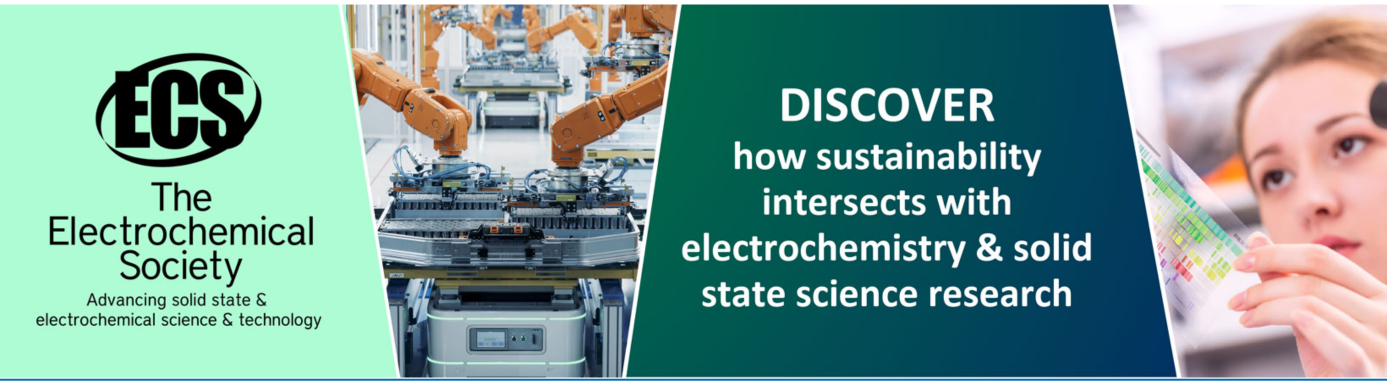
Journal of Physics: Conference Series

PAPER • OPEN ACCESS

IoT Real-Time Soil Monitoring Based on LoRa for Palm Oil Plantation

To cite this article: Muhammad Syarafuddin Md Saleh *et al* 2021 *J. Phys.: Conf. Ser.* **1874** 012047



IoT Real-Time Soil Monitoring Based on LoRa for Palm Oil Plantation

Muhammad Syarafuddin Md Saleh[1], Aznida Abu Bakar Sajak[2*], Rafidei Mohamad[3], Mohd Ariff Majmi Zaaba[4]

[1-4]Universiti Kuala Lumpur, 1016, Jalan Sultan Ismail, Bandar Wawasan, Kuala Lumpur, Wilayah Persekutuan Kuala Lumpur 50250, Malaysia

Abstract— IoT Real-Time Soil Monitoring based on LoRa for Palm Oil Plantation is a prototype that can send data to the receiver using LoRa technology. The prototype used LoRa technology because it is a long range and low-cost technology. The prototype used LoRa SX1278 and the sensors as the main components. It shows the communication between the sender and receiver of LoRa technology and notifies the user soil tilt and temperature in real time via the ThingSpeak platform. A tilt and temperature sensors must be attached at the LoRa sender. It then sends data to the LoRa receiver. As the data received by the receiver, it will then display the data using the serial monitor and also at the LoRa receiver's OLED. This prototype is easy to use and easy to set up as the soil monitoring system. This Real-time Soil monitoring system helped the user to know the tilt and temperature readings via the ThingSpeak.

1. Introduction

This project is about monitoring the soil temperature and tilt in real-time by palm oil plantation workers. In agriculture technology, manual method of measuring soil temperature and tilt is the reading is not accurate because the different soil sample taken at the field and when the soil sample is measured in a laboratory. It must become necessary to create some smarter technology from the Internet of Things (IoT) to overcome the challenge to overcome this problem. For this project is about monitoring the soil temperature and tilt using LoRa based in palm oil plantation. In plantation which usually in a rural area, it quite hard to monitor the soil temperature and tilt because it lacks Internet such as Wi-Fi or cellular coverage. Hence, LoRa must be used because of it mostly flexible for rural or indoor use cases in smart cities, smart homes and buildings, smart agriculture, smart metering, and smart supply chain and logistics[1]. The objective of this project is to develop a prototype using a temperature sensor to determine its ideal soil temperatures. Second is to create a prototype using a tilt sensor, determine the level of inclination of soil and for the last is to facilitate oil palm plantation workers to check the soil condition through ThingSpeak.

Palm oil has already been a long time planted which has area thousands of hectares and been manually monitor by the workers, but it is not the most efficient way to do the work. The workers manually need to check and maintain the appropriate soil temperature and tilt content throughout the year. The farmers mostly rely on their little knowledge they gain from experience or by just looking at the crops. This leads to many mistake and damage happen to the plants. If the appropriate amount is not maintained, it can be harmful to the plants. Example, during draughts season, keeping the water supply is very crucial to the plants.

Scope of this project is developing an IOT project that can monitor the soil temperature and tilt using a LoRa module. The boundary or coverage of this project was limited to palm oil plantation workers only. They can monitor the soil temperature and tilt reading using their smartphone by mobile apps. For this project, it will only use temperature and tilt sensor to determine and measure the reading of temperature and tilt in soil. The convenience of mobile application also will be developed to display the reading of soil temperature and tilt.

For the limitations, the basic limitation of LoRa is Line of Sight (LOS). Line of Sight (LOS) is the straight path between a transmitting antenna (as for radio or television signals) and a receiving antenna when unobstructed by the horizon. This is complemented by three calculation models for network coverage which is LoRa signals in forest areas, indoors and underwater – admittedly very special, but interesting, as we found out.

2. Methodology

For this project, the process model proposed is the Iterative Waterfall model. This platform supports redesign for any project changes. If there were no conditions or failures during the program execution, the stage would be returned to the previous iteration[2]. The model's functionality is shown in Figure 1. The model consists of six steps:

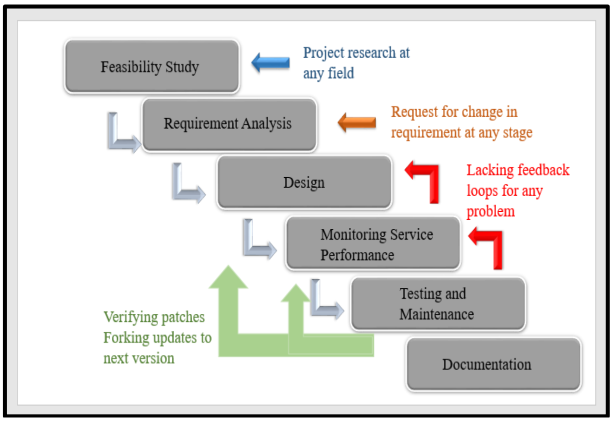


Fig. 1 Waterfall Model

i. Feasibility study

The feasibility study is an analysis that involves economic, technological, legal and planning considerations in order to determine the probability of the project's successful completion takes into account all the relevant factors in the project. Project managers are using feasibility studies to detect the advantages and disadvantages of thinking before investing plenty of time.

ii. Requirement Analysis

All possible project information and the requirements are therefore recorded and documented in this phase. It is because the new concept needs to be understood, and the project specifications need to be created. The parameters required to operate this project are defined, supported by the preliminary analysis, the hardware and software.

iii. Design

During this phase, the requirements for the primary stage studied and system design are ready. System Architecture helps to determine specifications of hardware and device and to describe the overall system architecture. In the next step, the software code has been developed.

iv. Monitoring Service Performance

Both hardware and software will be checked during this stage to ensure that everything is fit and works appropriately. This is also necessary to ensure that the completion of this project does not cause any complications or issues. Each hardware must also be tested during this process if it has been appropriately wired and there will be no system harm if it is mounted improperly. If all goes well, the project will be expanded to the next level.

v. Testing and Maintenance

At this point, the systems are checked, and the specification will, therefore, be evaluated in accordance with the purpose and scope of the project. So, both experiments will be performed at different locations and conditions. In the event of any error, the system or computer needs to be rebuilt and debugged, and some experiments will be carried out in this process.

vi. Documentation

The last step of this model is documentation. The report is corrected and amended if a grammatical error exists. All the five previous phases will be included in the study in order to measure the progress achieved in this process.

3. Hardware and Software

For this project, the hardware is necessary as a platform to develop. During this step, it is needed to define the project's purpose, requirements and specifications, including tooling and software. This phase is important for gathering project information. The requirement selection should be completed before progressing to the next level. Also, a network element such as a router, a switch or wireless technology should be the most important requirement of the project. The project uses wireless technology from LoRa. Also, it needs software for the android application to be designed and functional.

3.1 Hardware and Software Development

Figure 2 shows the flowchart of the IoT Real-Time Soil Monitoring Based on LoRa for Palm Oil Plantation. During the development phase, all physical components are connected and configured. To start the configuration on TTGO ESP32 with LoRa, it needs to be connected to a computer. The microcontroller will automatically be powered up once it is related to the USB port of the computer. Once connected, the Arduino IDE and related drivers need to be installed in the microcontroller.

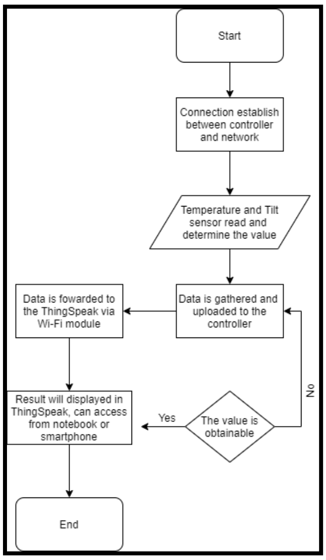


Fig 2. Flow Chart.

Table I
Hardware and Software

Items	Quantity
Hardware	
TTGO ESP32 LoRa 32	2
DS18B20 Temperature Probe	1
ADXL355	1
Jumper	1 Set
Breadboard	1
Software	
Arduino IDE	1
Thingspeak	1

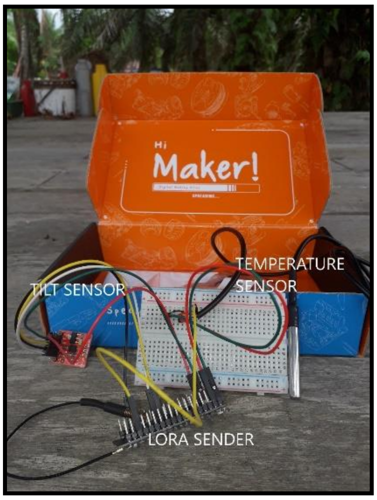


Fig 3. LoRa Sender

Based on figure 3 above, TTGO ESP32 was used to connect all sensors in one board. ESP32 has built-in LoRa SX1278, which is transceiver adds support for LoRa protocol that needed for The Things Network. It will use the TTGO LoRa 32 board for sending and receiving LoRa messages using the ESP32. All LoRa modules are transceivers that enable information to be sent and received. It will need two of them which is one as sender and another on as receiver. During the development phase, all physical components connected to a computer. LoRa used for the sender and receiver. LoRa sender will send sensors data to LoRa receiver, and LoRa receiver will capture the data then send it to the database or cloud (Thingspeak). To start, LoRa must need to be connected to the computer. For the Asia region, the TTGO board was recommended to use the 433MHz frequency band.

Fig 4. LoRa Receiver

For LoRa receiver, it will receive the sensor (temperature and tilt sensor) data from LoRa sender. The sensor data can also be displayed on the TTGO OLED and the ThingSpeak. All ThingSpeak configuration must be uploaded to this LoRa receiver.

Fig 5. Temperature Probe

Based on figure 5, DS18B20 (Temperature Probe) will connect to the TTGO board on the LoRa sender[3]. The temperature sensor is connected to the TTGO LoRa32 board by three pins:

- VCC = +5.5V pin
- GND = GND pin
- GPIO = 4

Create the instances needed for the temperature sensor. The temperature sensor is connected to GPIO 4. This temperature sensor can detect the heat until 85 degrees and it also waterproof. The temperature on soil or water can also be detected with this sensor. The sensor will poke to the soil to take the accurate value. For temperature sensors, the user will poke the in the soil.

Fig 6. ADXL 355 (Tilt Sensor)

The tilt sensor to ensure that the X, Y and Z axes are correctly positioned on the surface of the ground is shown in Figure 6. On the tilt sensor board, the X, Y and Z-axis indicators are shown[4]. The tilt sensor should be located on the left side of the board with the pin to achieve an accurate result. For the connection on the TTGO board, tilt sensor will be used:

- X-axis = GPIO 32
- Y-axis = GPIO 12
- Z-axis = GPIO 33
- VCC = +5.5V pin
- GND = GND pin

3.2 Sensor Connection

As the procedure, on **LoRa sender**, all the sensors must connect to the LoRa sender pin. Also, all the sensor coding must be configured on the LoRa sender. Connect the temperature sensor and tilt sensor to the correct pins. The incorrect pin may cause data value misreading on ThingSpeak later. LoRa, temperature, and tilt sensor coding must be placed in one-page coding on Arduino IDE. Upload the coding and check on the serial monitor; it will display the sensor data on that serial monitor.

For **LoRa receiver**, only upload the LoRa with ThingSpeak coding to establish a connection between the ESP32 and user network credentials. LoRa receiver will capture the sensor data from the LoRa sender, and the sensor data will display on the Thingspeak. Sensor data also showed on OLED at the

TTGO board LoRa receiver. ThingSpeak coding must be configured at the LoRa receiver because LoRa receiver was placed within the user Wi-Fi home network, which is the user can monitor their sensors reading via smartphone at their home or office. ThingSpeak uses the Wi-Fi module to display the soil status graph utilising a smartphone for workers in palm oil plantations. If no link is formed between sensors and controllers, the data can not be transmitted either to the microcontroller or to the cloud database. End-users must be connected to the Wi-Fi in order to display the output. Users must turn on the hotspot so the LoRa receiver can be connected to the smartphone.

3.3 ThingSpeak Configuration

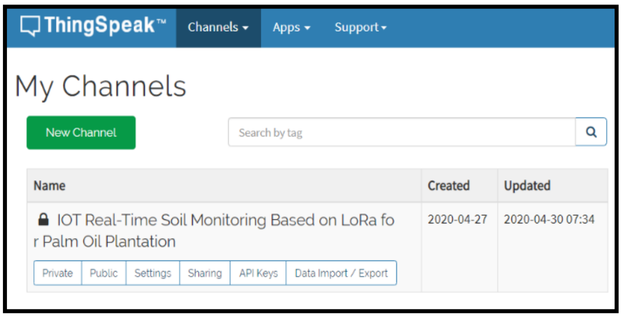


Fig. 7 ThingSpeak Channel

Go to https://thingspeak.com/ and create an account if you do not have one. Login to the account. Create a new channel by clicking on the button. Enter the necessary details of the channel. Then**,** scroll down and save the channel. Channel Id is the identity of our ThingSpeak channel. Note down this. Then go to API keys copy and paste this key to a separate notepad file will need it later.

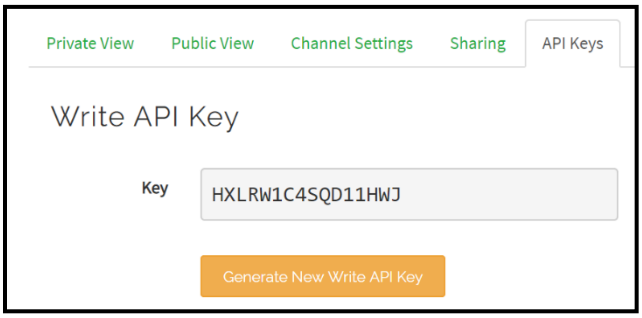


Fig. 8 API Keys

Based on figure 8, the user must copy the API key to the ThingSpeak coding on the LoRa receiver to establish the communication between the Wi-Fi module and the ThingSpeak.

4. Result and Discussion

F5

	A	B	C	D
1	created_a	entry_id	temperatu	tilt
2	2020-04-3	1	31	29
3	2020-04-3	2	31	29
4	2020-04-3	3	32.5	29
5	2020-04-3	4	33.5	28
6	2020-04-3	5	33.5	27
7	2020-04-3	6	33	27
8	2020-04-3	7	32.5	27
9	2020-04-3	8	32	27
10	2020-04-3	9	32	27
11	2020-04-3	10	31.5	26
12	2020-04-3	11	31.5	27
13	2020-04-3	12	31.5	29
14	2020-04-3	13	31	28
15	2020-04-3	14	31	28
16	2020-04-3	15	31	29
17	2020-04-3	16	31	28

Fig. 9 Database Table

Figure 9 shows the results retrieved from sensors stored in the cloud database. It has four columns and 18 rows. First-row display about the title for each of the four columns. The first row shows when the database was built and shows the time zone of the database. The sequence of the data collected is displayed on the "entry id.". Next, the third column was the reading temperature sensor value. Last, the fourth column was the reading of the tilt sensor in the degree unit. Each “time zone”, “entry_id”, “temperature” sensor, and “tilt” sensor will be updated automatically when the sensor data collected.

4.1 Temperature Sensor Result

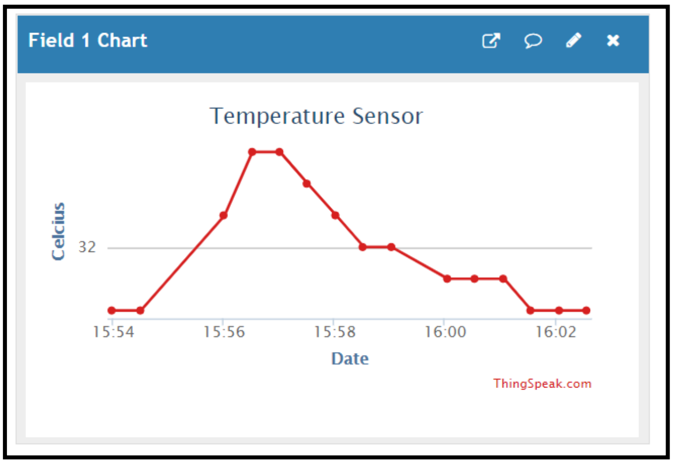


Fig. 10 Temperature Graph

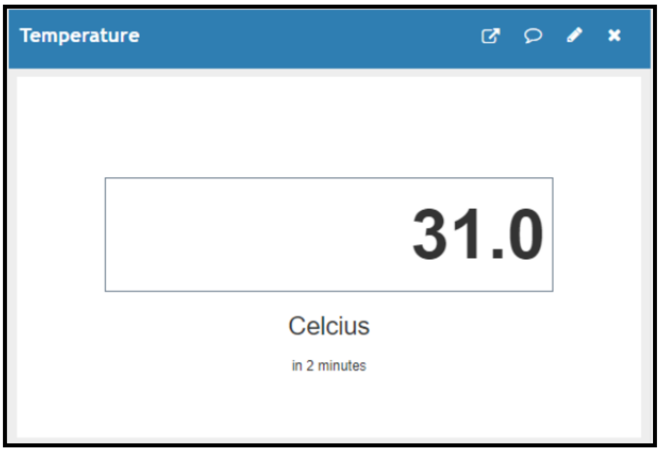


Fig. 11 Temperature Numeric

Based on figure 10, it shows data from the temperature sensor, and it created by ThingSpeak. It is a line graph and numeric view. The line graph will be showing how its output changes as vary its input. Meanwhile, for the digital look is to easy the user the read the temperature data by their mobile devices or smartphone. The collected data is given by the temperature sensor. The x-axis of the graph represents the temperature of the soil, while the y-axis of the graph represents the time data was collected.

4.2 Tilt Sensor Result

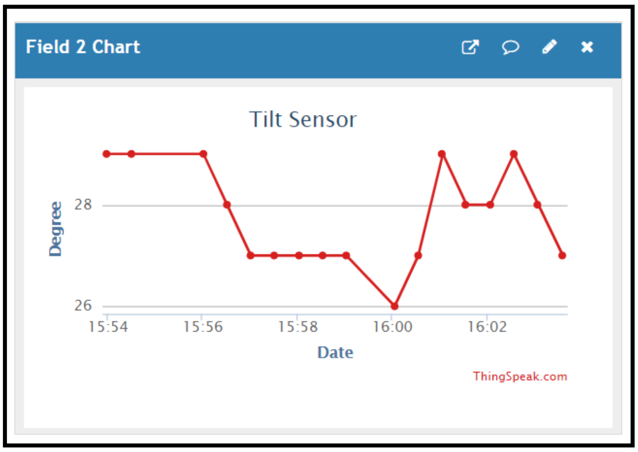


Fig. 12 Tilt Graph

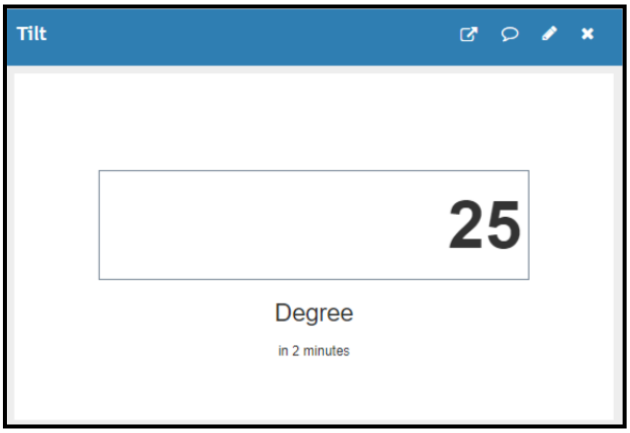


Fig. 13 Tilt Numeric

Figure 11 shows a graph is created using ThingSpeak. It shows the line graph and the digital view. This graph is plotted based on the angle of the tilt of the soil over time. The data is given by the collected data of the tilt sensor. The graph's x-axis indicates the degree of tilt of the soil, while the y-axis of the graph indicates time. It also shows the user in the form of numeric view to easy the user read the data sensor on their smartphone or mobile devices.

4.3 Analysis and Discussion

a) Soil Temperature (Minimum)

54	2020-04-3	53	29.5	
55	2020-04-3	54	29.5	
56	2020-04-3	55	29.5	
57	2020-04-3	56	29.5	
58	2020-04-3	57	29.5	
59	2020-04-3	58	29.5	
60	2020-04-3	59	29	
61	2020-04-3	60	24	Min
62	2020-04-3	61	23	Min
63	2020-04-3	62	22	Min
64	2020-04-3	63	29	
65	2020-04-3	64	29	
66	2020-04-3	65	29	
67	2020-04-3	66	29	
68	2020-04-3	67	29	

Fig. 14 Soil Temperature (Minimum) Table

Based on figure 12, it shows the soil temperature table from the ThingSpeak database. As for palm oil plantation, the ideal soil temperature (minimum) between 24 °C below and 36°C above was not suitable for the growth of palm oil plantation[5]. For example, data with entry id for 61 until 63 was not ideal because the temperature was at 23°C on average. Therefore, some action needed to be taken by the worker to increase the soil to the perfect temperature.

b) Soil Temperature (Good)

54	2020-04-3	53	29.5	
55	2020-04-3	54	29.5	
56	2020-04-3	55	29.5	
57	2020-04-3	56	29.5	
58	2020-04-3	57	29.5	Good
59	2020-04-3	58	29.5	Good
60	2020-04-3	59	29	Good
61	2020-04-3	60	24	Min
62	2020-04-3	61	23	Min
63	2020-04-3	62	22	Min
64	2020-04-3	63	29	
65	2020-04-3	64	29	
66	2020-04-3	65	29	
67	2020-04-3	66	29	

Fig. 15 Soil Temperature (Good)

Based on figure 13, it shows the soil temperature table from the ThingSpeak database. As an example, data from entry id 58 until 60, it shows the ideal temperature for palm oil plantation soil. This means the soil is good. The perfect soil temperature range was between 24°C to 36°C. Consequently, workers should not take action.

c) Soil Tilt (<25°)

52	2020-04-3	51	23
53	2020-04-3	52	25
54	2020-04-3	53	25
55	2020-04-3	54	26
56	2020-04-3	55	20
57	2020-04-3	56	24
58	2020-04-3	57	23
59	2020-04-3	58	19
60	2020-04-3	59	24
61	2020-04-3	60	20
62	2020-04-3	61	21
63	2020-04-3	62	24
64	2020-04-3	63	23
65	2020-04-3	64	22
66	2020-04-3	65	20
67	2020-04-3	66	23
68	2020-04-3	67	24

Fig. 16 Soil Tilt (<25°) Table

Based on figure 14, it shows about the soil tilt sensor data from the ThingSpeak. For example, entry id data from 58 until 67 shows, the reading of soil tilt was below 25 degrees. The soil is therefore ideal for the plantation of palm oil. In addition, workers had no action to take.

d) Soil Tilt (>25°)

1	created_a	entry_id	tilt
2	2020-04-3	1	29
3	2020-04-3	2	29
4	2020-04-3	3	29
5	2020-04-3	4	28
6	2020-04-3	5	27
7	2020-04-3	6	27
8	2020-04-3	7	27
9	2020-04-3	8	27
10	2020-04-3	9	27
11	2020-04-3	10	26

Fig. 17 Soil Tilt (>25°) Table

Based on figure 15, it shows about the soil tilt sensor data from the ThingSpeak. For example, entry id data from 1 until ten shows, the reading of soil tilt was upward to 25 degrees. This indicates that the land is not suitable for planting. The acts needed for the workers are therefore cut off from the cliff into a sort of a terrace or staircase.

5. Conclusion
This section will discuss the conclusion of the report and recommendation for future use. Some recommendations are provided for future improvement and enhancing the project. Generally, the objective of this project has been achieved successfully. The hardware and software components are works properly for this project.

5.1 Summary
In conclusion, TTGO ESP32 with build-in LoRa SX1278 had been able to function as wireless technology and work properly for the project. The developed prototype has fulfilled the objective to develop a prototype that detects the tilt and temperature reading using LoRa technology. The sensor read the temperature data reading and send data to the receiver via wireless communication. Besides, the results show the real-time soil monitoring using LoRa technology provide an advantage to the user, which is the user can monitor the soil tilt and temperature at long distance. Based on data collected, LoRa should be able to communicate at long range which is 10 KM. The user does not need to be worried if some changes in the soil tilt and temperature. The prototype is easy to use and easy to set up at the palm oil plantation. In conclusion, the Real-time soil monitoring helped the user to know the reading of tilt and temperature in the palm oil plantation.

5.2 Future Recommendation
For the future recommendation, this project can be developed into a completed prototype which is completed with four soil parameters (ph, moisture, temperature and tilt) sensors which will be connected to the microcontroller.

6. References
[1] A. Augustin, J. Yi, T. Clausen, and W. Townsley, "A Study of LoRa: Long Range & Low Power Networks for the Internet of Things," *Sensors*, vol. 16, no. 9, p. 1466, Sep. 2016, doi: 10.3390/s16091466.

[2] "SDLC Models Explained: Agile, Waterfall, V-Shaped, Iterative, Spiral | Existek Blog." https://existek.com/blog/sdlc-models/ (accessed Jun. 19, 2020).

[3] "DS18B20 Temperature Sensor Pinout, Specifications, Equivalents & Datasheet." https://components101.com/sensors/ds18b20-temperature-sensor (accessed Jun. 19, 2020).

[4] "SparkFun Triple Axis Accelerometer Breakout - ADXL335 - SEN-09269 - SparkFun Electronics." https://www.sparkfun.com/products/9269 (accessed Jun. 19, 2020).

[5] "Plantations International Palm Oil." https://www.plantationsinternational.com/palm-oil/ (accessed Jun. 09, 2020).