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The Design of Monitoring System of Smart Farming Based on IoT Technology to Support Operational Management of Tea Plantation

Nadia THEREZA[1*], Iwan Pahendra A. SAPUTRA[2], and Antonius HAMDADI[3]

[1,2,3]*Department of Electrical Engineering, Universitas Sriwijaya, Palembang, Indonesia*
**Corresponding author: nadiathereza@ft.unsri.ac.id*

ABSTRACT

Indonesia is one of the seventh largest tea producers in the world. Certainly, tea is Indonesia's export commodity that must be maintained. However, some systems of tea plantations, both monitoring and maintenance are also still run with conventional systems so the operational system is still constrained to be able to create efficient and precise management. Taking action or responding to disturbances in the field is also still relatively slow and the estimation process in operational management is also constrained. The monitoring system is surely necessary for better conditions to overcome the problems, which is an important part of the smart farming system with IoT-based. It uses IoT technology to allow objects to be detected and controlled remotely through an access network so that various physical objects can be directly integrated with a computer system. Four sensors were used in this study, namely the temperature sensor, pressure sensor, humidity sensor, and altitude sensor. In this study, LoRa is utilized as a wireless communication system. Lora is an LPWAN technology which is a new technology platform for the Internet of Things (IoT). The LoRa specifications are as follows: ultra range 10 km, wireless standard with 433 MHz (frequency range 420 - 450 MHz) and with operating voltage 1.8 - 3.7V (default 3.3V). In this study, we use database postgre SQL (to build data storage) and python programming language. At the end of this study, we successfully built a monitoring system that can be implemented in the tea plantation with the hope that it will be improved with an automation system in the next study.

Keywords: *monitoring system, smart farming, Internet of Things (IoT), LoRa, sensor*

INTRODUCTION

In this industrial revolution 4.0 era, it cannot be separated from the term Internet of Things or commonly known as IoT. IoT is a key element that influences a variety of sectors, such as health, agriculture, and plantations. Regarding the plantation sector, Indonesia is one of the seventh largest tea producers in the world, but the yield of tea production has decreased in recent years and some tea plantations have been converted into oil palm plantations (source: https://www.indonesia-investments.com, 22 November 2015). In addition, some systems of tea plantations in Indonesia, both the monitoring, maintenance, and operational systems are also still run with conventional systems or using human power. Especially, the tea plantations have a very large area of land, so the implementation is still constrained to be able to create efficient and precise management. Besides, the problems that often appear are taking action or responding to disturbances in the field is still relatively slow and the estimation process in operational terms is also constrained.

So, the monitoring system for smart farming with IoT-based is required to be implemented in the tea plantation area to overcome the problems. The monitoring system of smart farming utilizes the IoT to improve the quality and quantity of the production yields in the industry of tea plantation. We can know the real-time conditions and environmental trends in the form of the exact number. The exact condition comes from data taken from environmental sensors. With this exact data, we can do several things to increase the quality and quantity of the production yields, including:

1. *Monitoring environmental conditions*

We can monitor the conditions of the plantation directly, whether it is in good condition or not, without having to use human labor to come directly to the plantation area. Using IoT, we can measure the parameter (humidity, temperature, pressure, and altitude) every minute without having to check directly to the area of tea plantation. We eliminate many human interventions in the monitoring system, farming analysis, and system function It will reduce the cost of wages.

2. Getting more access to automation system

IoT help to get more access to deeper automation system. For example, if the sensor detects a lack of water an automatic watering (water treatment system) will be carried out through the pump engine which is executed by IoT.

3. Prediction analysis with machine learning

We can analyze prediction with machine learning for the operational activities, such as: harvest forecasting and fertilization forecasting. With accurate historical data, we can predict anything for the operational part. For example, harvest forecasting, fertilizer forecasting. Besides, if there are anomalous conditions in the field, they can be dealt with immediately. We also can optimize the standard process through analysis of large and rich data collections.

4. Risk management

From the results of prediction, we can minimize the risks that may occur in the future.

In this study, the author raised the topic of systems that can overcome the problems mentioned above. The monitoring system with IoT-based, for smart farming, emerged as a solution to the problems in the fields of plantation or agriculture. Simply, the IoT system works to find and collect various data and information from the field which will later be processed to determine actions or to execute by utilizing an automation system. In its implementation, one of the main parts of smart farming is a monitoring system that works to monitor several parameters in plantation land.
In this study, the emphasis is on designing a monitoring system on a smart farming system. Thus, the questions of the problems in this study include: what is the role of the monitoring system in smart farming and how to design a monitoring system that is a central system of smart farming.

INTERNET OF THINGS (IOT)

IoT is a system in which there is a communication and information network inside. IoT can connect various sensors with various devices through an internet connection. The monitoring system uses IoT technology to allow objects to be detected and controlled remotely through an access network so that various physical objects can be directly integrated with a computer system. IoT consists of several characteristics, namely: (i) communication between devices using an IP network in collaboration with various communication protocols, (ii) data transmission is done through a middle layer host on a cloud network, (iii) devices require an active internet connection, (iv) an unlimited integration system, so need a solution that can manage all communication. Figure 1 below shows the IoT elements that consist of sensors, actuators, processors, data storage, transceivers, and energy source [1].

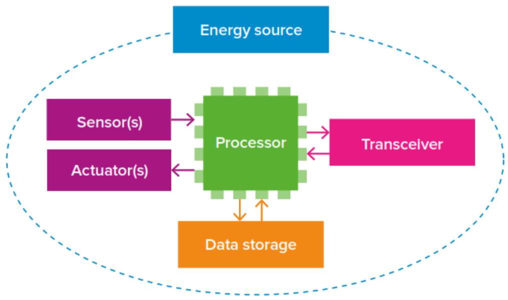


Figure 1. IoT elements

IoT: Environmental Monitoring

The applications of IoT in the field of environmental monitoring are divided into several areas, those are broad: environmental protection, extreme weather monitoring, water safety, protection of endangered species, and commercial farming. In this case, the sensors detect and measure every type of environmental change [2].

Commercial Farming

The commercial farm is currently utilizing leading-edge technology and biotechnology. IoT introduces more access to deeper automation and analysis. Figure 2 below shows an illustration of commercial farming which utilizes IoT as a system with communication and information network.

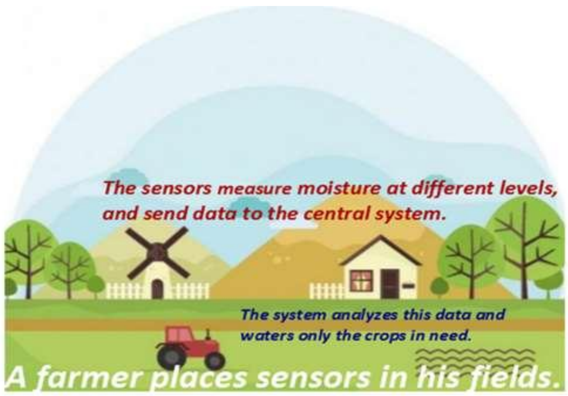


Figure 2. Illustration of commercial farming which utilizes IoT

IoT allows operations to eliminate many human interventions in the monitoring system, farming analysis, and system function. The system not only detects changes in plants, soil, and environment but also optimize the standard process through analysis of large and rich data collections [2].

Sensor

One of the most important devices in the IoT is the sensor. This device consists of an energy module, a power management module, an RF module, and a sensing module. RF modules manage communication through signal processing. The sensing module manages to sense based on active and passive measurement devices. This following is table 1, shows some measurement devices used in IoT [2]:

Table 1. List of some measurement devices used in IoT

Devices	
accelerometers	temperature sensors
magnetometers	proximity sensors
gyroscopes	image sensors
acoustic sensors	light sensors
pressure sensors	gas RFID sensors
humidity sensors	microflow sensors

Four sensors were used in this study, those are temperature, pressure, humidity, and altitude sensor.

LoRa

In this study, the wireless communication system used is LoRa. Lora is a Low Power Wide Area Network (LPWAN) technology which is a new technology platform for the Internet of Things (IoT). Lora was first issued by Semtech Corporation in 2015. LoRa comes as a choice of the wireless system which is the infrastructure of IoT. It can be seen in the figure below which shows a comparison graph between LoRa with cellular, WiFi, and BLE. From figure 3, we can see that LoRa is a technology that provides a wireless communication system with a wide range and with little power or bandwidth [3].

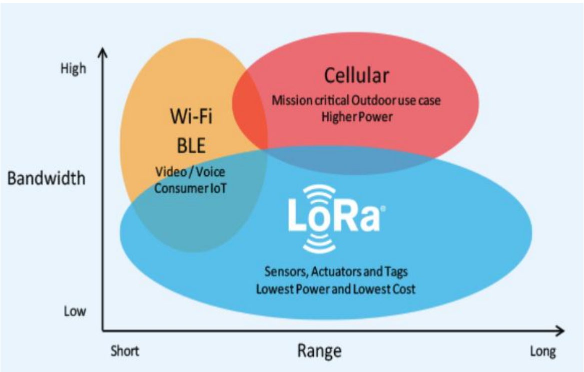


Figure 3. Comparison chart of LoRa, Wi-Fi, BLE, and cellular

The LoRa specifications are as follows: ultra range 10 kilometers, wireless standard with 433 MHz (frequency range 420 - 450 MHz), operating voltage 1.8 - 3.7 V (default 3.3V), and working temperature: -40 – 85 °C.

THE MONITORING SYSTEM DESIGN

Figure 4 below shows the scheme of monitoring system design. The node, which is a client, contains sensor devices and communication devices. It will be placed in designated blocks on the tea plantation. Practically, it is not possible to implement only one node. Some nodes are needed to cover up all of the areas of tea plantation, it depends on the designated blocks. A client sends the data from the measurement process to the receiver part using antenna devices. At the receiving end, the data is received by the antenna devices and then forwarded and stored to a database server (cloud internet services). In the database server, data is also displayed in real-time.

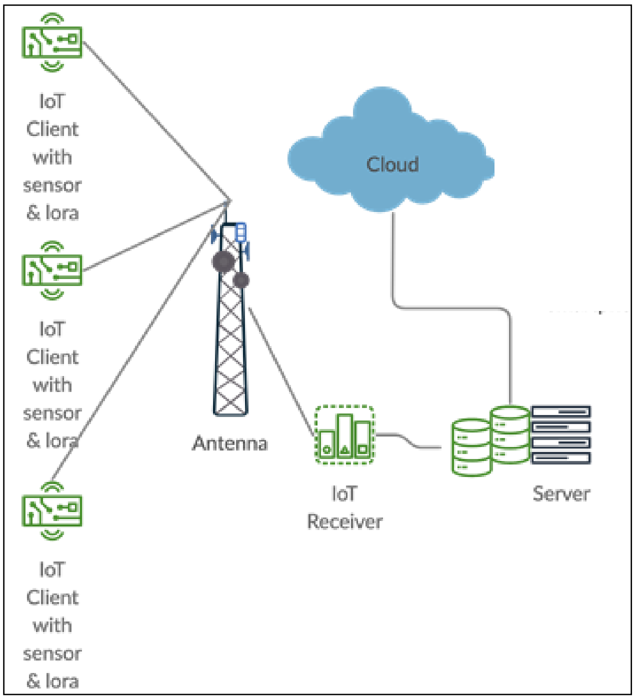


Figure 4. Scheme of monitoring system design

Hardware design

In this step, we divide it into two parts**.** For the first part, the devices that are put together are BME 280 sensor (temperature, humidity, pressure, and altitude), controller: esp8266 chip (D1 mini), proto shield & charging shield, dual base shield, and wireless communication device: LoRa (Long Range Packet Radio Transceiver) modules. As an energy source for this hardware, we use two options, they are a solar panel and Lithium-ion Battery (as a backup). The hardware is placed on a stake, as can be seen in figure 5 and figure 6 below.

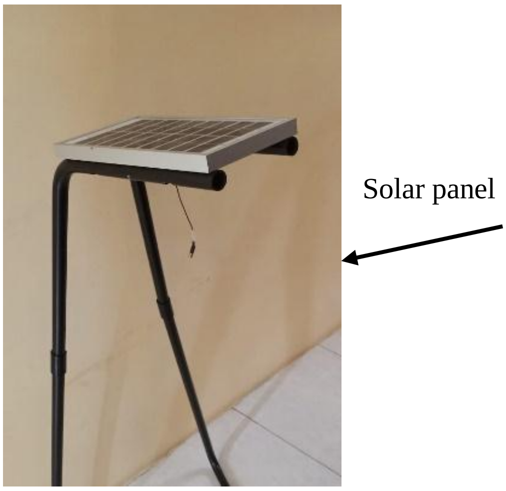


Figure 5. Display part 1 of hardware from above

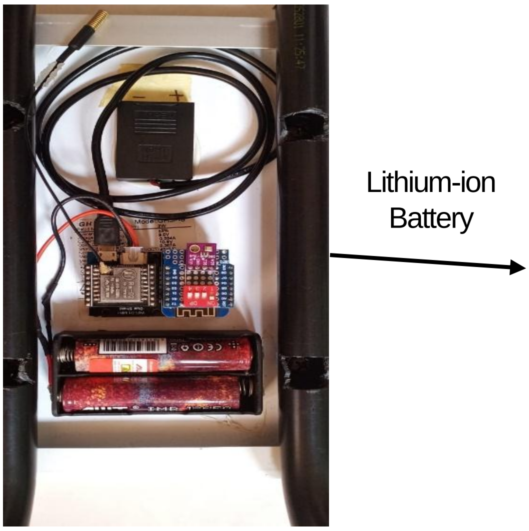


Figure 6. Display part 1 of hardware from below

Figure 7 below shows the hardware part 1 in detail. The sensor showed with number 3, measures and detects the value of pressure, humidity, temperature, and altitude from the area of tea plantation. Then, the values will be processed by microcontroller (D1 mini NodeMCU Lua based on ESP-8266EX) and will be forwarded to the communication device (Lora Ra-02 SX1278). This part of hardware runs as a transmitter side. The data will be transmitted to the receiver side through the antenna device. The anntena of the receiver side will receive the signal of data and will forward it into the server database (cloud).

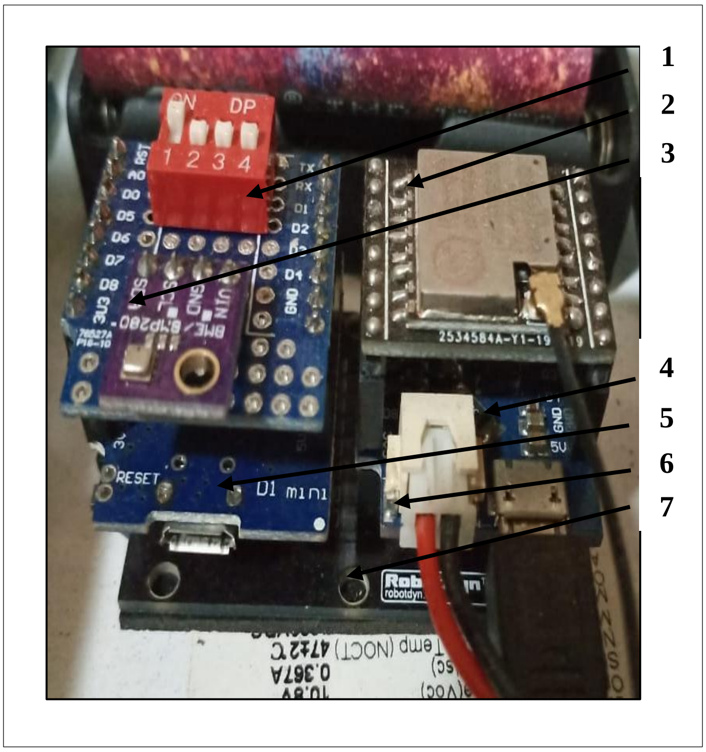


Figure 7. Hardware part 1 in detail (transmitter side)

Table 2 below shows the list of device specifications part 1 with the descriptions. All the devices of hardware part 1 are embedded with the solar panel and placed on the stake.

Table 2. List of hardware devices

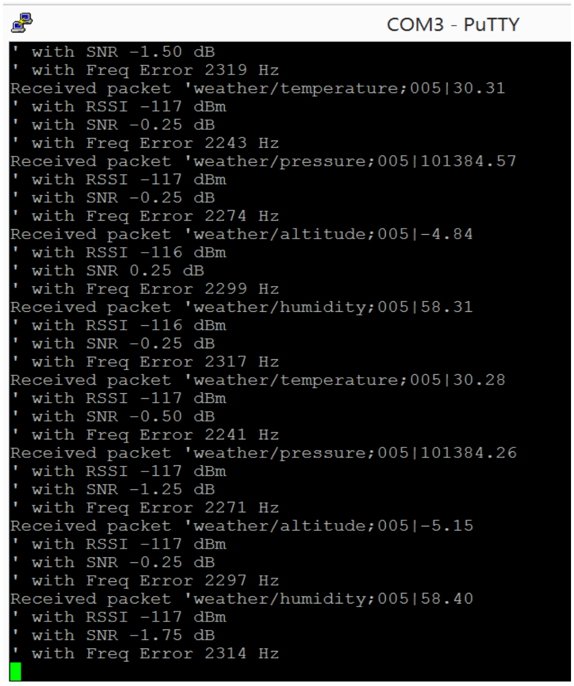
Number	Device Specifications	Description
1	D1 mini protoboard shield	Protoboard for D1 mini
2	LoRa Ra-02 SX1278	It is a long-range wireless module. Spread Spectrum Wireless Module Ultra 10 km with frequency range 420 – 450 MHz
3	BME280 Sensor	Able to measure pressure, temperature, altitude and humidity value. It is suitable for weather monitoring.
4	D1 Mini Lithium (LiPo) Battery Supply Charging Shield	Shield for power supply and battery charging
5	D1 mini NodeMCU Lua wifi board	Mini wifi board based on ESP-8266EX to connect to the communication system
6	Connector jst XH 2,5 2 pin (male & female)	It is used for rechargeable battery packs.
7	Dual Base Shield D1 Mini WiFi ESP8266 IoT	It is designed in a way to connect another shield to D1 mini.

For the second part, we also integrate the LoRa module with D1 mini NodeMCU Lua wifi board and IPX Spring Antenna for LoRa modules. This part runs as a receiver, it will forward the data to the server cloud. We can see the hardware part 2 in figure 8 below.

Figure 8. Hardware part 2 (receiver side)

ANALYSIS OF TEST RESULTS

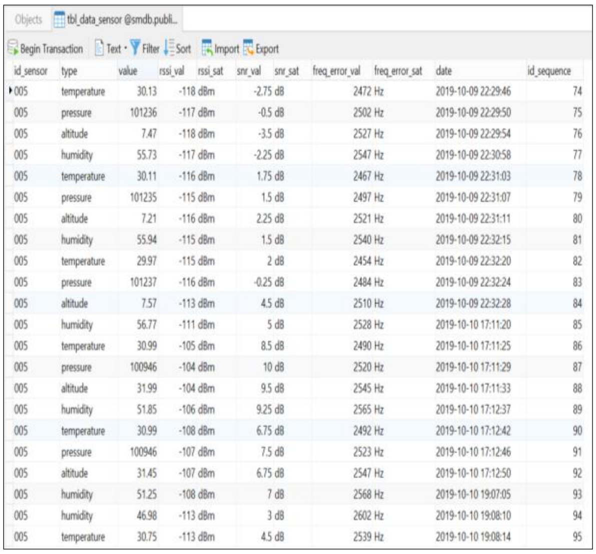
The test result shows that the parameter values have been successfully detected, measured, and delivered so that they can be monitored from the receiver side. Figure 9 shows the real-time data consisting of four parameters namely, temperature which shows the value of temperature in units of degrees Celsius, humidity which shows the value of air humidity in units of RH (relative humidity), pressure which indicates the value air pressure in units of Pa, and altitude which indicates the height value from sea level. The system will send data once every minute.



```
COM3 - PuTTY
' with SNR -1.50 dB
' with Freq Error 2319 Hz
Received packet 'weather/temperature;005|30.31
' with RSSI -117 dBm
' with SNR -0.25 dB
' with Freq Error 2243 Hz
Received packet 'weather/pressure;005|101384.57
' with RSSI -117 dBm
' with SNR -0.25 dB
' with Freq Error 2274 Hz
Received packet 'weather/altitude;005|-4.84
' with RSSI -116 dBm
' with SNR 0.25 dB
' with Freq Error 2299 Hz
Received packet 'weather/humidity;005|58.31
' with RSSI -116 dBm
' with SNR -0.25 dB
' with Freq Error 2317 Hz
Received packet 'weather/temperature;005|30.28
' with RSSI -117 dBm
' with SNR -0.50 dB
' with Freq Error 2241 Hz
Received packet 'weather/pressure;005|101384.26
' with RSSI -117 dBm
' with SNR -1.25 dB
' with Freq Error 2271 Hz
Received packet 'weather/altitude;005|-5.15
' with RSSI -117 dBm
' with SNR -0.25 dB
' with Freq Error 2297 Hz
Received packet 'weather/humidity;005|58.40
' with RSSI -117 dBm
' with SNR -1.75 dB
' with Freq Error 2314 Hz
```

Figure 9. Display data in real-time

For monitoring systems, this time we use software to manage a database that is displayed in a graphical user interface (GUI). The data or information about parameter values is displayed in the table form, as shown in figure 10 below.



Objects | tbl_data_sensor @smdb.publi...
Begin Transaction | Text | Filter | Sort | Import | Export

id_sensor	type	value	rssi_val	rssi_sat	snr_val	snr_sat	freq_error_val	freq_error_sat	date	id_sequence
005	temperature	30.13	-118	dBm	-2.75	dB	2472	Hz	2019-10-09 22:29:46	74
005	pressure	101236	-117	dBm	-0.5	dB	2502	Hz	2019-10-09 22:29:50	75
005	altitude	7.47	-118	dBm	-3.5	dB	2527	Hz	2019-10-09 22:29:54	76
005	humidity	55.73	-117	dBm	-2.25	dB	2547	Hz	2019-10-09 22:30:58	77
005	temperature	30.11	-116	dBm	1.75	dB	2467	Hz	2019-10-09 22:31:03	78
005	pressure	101235	-115	dBm	1.5	dB	2497	Hz	2019-10-09 22:31:07	79
005	altitude	7.21	-116	dBm	2.25	dB	2521	Hz	2019-10-09 22:31:11	80
005	humidity	55.94	-115	dBm	1.5	dB	2540	Hz	2019-10-09 22:32:15	81
005	temperature	29.97	-115	dBm	2	dB	2454	Hz	2019-10-09 22:32:20	82
005	pressure	101237	-116	dBm	-0.25	dB	2484	Hz	2019-10-09 22:32:24	83
005	altitude	7.57	-113	dBm	4.5	dB	2510	Hz	2019-10-09 22:32:28	84
005	humidity	56.77	-111	dBm	5	dB	2528	Hz	2019-10-10 17:11:20	85
005	temperature	30.99	-105	dBm	8.5	dB	2490	Hz	2019-10-10 17:11:25	86
005	pressure	100946	-104	dBm	10	dB	2520	Hz	2019-10-10 17:11:29	87
005	altitude	31.99	-104	dBm	9.5	dB	2545	Hz	2019-10-10 17:11:33	88
005	humidity	51.85	-106	dBm	9.25	dB	2565	Hz	2019-10-10 17:12:37	89
005	temperature	30.99	-108	dBm	6.75	dB	2492	Hz	2019-10-10 17:12:42	90
005	pressure	100946	-107	dBm	7.5	dB	2523	Hz	2019-10-10 17:12:46	91
005	altitude	31.45	-107	dBm	6.75	dB	2547	Hz	2019-10-10 17:12:50	92
005	humidity	51.25	-108	dBm	7	dB	2568	Hz	2019-10-10 19:07:05	93
005	humidity	46.98	-113	dBm	3	dB	2602	Hz	2019-10-10 19:08:10	94
005	temperature	30.75	-113	dBm	4.5	dB	2539	Hz	2019-10-10 19:08:14	95

Figure 10. Display of remoting database

Other than the four parameter values that are sent in real-time, information about RSSI, SNR, and frequency errors is also generated at each time the information sent. RSSI is Received Signal Strength Indication which is a measurement of the power received by a wireless device in dBm units, the greater the value, the better the signal reception. SNR is the Signal to Noise Ratio which is the ratio between signal strength and noise level in dB units, the greater ratio value the better quality of the channel. Frequency error is the difference in frequency after adjusting due to the effects of modulation and phase errors between the RF transmission from the mobile station and the testing device.

CONCLUSION

At the end of this study, we have built a monitoring system that can be implemented in tea plantations. The data (parameter values) has been successfully detected and measured by sensors and controller. LoRa also successfully works and it's able to transmit the data and information to the receiver side and the data storage. This system has been designed to be a solution to overcome the problems of the operational management of tea plantations so that the quality and quantity of the production yields will be increased. For further study, it will be improved by deploying automation systems and mobile applications.

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