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Soil Moisture Prototype Soil Moisture Sensor YL-69 for Gaharu (Aquilaria Malaccensis) Tree Planting Media

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ABSTRACT

The amount of water present in the spaces between soil particles is known as soil moisture. High levels of soil moisture can cause problems for plant growth as they can deviate from the ideal conditions required by plants for root absorption. The study used a prototype tool to monitor the humidity of the planting media used for Agarwood/Gaharu trees by utilizing the YL-69 soil moisture sensor. The results of the prototype tool showed that it was able to detect when the humidity of the planting media was above 80%, at which point it would activate a water pump to water the media and maintain the humidity. Once the humidity dropped below 80% as per the requirements of the plants, the water pump would be deactivated, and no more water would be supplied. The YL-69 sensor was found to have an accuracy of 88.76%.

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1. INTRODUCTION

Agarwood/Gaharu (Aquilaria malaccensis) is a non-timber forest product (NTFP) commodity that is quite reliable, especially when viewed at an exceptional price compared to other NTFPs. The high selling value of Gaharu encourages people to take advantage of it [1]. In 2001, in East Kalimantan, to be precise, in Pujangan (Kayan), the price of Gaharu could reach Rp. 600,000, - per kilogram. At the retail level in big cities, this price will, of course, be even higher. Gaharu's contribution to the acquisition of foreign exchange also shows a graph that continues to increase. According to the Central Statistics Agency, the average export value of Gaharu from Indonesia from 1990-1998 was US $2 million; in 2000, it increased to US $2.2 million [2], in 2020 export value of Gaharu was US $39.9 million [3].

Aquilaria malaccensis is a species of plant in the family Thymelaeaceae. This plant is found in Bangladesh, Bhutan, India, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, and Thailand [4], which is already threatened with extinction. Aquilaria malaccensis (Agarwood/Gaharu) grows well in red-yellow podzolic soil, and sandy loam soil, with moderate to good drainage, 80% humidity, temperature 22-28°Celsius. Agarwood/Gaharu does not grow well in flooded soils, swamps, or soils with a pH<4. In the past, Gaharu was obtained directly from nature. However, in its development, Gaharu has become a rare commodity because it has been exploited on a large scale and has begun to be traded in various parts of the world (China, Arabia, India, Europe, etc.). It is not easy to obtain large quantities of Gaharu because the forests have been protected and conserved [5], so the cultivation of Gaharu must prepare the planting media that suits their needs.

The amount of water in the soil is known as soil moisture. The amount of water in the soil affects the permittivity of the soil. The soil and moisture play a role in how weather patterns evolve and how much is produced. For plants to grow, the soil must be wet. Because groundwater is the medium through which ions flow and forms a water film that affects how easily nutrients can be transported to the roots, moist soil accelerates the rate of diffusion.

This prototype was made to measure the soil moisture level for Gaharu tree planting media in poly-bags or pots to help Gaharu farmers cultivate Gaharu.

2. TECHNIQUES FOR MEASURING SOIL MOISTURE

Furthermore, keeping the soil moist (moist) to an ideal level for the plant is very important. Soil moisture content can be measured using several different methods.

2.1. Electrical Methods

The standard of electrical estimation of soil moisture in 1897 was first introduced by Whitney et al. [6]. The framework measures the adjustment of the water mass from a metal barrel in the shape of a mousing circle example using an accuracy balance, while the soil moisture measurement approach employs the electrical resistivity technique. Resistivity is needed in the estimated clock for this plastic cover. Using fluctuations in moisture content, the electrical resistance test calculates the soil's resistivity. The resistivity decreased from 338 ΩM to 8 ΩM while the volumetric moisture content increased from 5.8% to 38.5%. For dry soils, values greater than 50 Ωm cause the resistivity to react.[7].

Time Domain Reflectometry (TDR) method Is a method that utilizes the dielectric properties of dirt to estimate soil humidity levels. Dielectric stability estimate by estimating the electromagnetic wave's full circle velocity time at a consistent repeat (high repeatability from 30 MHz to 3 GHz) to and from the ground-covered metal terminal. The link analyzer provides high repeating electromagnetic pulses and filters out reflected waves, ground embedded poles, and links connecting analyzer and rods [8]. TDR estimates a small volume of soil, so no data of horizontal spatialization notice [9].

Capacitance Technique , this method estimates water content by estimating the dielectric consistency, which can estimate by capacitance. The dielectric steady of water is around 81 for wet soil, around 3 to 5 for dry soil, and 1 for air. The capacitance technique utilizes to gauge soil dampness content because of the consistent dielectric increments with expanding air content. Capacitance, C is straightforwardly relative to the dielectric steady. Gc addresses the structure factor, which relies upon the size and state of the sensor capacitance, and the distance between the electrode's ar content estimates by estimating the dielectric consistency, which estimates by capacitance. The dielectric steady of water is around 81 for wet soil, around 3 to 5 for dry soil, and 1 for air.

$$C = G_c K_d \tag{1}$$

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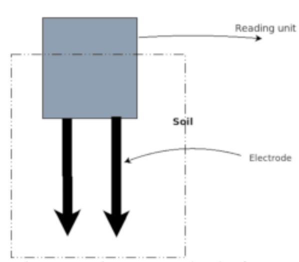

Figure 1. Schematic for the capacitance method of measuring soil moisture [10]

Figure 1 shows a capacitance technique for measuring soil moisture. Two electrode rods that enter into the ground make up the capacitance sensor. The ground serves as a dielectric and the two electrodes together make up a capacitor. On the reading equipment, changes in electrical capacity are read and show changes in soil moisture [10].

2.2. Non Electrical Methods

Wetness The most common method for soil moisture is to take a physical sample from the measurement site. The samples were weighed, dried in an oven at a temperature of 100 °C to 110 °C for 24 to 48 hours, then reweighed. The gravimetric moisture content, called wettability (w), is then determined by the formula on Equation 2.

$$w = \frac{Soil\ Mass_{wet} - Soil\ Mass_{dry}}{Soil\ Mass_{dry}} \tag{2}$$

The advantage of this system is that the sample is easy to obtain, and the moisture content is easy to determine. However, this is offset by the destructive nature of the method, making it impossible to repeat sampling at the exact location in the field. Second, w(Mg Mg-1), although a good indication of moisture status, is not as valuable for plant scientists as volumetric and potency humidity [11].

The amount of water that is accessible to plants (for transpiration) or the energy status of water cannot always be determined by measuring the water content of soil (or other porous media). Water will flow from high-energy to low-energy regions, with water potential indicating the energy condition. [11].

volumetric moisture content Other non electrical method is volumetric moisture content [11]. Groundwater status can determine by volume ($m^3\ m^{-3}$), where is the volume of the liquid phase per unit volume of bulk soil. This method is a popular method for providing soil moisture status information. However, measurements at the site must be repeated, especially during irrigation scheduling. If Θ is the degree of wetness, and the density of the soil is known, it can calculate by Equation 3:

$$\Theta = w \times \frac{\rho_b}{\rho_w} \tag{3}$$

Where Θ is the degree of wetness, w is wetness ($Mg\ Mg^{-1}$), ρ_b is the bulk density of the soil ($Mg\ m^{-3}$), and ρ_w is the bulk density of water ($Mg\,m^{-3}$).

The bulk density of the soil can be calculate with formula on Equation 4

$$\rho_b = \frac{dry\ soil\ weight}{Vo;ume\ of\ sampler} \tag{4}$$

In this prototype, we combine two methods, the electrical Capacitance Technique and the wetness non-electrical technique. To get data from electrical devices which use the YL-69 sensor, we collect data by connecting it to Arduino.

3. RESEARCH METHOD

3.1. Research Model

The design of a soil moisture control system on Gaharu tree planting media using several types of hardware such as soil moisture sensor YL-69, 16 x 2 LCD, Arduino mega 2560, driver motors, and DC water pumps. The working principle of the soil moisture control system is that the YL-69 sensor measures soil moisture on Gaharu tree planting media, the measurement data from the soil moisture sensor is received by the Arduino micro-controller, which processes predetermined procedures. The processing results on the micro-controller display on a 16 x 2 LCD screen uses as a reference for turning on the DC water pump to control soil moisture. Figures 2 show the diagram flow block design of the soil moisture control system on Gaharu tree planting media.

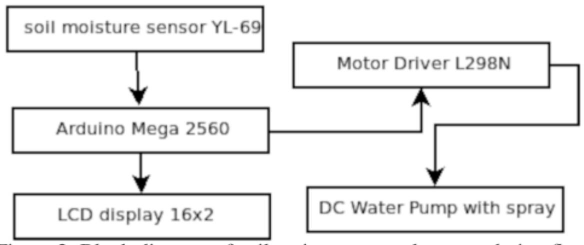

Figure 2. Block diagram of soil moisture control system design flow

3.2. Prototype Design

1. Hardware Design
   This stage includes design using fritzing software, software design (source code compilation), and component design. Each step in the design stage will be interconnected so that the researcher can return to the previous step if there is a failure. The design uses a fritzing application to support the primary data collection of the components and the placement of the pin wires that need in the development of the prototype. The design results are a reference in the form of components used in conducting development. More details can be seen in Figure 3 below:

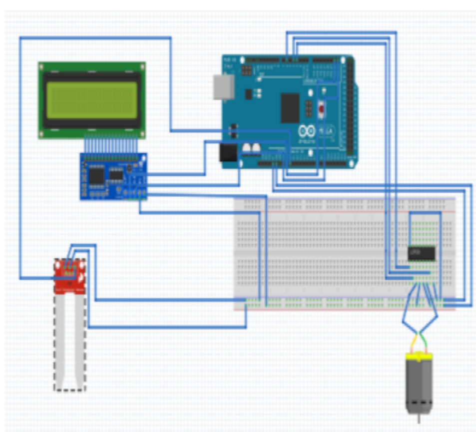
Figure 3. Design using fritzing

2. Software Design
   The proposed design for the soil moisture control system for Gaharu tree planting media utilizes various hardware components, including a soil moisture sensor (YL-69), a 16x2 LCD screen, an Arduino Mega 2560 micro-controller, driver motors, and DC water pumps. The system operates by measuring the moisture level of the soil using the YL-69 sensor and sending the data to the micro-controller, which then processes the information according to predefined procedures. The results of this processing are displayed on the LCD screen, which serves as a reference for activating the DC water pump to control the moisture level of the soil. The overall design of the system is illustrated in a diagram flow block design (Figure 4).

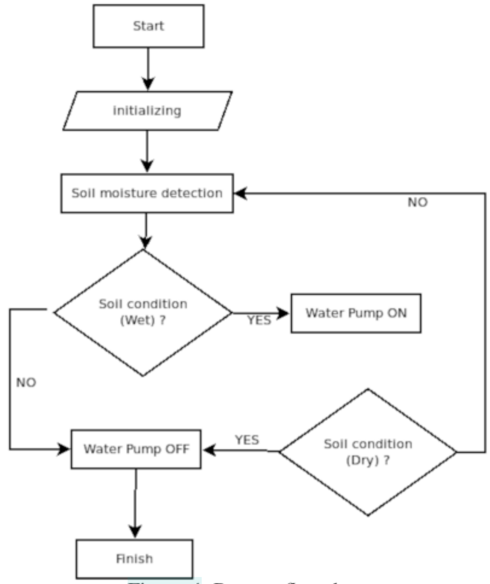

Figure 4. Process flowchart

A basic outline of the process can be viewed in the algorithm referenced as Algorithm (1).

Algorithm 1 Soil moisture control system

Initialize and calibrate the YL-69 sensor and the Arduino Mega 2560 microcontroller.
while true **do**
  Continuously measure the moisture level of the soil using the YL-69 sensor.
  Send the soil moisture data to the micro-controller for processing.
  if soil moisture level $<$ threshold **then**
    Activate the DC water pump to add water to the soil.
  end if
  Display the current soil moisture level on the 16x2 LCD screen.
end while
Repeat steps 2-6 continuously to maintain proper soil moisture levels for the Gaharu trees.

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3. Sensor Calibration
   The calibration process using Gravimetric Water Content;

   - Prepare two containers filled with soil from the exact location (taken at the same time and depth) with a net weight of 100gr each (Container A and Container B).
   - The soil in container A dried using an oven at a temperature of 100-110^{o}C for 24 hours until constant weight.
   - Calculate wettability (w) using grafitimatric methods, using the Equation 2

$$w = \frac{Soil\ Mass_{wet} - Soil\ Mass_{dry}}{Soil\ Mass_{dry}}$$

   - Calculate analog sensor voltage with formula on Equation 5 [12].

$$V_sensor = \frac{analog\ read}{1023} \times 5V \tag{5}$$

4. RESULT AND DISCUSSION

4.1. Non Electrical and Electrical Gap

After calibration of the sensor, we calculate the difference between the sensor readings used by manual calculations (nonelectrical). The weight of the soil used is 100gr per sample and in dry condition (oven-dried for 24 hours and until the weight is stable). Then add water by spraying it slowly with a certain amount of water. The calculation results can see in Table 1.

Table 1. Soil Moisture Calculation Results

No.	Soil dry weight(gr)	water weight(gr)	Soil moisture(%)		Gap
			Manual	With sensor	
1	100	0	0	0.96	0.96
2	100	10	10	10.95	0.95
3	100	20	20	29.97	9.97
4	100	30	30	48.40	18.40
5	100	40	40	54.90	14.90
6	100	50	50	71.00	21.00
7	100	60	60	77.70	17.70
8	100	70	70	77.98	17.98
9	100	80	80	82.54	2.54
10	100	90	90	85.35	4.65
11	100	100	100	85.45	14.55
				Avg. Gap	**11.24**

In the following Figure 5, it can see that there is a reasonably high fluctuation in sensor measurements. The low gap is at 10%, 20%, 80%, and 90% humidity measurements. Although the measurement fluctuations are pretty high, with an average gap of 11.24%, the prototype can be done because the desired soil moisture requirement is at the level of 80%.

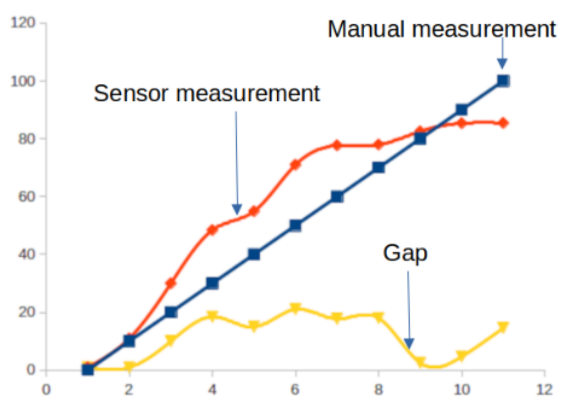

Figure 5. Calculation Graph

4.2. Prototype

The prototype is designed as shown in Figure 6. There are three samples of Gaharu tree planting media with three water pumps. The three planting media used the same soil with the same humidity conditions.

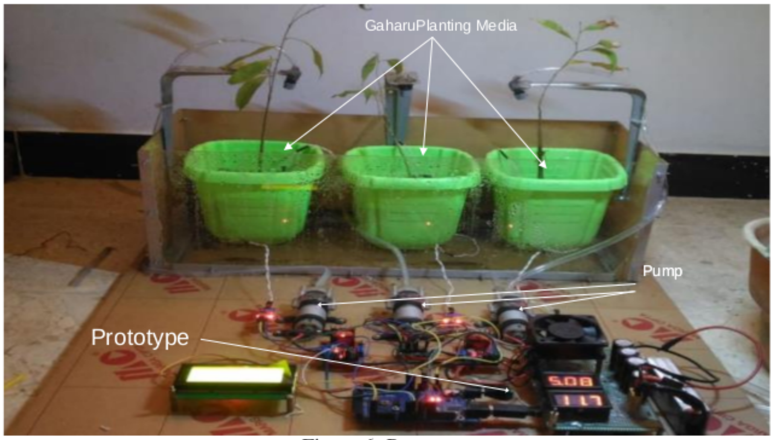

Figure 6. Prototype

The soil moisture regulator on Gaharu tree planting media uses a soil moisture sensor YL-69 and Arduino Mega 2560 specially programmed. The soil moisture sensor will detect the level of soil moisture in the Gaharu tree soil media. If the soil is dry, the Arduino Mega will instruct the water pump (a controllable water faucet) to turn on and flow water to water the plants. If the soil is wet, as the plant needs, the water pump will die, and the water will not flow.

At 0% soil moisture, the water pump will irrigate the soil until it reaches the specified value, as shown in Table 2 below:

Table 2. Water Pump Response to humidity

	Water Presentation(%)								
	10%	20%	30%	40%	50%	60%	70%	80%	90%
Med. A	√	√	√	√	√	√	√	×	×
Med. B	√	√	√	√	√	√	√	×	×
Med. C	√	√	√	√	√	√	√	×	×

√ Water pump running on media
× Water pump stop on media

In table 2, it can see that the soil moisture sensor on Media A, B, and C reads 10% soil moisture data, so the water pump is on, and the water pump will still turn on if the soil moisture sensor reads the humidity data soil to 80%, then the water pump will stop.

5. CONCLUSION

The prototype was done well, and the sensor has been able to detect soil moisture in the Gaharu planting media, where water pumps can water the soil at the desired humidity level. There are several disadvantages of the YL-69 sensor, as shown in Figure 6, where the sensor has a high gap at 30% to 70% humidity and then seems to continue to record values that do not change too much at 80 humidity. The YL-69 sensor can be used for small scales, but larger scales, the sensor cannot measure humidity steadily. A more sensitive sensor can be used on a larger scale on agricultural land and potted planting media or polybags.

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