

Design and Build a Website-Based Landslide Early Warning System

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ABSTRACT

An early warning system is very important to implement to minimize losses received when a disaster occurs, one of which is a landslide disaster. An early warning system for landslides is carried out so that people can find out the signs of a disaster that can be accessed anywhere, so they can prepare themselves. For this reason, a tool is needed that can detect and provide early warning of landslides to the public which can be accessed through the website. In this study, a website-based landslide early warning system has been designed using a soil moisture sensor to measure it and the MPU6050 sensor to measure the slope of the soil. Sensor data will be displayed on the LCD and sent to the database and can be monitored through the website. The avalanche detector made is powered by a 15 V DC battery to provide 5V output to the NodeMCU ESP8266. Soil moisture sensor, MPU6050, LCD I2C, LED, and relay work at 5V. A Relay is used to turn on the siren at 12V voltage. Based on our research, the soil moisture measurement value between the sensor and the comparison device is around 1.55% and the soil slope measurement value between the sensor and measuring tool is around 0.14%, these two factors influence each other. The measurement error is still fairly normal according to the soil moisture sensor datasheet and MPU6050, which are $\pm 3\%$ together.

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1. INTRODUCTION

Landslides are a disaster that often occurs in hilly and mountainous areas [1]. The condition of the soil in parts of Indonesia is classified as prone to landslides. Based on the landslide vulnerability zone map according to the National Disaster Management Agency (BNPB) in 2023, there were 634 landslides in Indonesia [2].

Geographical conditions, which are generally mountainous areas with slopes, make the soil unstable. As a result, when the soil is moved, it becomes prone to landslides [3, 4]. Movement of soil and excess water content are the main causes of landslides. Landslides are also affected by the presence of a driving force on the ground which is greater than the resisting force [5, 6, 7]. In general, the Center for Volcanology and Geological Hazard Mitigation said that landslides have several symptoms that can be observed visually, including occurring after rain, cracks appearing on the slopes parallel to the direction of the cliff, buildings starting to crack, trees or electricity poles slanted, and

new springs appear [8]. Landslide disasters can cause many losses, including causing casualties, disruption of transportation facilities, damaging agricultural land, and various other consequences that are detrimental to community activities [9]. The impact of this landslide disaster can be avoided with prevention efforts using an early warning system for landslides so that people can know the signs of landslides and receive warnings that landslides will occur [10, 11]. Information technology that is integrated into various aspects of life is often referred to as the Internet of Things (IoT) [12,13,14]. Its reliability makes everything connected, monitored, and controlled as expected [15]. The use of soil moisture sensors to detect soil moisture levels capacitively [16]. MPU6050 sensor to detect conditions at a certain level of slope that is integrated with the gyroscope sensor [17]. The ESP8266 module is complete and unified as an application provider that is integrated with sensors or with certain application tools [18].

In research conducted by Supriyatna entitled "Design and Build Early Warning Systems for Landslide Prone Areas". In this study designing a tool using an accelerometer sensor and LDR sensor, the system can be monitored wirelessly by adding a telemetry radio connected directly to Arduino and a computer using Labview [19]. However, it still has drawbacks, namely not using Android applications and not being based on IoT.

Research conducted by Muhammad Reza Maulana, et al entitled "Design of a Landslide Detection System Using IoT-based Gyroscope and Hygrometer Sensors" [20]. The designed system will provide information via telegram notifications. However, it has a drawback, namely sensor data is not stored in the database. So that the community cannot monitor the value of soil moisture and the slope of the land.

Based on previous research, the solution we want to offer is to create an avalanche detection design with the innovation we want to develop, namely by utilizing a soil moisture sensor to measure soil moisture and the MPU6050 sensor to measure the slope of the soil. Where sensor data can be monitored through the website so that it can be accessed from anywhere and at any time by the general public, which can complement a landslide early warning system that is reliable and user-friendly.

2. RESEARCH METHODS

2.1. Research procedure

In making this research the authors used the DSRM research method (Design Science Research Method). This method is used to create and design systematically to produce an output in the form of this design. The design of this website-based landslide detector tool begins with conducting a literature study of the research to be carried out to determine the tools and materials needed. The next step is to design a series of devices and do programming on the controller. After the program is successful, then the assembly of the device components is carried out. Further testing and analyzing the test results according to Figure 1.

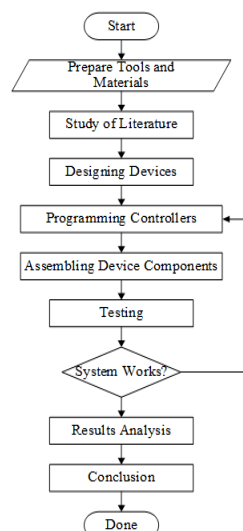


Figure 1. Research procedure

2.2. Diagram Block System

This landslide detector was designed using Nodemcu ESP8266 as the main control system, a soil moisture sensor to measure soil moisture, and an MPU6050 sensor to measure soil slope. Both sensors will send data to MySQL as a database. Then the data that has been stored will be displayed on the website according to Figure 2. After that, the sensor value is also displayed on the LCD. The siren will sound and the LED will flash simultaneously if there are signs of an impending landslide. The system block diagram can be seen in the following figure.

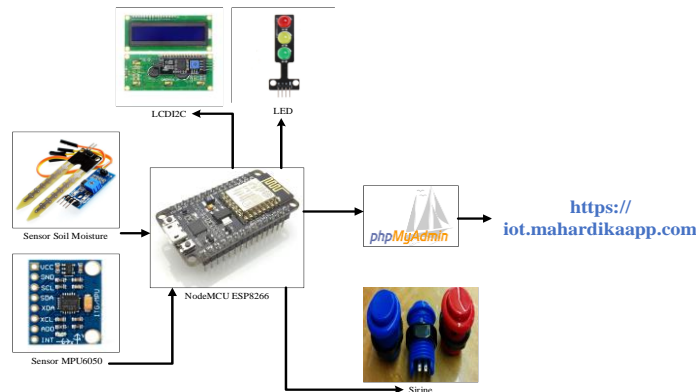


Figure 2. System block diagram

2.3. Device System

The series of systems in this study can be seen in Figure 3. All of these circuits function to read the parameters of soil moisture and soil slope in real-time through the website. So, the user can find out the sensor reading data remotely.

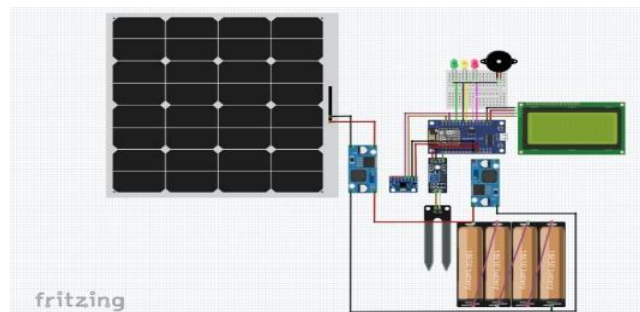


Figure 3. System Device

2.4. Flow Chart System

The working system of the avalanche detector design begins with initializing the data and then connecting the device to the internet using the ESP8266. Sensor data and ground state levels will be processed into three classifications, namely safe, alert, and dangerous. If the ground state is in Safe condition, the green LED will light up. However, if the ground is in an alert condition, the yellow LED will light up. And if the ground is in a Danger condition, the red LED and siren will light up simultaneously. Then the sensor data and soil condition classification will be displayed in real-time on the 12C LCD and the website if the serial number has been registered. The flow diagram of the avalanche detector work system can be seen in Figure 4.

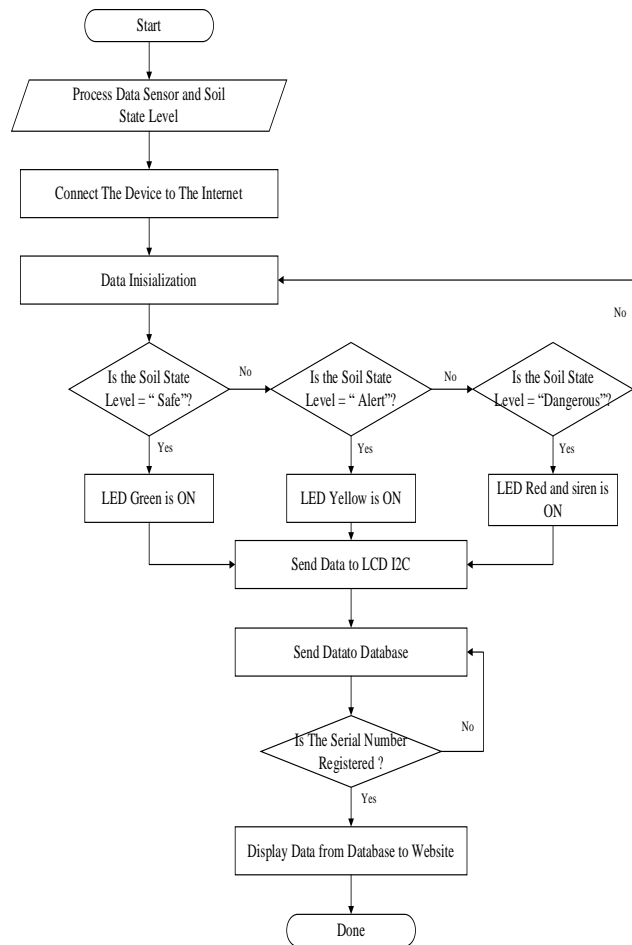


Figure 4. System flowchart

2.5. Software System

The use of the website as an IOT implementation is required to display sensor data that has been sent from ESP8266 to the database. To access the website, two types of users have been provided, namely admin and operator. Where both have different access rights.

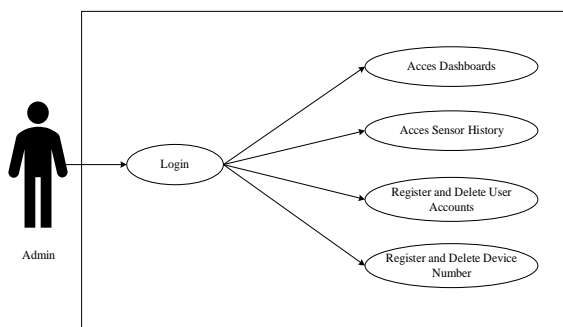


Figure 5. Admin charts

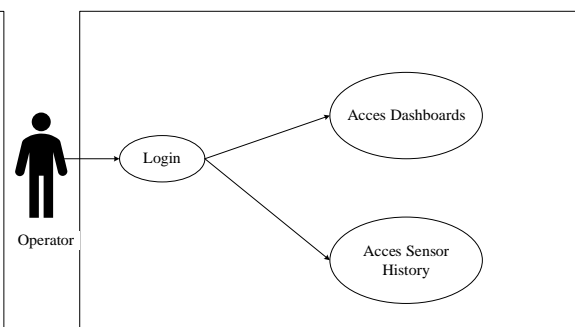


Figure 6. Operator charts

In Figure 5 the admin after logging in can access the dashboard, sensor history, users, and devices. Meanwhile, if you enter as a user, you can only access the dashboard and sensor history. As described in Figure 6.

In making the website, there are several menus, namely login, dashboard, sensor history, users, and devices.

a. Login and Register



Figure 7. Login menu display

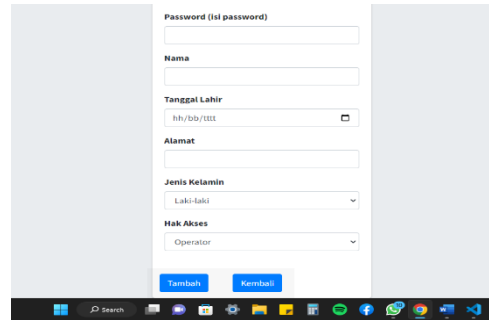


Figure 8. Display menu register

In Figure 7, we can see that the login menu must fill in the username and password for the account that has been registered. If the username and password do not match the database, a notification will appear "incorrect username or password". On the Register menu, if someone wants to visit the website but doesn't have an account, then he can press the "register" button to create an account. But accounts that have been registered are only as operators. More details can be seen in Figure 8.

b. Dashboard

On the dashboard menu, soil moisture and soil slope sensor data sent from NodeMCU ESP8266 to Mysql will be displayed in graphical form in real-time. The dashboard display can be seen in Figure 9.

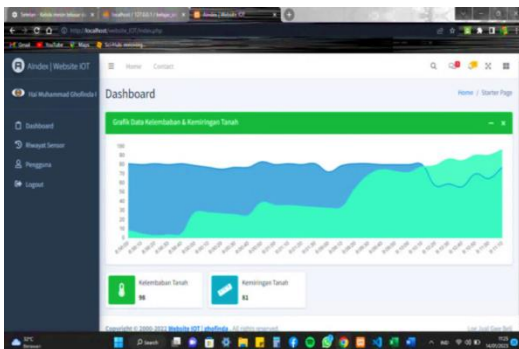


Figure 9. Dashboard view

ID	Serial Number	Sensor	Nilai	Sensor2	Nilai2	Waktu
2720	10284251	Soil_Moisture	51	MPU6050	161	2023-11-02 15:18:28
2722	10284251	Soil_Moisture	50	MPU6050	161	2023-11-02 15:18:30
2723	10284251	Soil_Moisture	50	MPU6050	161	2023-11-02 15:18:30
2724	10284251	Soil_Moisture	50	MPU6050	161	2023-11-02 15:18:32
2725	10284251	Soil_Moisture	50	MPU6050	161	2023-11-02 15:18:32

Figure 10. Display of sensor history

c. Sensor History

In addition to displaying data in graphical form on the dashboard menu. The sensor history menu is also used to display sensor data. However, the difference is that the data displayed in table form is based on the serial number on each controller that has been registered. In Figure 10 the sensor data shown comes from the Nodemcu ESP8266 controller with serial number 10284251. In addition, data on sensor history can also be printed to make it easier to analyze the design.

d. User

This menu can only appear if you are an admin user. The user menu contains registered user data in tabular form. Users who have access rights as admin can register, change or delete user data. The user menu display can be seen in Figure 11.

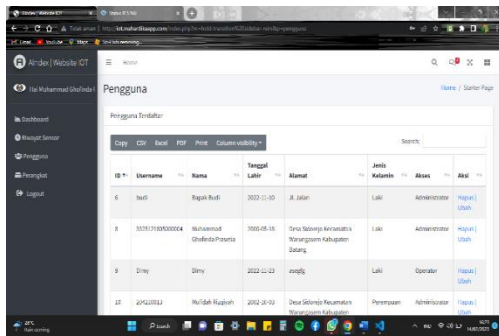


Figure 11. User menu display

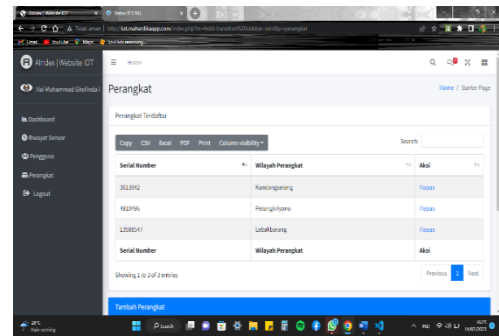


Figure 12. Device menu display

e. Device

The device menu functions to register the controller serial number in the design so that it can send sensor data to the database. Because only the controller on the device whose serial number has been registered can send sensor data to the website. In Figure 12 the device data contains the serial number that has been registered and the name of the area of the design device that is placed.

3. RESULTS AND DISCUSSION

3.1. Calibration

The calibration process of the soil moisture sensor and MPU6050 is used to determine and obtain the accuracy of the sensor when collecting data as a standard or reference in measuring soil moisture and soil slope.

The measurement of soil moisture is carried out by comparing the measurement of the soil moisture sensor and the measurement of the soil tester. Then, measuring the slope of the land is done by comparing the MPU6050 sensor measurements with protractor measurements.

a. Calibrate Soil Moisture with a Soil Tester

Before calibrating the soil moisture value, it is necessary to convert the soil moisture sensor resistance value into percentage units. Based on reading the value of the soil moisture sensor data, the resistance value of the soil moisture sensor reading is from the numbers 0 – 1023 bits which indicate the moisture value of the soil. The higher the value reading, the lower the soil moisture condition or it can be said to be dry. And conversely, the lower the value read by the sensor, the higher the soil moisture condition.

Therefore, to facilitate research, it is necessary to change the sensor value to a percent value (%). Refer to the manual calculation of soil moisture to change the sensor value to a percent value using equation (1).

$$\text{Percent Value} = \frac{1023 - \text{sensor value}}{1023} \times 100\% \tag{1}$$

Equation (1) explains that the sensor values obtained are reduced by the sensor value range, which amounts to 1023 and multiplied by 100%. The purpose of changing this value is so that the tool can directly detect the percentage of soil moisture so that it can be easily understood. The results of changing the sensor value from the resistance value to the percent value (%) are as follows.

Table 1. Conversion of sensor values to percent values

Sensor Value	Percent Value (%)
0	100%
353	65,5%
413	59,6%
560	45,2%
821	19,8%
1023	0%

After converting the unit value on the sensor to a percentage value, what needs to be done is calibrate the soil moisture sensor against similar comparison devices. Calibration is carried out by preparing varied soil samples based on the level of water content. Then the sample was measured using a soil moisture sensor and a soil tester as a comparison tool. Measurements were repeated three times for each sample. So that the measurement data is obtained in Table 2 as follows.

Table 2. Soil moisture calibration data with a soil tester

No	Soil Tester (%)	Soil Moisture (%)	Error (%)
1	23.3	21.3	2
2	24	22.3	1.7
3	31.7	30.3	1.4
4	33.3	30.7	2.6
5	41.3	40	1.3
6	43.3	43	0.3
Average			1.55%

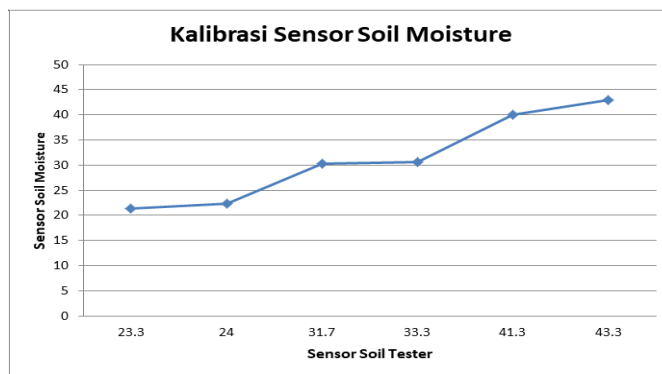


Figure 13. Average in the measurement results of the soil moisture sensor and the soil tester

Figure 13 shows that the average difference in the measurement results of the soil moisture sensor and the soil tester is 1.55%, so it can be interpreted that the soil moisture sensor can measure soil moisture with relatively good measurement results.

b. MPU6050 Calibration with Protractor

The test is carried out by comparing the slope of the tool with the slope of the protractor. Data collection is not carried out directly on the ground to determine the compatibility between the tool and the protractor directly. The reading results of the tool and the protractor must be the same because the tool is used as a detector of the slope of the land in degrees. Data collection at certain angles starting from 0° - 180° is carried out to ensure the accuracy of the tool and ensure that the status of the avalanche detector is displayed properly. The results of testing the tool can be seen in Table 3 as follows.

Table 3. MPU6050 calibration data with protractor

No	Protractor (°)	Sensor MPU6050 (%)	Error (%)
1	0	0	0
2	30	30	0
3	45	45	0
4	60	60.4	0.4
5	90	90.2	0.2
6	135	135	0
7	180	180.4	0.4
Average			0.14%

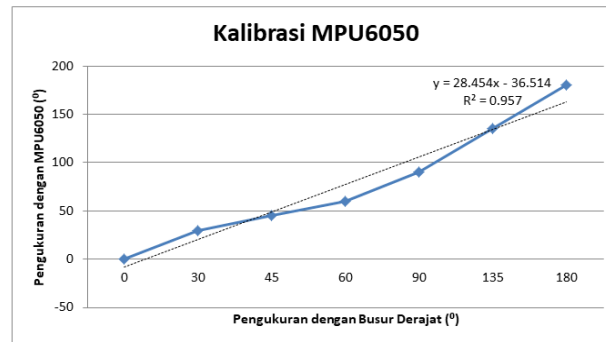


Figure 13. MPU6050 Calibration Measurement

It can be interpreted that the slope of the protractor with the results of the MPU6050 sensor reading is almost the same. The average difference in the measurement results of the MPU6050 sensor and the protractor is 0.14%, the difference between the slope of the protractor and the MPU6050 sensor is because the sensor is very sensitive so it easily changes when the sensor is exposed to small movements. Therefore, the sensor must be installed in a very stable position to produce more accurate data.

3.2. Testing

Tests on the design of the landslide detector are carried out based on the probability that the cause of the landslide will occur from the level of soil moisture and the slope of the soil. The probability of a landslide occurring is then tested every 10 seconds and repeated five times for each variable. So the following results are obtained:

Table 4. Test data sample

NO	ID	Serial Number	Nilai	Nilai	Waktu
			Sensor Soil Moisture	Sensor MPU6050	
1	1180	16723438	1023	100	2022-11-14 17:20:18
2	1185	16723438	415	41	2022-11-14 17:20:28
3	1190	16723438	413	40	2022-11-14 17:20:39
4	1195	16723438	416	41	2022-11-14 17:20:49
5	1200	16723438	1023	100	2022-11-14 17:20:59

In Figure 14 it can be seen that the average value changes every 50 seconds with a delay in sending data from the controller to the server average of approximately 1 second as shown in Table 4 because the design was tested with several treatments. In the first treatment, the design was in an upright position from an angle of about 80°, and the soil moisture sensor was planted in dry soil. In the second treatment, the design was at an angle <80° Soil moisture sensors were planted in soil that was sprinkled with a little water. In the third treatment, the design was at an angle of about 80°, and the soil moisture sensor was planted in the same soil and added a little water until it was moist. In the fourth treatment, the design was made at the same angle, and the soil moisture sensor was planted in water-soaked soil until the soil became soft. In the fifth treatment, the design was at an angle of <80° and planted in watery soft soil. Each treatment in design testing is classified into three conditions: safe, alert, and dangerous. This classification is distinguished from changes in the value of the soil moisture sensor and the MPU6050 sensor. According to the following table:

Table 5. Classification of Lanslide condition

No	Condition	Soil Moisture Value	MPU6050 Value
1	Safe	< 30	≥80° & ≤91°
2	Alert	< 30	<80° & >91°
		≥ 40	≥80° & ≤91°
		> 30 dan <50	≥80° & ≤91°
3	Dangerous	≥ 40	<80° & >91°
		> 30 dan <50	<80° & >91°

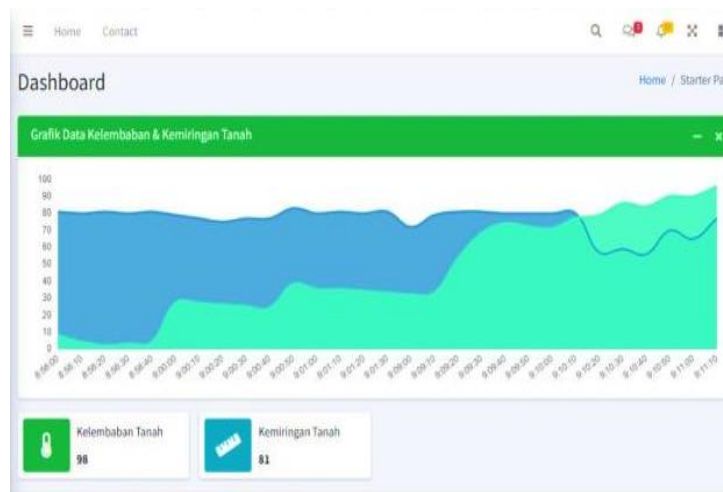


Figure 14. Graph of soil moisture and slope data

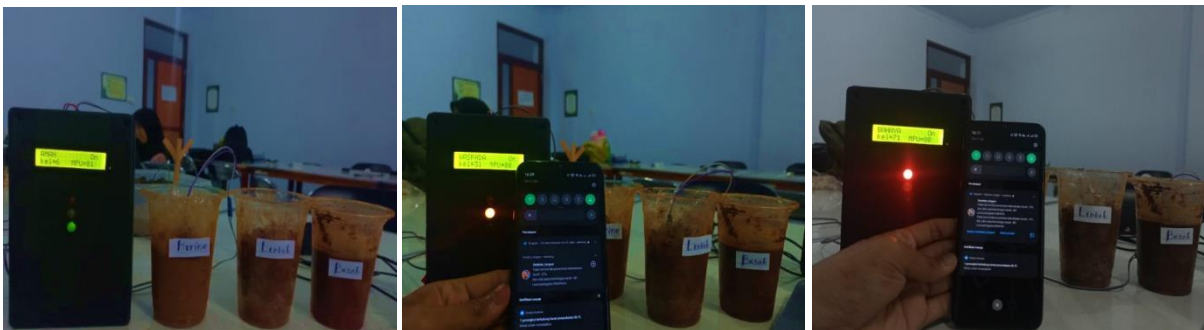


Figure 15. Equipment testing documentation

4. CONCLUSION

Based on the design, observation, and testing that has been done, the following conclusions can be drawn:

- A landslide detection design has been made using the MPU6050 sensor as a soil slope detection and a soil moisture sensor as a soil moisture detector which can be monitored from the website.
- The MPU6050 sensor can detect the slope of the land well, which only has an average error value of 0.14% for a square as a comparison tool. The Soil Moisture sensor can detect soil moisture well, where the average error value is 1.55% against the soil tester as a comparison tool.
- Each treatment in design testing is classified into three conditions: safe, alert, and dangerous. The classification is distinguished from changes in the value of the soil moisture sensor and the MPU6050 sensor.
- The design of this landslide detector device can run as expected, namely, it can provide notifications in real-time containing information on soil conditions, soil moisture values, and soil slope when in an alert and dangerous condition via the website optimally.

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