International Journal of Technology 16(5) 1453-1466 (2025)

International Journal of Technology

http://ijtech.eng.ui.ac.id

Research Article

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

Aznida Abu Bakar Sajak [1,*], Nur Fatihah Mohd Shukor [1], Mohd Sallehin Kassim [1], Siti Rahmah Rahman [2] Azrina Abd Aziz [3]

[1]*Advanced Telecommunication Technology Research Cluster, Universiti Kuala Lumpur British Malaysian Institute, Batu 8, Jln Sungai Pusu, 53100, Selangor*
[2]*Malaysia Palm Oil Board Malaysia, Lembaga Minyak Sawit Malaysia 6, Persiaran Institusi Bandar Baru Bangi, 43000 Kajang, Selangor*
[3]*Department of Electrical and Electronics Engineering, Universiti Teknologi PETRONAS, 32610 Seri Iskandar, Perak*
[*]*Corresponding author: aznida@unikl.edu.my; Tel.: +60163314231*

Abstract: Comprehensive Long Range (LoRa) Based Internet of Things (IoT) Real-Time Soil Monitoring for Oil Palm Plantations 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 analytics. This prototype uses LoRa technology, a long-range and low-cost technology. The prototype's main components are the LoRa SX1278 and four specific sensors demonstrating communication between the LoRa technology sender and receiver. The prototype notifies the user of the soil's tilt, pH, moisture, and temperature value in real-time via the ThingSpeak platform. This paper aims to zanalyze the data obtained and send an 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 ensure crop quality.

Keywords: Long range (LoRa); Oil palm; Soil

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 (Parveez et al., 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 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 drought seasons, maintaining a sufficient water supply is crucial for plant growth.

The usage of the Internet of Things (IoT) in the agriculture sector is relatively new due to limitation of exposure to the new technology in agriculture. LoRa refers to wireless data communication technology that uses a radio modulation technique generated by Semtech LoRa transceiver chips (SEMTECH, 2020). This modulation technique allows long-range communication

This work was supported by the Universiti Kuala Lumpur, funded by Short Term Research Grant STR21041

https://doi.org/10.14716/ijtech.v16i5.5139
Received September 2021; Revised July 2022; Accepted September 2022

of small amounts of data, which means a low bandwidth and high immunity to interference while minimizing 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, which can be used for IoT applications (MCMC, 2021). MCMC is the regulator for the converging communications and multimedia industry in Malaysia. This paper utilized the 433 MHz bad. In the paper, the chip LoRa SX1278 is the physical layer. The usage of LoRA In IoT application had been studied and deployed in various applications (Chaudhari et al., 2020; Sallum et al., 2020; Bembe et al., 2019; Mekki et al., 2019; Sinha, 2017; Barriquello et al., 2017; Blenn and Kuipers, 2017; Augustin et al., 2016; Lee and Lee, 2015).

Much research has been carried out about oil palm monitoring systems (Hermansyah, 2019; Hossain, 2018). The first project was based on the remote tracking of soil conditions via a smartphone. Bluetooth communication is used to submit sensor data to a smartphone (Na et al., 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, standardizing IoT networks and providing an authoritative standard for WSN equipment (Anitha, 2018). Zigbee technology also covers a shorter range than LoRa.

Furthermore, in Rawi et al. (2020) paper, a soil monitoring system that utilizes IoT technology to detect pH value, moisture, and tilt in palm oil plantations is introduced. The system utilizes ThingSpeak, where the results are sent to the ThingSpeak application and displayed as a graph on a smartphone. The data are sent via WiFi technology. Similar to Bluetooth and Zigbee, WiFi coverage is smaller than LoRa. In Ruslan et al. (2021) and Saleh et al. (2021) papers, two 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 excellent soil condition in palm oil plantations.

This proposed system combines all four 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 et al., 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 et al., 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). Maintaining sufficient soil moisture is essential to increase oil palm productivity, as too little or too much can negatively impact 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 (Kamil and Omar, 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 novelty of this paper is the usage of LoRa as the data transmission medium in the agriculture sector, where the wireless signal is scarce (Cisco, 2021). 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.

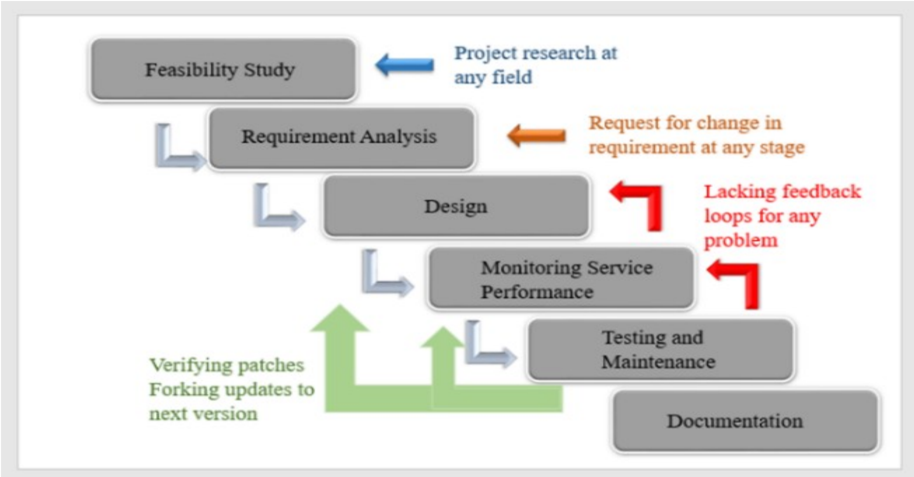

Figure 1 Iterative Waterfall Model

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 the successful completion of the paper. For instance, a feasibility study will determine whether developing IoT real-time soil monitoring for palm oil plantations is worthwhile or not. This study will rely on the input of farmers who manage 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 (Ruslan et al., 2021; Saleh et al., 2020) 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 analyze the data using ThingSpeak. The input section consists of four sensors where all the sensors are connected to 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 visualize 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, 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 as a 5V power supply.

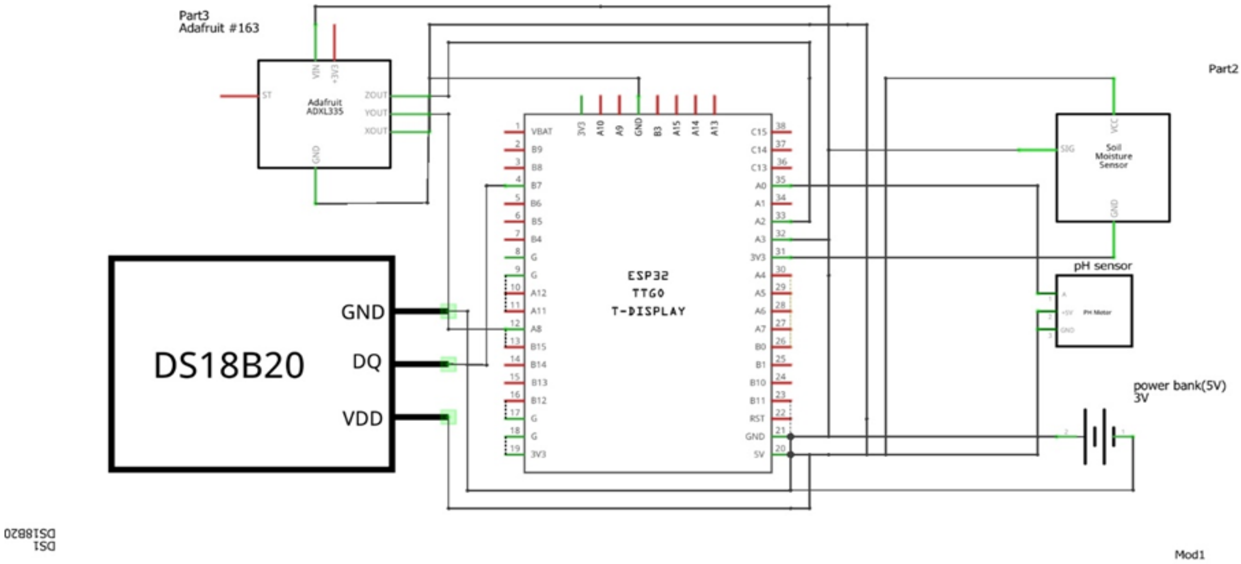

Figure 2 The Schematic Diagram of the Comprehensive LoRa Based IoT Real-time Soil Monitoring for Oil Palm Plantation

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.

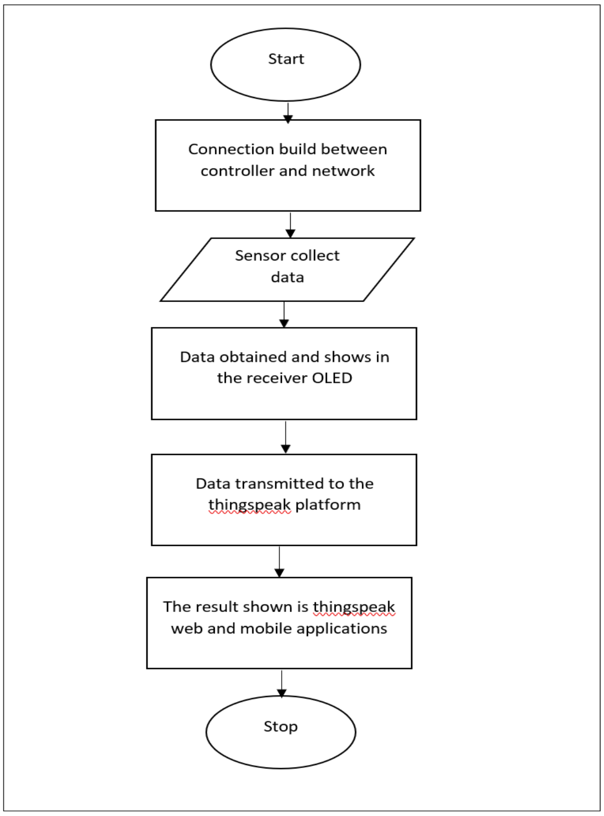

Figure 3 Flowchart of the Comprehensive LoRa Based IoT Real-time Soil Monitoring for Oil Palm Plantation

2.4. Monitoring Service Performance Phase

During this process, the developer will monitor the system's performance. Data analysis will be done using ThingSpeak, and the developer will then allow farmers to take proper action once the design phase is completed. The developer will also keep track of 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 any bugs. Hardware testing should be conducted to ensure that each part is functioning correctly. In addition, software testing is necessary to ensure that the program can work according to specific specifications 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.

3.1.1. <u>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 kilometers.

3.1.2. <u>DS18B20 Temperature sensor</u>

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. <u>SN-ADXL335-CY (Tilt Sensor)</u>

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, 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 (Tong and Zhang, 2016; Unjan et al., 2017; Wang and Xue 2014). This platform can send data from devices to ThingSpeak and create instant live data visualization and alerts. Besides, the ability to execute MATLAB code in ThingSpeak to analyze 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 the Oil Palm Plantation Prototype, which is the outcome of this paper. TTGO ESP32 was used to connect all sensors to one board.

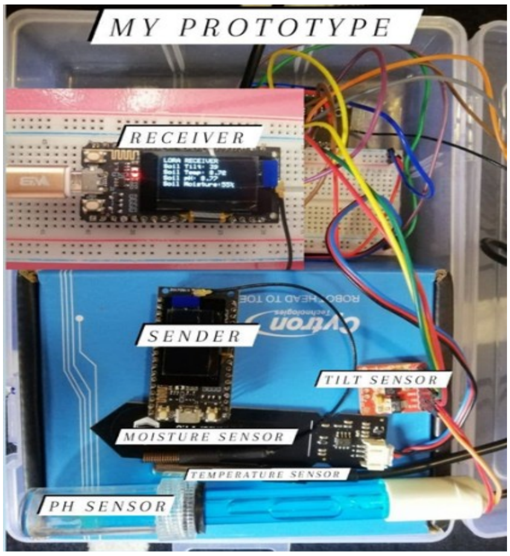

Figure 4 The Comprehensive LoRa Based IoT Real-time Soil Monitoring for Oil Palm Plantation Prototype

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.

4. Results

This soil test took 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 of 250 m range.

4.1. Results in Thingspeak

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.

	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 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 color, timescale, chart type, and a number of results for public channels. Three figures shown in Figure 6 shown the data of the tilt, the data of the soil's temperature in degrees, the data of the soil's pH, and moisture sensors are shown as line graphs where the sensor data are plotted against time in seconds. 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 Sample of a Screenshot of Thingspeak Mobile Apps

4.2. Analysis

4.2.1. Recommended soil temperature

Figure 7 shows the soil temperature table from the ThingSpeak database. The lowest temperature reading is 25°C, while the highest 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, categorized as the soil is too warm for plantation. 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. 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 Saleh et al. (2020). This should not be a problem as Malaysia's sunlight exposure is more than 5 hours per day.

Figure 7 display data, represented as a line graph and numeric values, obtained from ThingSpeak. The graph shows the variation in soil temperature over time. The data is given by the collected data of the temperature sensor (SparkFun, 2021; Components 101, 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 7 shows that the temperature is optimal.

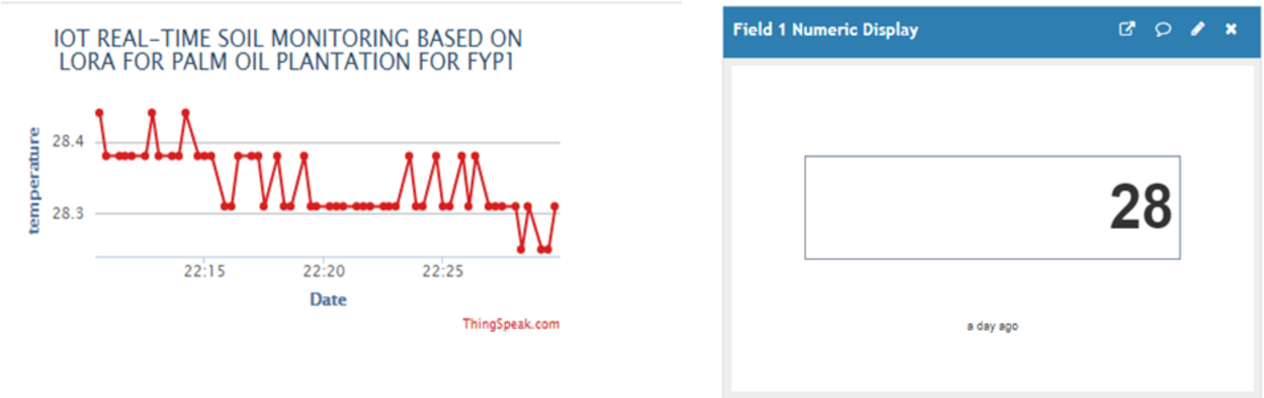

Figure 7 Temperature line graph and numeric display

4.2.2. Recommended soil tilt

If the tilt is less than 25°, the soil is suitable for palm oil plantations. Furthermore, workers had no recourse. However, if the tilt exceeds 25°, the land is categorized 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 8. Figure 8 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.

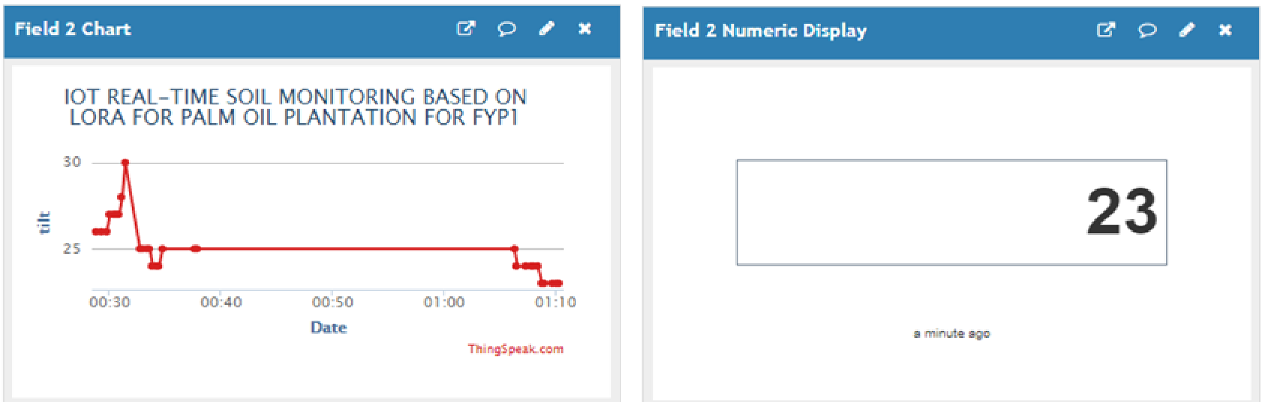

Figure 8 Tilt line graph and numeric display

4.2.3. Recommended soil pH

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. 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 a suitable amount of fertilizer. The pH sensor readings are represented through a ThingSpeak graph and numeric value, as shown in Figure 9, which visualizes the sensor data over time using a line graph.

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.

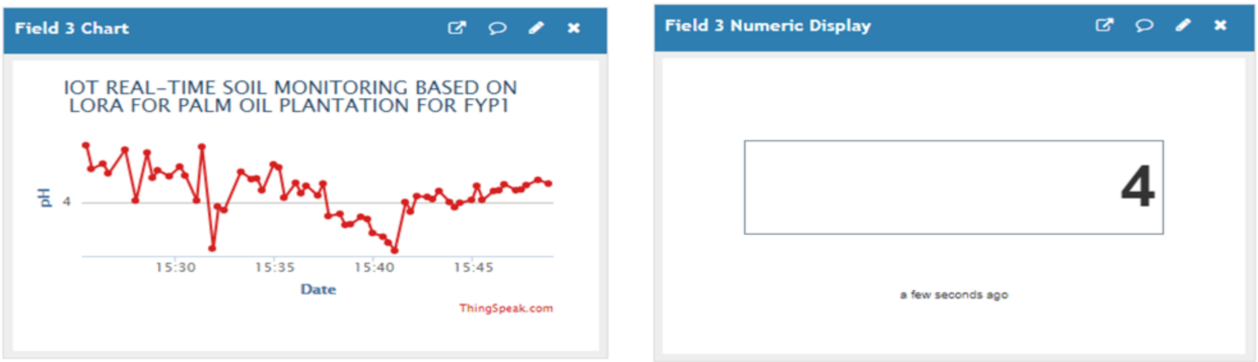

Figure 9 pH line graph and numeric display

4.2.4. <u>Recommended soil moisture</u>

The soil is classified as dry when the moisture reading is 30% or less and wet when the moisture reading is 75% or more (Anitha, 2018). As a result, the worker must water the soil to obtain the recommended moisture reading. Figure 10 shows the Thingspeak graph and numeric number depicting the moisture sensor reading. The sensor data vs time is visualized 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.

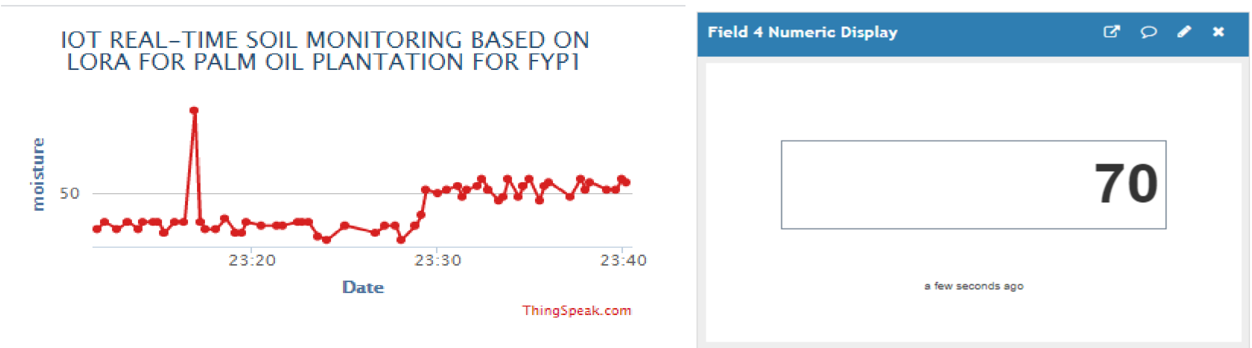

Figure 10 Moisture line graph and numeric display

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 (Rokach and Maimon, 2015; Blei 2012; Gruen and Hornik 2011). MATLAB can read and analyze 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 (Scharler, 2020) and Twitter (Putri and Kusumaningrum, 2017; Philander and Zhong, 2016) 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%.Examples of the alert notification through email and Twitter are shown in Figure 11 and Figure 12, respectively.

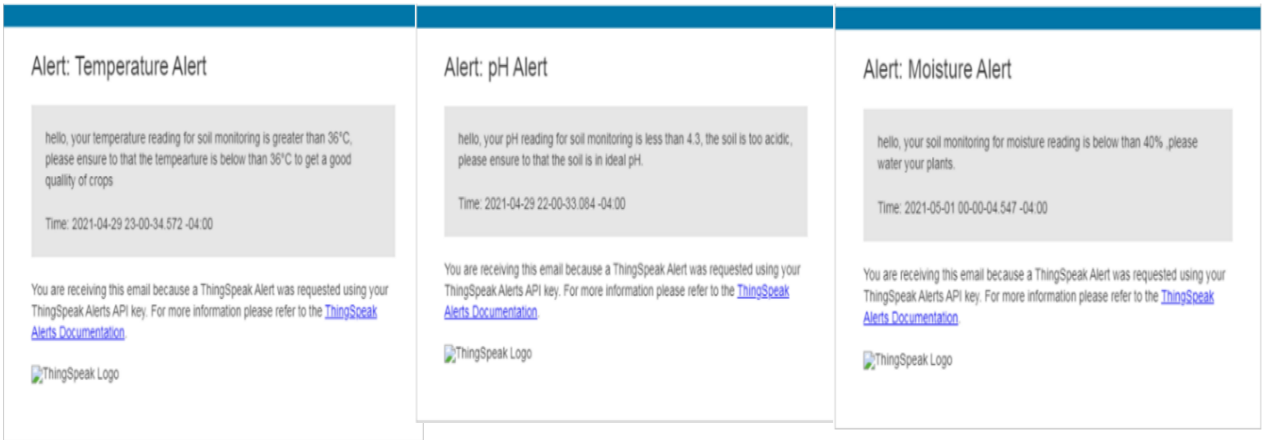

Figure 11 Alert Notification via email

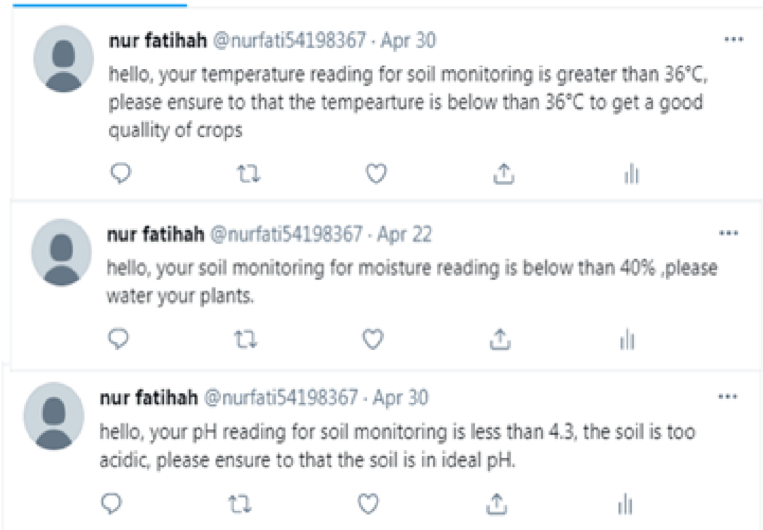

Figure 12 Alert Notification by Twitter

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, maximize productivity, and decrease cost by analyzing 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 analyzed to get a good quality of crops.

From the results which had been verified by the MPOB experts, the soil is classified as dry when the moisture reading is 30% or less and wet when the moisture reading is 75% or more. 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. If the tilt is less than 25°, the soil is suitable for palm oil plantations and if the tilt exceeds 25°, the land is categorized as unsuitable for planting. These are the reasons the cliff in oil palm plantations are transform into a terrace or staircase. Lastly, ideal soil temperature range for oil palm plantations should be between 24°C and 33°C.

6. Conclusions

The IoT Real-Time Soil Monitoring model based on LoRa for Palm Oil Plantation is working as expected and has achieved all the objectives established in the previous segment. The proposed system is intended to determine the soil condition using four types of sensors: a temperature sensor, tilt sensor, pH sensor, and moisture sensor via LoRA since most oil palm plantations do 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 of the soil conditions based on the data analytics. These data are very useful to ensure crop productivity, where soil conditions supply adequate and essential nutrients and water throughout every crop cycle.

Acknowledgements

Thank you to the Universiti Kuala Lumpur and the Malaysia Palm Oil Board Malaysia

Author Contributions

Aznida Abu Bakar Sajak wrote the final draft
Nur Fatihah Mohd Shukor wrote the first draft
Mohd Sallehin bin Kassim verified the results and the references
Siti Rahmah Rahman verified the results
Azrina Abd Aziz wrote the discussion section

References

Anitha, R, Suresh, D, Gnaneswar, P & Puneeth, MM 2019, 'IoT based automatic soil moisture monitoring system using raspberry PI', *International Journal of Innovative Technology and Exploring Engineering,* vol. 9, pp. 4375-4379, https://doi.org/10.35940/ijitee.B9002.129219

Augustin, A, Yi, J, Clausen, T & Townsley WM 2016, 'A study of Lora: long range and low power networks for the internet of things', *Sensors,* 16, no. 9, 1466–1518, https://doi.org/10.3390/s16091466

Barriquello, CH, Bernardon DP, Canha LN, Soares E Silva FE, Porto, DS & Da Silveira Ramos, MJ 2017, 'Performance assessment of a low power wide area network in rural smart grids', *In*: 2017 52nd International Universities Power Engineering Conference (UPEC), Heraklion, Greece, 2017, pp. 1–4, https://doi.org/10.1109/UPEC.2017.8231904

Bembe, M, Abu-Mahfouz, A, Masonta, M & Ngqondi, T 2019, 'A survey on low-power wide area networks for IoT applications', *Telecommunication Systems,* vol. 71, no. 2, pp. 249–274, https://doi.org/10.1007/s11235-019-00557-9

Blei, DM 2012, 'Probabilistic topic model', *Communications of the ACM*, vol. 55, no. 4, pp. 77-84, https://doi.org/10.1145/2133806.2133826

Blenn, N & Kuipers, F 2017, 'LoRaWAN in the wild: measurements from the things network', arXiv:1706.03086v1, http://arxiv.org/abs/1706.03086

Chaudhari, BS, Zennaro, M & Borkar, S 2020, 'LPWAN technologies: emerging application characteristics, requirements, and design considerations', *Future Internet,* vol. 12, no. 3, article 46, https://doi.org/10.3390/fi12030046

Cisco 2021, Cisco - networking, cloud, and cybersecurity solutions 2021, Viewed 27 June, 2021, (https://www.cisco.com/)

Components 101 2021, 'DS18B20 Temperature Sensor Pinout, Specifications, Equivalents & Datasheet 2021', viewed 27 June 2021, (https://components101.com/sensors/ds18b20-temperature-sensor)

Gruen, B & Hornik, K 2011, 'Topic models: An R package for fitting topic models', *Journal of Statistical Software*, vol. 40, no. 13, pp. 1-30, https://doi.org/10.18637/jss.v040.i13

Hermansyah, H, Putri, DN, Prasetyanto, A, Chairuddin, ZB, Perdani, MS, Sahlan, M, & Yohda, M 2019, 'Delignification of oil palm empty fruit bunch using peracetic acid and alkaline peroxide combined with the ultrasound', *International Journal of Technology*, vol. 10, no. 8, pp. 1523-1532, https://doi.org/10.14716/ijtech.v10i8.3699

Heryani, H, Legowo, AC, Yanti, NR, Marimin Raharja, S, Machfud Djatna, T, Martini, S, Baidawi T & Afrianto I 2022, 'Institutional development in the supply chain system of oil palm agroindustry in south kalimantan', *International Journal of Technology*, vol. 13, no. 3, pp. 643-654, https://doi.org/10.14716/ijtech.v13i3.4821

Hossain, N, Zaini, J, Jalil, R & Mahlia, TMI 2018, 'The efficacy of the period of saccharification on oil palm (elaeis guineensis) trunk sap hydrolysis', *International Journal of Technology*, vol. 9, no. 4, pp. 652-662, https://doi.org/10.14716/ijtech.v9i4.2229

Hsu, CW & Lin, CJ 2002, 'A comparison of methods for multiclass support vector machines', *IEEE Transactions on Neural Networks*, vol. 13, pp. 415-425, Taiwan: IEEE, https://doi.org/10.1109/TNN.2002.1017623

Kamil, NF & Omar, SF 2016, 'Climate variability and its impact on the palm oil industry', *Oil Palm Industry Economic Journal,* vol. 16, no. 1, pp. 18-30

Lee, I & Lee, K 2015, 'The internet of things (IoT): applications, investments, and challenges for enterprises', *Business Horizons,* vol. 58, no. 4, pp. 431–440, https://doi.org/10.1016/j.bushor.2015.03.008

Lim, KW, & Buntine, W 2012, 'Twitter opinion topic model: extracting product opinions from tweets by leveraging hashtags and sentiment lexicon', *The 21st ACM International Conference on Information and Knowledge Management*, pp. 1319-1328, https://doi.org/10.1145/2661829.2662005

Malaysian Communications and Multimedia Commission (MCMC) 2021, Malaysian Communications and Multimedia Commission (MCMC), Suruhanjaya Komunikasi dan Multimedia Malaysia (SKMM), viewed 27 June 2021, (https://www.mcmc.gov.my/)

Mekki, K, Bajic, E, Chaxel, F & Meyer, F 2019, A comparative study of LPWAN technologies for large-scale IoT deployment, ICT Express. 2019, vol. 5, no. 1, pp. 1–7, https://doi.org/10.1016/j.icte.2017.12.005

Na, A, Isaac, W, Varshney, S & Khan, E 2016, 'An IoT based system for remote monitoring of soil characteristics', *International Conference on Information Technology (InCITe). The Next Generation IT Summit on the Theme - Internet of Things: Connect your Worlds*, pp. 316-320, https://doi.org/10.1109/INCITE.2016.7857638

Parveez, GKA, Hishamuddin, E, Loh, SK, Ong-Abdullah, M, Salleh, KM, Bidin, MNIZ, Sundam, S, Hasan, ZAA & Idris, Z 2020, 'Oil palm economic performance in Malaysia and R&D progress in 2019', *Journal of Oil Palm Research*, vol. 32, pp. 159-190, https://doi.org/10.21894/jopr.2020.0032

Philander, K & Zhong, Y 2016, 'Twitter sentiment analysis: Capturing sentiment from integrated resort tweets', *International Journal of Hospitality Management*, vol. 55, pp. 16-24, https://doi.org/10.1016/j.ijhm.2016.03.004

Putri, IR & Kusumaningrum, R 2017, 'Latent Dirichlet Allocation (LDA) for Sentiment Analysis Toward Tourism Review in Indonesia', *Journal of Physics: Conference Series*, vol. 801, no. 1, pp. 1-6, https://doi.org/10.1088/1742-6596/801/1/012085

Rawi, R, Hasnan, MSI & Sajak, AAB 2020, 'Palm oil soil monitoring system for smart agriculture', *The International Journal of Integrated Engineering (IJIE)*, vol. 12, no. 6, pp. 1-10.

Rokach L, & Maimon O 2015, *Data Mining with Decision Trees: Theory and Applications,* 2nd ed, World Scientific Publishing, Singapore

Rozieta, R, Sahibin, AR & Razi, IWM 2015, 'Physico-chemical properties of soil at oil palm plantation area, Labu, Negeri Sembilan', *In:* AIP Conference Proceedings, Vol. 1678, No. 1, p. 020031, https://doi.org/10.1063/1.4931216

Ruslan AA, Salleh MS, Hatta SFWM, & Sajak AAB 2021, 'IoT Soil Monitoring Based on LoRa Module for Oil Palm Plantation', *International Journal of Advanced Computer Science and Applications (IJACSA)*, vol. 12, no. 5, pp. 215-220, https://doi.org/10.14569/IJACSA.2021.0120530

Saleh, MSM, Zaaba, MAM, Mohamad, R, & Sajak, AAB 2020, 'IoT real-time soil monitoring based on LoRa for palm oil plantation', *Journal of Physics*, vol. 1874, https://doi.org/10.1088/1742-6596/1874/1/012141

Sallum, E, Pereira, N, Alves, M & Santos, M 2020, 'Improving quality-of-service in Lora low-power wide-area networks through optimized radio resource management', *Journal of Sensor and Actuator Networks*, vol. 9, no. 1, article 10, https://doi.org/10.3390/jsan9010010

Scharler, H 2020, 'Send email alerts from ThingSpeak', viewed 10 May 2021, (https://medium.com/mathworks/send-email-alerts-from-thingspeak-e8d2294d0e64)

SEMTECH 2020, Platform for IoT 2020, viewed 27 June 2021, (https://www.semtech.com/lora)

Sinha, RS, Wei, Y & Hwang, S-H 2017, 'A survey on LPWA technology: LoRa and NB-IoT', *ICT Express,* vol. 3, no. 1, pp. 14-21, https://doi.org/10.1016/j.icte.2017.03.004

SparkFun 2021, SparkFun Triple Axis Accelerometer Breakout - ADXL335 - SEN-09269 - SparkFun Electronics 2021, viewed 19 June 2021, (https://www.sparkfun.com/products/9269)

ThingSpeak 2021, ThingSpeak for IoT Platform 2021, viewed 20 May, 2021 (https://thingspeak.com/)

Tong, Z & Zhang, H 2016, 'A Text Mining Research Based on LDA Topic Modelling'*, In:* The Sixth International Conference on Computer Science, Engineering and Information Technology, http://dx.doi.org/10.5121/csit.2016.60616

Unjan, R, Nissapa, A & Chiarawipa, R 2017, 'Climatic considerations which support the choice between natural rubber and oil palm in Nakhon Si Thammarat, southern Thailand', *Kasetsart Journal of Social Sciences*, pp. 273-281, https://doi.org/10.1016/j.kjss.2016.07.006

Wang, Z & Xue, X 2014, 'Multi-class Support Vector Machines', In: *Support Vector Machines Applications*, Springer International Publishing, Basel, pp. 23–49