - 17:00 WIB
		40-80%	(Moist)	05:00 WIB - 10:00 WIB
		> 90%	(Wet)	> 18:00 WIB

In this state were also doing a calibration testing by *Capacitive Soil* Sensor. The sensor that will used in Soil Moisture Monitoring System and Plant Water Pump Control Decorate Based on IoT to which has been calibrated using an appropriate tool to measure the desired parameters. From the result data, sensor calibration are used to compare measurements read by the sensor with the measurement tool , which can seen in **Table 3.**

Table 3. Relay and water pump testing table

No	Instructions			Sensor Reading (Analog)			Output *mapping* (Percentage (%))			Condition		
	A	B	C	A	B	C	A	B	C	A	B	C
1.	OFF	ON	ON	271	478	610	100	56/60	<10	OFF	ON	ON
2.	OFF	OFF	ON	277	377	617	98	30	< 10	OFF	OFF	ON

3.	OFF	ON	ON	273	486	587	99	60	< 10	OFF	ON	ON

Trigger Level is at the value of 40%. Overall, the relay worked optimally, giving order or *code* accordantly, with water value pumped into land surface. The pump is on the Off condition when moisture level reaches moist and wet condition, so that it doesn't do excessive overflowing to the irrigation , value Can seen in **Table 4.**

Table 4. *Capacitive Soil* Sensor Testing Table

No	Data *Wordsheet* sensor count per (cm)	Test Results Mark Sensor	Output Measuring instrument Humidity Land
1	10% / 0.8	11.67% / 0.8	*Dry*
2	20% / 0.8	20.67% / 0.8	*Dry*
3	30% /0.8	31.01% / 0.8	*Dry*
4	40% / 0.8	39.69% / 0.8	*Moist*
5	50% / 0.8	50.64% / 0.8	*Moist*
6	60% / 0.8	59.76% / 0.8	*Moist*
7	70% / 0.8	70.58% / 0.8	*Moist*
8	80% / 0.8	80.75% / 0.8	*Wet*
9	90% / 0.8	89.02% / 0.8	*Wet*

4. Conclusion

Soil Moisture Monitoring System and Iot-Based Ornamental Plant Water Pump Control, it has 3 levels of soil moisture status and each level has an action carried out by the Capacitive Soil sensor to provide a value to the Relay which will trigger the pump to send water to the container. The condition in the first container is "Dry" (soil moisture <40%), the second is "Moist" (soil moisture between 40-80%) and "Wet" (Humidity> 90%). Testing of this tool was carried out 10 times by engineering the water level as soil moisture readings were carried out by adding water to an 11 cm measuring cup filled with 9 cm of soil, then measured using a Capacitive Soil sensor to get the sensor reading value. Each addition of water was carried out with a height of 0.8 cm, the treatment was repeated until the maximum height of the sensor. There is a slight error in reading soil moisture. The error occurred because the signal sent by the Captivative Soil Sensor did not return correctly. This sensor also reads data when the sensor is not in contact with the ground or directly exposed to air, resulting in an error in the reading and also causing the pump to start before it is fully operational.

The plant itself showed several striking changes, visible in the number of stems and height. During the maintenance period, the White Butterfly ornamental plant typically has 10 to 13 stems, each plant had 5 to 12 cm tall. This number increased over 24 days, from July 12 to August 5. From this trial, the plant now has 89 stems, which have begun to grow to a height of 13.5 cm and a diameter of 14.2 cm.

Design and manufacture IOT-based Soil Moisture Monitoring and Water Pump Control System for Ornamental Plants has pass stages of discussion and testing , then it taken conclusion . This device prototype tool can help alleviate decorative plant farmers in monitoring a good levels of humidity and land moisture, as well as in the watering the irrigation process periodically, which are the two essential objective to achieved producing better planting medium. And with the websites and applications that are connected using *Arduino Cloud* as a database, printing, download and also send a data about ground moisture, will helps the farmers with timetable periodic irrigation plants during the plant care period . However this tool still need updates in some functions such as not yet existence detector humidity ambient temperature , also a detector tool for measuring height plant as supervision development .

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