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Android-based System Monitoring of Supporting Variables for Nursery-Plant Growth in Plantation Areas

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***Abstract*— In cultivating timber trees, farmers must pay attention to the seed selection with superior heredity, hormones, and the condition of the plantation area that supports the growth of nursery plants properly. Several factors that support the growth of nursery plants are nutritional factors, sunlight, temperature, soil pH, water, and soil moisture. In terms of effectiveness and ease of access to information in monitoring the supporting condition factors and facilitating the farmers, an Android-based monitoring system was built to monitor the growth of nursery plants. The system consists of several sensors, such as a soil pH sensor, UV light sensor, and soil moisture sensor embedded with Raspberry pi and firebase. The proposed system was examined on a plantation area of 900 square meters. The testing is conducted by placing a combination of 4 to 8 sensors in the plantation area. Data from each sensor is processed by calculating the average, and the results are rounded to the nearest value. The test stated that to monitor an area of 900 square meters, the area with five sensors implanted can be used as the optimal implementation. Apart from economic reasons, the minor rounding error equals 8.25% compared to the number of other sensors. The results that are informed to the farmers are also within the appropriate range. There are no significant differences, and this approach can be used to implement in a broader area.**

***Keywords*— Nursery plant; android-based; supporting variables; nutrients; sensors; plantation area.**

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I. INTRODUCTION

Timber plantations are an attractive business opportunity while contributing to the economy and the surrounding environment. So far, the Indonesian Government has taken the initiative to increase the development of timber plantations to alleviate poverty, increase forest cover and boost timber supply for industry. Research results from the Centre for International Forestry Research (CIFOR) found that many small farmers do not understand how to effectively cultivate and market timber, even though planting trees on plantations is more profitable than growing food crops because they do not require intensive care. However, timber plantation has a challenge in that the harvest time is required a long time to harvest than food crops. Timber plantations can be harvested for more than one year, while food crops can be harvested every three or six months or even one year [1].

Due to the long planting time and the risk of being susceptible to failure to grow timber plantations the first time the seedlings are planted, it is necessary to pay attention to the internal or external variables that affect the tree seedling's growth. Internal factors are related to the heredity and hormones of the plants selected from the best seeds by the farmers. External factors that influence tree growth include nutrients, sunlight, temperature, soil pH, water, and soil moisture [2]. In addition, nutrients such as nitrogen (N), oxygen (O), phosphor (P), hydrogen (H), sulfur (S), calcium (Ca), and Magnesium (Mg) [3] are also required.

Industrial forest plantations are usually located not too far into the forest, and tree nurseries are located on forest rim near villages [4]. However, a technique is required to monitor the seedling's growth remotely. The appropriate technique used to monitor the supporting variables of seedling growth is wireless sensor network (WSN) [5].

Several monitoring processes with WSN have been used to assist the supervisory process in the agriculture sector. In research proposed by Nandurkar [6], WSN is used to monitor temperature and soil moisture. Meanwhile, a crop monitoring system proposed by Zhao et al. integrated the system using the Internet of Things (IoT) to gather information from the field [7], [8]. The process of measuring soil moisture has been conducted by Sakthipriya [9] measured soil moisture that was linked to the watering process.

Therefore, the soil got moisture according to the crop requirements. The system was connected to a GSM modem, and the farmers could find the information through short message services (SMS) [9]. WSN is also used to monitor irrigation [10] that integrated the system with IoT and web applications. According to that research, the implemented WSN helps farmers automate plantation control and monitoring systems based on the system's requirements. Prathyusha et al. [13] have proposed the monitoring of the nursery plant using IoT to facilitate the monitoring. In addition, a monitoring system has been developed at the management level. All the activities from the initial purchase of the seed are implemented with Artificial intelligence and IoT [11], [12]. However, the monitoring is not translatable for ordinary people [13]. Nursery plant monitoring is also proposed by using the greenhouse model [14], [15], and aquaponic model [16] using IoT.

In this study, a monitoring system is required to help farmers more easily monitor the supporting variables that affect tree growth, starting from planting seeds until they are ready to be transferred to the forest. The system to be built will monitor the conditions of external soil factors that support tree growth. The parameters to be monitored are sunlight, soil pH, and soil moisture [17]. Through the monitoring process, farmers get accurate and real-time detailed data every certain period or any changes that can detain tree growth. Therefore, the plant seeds will immediately receive treatment. The data is sent to the farmer's Android-based smartphone. Hence, it can facilitate the cultivation of timber trees.

This research is expected to make a positive contribution that can provide a rapid process of forest regeneration and provide considerations regarding the location of sowing seeds to optimize high-quality sprouts [18]. In addition, this research is also expected to help farmers cultivate high-value forest products and revitalize agricultural activities. Therefore, it will create additional sources of income for farmers' families and encourage the promotion of natural products and local cultivation.

The rest of the paper is organized as follows. Section 2 defines the material and method of the proposed system. Section 3 describes the experimental system, result, and discussion. Section 4 represents the conclusions.

II. MATERIAL AND METHOD

This research is described by approaching the multimethodological research method proposed by Nunamaker [19]. This research resulted in a prototype form implemented in the plantation area of 900 square meters. The analysis begins with building concepts and ideas, then designing from ideas and making prototypes. Research continues by doing experiment testing, observing, and analyzing the prototypes in the real object.

The automation of environmental monitoring using WSN has increased significantly over the last few years. Remote environmental monitoring profoundly influences our environment and its development for humans. Many researchers have proposed similar works to make it easier for farmers to control plant growth, as submitted by Limprasitwong and Thongchaisuratkrul [20], which makes crop control for weather conditions in Thailand control crops based on temperature. IoT technology is also starting to play a role in the nursery plant supervision process, such as in India [21] utilizing Agri-Bot, a soil moisture sensor integrated with IoT. IoT integration proposed by Sande is used to control sugarcane growth in the germination phase and pay attention to changes in temperature and humidity [22].

Meanwhile, Kumar et al. [23] proposed smart gardening using many sensors. IoT is then integrated with a fuzzy logic system using soil moisture, temperature, and humidity [24]. At the same time, integrated IoT and machine learning with various sensors utilize solar panels to control plant health, also proposed by Singh, Singh, and Kharb [25]. Augmented Reality (AR) has also been integrated with IoT and temperature and humidity sensors to monitor the nursery plant [26] interactively.

The nursery and seed stock management system is extensive and includes several different stages, depending on geography [27] and needs [28]. This study uses a seed and nursery planting model on a eucalyptus plantation model in the Sumatran areas. The area modeling uses open land on the forest edge.

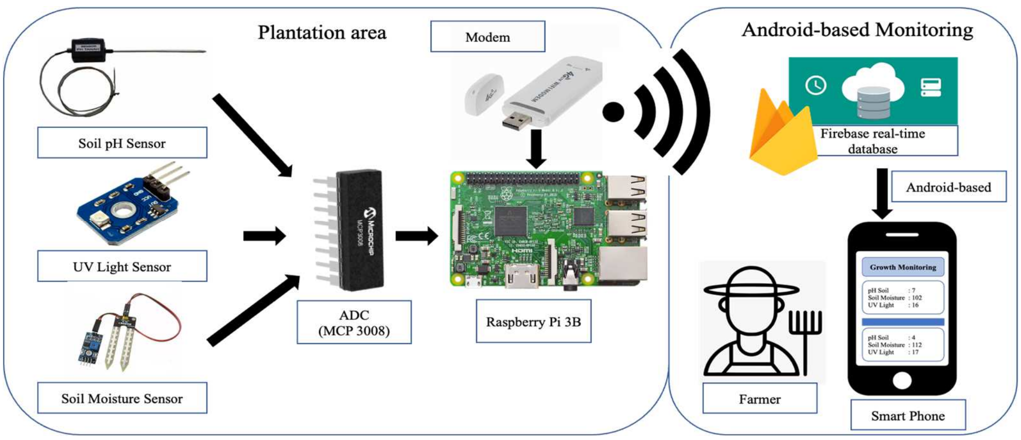


Fig. 1 Block diagram of the proposed system

As seen in Fig. 1, The system is designed with two modules: the plantation module and the android-based monitoring module. The plantation module uses Raspberry Pi 3B, soil moisture sensor, soil pH sensor, UV sunlight sensor, modem USB, and analog to digital converter MCP 3008. This module serves to measure the variables that support tree growth. The variables to be measured are soil moisture, soil pH, and UV sunlight intensity. Those variables are processed by Raspberry Pi 3B and sent to the android-based monitoring module through the internet network.

Meanwhile, the android-based monitoring module consists of an android-based software application and a firebase real-time database. This module aims to display information about the variable's condition that is measured at the plantation area. Due to the considerable mobility of farmers, the android platform is used to make it compatible with the requirements of farmers' smartphones.

The proposed system works can be seen in Fig.2. When the system runs, the pH sensor, UV sensor, and soil moisture sensor values are set to the default number. Then, the sensors start to read the soil moisture conditions in the plantation area. The value is converted to MCP 3008; then sent to Raspberry Pi to calculate the average value.

The final average value is rounded to the nearest fraction. The absolute value of each sensor is checked to determine whether it is still in the allowable range for the plant. Otherwise, the information will be sent marked in red as a warning. Farmers, as a user, check in on the application and press the find button to monitor soil fertility.

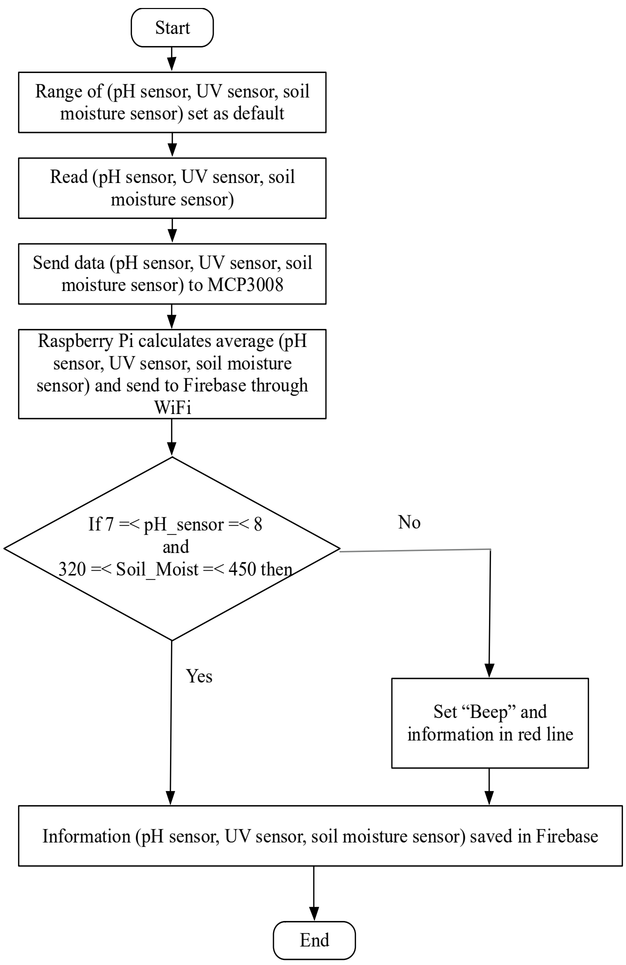


Fig. 2 Flowchart System

III. Result and Discussion

It is necessary to test the device's accuracy and get the appropriate range value regarding the actual plantation soil conditions, Soil pH values, soil moisture, and UV rays are set within a specific range according to the soil conditions required by plants. All the sensors are calibrated to get a range value corresponding to actual conditions.

To test the accuracy of the sample in describing the conditions of soil moisture, soil pH, and UV light intensity index in the plantation area, the test was carried out with several types of soil pH, soil moisture, and UV intensity categorized as seen in Table I.

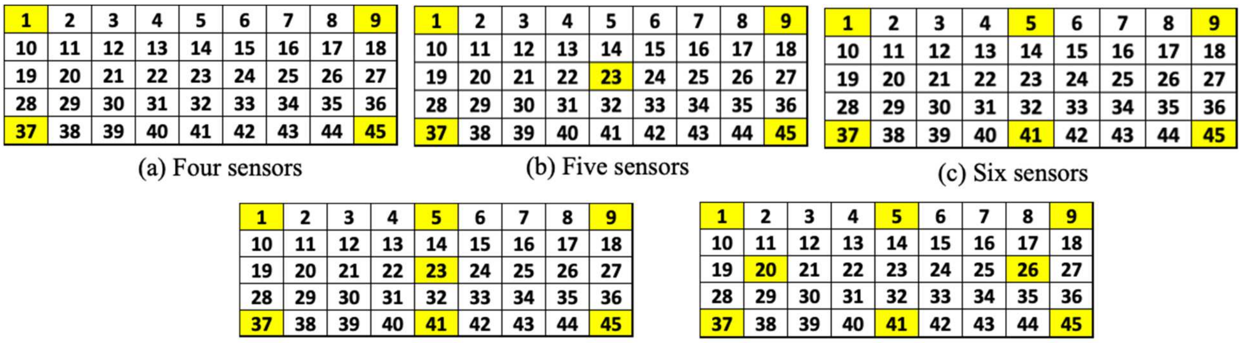
In Table I, soil moisture sensors are classified into five: flood, wet, moist well, dry, and very dry. Meanwhile, soil pH sensors are classified into acid, neutral, and alkaline. The light intensity index on the UV light sensor is carried out by converting the voltage to the index value.

This proposed system will be implemented for eucalyptus plants. Therefore, the soil moisture sensor is set to moist well, the soil pH is set to neutral, and the UV light intensity index is set until below 8. The normal condition setting is conducted to get eucalyptus plants to harvest as good nursery plants.

TABLE I
RANGES VALUE FOR SENSOR

Sensors	Range Value (ADC)	Description
Soil Moisture	800 - 1023	Very Dry
	501– 799	Dry
	385 - 500	Moist well
	100 – 384	Wet
	0 – 100	Flood
Soil PH	8.01 – 14.00	acid
	6.00 – 8.00	Neutral
	0.00 – 5.99	Alkaline
UV light intensity index	9 – 11+ Vout >= 851 mV	Very hot
	7 – 8 Vout = 701-850 mV	Hot (12 pm – 1 pm)
	5 – 6 Vout = 511-700 mV	Bright (10 am – 12 pm) and (2 pm – 4 pm)
	3 – 4 Vout = 321-510 mV	Warm (7 am – 10 am) and (4 pm – 6 pm)
	0 – 2 Vout = 0 - 320 mV	Night / Dark (6 pm - 7 am)

After determining the range value of each sensor, the next step is to examine the proposed system. The system testing was carried out in a eucalyptus plantation with a layout of the sensor placement composition at the test location, as shown in Fig. 3. The plantation area measuring 45x20 meters is arranged with the layout shown in Fig. 3. The plantation area is divided into 9-longitudinal sections and 5-wide sections. Therefore, one square area in the figure represents 20 square meters.



(a) Four sensors (b) Five sensors (c) Six sensors

(d) Seven sensors (e) Eight sensors

Fig. 3 Sensors layout composition

Sequentially, the tests were carried out for 4 to 8 sensors scattered throughout the plantation area. Figure 3(a) shows the implementation of 4 sensors spread over the plantation area. Likewise, for Figures 3(b) to 3 (e) which show the implementation of 5 to 8 sensors in the plantation area. Testing is then carried out on the same day. It ensures the tool works properly and gets the appropriate error value. In addition, the appropriate placement and the number of sensors for the plantation area as shown in Fig.3 can also be determined. The test results can be seen in Table II. The test was carried out on June 12. Data took at 9 am, 1 pm, in the afternoon after the rain at 3.40 pm, and at 7.30 pm. The proposed system is placed on the plantation area according to the blueprint in Fig. 3. It is plugged in at a depth of five to eight cm from the ground surface [29]. The data collection is carried out simultaneously at the same time for four to eight data collection points.

TABLE II
SENSORS RESULT VALUE

No of Sensors	pH Sensors				UV light sensors				Soil Moisture Sensors			
	9.00 am	1.00 pm	3.40 pm	7.30 pm	9.00 pm	1.00 pm	3.40 pm	7.30 pm	9.00 pm	1.00 pm	3.40 pm	7.30 pm
4	7,35	7,35	7,025	7,275	3	6,75	3	1	433	464,25	255,25	371,25
5	7,34	7,34	7,02	7,26	3	6,8	3	1,2	433	464	251,4	373,4
6	7,36	7,4	7,05	7,25	3,167	6,833	3	1	433,5	467,667	250,167	364,667
7	7,357	7,38	7,043	7,243	3,15	6,857	3	1,143	433,429	467	248,15	367,143
8	7,375	7,375	7,05	7,25	3,125	6,875	3	1	433,25	467,5	256,38	369,75

Based on Table II, using a pH sensor at four sensor points to eight sensors showed the stability of the real pH value in the plantation area. At 9 pm, the average pH value showed a variation of the measurement value of 7.35 to 7.375. While the average pH value is at 1 pm, the resulting data shows a variant of the pH value at 7.35 to 7.38. Data collecting results on average pH value in the afternoon after the rain showed a variant of pH value at 7.02 to 7.05. While at night on the same day, the average pH value of the data variance showed 7.243 to 7.275.

The entire data collection was selected based on the classification shown in Table 1 above. Information selection is conducted by calculating the average pH value using rounding up to one-tenth in decimal. According to Table 1 above, the results obtained based on these experiments are that many sensors, as shown in Fig. 3, indicate no significant differences in determining the final conditions on the user's smartphone application. The rounding results are still in the same classification range. As shown in Table 1, the average pH soil value in the plantation area showed stability varying from 7.02 to 7.38. It means that the soil pH value in the plantation area is neutral.

The result of data collection for the UV sensor showed sufficient variance to indicate the weather condition of the plantation area. Similarly, as pH value, UV sensor data collection is carried out at 9 am, 1 pm, 3.40 pm, and 7.30 pm. The average test results are then translated based on TABLE I. Value rounding is also applied in this calculation.

At 9 am, the UV sensor offers the range value in warm weather with a value of 3. At 1 pm, the UV sensor shows a range value in hot weather from 6.75 to 6.875. In the afternoon, at 3.40 pm, after it rained, the UV sensor showed warm weather conditions with a UV value equal to 3. When night comes, the UV light shows a value variation between 1 to 1.2. It is because there is still light obtained from fluorescent lamps in the plantation area.

In soil moisture sensors testing, at 9 am, the average soil moisture sensors obtained from the measurement of four sensors to eight sensors varies from 433 to 433.5. While at 1 pm, the average soil moisture value ranges from 464 to 467.667. After the afternoon rain at 3.40 pm, the average soil moisture value varied from 250.167 to 256.38. At 7.30 pm, the average soil moisture ranged from 364.667 to 371.25.

The test results are translated into TABLE I. The soil moisture sensor test result showed that the soil conditions were quite different due to the day's rain. At 9 am, all sensors indicate the soil moisture condition is a moist-well state. At 1 pm, the soil moisture still shows the moist-well state, but it increases towards the dry condition. At 3.40 pm, after the rain was over, the soil moisture indicated a wet condition since the ground surface was exposed to puddles of water. While at 7.30, the soil moisture state shows still in the wet state but ranges toward normal in the moist-well state.

Furthermore, the test results listed in Table II above is displayed as seen in Table III. This is conducted to observe whether the accumulated average rounding on the display information will cause a significant difference to the results.

TABLE III
DISPLAY INFORMATION RESULT

Number of Sensors	9 am	1 pm	3.40 pm	7.30 pm
4	Date: Saturday, June 12, 2021 pH Soil: 7.3 (Neutral Soil) Soil Moisture: 433 (Moist) UV Light: 3 (warm)	Date: Saturday, June 12, 2021 pH Soil: 7.3 (Neutral Soil) Soil Moisture: 464 (Moist) UV Light: 7 (Hot)	Date: Saturday, June 12, 2021 pH Soil: 7.0 (Neutral Soil) Soil Moisture: 255 (wet)UV Light: 3 (warm)	Date: Saturday, June 12, 2021 pH Soil: 7.3 (Neutral Soil) Soil Moisture: 371 (wet) UV Light: 1 (dark)
5			Date: Saturday, June 12, 2021 pH Soil: 7.0 (Neutral Soil) Soil Moisture: 251 (wet)UV Light: 3 (warm)	Date: Saturday, June 12, 2021 pH Soil: 7.3 (Neutral Soil) Soil Moisture: 373 (wet) UV Light: 1 (dark)
6	Date: Saturday, June 12, 2021 pH Soil: 7.4 (Neutral Soil) Soil Moisture: 433 (Moist) UV Light: 3 (warm)	Date: Saturday, June 12, 2021 pH Soil: 7.4 (Neutral Soil) Soil Moisture: 468(Moist) UV Light: 7 (Hot)	Date: Saturday, June 12, 2021 pH Soil: 7.0 (Neutral Soil) Soil Moisture: 250 (wet)UV Light: 3 (warm)	Date: Saturday, June 12, 2021 pH Soil: 7.2 (Neutral Soil) Soil Moisture: 365 (wet) UV Light: 1 (dark)
7			Date: Saturday, June 12, 2021 pH Soil: 7.0 (Neutral Soil) Soil Moisture: 248 (wet)UV Light: 3 (warm)	Date: Saturday, June 12, 2021 pH Soil: 7.2 (Neutral Soil) Soil Moisture: 367 (wet) UV Light: 1 (dark)
8			Date: Saturday, June 12, 2021 pH Soil: 7.0 (Neutral Soil) Soil Moisture: 256 (wet)UV Light: 3 (warm)	Date: Saturday, June 12, 2021 pH Soil: 7.2 (Neutral Soil) Soil Moisture: 370 (wet) UV Light: 1 (dark)

The average rounding value does not show a significant change or information statement in Table III. At 9 am and 1 pm, the information conveyed to the user is equal regardless of the number of sensors and average rounding value. The soil pH is in neutral soil, and the soil moisture is in a moist-well state; the UV light is in the warm range at 9 am and hot at 1 pm even though there are differences in the average values that are rounded up or down in the Table. The information results are in the same range condition as shown in Table I.

Likewise, the information submitted at 3.40 pm and 7.30 pm, the number of sensors, and the average rounding value also do not affect the information displayed for the user. Although the average value displayed has differences in each number of sensors, it does not cause a difference in the report stated. This is because the value is still in the same range as shown in Table I.

The test results in Table II is then displayed on a smartphone user display. Fig. 4 shows a smartphone display with the information stated based on five sensors. Data on June 12 was reported four times for data transmission at 9 am, 1 pm, 3.40 pm, and 7.30 pm. In addition, data transmission was also reported on June 13 at 9 am and 1 pm.

The data reported on June 12 at 9 am and 1 pm showed that the soil conditions in the plantation area were in average condition. While at 2.15 pm, there was heavy rain, and data reported at 3.40 pm and 7.30 pm stated that the soil plantation area was in wet conditions. Wet conditions are marked with red as a warning, and data was sent at 9 am the next day. The soil in the plantation area was reported to be acidic at 9 am and alkaline at 1 pm. Parameters outside the allowable value will be displayed in red as warning information to the user.

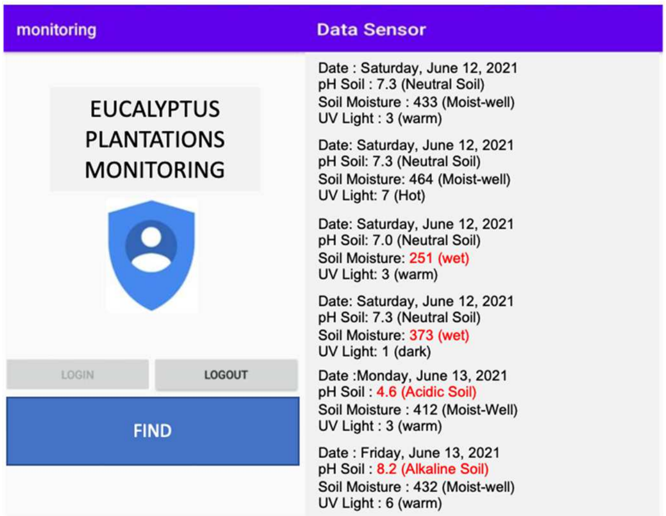


Fig. 4 Smartphone display

The red mark is intended to warn the user; hence, the user immediately pays attention to changes and makes improvements to the parameters that affect the soil conditions in the plantation area back in the range of value allowed. The last examination is to calculate the rounding error that occurs to determine the soil condition in the plantation area based on soil pH, soil moisture, and UV measurement. A rounding error that occurs due to the calculation of the average sensor parameter value can determine how many sensors will be implemented in monitoring a 900-square-meter plantation area.

Rounding error is obtained from the formula (1) calculation, where n is the number of sensors [30]. The results of the calculation rounding error can be seen in Table IV.

$$Error = \frac{\sum_{i=0}^{n} data\ Sensor}{n} - actual\ data \quad (1)$$

TABLE IV
ROUNDING ERROR CALCULATION

Number of sensors	Soil pH	Soil Moisture	UV Sensor	Error Average
4	0.0375	0.1875	0.0625	0.09583
5	0.035	0.15	0.0625	0.0825
6	0.066	0.4166	0.083333	0.18889
7	0.0607	0.1786	0.10714	0.11548
8	0.0625	0.34375	0.0625	0.15625

Based on Table IV, it can be seen that the slightest rounding error is stated in the use of five sensors as the optimum sensor implemented. Therefore, to monitor a plantation area of 900 square meters, it is enough to use only five sensors. In addition, saving on sensor implementation, the result obtained by using eight sensors does not make a significant difference.

IV. CONCLUSION

This research proposed a monitoring system for nursery plant growth in plantation areas located in remote areas near villages. It aims to facilitate the farmers in terms of effectiveness and ease of access to information in monitoring the supporting condition factors such as soil pH, UV light, and soil moisture. This integrated system can monitor changes quickly and accurately. The testing on the application is conducted by placing a combination of 4 to 8 sensors on 900 square meters of plantation area. The test result stated that the variety of 5 sensors is the optimal implementation because it has the slightest rounding error equal to 8.25% compared to other combinations.

This research can be used as the basis for developing a monitoring system for a broader coverage area, considering that every 900 meters area can use five sensors embedded at a certain depth to get optimal results. This research also encourages farmers to conduct better crop cultivation enhancement following the required nutrients. This research is also easy to integrate into other processes in the plantation consecutive procedures and easy to develop with the latest technologies in various platforms in the future.

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