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Comprehensive LoRa Based IoT Real-time Soil Monitoring for Oil Palm Plantation

Abstract. Comprehensive Long Range (LoRa) Based Internet of Things (IoT) Real-Time Soil Monitoring for Oil Palm Plantation is a prototype that can send data to the receiver using LoRa technology. This paper describes a paper that aims to improve the current technology and provides a solution to overcome the manual soil monitoring system. The objectives of this paper are to develop a prototype using a temperature sensor, tilt sensor, pH sensor and moisture sensor to determine the soil condition and to notify the farmers and the plantation managers of the soil conditions based on the data analytic. This prototype uses LoRa technology, a long-range and low-cost technology. The prototype's main components are LoRa SX1278 and four specific sensors that demonstrate the communication between the LoRa technology sender and receiver. The prototype notifies the user of the soil's tilt, pH, moisture and temperature value via the ThingSpeak platform in real-time. This paper aims to analyse the data obtained and send the alert notification to improve the soil quality. The Iterative Waterfall Model is the method that is used in this paper. This model is efficient and easy to adapt to the prototype. This proposed prototype can increase productivity and efficiency by monitoring the soil condition to maintain the excellent quality of crops.

Keywords: long range (LoRa); Soil; Oil Palm

1. Introduction

Oil Palm fresh fruit bunches (FFB) contributed 7.1 per cent (RM101.5 billion) to Malaysia's Gross Domestic Product (GDP) in 2019 (GKA Parveez, 2020). By using Information and Communication Technology ICT in the agricultural sector, this paper aims to provide a solution to overcome the manual soil monitoring system used previously by the plantation workers. The farmers mostly rely on the little knowledge they gain from experience or just looking at the crops resulting in an inaccurate assessment of the plants. If the appropriate amount of nutrients is not maintained, it can harm the plants. For example, during the draughts season, keeping the water supply is very crucial to the plants.

The usage of the Internet of Things (IoT) in the agriculture sector is relatively new due to this limitation. LoRa refers to wireless data communication technology that uses a radio modulation technique generated by Semtech LoRa transceiver chips (Platform for IoT, 2020). This modulation technique allows long-range communication of small amounts of data which means a low bandwidth and high immunity to interference while minimising power consumption. Hence LoRa allows long distance communication with low power requirements. LoRa uses unlicensed frequencies that are available worldwide. The most widely used frequencies in Europe are 868 MHz for Europe, 915 MHz for North America and 433 MHz for Asia. Long range and low power features offered by LoRa make it perfect for battery-operated sensors and low-power applications such as IoT. In point-to-point communication, two LoRa-enabled devices talk with each other using RF signals. Unlike WiFi or Bluetooth, which only support short-distance communication, two LoRa devices with a proper antenna can exchange data over a long distance. In December 2015, the Malaysian Communications and Multimedia Commission (MCMC) allocated 4 MHz of spectrum in the frequency band 919-923 MHz for the use of Short Range Device (SRD) in addition to bands 433-435 MHz, 2.4 GHz and 5.8 GHz that can be used for IoT applications (Malaysian Communications And Multimedia Commission (MCMC), 2021). MCMC is the regulator for the converging communications and multimedia industry in Malaysia. This paper utilised the 433 MHz bad. Basically, in the paper, the chip LoRa SX1278 is the physical layer.

Much research has been carried out in the past about oil palm monitoring systems (Hossain, 2018; Heri, 2019; Hossain, 2022). The first project was based on the remote tracking of soil conditions via a smartphone. Bluetooth communication is used to submit data from the sensors to a smartphone (Abdullah Na, 2018). However, Bluetooth covers a shorter range than LoRa. The second project concerns an automatic irrigation system remotely controlled by an Android smartphone leveraging Zigbee technology, standardising IoT networks and providing an authoritative standard for WSN equipment (Raju Anitha, 2018). Zigbee technology also covers a shorter range than LoRa.

Furthermore in (Rawi, 2020), a soil monitoring system paper to detect pH value, moisture, and tilt using IoT technology in palm oil plantations is introduced. The system uses ThingSpeak, where the results were sent to the ThingSpeak application and showed a reading on the smartphone in a graph form. The data are sent via WiFi technology. Similar to Bluetooth and Zigbee, WiFi coverage is smaller than LoRa. In (Ruslan,2021) and (Saleh,2021), two (2) separate soil monitoring systems are introduced. These current projects on a soil monitoring system do not have a complete combination sensor measuring the tilt, pH, moisture and temperature to check and maintain the excellent soil condition in palm oil plantations.

This proposed system combines all four (4) sensors and sends all the data to the receiver via LoRa as the transmission medium. The pH range between 4.3 and 6.5 is ideal for oil palm growth [Rozieta, 2015]. However, because oil palm trees can tolerate acidity, they can continue to develop even at pH levels as low as 3.9–4.2 [Rozieta, 2015]. If the pH falls too low, the growth of the oil palm will be hindered. Being a humid tropical crop, oil palm does best in regions with temperatures between 20°C and 33°C and a minimum of 22°C (maximum). Sufficient soil moisture is required to increase oil palm productivity since too little or too much of it will negatively impact oil palm nutrient uptake and fresh fruit bunch (FFB) yields. Oil Palm soil requires an annual rainfall of 1500-2000mm or more, uniformly distributed throughout the year, without any definite dry season, as stated by (Nur Nadia Kamil, 2016). This device integrates temperature, tilt, moisture, and a pH sensor connected to a microcontroller called ESP32, with built-in (low range) LoRa SX1278, which sends captured results to an IoT platform, ThingSpeak. It then shows data on an integrated serial monitor and the LoRa receiver OLED as data received by the receiver. Based on the data obtained, the sender and receiver can communicate up to a distance of 600 meters. In addition, this prototype analyses data collected from sensors and sends notification alerts in case action is needed to improve the soil quality of crops. The usage of LoRa as the data transmission medium in the agriculture sector, where the wireless signal is scarce (Cisco - Networking, Cloud, and Cybersecurity Solutions, 2021), is the novelty of this paper. This proposed system will use the Iterative Waterfall model, in which the project can be revised if some improvement is required while designing it. These input paths allow correcting errors at some phase if errors are found at some later step.

2. Methods

The Iterative Waterfall model is used as the methodology for this paper. The feedback paths enable the degree to which errors are committed to being re-worked, and these changes are reflected in the later stages. This model is simple and easy to adapt to the paper, making it suitable for the paper. Figure 1 illustrates the model's stages and explains each one. Each phase represents a distinct process that can be examined.

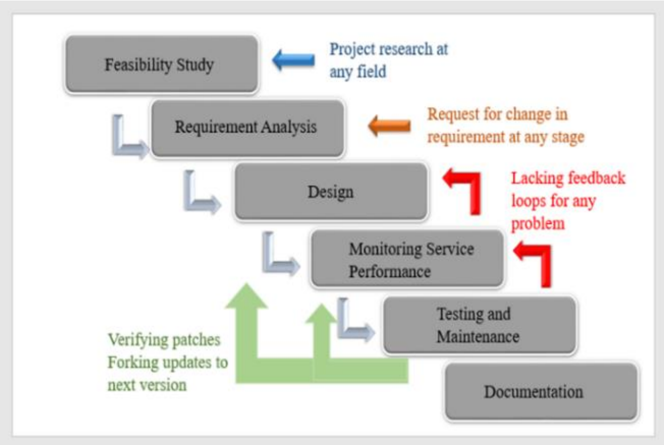

Figure 1 Iterative Waterfall Model

2.1. Feasibility study

The feasibility study is an analysis that considers all the relevant factors in the paper and requires economic, technical, legal and planning considerations to assess the possibility of successful completion of the paper. For example, a feasibility study aims to determine whether the IoT real-time soil monitoring for palm oil plantations is worth developing or not, which leans on farmers for palm oil plantations. All problem statements, goals, gaps, and the related existing paper for the project will be identified at this point.

2.2. Requirement Analysis Phase

At this point, customers are listed as a potential requirement required to build the proposed paper, and the developer tests whether or not the condition can be met. The hardware used for this paper includes four sensors, TTGO ESP32 with SX1278 OLED and TTGO ESP32 with SX1278 Non-OLED as sender and receiver. The software needed to deliver this paper is the Arduino IDE, and ThingSpeak will be used. Once all the requirements for developing the soil monitoring system based on LoRa (M. S. M. Saleh, Dec 2020), (A. A. Ruslan, May 2021)for palm oil plantation' achieve, the developer will continue to the next stage.

2.3 Design Phase

System Design helps to identify hardware and software requirements and explain the overall system's design. Soil Monitoring based on LoRa for Palm Plantation is proposed to help the farmers to monitor the soil condition and analyse the data using ThingSpeak. The input section consists of four sensors where all the sensors are connected with the LoRa sender and transmitted to the LoRa receiver. The LoRa receiver has a built-in WiFi module to connect with the plantation's office WiFi. The results will be displayed on the desktop to visualise data using ThingSpeak. Figure 2 shows the schematic diagram of this paper. The schematic diagram displays the circuit components as simplified standard symbols, like power and signal connections and the connections between the devices. Figure 2 shows how the temperature sensor, tilt sensor, moisture sensor and tilt sensor are connected with LoRa ESP32 that act as a sender with the correct pins. The schematic diagram also includes the power bank is a 5V power supply.

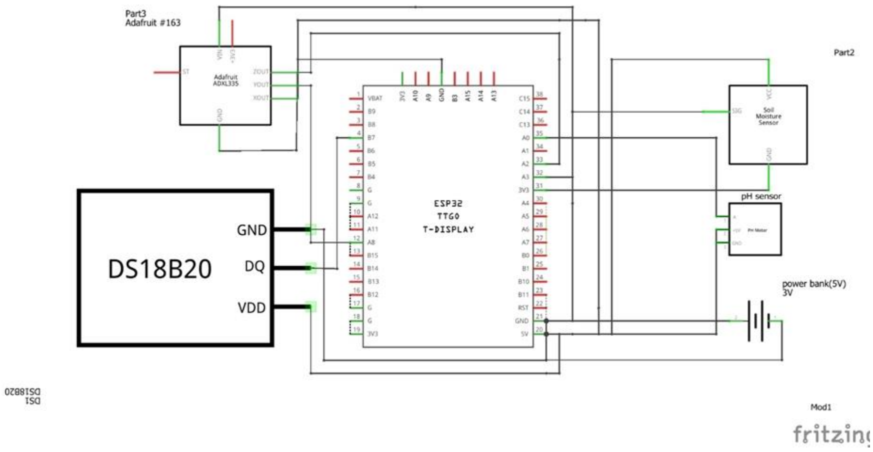

Figure 2 The Schematic Diagram of the Comprehensive LoRa Based IoT Real-time Soil Monitoring for Oil Palm Plantation

The developer will then continue with the flowchart design to demonstrate how the framework and the application will operate. The flow of the proposed system and implementation is shown in Figure 3 below.

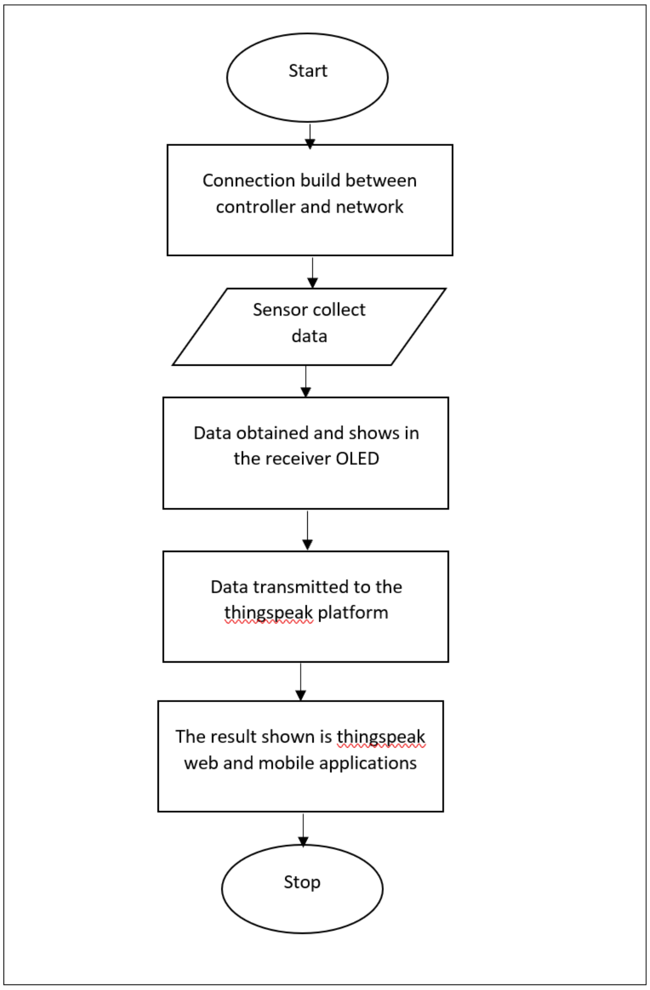

Figure 3 Flowchart of the Comprehensive LoRa Based IoT Real-time Soil Monitoring for Oil Palm Plantation

2.4 Monitoring Service Performance Phase

The developer monitors the system's performance in this process. The data analysis is done using ThingSpeak and decides to let the farmers take proper action after the designed phase is complete. If the data analysis is finished, the developer can adequately track the data analysis process to ensure that the coding is accurate. This device will automatically allow farmers to monitor the soil condition to produce adequate crop quality.

2.5 Testing and Maintenance Phase

The developer should ensure that the system runs smoothly without a bug. As for hardware testing, the test is conducted to ensure that each part is controlled correctly. In addition, it is necessary to ensure that the programme can work according to specific specifications in software testing and compile without errors.

2.6 Documentation Phase

The entire previous stage is recorded in a report to assess the whole progress of this project.

3. Hardware and Software

3.1. Hardware

The most important hardware used in this paper is TTGO ESP32 with SX1278 OLED, which acts as a receiver, and TTGO ESP32 with SX1278 Non-OLED, which acts as the sender in this paper. This paper also consists of four sensors: the DS18B20 temperature probe, SN-ADXL335-CY tilt sensor, moisture sensor and pH sensors. The hardware and the justifications can be found in Table 1.

Table 1 Hardware and Justifications

Hardware	Justifications
Moisture sensor	To measure the volumetric water content in the soil.
DS18B20 Temperature sensor	To measure the temperature of the water and soil.
Tilt sensor	To measure the angle of soil and the level of inclination.
pH sensor	To measure the parameter between values 0 to 14, the solution with less than 7 is acidic, and more than seven are alkaline.
TTGO ESP32 LoRa 32 with SX1278 OLED	Microchip LoRa Technology Module with OLED.
TTGO ESP32 with SX1278 Non-OLED	Microchip LoRa Technology Module with non-OLED.
Jumper	To interconnect the components of a breadboard.

<u>3.1.1 TTGO ESP32 LoRa 32 with SX1278 OLED</u>

This ESP32 includes a LoRa SX1278, a transceiver that supports the LoRa protocol required for The Things Network. The TTGO LoRa 32 board will be used to send and receive LoRa messages via the ESP32. Both LoRa modules act as transceivers, allowing data to be sent and received. It will need two of them, one as the sender and the other as the receiver. When the connection is made, the device can communicate with ThingSpeak. As a result, it can achieve better performance. Other LoRa solutions can easily reach a range of over 30 kilometres. .

3.1.2 DS18B20 Temperature sensor

A temperature sensor is an electronic device that records, monitors, or displays temperature changes by measuring its surroundings and converting the input data into electronic data. Temperature sensors come in a variety of shapes and sizes. Other than that, the operating temperature range is 55ºC to +125ºC, and the accuracy is +/-0.5 ºC (between the range -10ºC to 85ºC).

3.1.3 SN-ADXL335-CY (Tilt Sensor)

A tilt sensor, ADXL 355 is a digital SPI and I2C interface supported in 20-bit ADC. This prototype must ensure that the X, Y, and Z axes are properly aligned on the ground surface. Therefore, the tilt sensor board displays X, Y, and Z-axis indicators. The tilt sensor is placed on the left side of the board with the pin to get an accurate result.

3.1.4 Analog pH sensor

A pH sensor can measure the acidity or alkalinity of water with a value ranging from 0 to 14. The water becomes more acidic when the pH value falls below seven. Any value more than seven indicates that the system is more alkaline.

3.1.5 Moisture Sensor

Soil moisture sensors measure the volumetric water content in the soil. Electrical resistance through the sensor is measured when a modest charge is applied to the electrodes. Water is pulled from the sensor as plants use it, or the soil moisture falls, and resistance rises. In contrast, resistance reduces as soil moisture increases. Figure 8 shows the moisture sensor.

3.2 Software

3.2.1 Arduino IDE

Arduino IDE setup that uses special code structuring rules to support the languages C and C++. The Wiring paper includes a software library with the Arduino IDE and provides several standard input and output procedures. The correct software version compatible with the operating system must be installed for the environment to compile and upload the code without errors.

3.2.2 ThingSpeak

ThingSpeak (ThingSpeak for IoT Platform, 2021) is an open-source Internet of Things (IoT) application and IoT network analytics tool that collects, access, and analyses live data streams in the cloud. This platform can send data from devices to ThingSpeak and create instant live data visualisation and alerts. Besides, the ability to execute MATLAB code in ThingSpeak to analyse and interpret it online as it enters is also used to test IoT systems that require analytics and proof of concept. Table 2 shows the list of software requirements tools and their justifications.

Table 2 List of Software Requirements Tools and Justifications

Development tools	Justifications
Arduino Software (IDE)	They are used while running ESP32 on the TTGO board and uploading code.
ThingSpeak	To obtain data regarding system sensors on a cloud or website.

Figure 4 shows a compilation of all the sensors that build The Comprehensive LoRa Based IoT Real-time Soil Monitoring for Oil Palm Plantation Prototype, which is the outcome of this paper. TTGO ESP32 was used to connect all sensors to one board. The ESP32 includes a LoRa SX1278, a transceiver that adds support for the LoRa protocol, which is required for The Things Network. The TTGO LoRa 32 board will be used to send and receive LoRa messages via the ESP32. Both LoRa modules act as transceivers, allowing data to be sent and received.

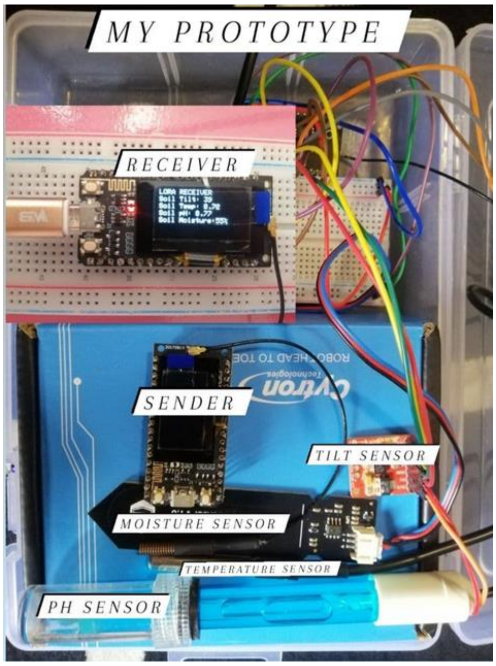

Figure 4 The Comprehensive LoRa Based IoT Real-time Soil Monitoring for Oil Palm Plantation Prototype

4. Results

This soil test was taking place in Malaysian Palm Oil Berhad(MPOB), located in Bangi, Selangor. Most oil palms grow either Nigrescens or Virescens type of fruit. Therefore, This test will focus on collecting from the soil that grows Nigrescens oil palm FFB.

The moisture, temperature and pH sensors were laid on the ground while the tilt sensor was put on the ground terrain. The data were transferred from the LoRA sender to the LoRA receiver within 250 m range.

4.1 Results in Thingspeak

	A	B	C	D	E	F
1	created_at	entry_id	temp	tilt	pH	moisture
2	2021-04-21 19:00:18 EDT	1	28.75	37	8.02	92
3	2021-04-21 19:00:45 EDT	2	28.75	37	7.74	78
4	2021-04-21 19:02:56 EDT	3	27	37	8.36	79
5	2021-04-21 19:03:31 EDT	4	26.81	37	8.4	68
6	2021-04-21 19:04:05 EDT	5	26.75	37	8.36	69
7	2021-04-21 19:04:54 EDT	6	26.69	37	8.41	71
8	2021-04-21 19:05:41 EDT	7	26.62	37	8.36	72
9	2021-04-21 19:06:31 EDT	8	26.62	37	8.4	72
10	2021-04-21 19:06:53 EDT	9	26.62	37	8.37	72
11	2021-04-21 19:07:37 EDT	10	26.62	37	8.41	72
12	2021-04-21 19:07:54 EDT	11	26.69	37	8.4	73
13	2021-04-21 19:14:35 EDT	12	26.56	37	8.5	86
14	2021-04-22 02:19:35 EDT	13	26.94	37	7.52	93
15	2021-04-22 02:22:57 EDT	14	26.94	37	8.07	93
16	2021-04-22 02:23:14 EDT	15	26.94	37	8.11	93
17	2021-04-22 02:23:31 EDT	16	26.87	37	8.12	93
18	2021-04-22 02:23:47 EDT	17	26.87	37	8.35	93
19	2021-04-22 02:24:04 EDT	18	26.87	37	8.05	93
20	2021-04-22 02:25:27 EDT	19	26.94	37	8.05	93
21	2021-04-22 02:28:00 EDT	20	27	37	7.97	93
22	2021-04-22 02:28:30 EDT	21	27	37	7.97	93
23	2021-04-22 02:29:36 EDT	22	26.87	37	7.96	93

Figure 5 Result Stored in Cloud Database

Figure 5 shows the results that are stored in the cloud database. This table has six columns and 23 rows. The first column contains the time zone, the second column contains the entry id, and the remaining columns contain data from temperature, tilt, pH, and moisture sensors. When the sensor data is collected, the “time zone”, “entry id”, “temp”, “tilt”, “pH” and “moisture” sensors will all be automatically updated.

Figure 6 shows the layout of ThingView, a mobile application that makes it simple to see various ThingSpeak channels; simply input the channel ID, and it's ready to go. The application will preserve the window settings for public channels, including colour, timescale, chart type, and a number of results for public channels. The data of the tilt, temperature, pH and moisture sensors are shown as line graphs where the sensor data are plotted against time. Nevertheless, the digital style is intended to simplify users' reading tilt data from mobile devices or smartphones. The graph's x-axis represents the degree of the reading sensors, while the y-axis represents time.

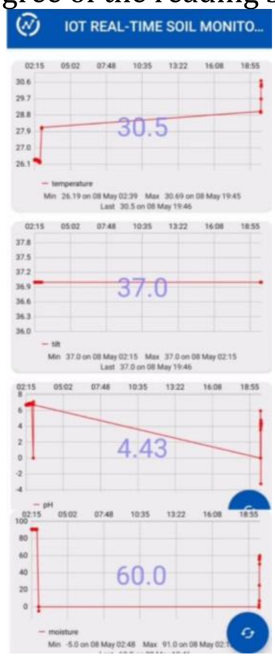

Figure 6 Screenshot of Thingspeak Mobile Apps

4.2 Analysis

4.2.1 Recommended soil temperature

6226	2021-04-29 23:47:35 EDT	6225	29
6227	2021-04-29 23:47:52 EDT	6226	29
6228	2021-04-29 23:48:08 EDT	6227	29
6229	2021-04-29 23:48:25 EDT	6228	29
6230	2021-04-29 23:48:42 EDT	6229	29
6231	2021-04-29 23:48:58 EDT	6230	29
6232	2021-04-29 23:49:15 EDT	6231	28.5
6233	2021-04-29 23:49:31 EDT	6232	28.5
6234	2021-04-29 23:49:48 EDT	6233	28.5
6235	2021-04-29 23:50:05 EDT	6234	28.5
6236	2021-04-29 23:50:21 EDT	6235	28.5
6237	2021-04-29 23:50:38 EDT	6236	28.5
6238	2021-04-29 23:50:54 EDT	6237	28.5
6239	2021-04-29 23:51:11 EDT	6238	28.5
6240	2021-04-29 23:51:28 EDT	6239	28.5

Figure 7 Cloud database for temperature reading

Figure 7 shows the soil temperature table from the ThingSpeak database. The lowest temperature reading taken is 25°C, while the highest temperature taken is 36°C. When the temperature reading is below 23°C is not suitable for palm oil to get good quality crops; if the temperature is higher than 36°C, categorised as the soil being too warm for plantation. The data from entry id 6226 to 6240 represent the ideal palm oil plantation soil temperature. The lowest temperature reading is 28.5°C, while the highest temperature reading is 29°C. The readings indicate that the soil is optimum for the oil palm plantation. This is consistent with the ideal soil temperature range, where the soil's temperature should be between 24°C and 33°C (Aznida Abu Bakar Sajak, 2020). As a result of the readings, the farmers should do nothing. The highest oil palm yields can be found in areas with a maximum average temperature of 29°C-33°C and a minimum average temperature of 22°C-24°C. For better oil palm yields, the crops need at least 5 hours of continuous sunlight per day (M. S. M. Saleh, Dec 2020). This should not be a problem as Malaysia's sunlight exposure is more than 5 hours per day.

Similar data is shown in Figure 8, where the data is now shown in a line graph and numeric display from Thingspeak. This graph is plotted based on the temperature taken of the soil over time. The data is given by the collected data of the temperature sensor (DS18B20 Temperature Sensor Pinout, Specifications, Equivalents & Datasheet., 2021), (SparkFun Triple Axis Accelerometer Breakout - ADXL335 - SEN-09269 - SparkFun Electronics, 2021). The temperature of the soil is represented on the x-axis, while time is represented on the y-axis. The digital approach makes temperature data from mobile devices or cellphones straightforward for users. For example, the digital value of 28 in Figure 8 shows that the temperature is optimal.

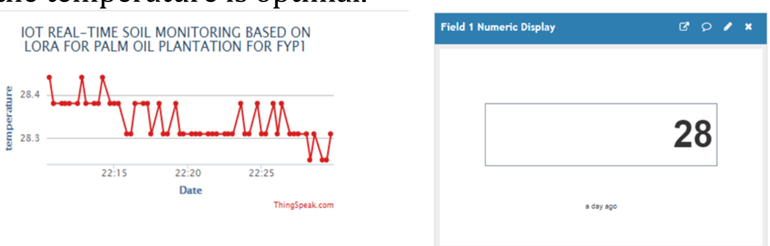

Figure 8 Temperature line graph and numeric display

4.2.2 Recommended soil tilt

Figure 9 (a) shows that the tilt sensor reading is less than and equal to 25°, and Figure 9 (b) shows the tilt sensor reading is greater than 25°. If the tilt is less than 25°, as shown in Figure 9, the soil is suitable for palm oil plantations. Furthermore, workers had no recourse. However, if the tilt exceeds 25°, the land is categorised as unsuitable for planting. These readings prompt the farmers to cut off the cliff and transform it into a terrace or staircase. These results also can be viewed in the graph via Thingspeak in Figure 10. Figure 10 shows the graph and numeric display for tilt sensor reading to measure the slope angle. The line graph is used to show the sensor data against time.

8723	2021-05-01 08:34:03 EDT	8722	25
8724	2021-05-01 08:34:20 EDT	8723	25
8725	2021-05-01 08:34:36 EDT	8724	25
8726	2021-05-01 08:35:09 EDT	8725	25
8727	2021-05-01 08:35:26 EDT	8726	25
8728	2021-05-01 08:35:43 EDT	8727	23
8729	2021-05-01 08:36:16 EDT	8728	23
8730	2021-05-01 08:36:33 EDT	8729	21
8731	2021-05-01 08:36:49 EDT	8730	21
8732	2021-05-01 08:37:22 EDT	8731	21
8733	2021-05-01 08:37:39 EDT	8732	21
8734	2021-05-01 08:38:29 EDT	8733	21
8735	2021-05-01 08:38:46 EDT	8734	21

(a)

8198	2021-05-01 05:04:56 EDT	8197	37
8199	2021-05-01 05:05:12 EDT	8198	37
8200	2021-05-01 05:05:46 EDT	8199	37
8201	2021-05-01 05:06:05 EDT	8200	38
8202	2021-05-01 05:06:52 EDT	8201	38
8203	2021-05-01 05:07:09 EDT	8202	38
8204	2021-05-01 05:07:25 EDT	8203	42
8205	2021-05-01 05:08:32 EDT	8204	42
8206	2021-05-01 05:09:05 EDT	8205	42
8207	2021-05-01 05:09:22 EDT	8206	42
8208	2021-05-01 05:09:38 EDT	8207	42
8209	2021-05-01 05:10:11 EDT	8208	38
8210	2021-05-01 05:10:28 EDT	8209	38
8211	2021-05-01 05:10:45 EDT	8210	37

(b)

Figure 9 Cloud database for tilt 25 ≤: (a) and (b) Cloud database for 25≥

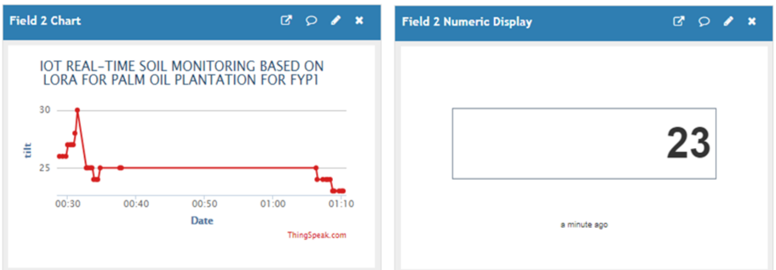

Figure 10 Tilt line graph and numeric display

4.2.3 Recommended soil pH

4792	2021-04-28 02:57:23 EDT	4791	5.02
4793	2021-04-28 02:57:40 EDT	4792	4.65
4794	2021-04-28 02:57:57 EDT	4793	4.94
4795	2021-04-28 02:58:13 EDT	4794	4.97
4796	2021-04-28 02:58:30 EDT	4795	5.06
4797	2021-04-28 02:58:46 EDT	4796	4.56
4798	2021-04-28 02:59:03 EDT	4797	4.72
4799	2021-04-28 02:59:20 EDT	4798	4.71
4800	2021-04-28 02:59:36 EDT	4799	4.57
4801	2021-04-28 02:59:53 EDT	4800	4.64
4802	2021-04-28 03:00:10 EDT	4801	4.83
4803	2021-04-28 03:00:26 EDT	4802	4.77
4804	2021-04-28 03:00:43 EDT	4803	4.65
4805	2021-04-28 03:01:00 EDT	4804	4.79
4806	2021-04-28 03:01:16 EDT	4805	4.68
4807	2021-04-28 03:01:33 EDT	4806	4.71
4808	2021-04-28 03:01:49 EDT	4807	4.71
4809	2021-04-28 03:02:06 EDT	4808	4.69
4810	2021-04-28 03:02:22 EDT	4809	4.76
4811	2021-04-28 03:02:39 EDT	4810	4.76
4812	2021-04-28 03:02:56 EDT	4811	4.65

Figure 11 Cloud database for pH sensor

In oil palm plantations, the optimal soil pH range is 4.3 to 6.5, which is slightly acidic. Other than the recommended readings, the crops could be harmed. Figure 11 shows the data entry id 4792 until 4812 shows the ideal pH reading. Additionally, if the reading falls below the recommended range, the worker is not required to take action. However, if the sensor reading value falls outside the recommended range, the worker must take action. The pH value can be increased or decreased by adding fertiliser. The pH sensor reading is represented via a Thingspeak graph and numeric value in Figure 12. A line graph is used to visualise the sensor data versus time.

On the other hand, the digital approach is intended to make pH data from mobile devices or cellphones simple for users. On the x-axis, the pH of the soil is indicated, while on the y-axis, time is indicated. The pH value of 4 indicates that the current soil's pH is optimal.

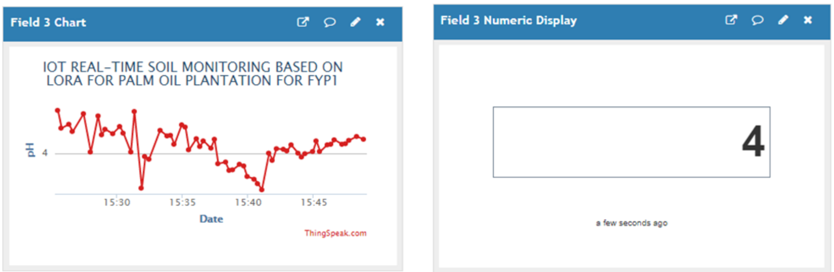

Figure 12 pH line graph and numeric display

4.2.4 Recommended soil moisture

3521	2021-04-26 18:40:55 EDT	3520	11
3522	2021-04-26 18:41:12 EDT	3521	11
3523	2021-04-26 21:32:46 EDT	3522	11
3524	2021-04-26 21:33:03 EDT	3523	11
3525	2021-04-26 21:33:20 EDT	3524	12
3526	2021-04-26 21:33:36 EDT	3525	13
3527	2021-04-26 21:33:53 EDT	3526	13
3528	2021-04-26 21:34:09 EDT	3527	88
3529	2021-04-26 21:34:26 EDT	3528	81
3530	2021-04-26 21:34:43 EDT	3529	82
3531	2021-04-26 21:34:59 EDT	3530	83
3532	2021-04-26 21:35:16 EDT	3531	83
3533	2021-04-26 21:35:32 EDT	3532	75
3534	2021-04-26 21:35:49 EDT	3533	82
3535	2021-04-26 21:36:06 EDT	3534	83
3536	2021-04-26 21:36:22 EDT	3535	83

Figure 13 Cloud database for the moisture sensor

The soil is classified as dry when the moisture reading is 30% or less and wet when the moisture reading is 75% or more (Raju Anitha, 2018). For example, entry id 3528 to 3536 has sufficient moisture reading for soil, while entry id 3521 to 3527 does not, as the soil is too dry to support crops due to a lack of water. As a result, the worker must water the soil to obtain the recommended moisture reading. Figure 14 shows the Thingspeak graph and numeric number depicting the moisture sensor reading. The sensor data vs time is visualised using a line graph. The soil's moisture is represented on the x-axis, while time is represented on the y-axis. The 70 % indicates that the current soil's moisture is optimal.

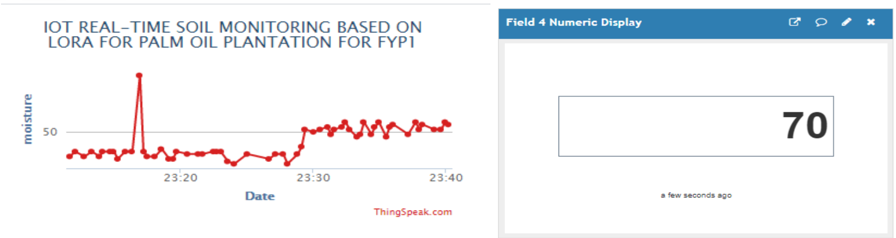

Figure 14 Moisture line graph and numeric display

4.3 Alert Notifications

Another additional feature in this prototype is the alert notification. The data collected in ThingSpeak would not be useful to the plantation workers if there is no mechanism to trigger and prompt any urgent action so that the soil condition would not be compromised. MATLAB code or any HTTP client can trigger emails, and the sent email history can be monitored using the new alerts API key. MATLAB can read and analyse channel values using MATLAB code in ThingSpeak. MATLAB can include information about the condition triggered using email. In this project, an alert notification is sent using email and Twitter. The email is set out to send alert notifications when a certain reading of sensors meets the maximum recommended values. Alert notification had been set for the temperature sensor where the system will automatically be triggered via email and Twitter when the temperature range is exceeded by 36°C. The same pH alert notifications will be sent for any pH value less than 4.3. The moisture alert will be sent if the soil moisture is below 40%. The alert notification sample via email is shown in Figure 15, and the alert notification sample via Twitter is shown in Figure 16.

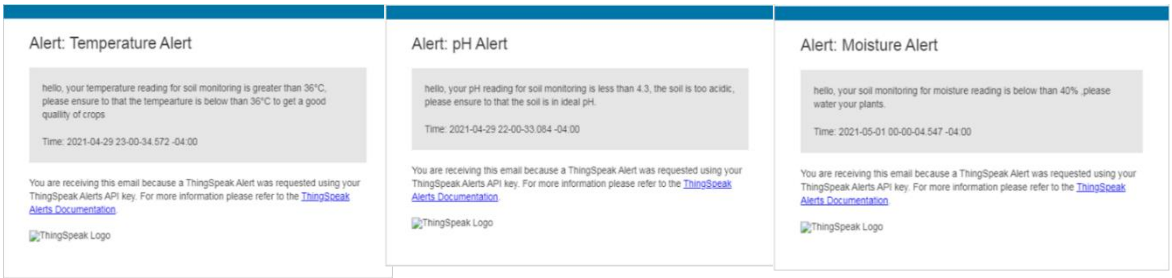

Figure 15 Alert Notification via email

Figure 16 Alert Notification by Twitter

5. Discussion

After the model's testing was completed, a few observations and discussions were made. The data collected affirmed that the Internet of Things (IoT) technology could be used in agriculture, allowing efficiencies that can reduce environmental impact, maximise productivity, and decrease cost by analysing ambient factors that influence crop production using LoRa technology. All data were stored using ThingSpeak and managed to be extracted into Xls format for further observation. For this paper, the data fetched for a more comprehensive review were successfully collected by each sensor and analysed to get a good quality of crops.

6. Conclusions

The IoT Real-Time Soil Monitoring model based on LoRa for Palm Oil Plantation is working as expected and achieved all the objectives established in the previous segment. The proposed system is intended to determine the soil condition using four (4) types of sensors: a temperature sensor, tilt sensor, pH sensor and moisture sensor via LoRA since most oil palm plantation does not have WIFI coverage. This is the novelty of this paper. In addition, the result displayed in ThingSpeak can be carried out in the data analysis to make informed decisions about the soil's condition. Furthermore, the alert notification will be sent through email and Twitter when a certain condition is met to notify the landowners or the planters on the soil conditions based on the data analytics. These data are very useful to ensure crop productivity where soil conditions supply adequate essential nutrients and water throughout every crop cycle.

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