Leveraging LoRaWAN technology for smart agricultural monitoring of Malaysian palm oil plantation

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Abstract. Palm oil is a vital cash crop in tropical Asia. Implementation of technology in palm oil industry not only increase production but also it reduces the plantation management cost significantly. Affordability of smart devices of the farm owners is the major concern behind not using technologies in production and process. There are a lot of technologies are being used in agriculture sectors to ease the manual labour with reduced cost. Study on the challenges faced by the plantation owners is needed to introduce new technological solutions for the plantation management in Malaysia. This article reviews some problems on technology-based monitoring. A qualitative research has been conducted to address the problems faced by the authority of Palm oil plantation. Based on the problem statement researcher introduced a conceptual study of LoRaWAN (Low power wide area network) embedded system suitable for low cost energy efficient Palm oil plantation monitoring. Installation of IoT based device will ensure smart monitoring as well as handling the agriculture activities of the Palm oil plantation with reduced manpower resources.

1. Introduction

The use of Internet of Things (IoT) is increasing day by day in agriculture sectors to maximise food production for the extended demand of global population. Nowadays low-power wide-area networks (LPWANs) have become very popular in various IoT applications for its low power consumption because of low data transmission rates. Among many of the LPWAN technologies, LoRaWAN (long Range Wide area Network) is considered the most suitable communication network in smart agricultural applications. Wireless sensor network (WSN) technology along with LoRaWAN embedded system has evolved to solve agricultural problems through cost-effective process leading to smart farm monitoring to increase crop yield. Moreover, use of IoT technology facilitates farmers to minimize the wastage of fertilizer, effective control of pests and as well as farm security by applying supplying adequate amount of nutrients for precision agriculture. Precision agriculture improves agriculture production by applying smart technologies to agricultural activities. A huge plantation area can be monitored using sensor nodes which can forward data through wireless communication to a receiving gateway. The diverse sensor nodes and their respective communication links provide precise information of the field by monitoring a wide range of environmental parameters required for smart agriculture monitoring.
LoRaWAN technology works based on data collection strategies, and by processing those data actions can be taken. Nowadays these type of applications are found in smart infrastructure [1] as well as environmental monitoring [2]. In agriculture sectors, diagnosis of several parameters along with forecasting disease, field operation and evaluation of precision agriculture techniques are also done using LoRa smart farm management system [3]. Similar approach can be applied to Malaysian palm oil plantation for various applications using LoRaWAN. In the field of precision agriculture, LoRaWAN technology employs a cost-effective management strategy using information technology. As it is an open communications standard there are many deployment and business model options available for farm management activities.

2. Research background
The Smart farm monitoring in Malaysia is still not applied thoroughly in all the agricultural sectors. However, there are some research and technology applications in Palm oil plantation that have been reported. Several Multi-sensory data fusion research [4]. Some of the research applications results in designing automatic tree trimming, tree counting and classification [5], structural change detection [6] and plant’s age estimation. Recently another potential use of UAV by utilizing imaging tool is noticed in the oil palm industry to frequent monitoring of the palm plants on daily basis. Satellite imaging is used for massive monitoring of palm oil plantation [7]. However, the tropical countries in Asian region are very prone to rainfall and the cloudy environment blocks the satellite imaging for proper monitoring. To cope with this problem synthetic aperture radar sensors is used in Malaysia to get ‘cloud-free’ images with maximum accuracy [8]. Moreover, the usage of drones in the plantation area is a feasible solution of a time and cost-efficient monitoring [9]. In order to get geographic information like soil elevation map utilizing LiDAR sensors has made the monitoring purpose more efficient [10]. However, these technology-based satellite monitoring incurred more cost and to carry out plantation management operations [11]. Therefore, precision agriculture has brought a revolutionary change in the agricultural sectors with massive use of low-cost sensors.

In tropical climate region like Malaysia most of the plantation areas are very prone to flood because of heavy rainfall. Moreover, frequent rainfall poses stresses on oil palms which may lead to, lower yield or death of newly planted trees from prolonged rainfall. However, poor watering routine and not planning a proper drainage system is the main reason of flood in palm oil peatlands [12]. Palm oil tree plantation in a hilly area may solve the problem of flood occurrence but there will be irrigation difficulty in hills and possibility to dry out the farmlands. Prior to massive plantation, 3D mapping of the terrain gathering all necessary information of the farmland could help the risk of flood in plantation areas. Nevertheless, risk assessment requires a sound knowledge on hydrology, geology, and civil engineering which will not a time a cost-efficient solution [13]. Moreover, geological changing because of soil erosion may also bring change in terrain type and be a reason behind food occurrence. Therefore, conducting research on water level monitoring based on remote sensing in palm oil farmland is a feasible solution which have not yet been implemented. Another concerning sector for plantation management is soil quality monitoring of oil palm plantations using remote sensing technology leveraging the latest IoT technologies. Soil nutrition is one of the key factors for the growth of the plants to get good yield performance. Spectroscopy is being used in order to determine soil contamination level, but it poses inefficient because of its expense and proper detection inability [14]. Another research focused on machine learning based photon counting is capable of detecting the contamination rate but to identify other properties like soil type, soil texture and soil structure there is a need of extensive research on soil quality monitoring [15]. Recent study conducted on palm plantation soil monitoring utilizing sensors for pH, moisturizer and tilt monitoring [16]. Moreover, soil can be exposed to various chemicals and exposure of sun and rainfall can bring significant change to the properties of the soil. To get a good yield continuous monitoring of soil’s characteristics using latest low cost IoT technologies will help the plantation owner to obtain desired production. Hence, it can reduce the tedious workload of long-term soil sampling procedures. In order
to ensure sound health of the trees stress detection is being used utilising Unmanned Airborne Vehicle (UAV) mounted optical sensors (including a stress detection lens) is witnessed as a useful approach for the detection of unhealthy / stressed palms [17]. In palm oil plantation management system pest control is terms of bagworm infestation is only achievable only in close-distance sensing using satellite imaging [18]. However, IoT technology has made the pest detection procedure more efficient using light weight camera and sensor establishing a remote monitoring embedded system. The use of low cost smart IoT technologies for insect detection in Malaysian palm plantations should be investigated.

Majority of palm oil plantation area in Malaysia are monitoring manually by labours to perform regular activities like irrigation, pesticide, fertilizer-providing, and pest control activities. From the previous review papers, several authors stated that there are several technologies with the use of Information and Communication Technologies are developed for agriculture to get maximum yield and minimize the manpower. There are no attempts made to develop a low-cost affordable plantation monitoring management system for all types of routine-based monitoring services. This study addresses the issues faced by palm oil plantation owner to find ways how to manage the farms by implementing LoRa embedded system for selective monitoring problems.

3. Methodology
The smart Agri-monitoring methodology of this research is conducted in two steps as in Figure 1.

![Smart Agri-monitoring framework](image)

**Figure 1.** Smart Agri-monitoring framework.

**Step 1 (Implementation Framework):** The first step of methodology was conducted based on qualitative research approach to find plantation management problems to choose suitable sensors. Although IoT-based smart agriculture techniques are used in many vegetation sectors in Malaysia, the palm oil plantation is lagged using smart technologies for plantation management.

**Step 2 (LoRaWAN embedded system):** The objective of the study is to develop a customized IoT based automatic smart monitoring system which will ease the addressed problems stated in Step 1. Implementation of LoRaWAN based IoT system is suitable for the smart management of the palm plantation of Malaysia. LoRaWAN monitoring module works upon a 3-tier based framework. The design of a 3-tier Smart LoRaWAN monitoring system as in Figure 2.
3.1. Implementation framework
An intensive data gathering process was conducted by interviewing 6 palm oil plantations of Malaysia to find the plantation management problems. It has been found that the palm oil plantations of Malaysia still following the conventional approach to conduct its routine-based activities. A questionnaire-based approach was conducted to find the problems faced by the plantation area. The problems were marked by the numbers (10 to 1) regarding the intensity of the problems. It was found that all the Malaysian Plantations are not facing the problems in same intensity. Based on the intensity, the problems (10 to 5) were sorted as acute problems. The acute problems of palm oil plantation monitoring are addressed by the palm oil Plantation workers as in Table 1.

| Issues                                                                 | Problem statement                                      |
|------------------------------------------------------------------------|--------------------------------------------------------|
| A. Lack of water flow controlling system                               | Waste of water / causes excessive watering to the plants during rainfall |
| B. Use pest control manually once in a month                            | Excess use of pesticides                                |
| C. Use fertilizer after a certain period without continuous soil quality monitoring | Lack of proper nutrition to the plants                  |

The following table contains the palm oil plantation list in which the acute problems were found in the Malaysian palm oil plantations.
Table 2. Problems faced by palm oil plantations.

| Plantation name                  | Intensity of problem |
|---------------------------------|----------------------|
| 1. Carotino Sdn Bhd             |                      |
| 2. Yee Lee Corporation Bhd      |                      |
| 3. Innovans Palm Industries Sdn Bhd |                |
| 4. Innovans Palm Industries Sdn Bhd |                |
| 5. Taner                        |                      |
| 6. BELL Group of Companies      |                      |

A smart soil monitoring includes moisturizer sensor, pH sensor and tilt measuring sensor. The rise in ambient temperature beyond 25° causes the soil dry and platted leaves turn into yellow. Again, for the tree plantation the soil must not be acidic rather soil must be neutral to slightly alkaline otherwise the plant will die. Tilt measuring sensor helps to select the terrain suitable for plantation because soil tilt rises 25 degree may cause uprooted. To control harmful insect’s pest control sensor can be installed which helps to detect the presence of pests through camera image. Flood is a very common problem in plantation area and checking water level of the watering canals may help to take measures for excess waterflow. To build a smart LoRaWAN embedded system the above mention sensor can be used according to the problem statement of the research methodology. For the desired application useful sensors name are listed in following table:

Table 3. Sensor activities for monitoring.

| Purpose                  | Sensor name | Monitoring metrics | Monitoring scenario                                                                                  |
|--------------------------|-------------|--------------------|------------------------------------------------------------------------------------------------------|
| Soil Monitoring          | Moisturizer sensor | 30% - 75% = Good in quality | less than 30% implies that dry soil and greater than 75% implies that the soil is wet condition        |
|                          | pH sensor   | 3.5 to 10          | 3.5 - 6 = Acidic and 7 - 14 = Alkaline                                                                 |
|                          | Tilt measuring | Should keep below 25° | 25° and above is considered as slant terrain                                                          |
| Pest control             | Camera      | Image              | Sends image to the server                                                                              |
| Waterflow Control        | Water-level Checking | Valve Control | After certain water height the water flow will be stopped                                             |

3.2. LoRaWAN embedded system construction
According to the problem statement of Malaysian palm oil plantation the useful sensors has been found and a 3-tier LoRaWAN smart Agri-monitoring model constructed (as described in methodology part):
Figure 3. LoRaWAN embedded system for palm oil plantation monitoring.

The 3-tier model according to the picture is elaborated in the following table:

| Tier 1                      | Tier 2                        | Tier 3                                   |
|-----------------------------|-------------------------------|------------------------------------------|
| Application Sensors:        | LoRaWAN Gateway:              | Data storage Server:                     |
| Cytron Sensor-node which    | It ranges from 5Km to 10Km.   | Laptop/mobile application for display     |
| works as a microcontroller  | One gateway is suggested for 5 | of the data.                             |
| and powered by lithium battery. | kilometres of farmlands.      |                                          |

Moisture sensor, Pest sensor and Water valve control are used as application sensor in the palm oil plantation area. Cytron LoRa sensor node is used to connect the sensors Since LoRa technology works upon star of the star topology, thousands of sensors can be connected to it. Whenever the water level increases notification will be send to the administrator. However, in the scenario of the lacking water in the plantation the soil sensor will indicate dry soil scenario. Different types of bugs and insects which are harmful for the palm kernel can be indicated by the motion sensor and confirmed by the camera image. The motion sensor detects the presence and the movement of the pests and sends the data to the server. The signals from the sensor nodes are routed through LoRaWAN wireless transmission to the gateway. Again, LoRa Gateway sends all the signals to the cloud server and those data are displayed in computer screen. A simplified application is used to analysis data and display it to farm administrator’s mobile. Based on the information received from the sensing devices the farmer will understand the current condition in the plantation and reacts to it.

4. Results and Discussion

The plantation areas are being monitored manually by man force which causes not only additional cost in the palm oil plantation industry but also without continuous monitoring the plantation quality can be degraded. Therefore, LoRaWAN based plantation monitoring can be used for reduction of the routine-based monitoring costs. Since LoRa is a low power long range-based technology only one gateway would be enough for collecting data up to 5km of the farmland. The following table shows the cost estimation for per unit of the devices. Therefore, this research finds a suitable technology which can solve automatic continuous monitoring of the palm oil plantation area with minimal costing.
Table 5. Equipment cost per unit.

| Equipment                  | Cost per unit |
|----------------------------|---------------|
| Cytron LoRa-Farm Shield    | RM 99         |
| DRAGINO LoRa Gateway       | RM 364.69     |
| LoRa Sensors               | RM 100        |
| Sum of the cost            | RM 563.69     |

5. Conclusion

From this study, it has found was found that Malaysian palm oil plantation is facing some problems in managing their day routine-based activities. The problem could be resolved using smart LoRaWAN technology. The problems become acute for the shortage of manpower and sometimes it increases the maintenance cost. Water scarcity and flood both poses harm to the plantation and cause behind less production. To overcome these problems, the adoption of these smart sensors with LoRaWAN embedded system is a feasible solution to manage the palm oil plantations efficiently. This embedded system approach is designed to solve the specific problems faced by palm oil plantation. Furthermore, LoRaWAN embedded system proposed in this article can serve palm oil plantation. Also, it can be used in other farmlands which are facing similar problems. Finally, it is suggested that the installation of the sensor devices in critical areas of the farmland that would help the Malaysian palm plantation authority to manage the farms efficiently with a significant increase in yield of palm oil.

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