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IoT Based Soil Nutrient Sensing System for Agriculture Application

N. N. C. Othaman[1], M. N. Md Isa[1*], R. Hussin[1] , S. M. M. S. Zakaria[1], and M. M. Isa[1]

[1]Faculty of Electronic Engineering Technology Universiti Malaysia Perlis, Perlis, Malaysia

ABSTRACT

Rice is the primary food source for millions of Asians and satisfies the most fundamental requirement for human survival. The paddy scarcity has heightened public awareness of the global food problem. Rice yield and quality are affected by various factors, including soil nutrients, irrigation, types of soil, and pests. This work proposed developing an Internet of Things (IoT) based mobile device for measuring soil nutrients in real-time. The proposed system consists of electrical conductivity (EC) and temperature sensors with TTGO T-Beam microcontroller and IoT connectivity. During experimental work, the results showed that the observed EC data near the calibration solution conductivity of 12.88mS/cm and 150mS/cm, which are less than 2% from the calibration solution's stated value. Furthermore, it is found that the measured EC value increases with temperature (linearly proportional). The study showed that the soil's EC of sensor node 1 at 5 cm depth without fertiliser is 1.04375mS/cm and with fertiliser is 3.86mS/cm, while at 10 cm depth without fertiliser is 0.65625mS/cm and with fertiliser is 420mS/cm. These investigations show that soil EC is directly linked to nutrient availability and soil depth.

Keywords: electrical conductivity, paddy, temperature, total dissolved solids

1. INTRODUCTION

Lack of research on improved technologies for soil electrical conductivity (EC) monitoring systems for paddy plants is one of the issues. Farmers have long struggled to find the optimal composition of fertilisers to maximise crop output. However, few studies have examined the link between electrical conductivity (EC) and temperature-dependent NPK (nitrogen, phosphorus, potassium) concentrations in macronutrients. As a result, an attempt has been made to determine the relationship between the NPK level and temperature with the EC value to maximise paddy productivity.

Monitoring soil nutrient levels is a highly desirable capability that is not possible without good soil mapping. As a result, there is a requirement for the development of an on-the-go soil treatment map. This would enable efficient nutrient mapping at a relatively cheap cost. Additionally, farmers who lack information about the quantity of fertiliser to apply in various regions and cropping systems are a significant source of concern. The treatment map employs sensors to collect on-site data testing (paddy field) and is an excellent method of monitoring rice fields and providing information on paddy development. This work aims to create an EC sensor to facilitate the monitoring of paddy soil nutrients, which offer high cost and time savings [1 – 3]. Numerous researches [4 – 6] on soil EC have been conducted utilising machine technology rather than IoT technology. However, collecting data from the field through Veris technology is costly, and the investigations lack wireless data transfer. As a result, the newly provided technology must be dependable, quick, easy, and affordable.

Most researchers utilise laboratory techniques or significant, non-portable technologies to determine the soil's electrical conductivity (EC) in the conventional method. However, these procedures are costly, time-consuming, and challenging to obtain data. As a result, IoT-based

*nazrin@unimap.edu.my

smart farming is gaining more popularity than conventional-based farming systems [7], [8]. The sensor is the most straightforward and efficient method for estimating soil characteristics [9], [10].

This project aims to develop a sensing device consisting of a microcontroller and numerous sensors connected to conduct on-site tests. The sensor node (SN) collects the sensor data, and the TTGO T-Beam is utilised as a core microcontroller. The data from the sensors can be seen through the internet via the Wi-Fi system. The sensor node's EC readings and corresponding water temperature from the testing site will determine the quantity of NPK nutrients required. Thus, soil nutrients will be estimated based on the measured EC and water temperature in this work. Furthermore, this study will examine the relationship between the electrical conductivity (EC) value observed with the soil temperature and salinity. Additionally, it was determined that the system operates reliably, and the acquired findings demonstrate the design's stability and resilience. The connection between electrical conductivity (EC) and water temperature is seen in Figure 1.

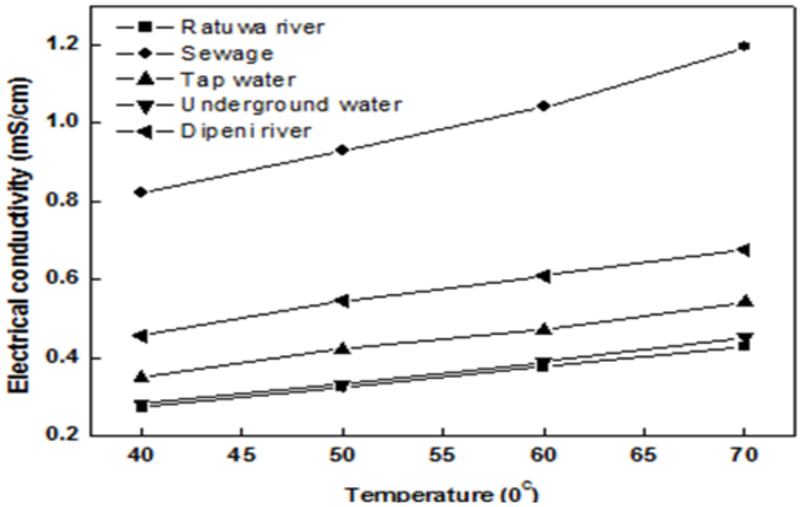


Figure 1. Temperature-dependent variations in EC [11]

2. MATERIAL AND METHODS

In this experiment, measurements were carried out using conductivity probe K 10 and DS18B20 digital temperature sensor. Calibration solutions of 12880µS/cm and 150000µS/cm were utilised in the laboratory. The accuracy of the preliminary calibration performed before the sensor system being used for the first time was studied. Soil samples were taken from the paddy field at depths of 5, 10, 15, 20, and 25 cm for laboratory soil testing, as Cheng et al. suggested [12], [13]. In addition, the soil properties without and with fertiliser were investigated. The schematic of the setup sensing system is shown in Figure 2. The system architecture comprises three main parts; sensor node, gateway node, and cloud database. The proposed number of sensor nodes is planned to be three with an area of about 300 meters between each sensor node for soil treatment mapping, according to Muangprathub et al. and Ahmad et al. [14], [15]. Each sensor node comprises a microcontroller for controlling the sensors, which includes an EC sensor and a temperature sensor. A Wi-Fi LoRa ESP32 microcontroller serves as the gateway node. It sends data to a cloud server for backup and analysis, which users can access via their cellphones or PCs.

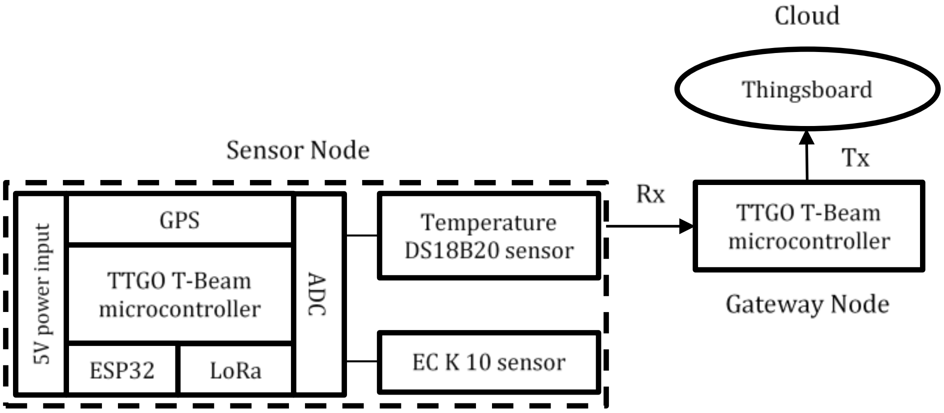


Figure 2. The sensing system's architecture.

The flowchart in Figure 3 depicts the overall system's operation. Data that is collected by sensor nodes is transmitted to the gateway node by using a LoRa transceiver. The TTGO T-Beam acts as the gateway node of WSN. First, it collects data from all the sensor nodes in its network. Next, the data collected needs to be sent to the cloud. This process is done when the gateway node receives the collected data from the sensor nodes using Rx LoRa transceiver, and the gateway node sends the readings to the cloud using the Tx LoRa transceiver. Electrical conductivity (EC), total dissolved solids (TDS), and temperature measurements can be determined on-site and monitored remotely via a website/cloud database. The ThingsBoard platform can be used to store any data or findings of soil qualities. ThingsBoard is an open-source Internet of Things platform for managing devices, collecting data, processing data, and visualizing IoT projects. Hence, farmers can easily store the data gathered from sensors through the cloud platform to observe and maintain the health properties of paddy soil. GPS module in the TTGO T-Beam will be used to obtain an accurate determination of its location. The location data is used for mapping the specific location of the sensor of the nodes. This gives a better specification position of the sensor nodes. The location of the sensor nodes is plotted at multiple locations. The GPS module is also necessary for keeping the sensor node is placed.

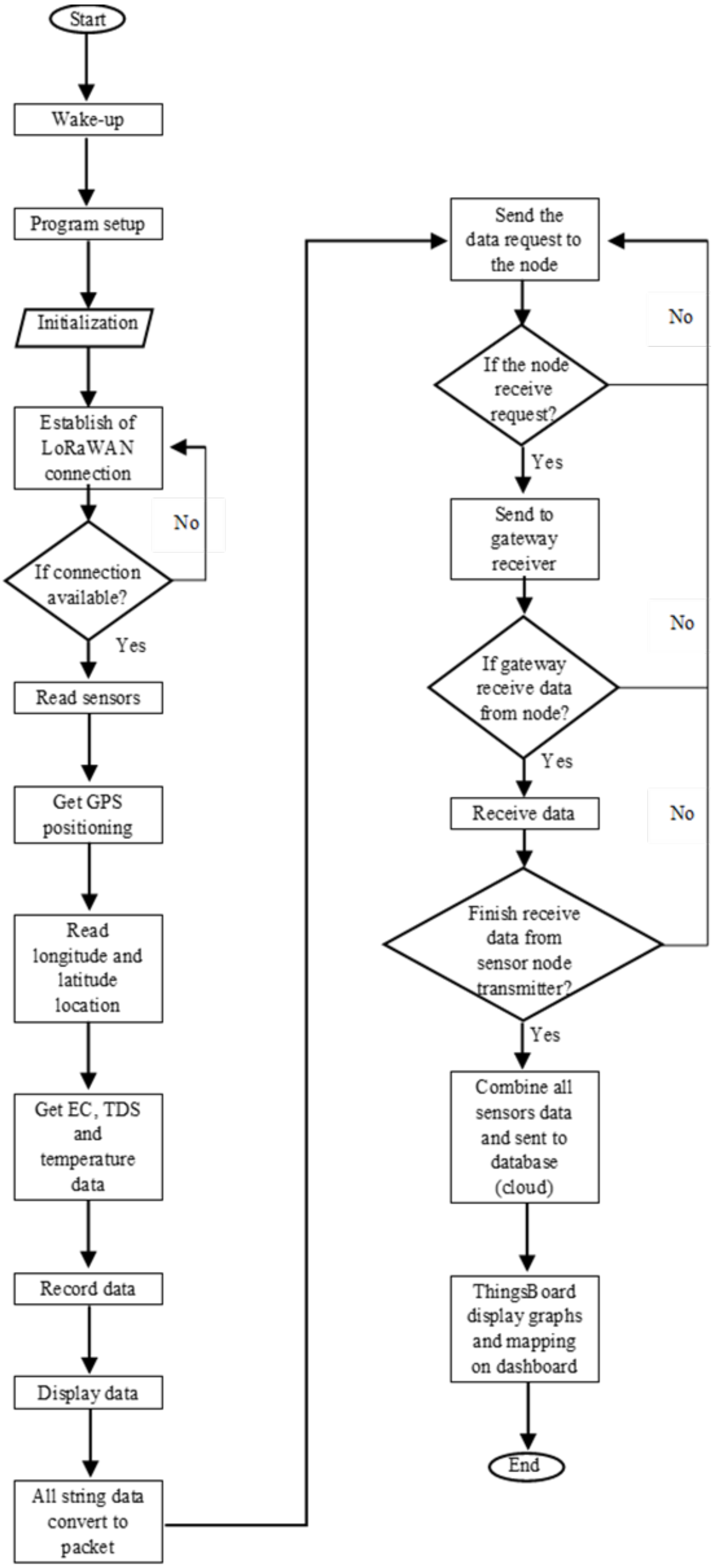


Figure 3. Data flow diagram from sensor node to gateway and cloud.

3. RESULTS AND DISCUSSION

To investigate the electrical conductivity (EC), the temperature was studied, and then the condition of the soil with the depths of soil was investigated.

3.1 Relationship of EC with Temperature

Electrical conductivity (EC) is assessed based on the experimental results to determine the sensing system's accuracy. The EC is measured at 5 – 50 °C. The measured results are depicted in Figure 4 and Figure 5.

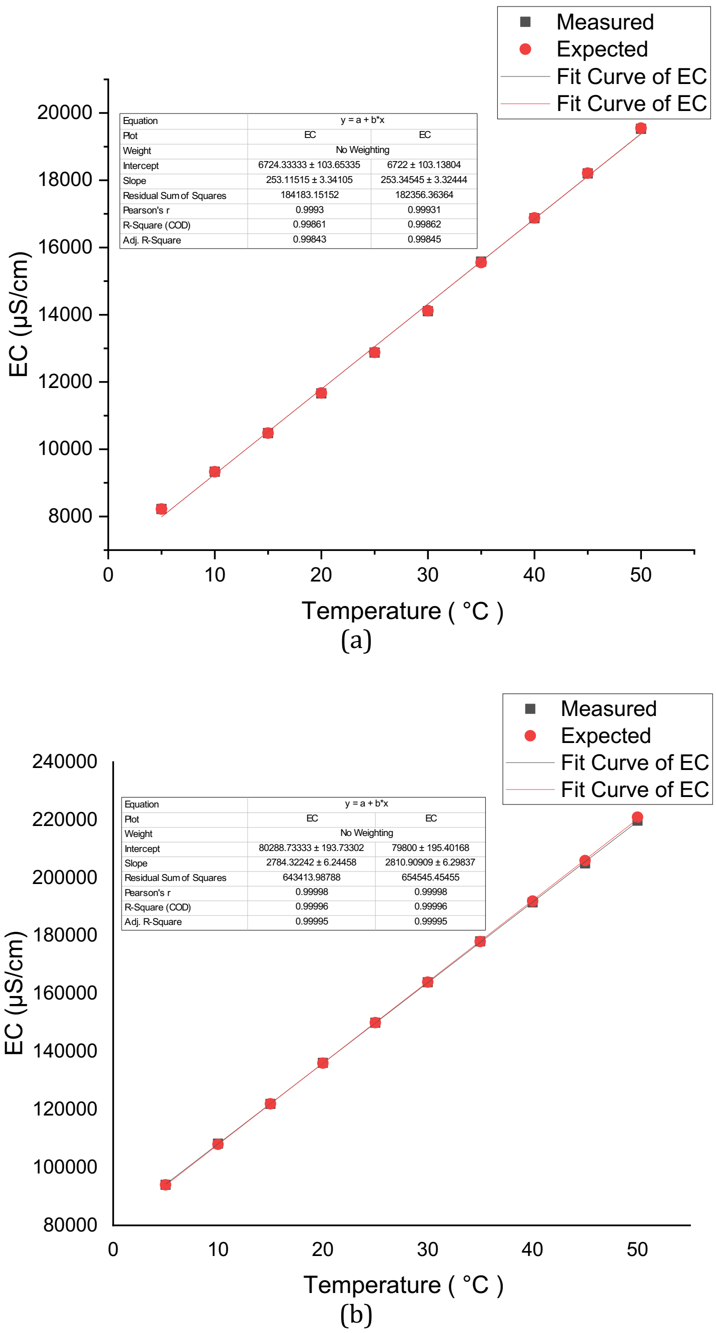
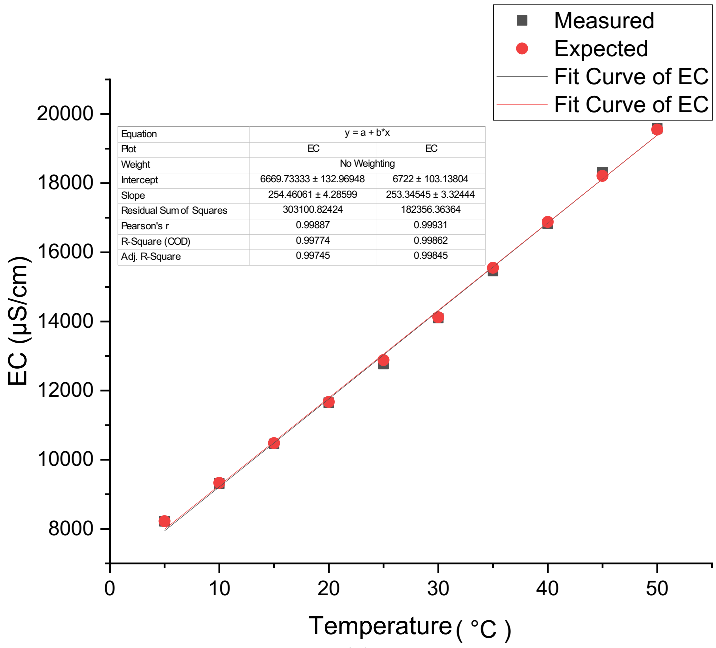
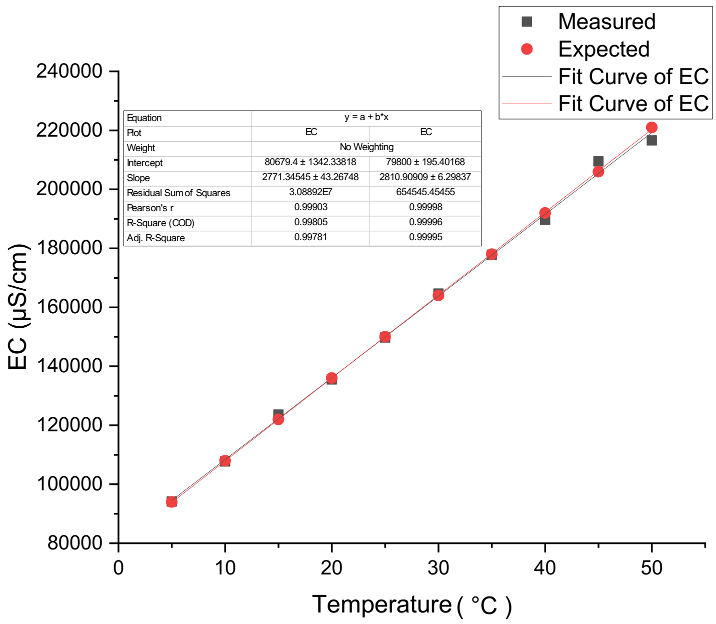


Figure 4. EC measurements of the sensor node 1 calibration solution at (a) 12880µS/cm and (b) 150000µS/cm.



(a)



(b)

Figure 5. EC measurements of the sensor node 2 calibration solution at (a) 12880µS/cm and (b) 150000µS/cm.

The variation seems directly exponential and satisfied the proposed relation between EC and temperature based on equation (1) [16]:

$$EC_t = EC_{25}\,[1 + \alpha\,(t - 25)] \qquad (1)$$

Where EC_t is the conductivity of water at temperature, t (°C), EC_{25} is the conductivity of water at 25°C, and α is a temperature compensation factor. The results are almost similar to those of previous research [11], [17].

3.2 Relationship of EC with Fertiliser Condition and Soil Depth

TDS (total dissolved solids) is used to quantify the concentration of dissolved compounds in the liquid. The electrical conductivity (EC) with different soil conditions and depths are measured at 5 – 25 cm. From the experimental results (Figure 6), the relation of EC and soil condition can be simplified. The soil condition is a linear equation and satisfies the proposed relationship between EC and TDS using equation (2) [18]–[20]:

$$TDS = k \times EC \tag{2}$$

Where TDS is total dissolved solids and is expressed in parts per million (ppm), and EC is expressed in millisiemens per centimeter (mS/cm). The k value is the ratio of TDS to EC. The particular k value for natural water for irrigation under 25°C is between 0.55 and 0.75 g/L [21], water with TDS levels less than 450 mg/L and an EC value less than 0.7 dS/m has a low salt level and no limits on use [22]. So, it determined that:

$$k = 640 \text{ ppm}$$

Therefore, it can be calculated using equation (3):

$$TDS = 640 \times EC \tag{3}$$

As illustrated in Table 1, the EC is inversely related to soil depth and is more significant in the presence of fertiliser than in the absence of fertiliser.

Table 1 The electrical conductivity (EC) of the soil.

Fertiliser	**Depth (cm)**	**Temperature (°C)**		**EC (mS/cm)**		**TDS (ppm)**	
		SN1	**SN2**	**SN1**	**SN2**	**SN1**	**SN2**
Without	5	24.25	20.50	1.04375	0.080	668.00	51.20
	10	23.62	20.27	0.65625	0.070	420.00	44.80
	15	22.83	20.25	0.63875	0.060	408.80	38.40
	20	22.68	19.76	0.62000	0.055	396.80	35.20
	25	22.62	19.73	0.42625	0.050	272.80	32.00
With	5	21.31	27.81	3.86000	0.180	2470.4	115.2
	10	21.19	27.45	1.73000	0.170	1107.2	108.8
	15	21.06	27.00	1.71125	0.160	1095.2	102.4
	20	21.00	26.64	1.65875	0.150	1061.6	96.00
	25	20.81	26.08	1.60000	0.140	1024.0	89.60

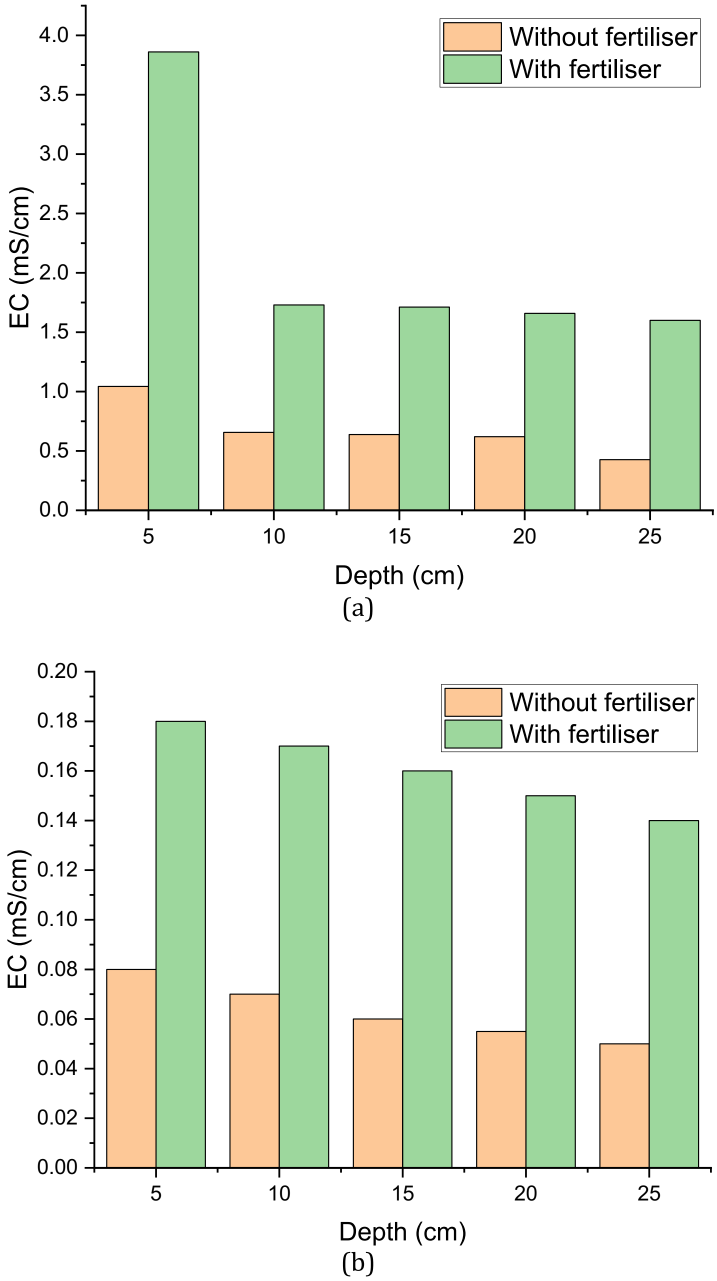


Figure 6. Bar graph illustrating a range of EC values at various soil depths with and without fertiliser for (a) sensor node 1 and (b) sensor node 2.

4. CONCLUSION

In conclusion, electrical conductivity (EC) depends on temperature, soil condition, and soil depth. Results show that EC increases with temperature and with fertiliser while decreases with depth of soil. The relationship among EC, temperature, soil condition, and soil depth has been analysed, and the results show that the sensing system has potential in paddy soil EC sensing due to its sensitivity of EC reading.

The Internet of Things (IoT) is critical in smart farming because it enables high-precision crop management and provides extensive information on soil nutrition and characteristics [23]. The ThingsBoard platform may be used to store any data of soil characteristics. Other electrical conductivity (EC) measurement and monitoring applications will be investigated for future studies and enhancements. Adding other features such as sleep mode function and high-capacity battery can improve the power consumption of the sensor nodes.

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