Intelligent Farm Monitoring System using LoRa Enabled IoT

1st Shraddha Gore
Dept. of Instrumentation Engineering
Ramrao Adik Institute of Technology
DY Patil deemed to be University
Nerul,Navi Mumbai,India 400706
goreshraddha12@gmail.com

2nd Shital Patil
Dept. of Instrumentation Engineering
Ramrao Adik Institute of Technology
DY Patil deemed to be University
Nerul,Navi Mumbai,India 400706
shital.patil@rait.ac.in
https://orcid.org/0000-0001-6590-1588

3rdVivek Khalane
Dept. of Instrumentation Engineering
Ramrao Adik Institute of Technology
DY Patil deemed to be University
Nerul,Navi Mumbai,India 400706
vivek.khalane@rait.ac.in

***Abstract*—A change in agricultural practices is necessary to prevent future food shortages caused by global overpopulation. With the Internet of Things (IoT) and low-power and low-cost devices, the agriculture industry can automate irrigation systems to efficiently use water resources by monitoring farm fields. Low Power Wide Area Networks (LPWAN), along with IoT, can solve bandwidth, coverage and power problems which are the main drawbacks of other wireless communication technologies. Long Range Wide Area Network (LoRaWAN) protocol is known as LoRa in LPWAN space. This protocol provides additional benefits like security, scalability, and robustness. In this paper, a smart agriculture model is proposed to assist in farmers' decision-making and help them to get more productive results. The result of this paper is a prototype equipment for measuring humidity and soil moisture content done by combining the data obtained from the sensors via a LoRaWAN network. This model sends sensor Data such as temperature(degree Celsius), soil moisture (percentage), and humidity (percentage) from the transmitter node to the receiver node using the LoRa communication method. The readings from these nodes are transmitted and then forwarded to the network server through a single gateway. The Wi-Fi-enabled receiving node track data daily on the ThingSpeak platform. The primary goal of this paper is to help farmers monitor their farms more effectively.**

***Index Terms*—LoRaWAN, Agriculture, Wireless Communication, Internet of Things(IoT).**

I. Introduction

The IoT technology has the potential to provide various solutions that will modernize agriculture. There are now numerous efforts being made to improve agricultural productivity while maintaining food quality and preserving the environment. In this regard, several studies and initiatives using Internet of Things principles emphasize precision agriculture [17]. It uses sensors and embedded technology that connects them in a network, enabling real-time data collection, transmission and monitoring. Farmers can use IoT to deploy different types of soil and environmental sensors and leverage the insights gained from sensed data. IoT in agriculture is used to analyze plant development and produce the highest possible crop yields by detecting soil moisture information, weather information, and information about the availability of limited water resources to avoid wastage [7]. Data is collected by the microcontroller (Arduino UNO) and transmitted to the server. The data is processed, and tailored feedback is provided. For predictive analysis, time series data are created for each temperature and humidity variable. The model proposed in this paper uses LoRaWAN technology with IoT and has a soil moisture sensor, temperature and humidity.

This paper presents a method for tracking soil moisture, ambient temperature, and relative humidity by using a model.It transmits data using the LoRaWAN protocol and stores it in a database in real-time, allowing historical data logging and access via an IoT platform. The following sections are organised section II contains a literature review, and section III talks about the fundamentals of LoRa. Section IV represents system architecture, Section V gives information about implementation.

II. LITERATURE REVIEW

Several investigations have produced conflicting results in the last fifteen years. According to a 2005 report, the prospects for decision support system (DSS) acceptability and approval remain dim due to such a system's sluggish and gradual uptake and deployment. The results of this study imply that for contemporary DSS to be extensively used, they must be generally successful. To do this, they must be affordable, low-cost, and flexible enough to adapt to any given situation [12]. Even though they underline that DSS are the foundation of precision agriculture, the findings from research published in 2014 remained the same after nine years [8]. DSS still need to be generally recognized and used [6]. Finally, Hungarian research revealed that farmers, particularly those in Europe, are reluctant to adopt precision farming because of DSS.

If precision farming is not implemented with efficient DSS, these systems cause increased working hours and high operating expenses, which prevent agriculture from becoming e-agricultural [7]. Prototypes of IoT-integrated, cloud-based, and GPS-based environmental monitoring systems have been shown by Fang et al. [6]. A web API was created by the company to gather meteorological data in Xinjiang. On Malaysia's university of Teknologi PETRONAS' campus, Han et al. used a mesh topology Wireless sensor together with IoT to measure the weather and humidity. They utilized the findings gained through web applications. A wireless network was used to detect PM 2.5, and PM 10 air pollution by Xu et al. IoT architecture was submitted by Shinde et al. to assess the interior and outdoor surroundings. Cunin et al. utilized data from IoT devices for environmental monitoring at the University of Limerick in Ireland and displayed it via a mobile application and website [5]. With web apps, Mulani et al. incorporated temperature, humidity, barometer, and gas sensors into IoT devices and utilized fuzzy logic to assist with system environmental decisions. ESP8266 node MCUs were developed by Martha et al. [7] to transmit and receive real-time ecological data. All of these studies, it can be argued, will only be able to function if the sensor that sends the data is linked to the internet; as a result, these studies cannot be employed in rural regions owing to the constraints of information receipt and transmission. The power supply issue cannot be provided in open spaces [9].

III. FUNDAMENTALS OF LORA

A. Overview of LoRa Technology

LoRaWAN technology is preferred over other traditional wireless technology for having a long transmission range. In addition, it is chosen for its vast coverage area and low power consumption. Long Range (LoRa) is a physical layer and data link layer protocol licensed by Semtech corporation. It is on the chirp spread spectrum (CSS) modulation technique. Lora employs modifications to frequency shift modulation to transmit data over long distances with minimal power. Its transmission range is up to 15 Kilometres in rural regions and 5 Kilometres in urban regions [1]. LoRaWAN is designed to function as a long-distance transmission range having frequency for industrial, scientific and medical (ISM) bands of 433 megahertz (MHz),868 MHz and 915 MHz [1]. Chirp Spread Spectrum (CSS) modulation uses a frequency increase or decreases technique over time, increasing its efficiency and resistance to interference, making it transmit data at low sampling frequencies [2]. Each country has a different frequency band. For example, India has adopted 865 to 867 MHZ, Brazil has 915 MHz, and Europe has 868 MHz. Also, in most countries, time restrictions are imposed on utilising the air interface by using 1% duty cycle [3]. Lora uses CSS modulation with data rates from 250 bits/second to 5.5-kilobits/second and 50 bits/second with a frequency shift key (FSK). The LoRaWAN network comprises three components: the end devices, the gateway and the LoRaWAN network server. The end devices are in charge of data collection and network activation. Gateways are responsible for receiving messages from all the end devices and then forwarding them to a network server. The LoRaWAN uses a star-to-star topology where all the end devices transmit their data directly to a gateway. A LoRa device is set up to adjust link performance and energy consumption using LoRaWAN fundamentals.

Cellular networks provide extensive high-speed data coverage. However, high-speed data is not necessary for the Internet of Things applications. Cellular network-based devices frequently have relatively short battery lives and multiple coverage gaps. Mesh networks and ZigBee are utilised in home automation. They provide low to medium-distance performance. However, these must be better for long distances (a few kilometres) [11]. Although Bluetooth/BLE gives reasonably excellent data speeds, its range is a significant drawback. For long-range Internet of Things applications, the range provided is just unacceptable. The IEEE802.11 WLAN standard is one of the most extensively adopted of all the wireless technologies. It is because of the high bandwidth and data rate alone. Sadly, it has a very narrow operating range and uses battery power [10]. Wi-Fi-enabled devices have short lifespans and frequently require proximity to the access point to function effectively. Moreover, the waves have high operating frequencies (2.4 and 5 GHz), which makes it difficult for them to pass past barriers. LoRaWAN technology is quickly developing and incorporated into various IoT-driven applications for addressing those issues.

B. Spreading Factor (SF)

LoRa is based on CSS technology, which uses chirps to carry data, also known as symbols. The spreading factor regulates the chrips rate, which is the data transmission speed. A low spreading factor indicates faster Chrip, which results in faster data transmission [14]. The chrip rate is divided into equal parts for every increase in the spreading factor; data transmission is also divided. The more chrips utilized to represent a symbol, that is, data, the higher the spreading factor Value will be, which means the receiver has more processing gain. As a result, the receiver can recognize data transmissions with low signal-noise Ratios (SNR). The spreading factor has an integer value from 7 to 12.

C. Bandwidth (BW)

The frequency range in the transmission band is referred to as bandwidth. Higher bandwidth results in more data flow which means less time on air. However, more noise is added to the signal, reducing its sensitivity. A 125-kilo cycles per second (kcps) chip rate corresponds to a 125 kHz bandwidth. So LoRaWAN uses frequencies of 125 kHz, 250 kHz or 500 kHz.

D. Transmission Power (TP) and Coding Rate (CR)

Transmission Power is set to 2 dBm to 20 dBm in 1 dB steps. Power levels above 17 dBm are used with a 1% duty cycle. The coding rate protects against burst interference. It is set with 4/5, 4/6, 4/7 or 4/8. Greater Value offers high protection, but at the same time, it increases the time on air. Because the packet header is 4/8-encoded and stores the coding rate of the payload, different coding rates can communicate with one another. [4].

E. Signal to Noise Ratio (SNR) and Link Budget

LoRa signal to noise Ratio (SNR) lies between -20 dB to +10 dB. The receiver signal is less distorted when the value is closer to +10 dB. It operates above the noise floor level when SNR is more significant than zero and below the noise floor level when SNR is smaller than zero. However, LoRa can work below the noise level and demodulate the signals between the range of -7.5 dB to -20 dB below the noise level [4]. A link budget is comprehensive of all gains and losses experienced from the transmitter to the receiver as they pass through the medium, also called free space. It is a method of measuring link performance. The receiver sensitivity is the lowest power level at which the receiver can detect or demodulate the signal.

IV. SYSTEM ARCHITECTURE

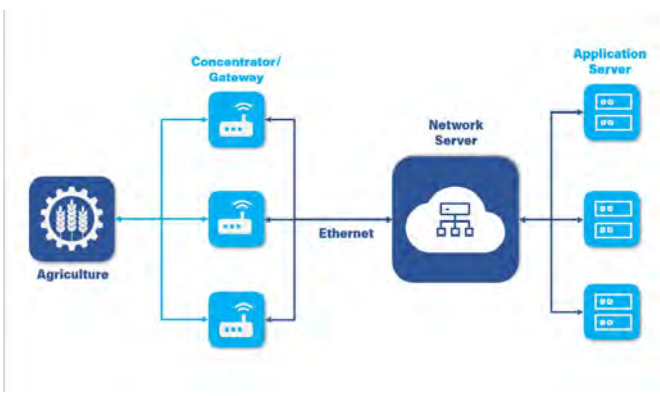

Fig. 1. LoRaWAN System Architecture

A. LoRa Nodes or End Devices

LoRa means wireless modulation and physical layer that establishes long-distance networks for communication. LoRa alliance has standardized this network protocol. The LoRaWAN architecture is a layered architecture. LoRa defines the physical layer, while LoRaWAN defines the communication protocol and system architecture (refer figure 1). The sensors or the applications that perform sensing and controlling are known as LoRa End devices. Those sensors collect data and communicate it to gateways via the LoRaWAN capabilities integrated into them. These nodes are placed remotely.

B. LoRa Gateways and Network Server

Gateways are base stations that receive transmitted data. They perform the function of a router having a LoRa concentrator installed within them and accepting LoRa packets. All end devices can communicate in both directions. Data is transmitted to the network server. Wifi connects gateways and network servers. All intelligence resides on the network server. It performs the security Check, filters out duplicate packets from several gateways and sends an acknowledgement (ACK) signal to the gateways. The application layer is the packet's final destination, and the network server forwards the data to the particular application server. It also the authentication of the network devices. Network Server has different device classes such as class A, B, and C (refer figure 2) [15].

Fig. 2. LoRaWAN Communiction Stack

C. LoRaWAN Media Access Control (MAC) layer and Physical layer

LoRaWAN's MAC layer is the second layer of the open system interconnection (OSI) model. It assigns spreading code, frequency and data rate to each device. It also schedules acknowledgements by adapting different data rates. LoraWAN's physical layer uses region-specific and licence-free ISM bands. But it is also configured to operate on lower frequency bands of 433 MHz and 169 MHz [12]

V. IMPLEMENTATION

A. LoRaWAN RFM95 transceivers

LoRaWAN RFM 95 transceiver (refer figure 3) is incorporated with LoRa modem, which requires very little power and provides an ultra-long range spread spectrum for communication. It uses low-cost crystal and bill of material (BOM) and reaches a sensitivity of over -148 decibels per milliWatt (dBm) [16]. It has high sensitivity and a power amplifier with a build of +20 dBm, which leads to a link budget, making it perfect for any application requiring range and durability [13].

Fig. 3. LoRaWAN RFM95 Transmitter

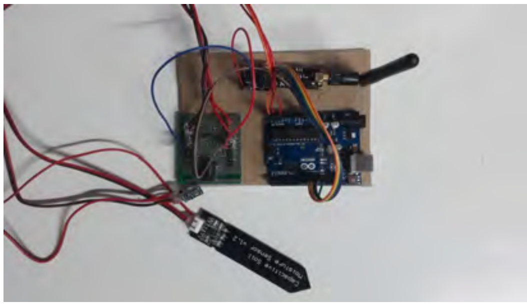

Fig. 4. LoRaWAN RFM95 Transmitter with Sesnor Set Up

B. Capacitive Soil Moisture Sensor Version 1.2

The volumetric water content of the soil is determined using a soil moisture sensor. They are two types that are resistive and capacitive. Two probes are used in resistive-type sensors to measure the volumetric water content of the soil. Current can flow through the ground through the probes, and the resistance value determines how much moisture is in the soil. Corrosion of the sensor probes is a severe issue with this type of sensor [2]. Soil moisture sensors, capacitive rather than resistive, are more corrosion-resistant and provide a bette readout of moisture content (refer figure 4 and 6) [6]. I addition, the sensor's groundbreaking soil moisture solutio is self-contained and portable. Calibration of the soil moistur sensor is done to determine the threshold between wet an dry. It is done by embedding a sensor in the soil, and water i poured into the sample by observing the values change whe the soil changes its moisture from dry to wet. This value wil then be called the threshold. A given soil comprises numerou components with relative dielectric permittivity ranging fror 2 to 6 when dry [18]. As a point of comparison, the dielectri constant of air is approximately 1 (the same as that of vacuur space). For ordinary temperature and pressure, the dielectri constant of water is around 80. This high permittivity allow electricity to flow more freely, increasing capacitance an resulting in a lower resonance value. Because of the relativ impact of water on electrical permittivity in soil materials capacitance is an excellent measure of soil moisture [16].

C. Atmospheric Temperature and Humidity Sensor AHT10

The AHT10 sensor (refer figure 7) produces a calibrated digital output. It offers long-term stability and reliability. Also, it has a meagre cost. It consists of a sensor chip package which provides excellent calibration and precision. In addition, it has re-flow soldering capabilities. It comprises a dual-row flat lead-less surface mount device (SMD) package with a bottom dimension of 4x5 mm and a height of 1.6 mm. It has a power supply range of 1.8 to 3.6 volts, while 3.3 volts is the recommended operating voltage. [4].

D. Processing Unit Arduino UNO

For processing, an Arduino UNO with an Atmega controller is employed. Sensors are connected with analogue and digital

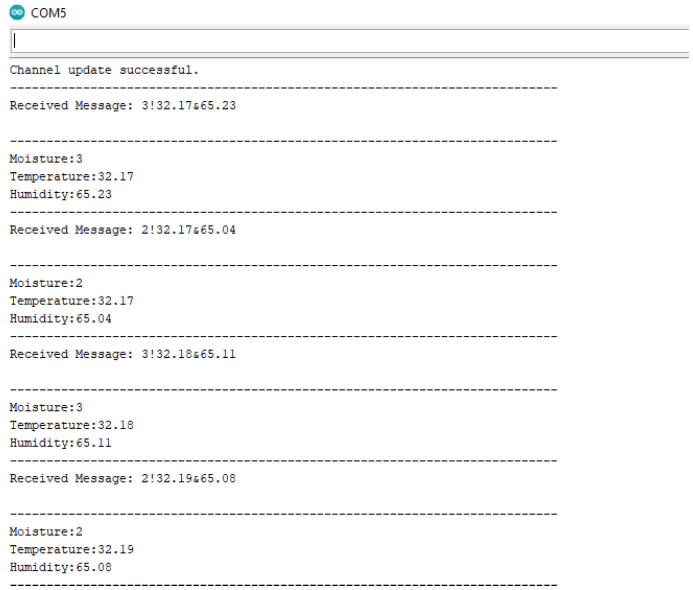

Fig. 5. Receiver Data

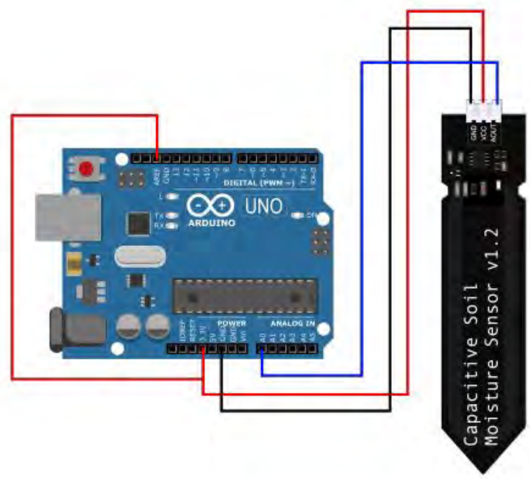

Fig. 6. Capacitive Soil Moisture Sensor

Fig. 7. AHT10 Sensor

pins to this processing unit Arduino UNO, a microcontroller. LoRa chip is connected through a serial peripheral interface (SPI). It is an open-source electronics platform built on simple hardware and software [8].

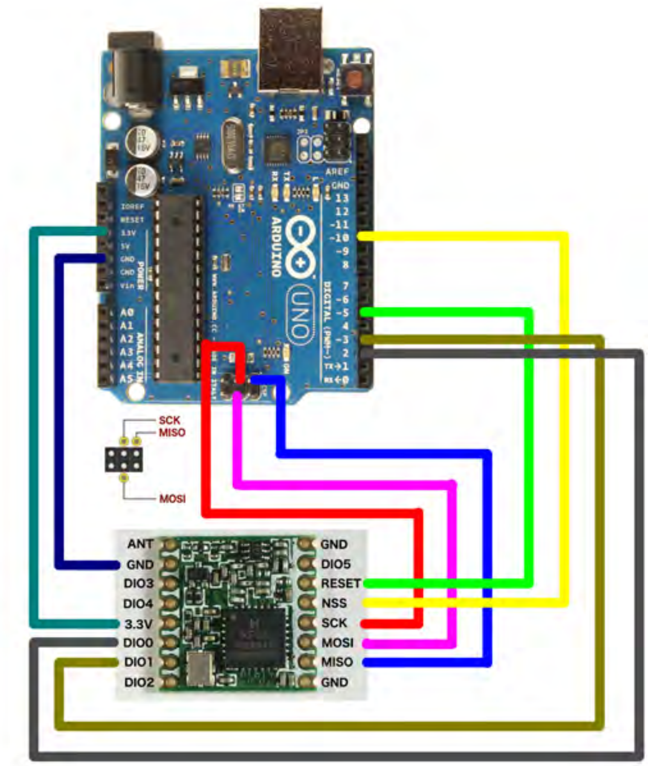

Fig. 8. Arduino connected with LoRa module

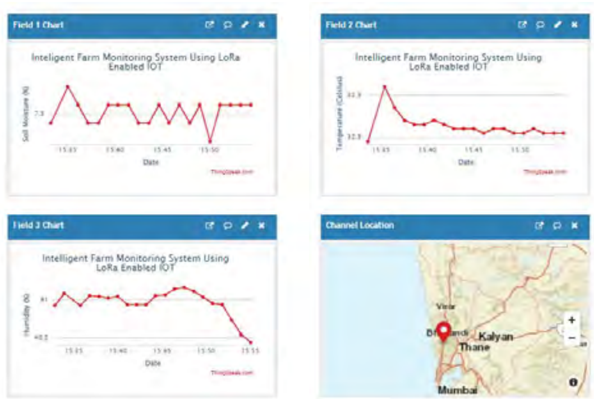

Fig. 9. Collection of Live data in Graphical form on ThingSpeak

E. Experimental Setup and Result

The AHT10 sensor senses the surrounding temperature and humidity. In addition, a capacitive soil moisture sensor measures moisture content in the soil [11]. The transmitter side consists of one LoRa transmitter model. Both sensors are connected and programmed as per the requirement. Using the LoRa modulation technique, the transmitter sends data to the receiver, another LoRa module. Finally, the data is displayed in the graphical format on the ThingSpeak web interface. Accurate assessment of soil water content is critical for agronomy and botany applications, where under and over-watering of soil can result in useless or lost resources. If the soil moisture value lies between 2 to 6, it indicates the soil is dry, and watering will be required. Based on different soil compositions, these values vary. If the moisture content is more than 8, it is inferred that the soil is moist enough and would require the same watering sequence as the farmer. This analysis prevents over-watering, which maintains the soil nutrition and hence maintains the cultivated crop quality. The Arduino platform programs a microcontroller that reads an analogue signal from a capacitive sensor and outputs a voltage. Using gravimetric methods, the inverse of this voltage can be linearly fit to estimate volumetric soil moisture content. The goal of hardware development is to make each gadget work together as intended. For example, the Arduino UNO is seen in Figure 8, linked. Hardware package devices are composed of 5 circuits, including an Arduino UNO connected circuit board to the ATH10 temperature and humidity sensor LoRaWAN RFM 95 model device location sensor and version 2.1 of the soil moisture sensor model.

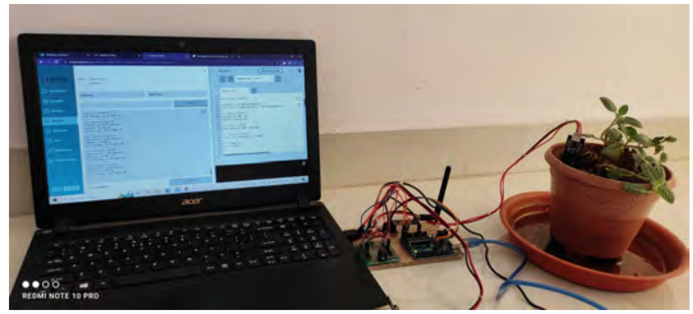

Fig. 10. Implemented Nodes Transmitter Reciever Output

F. Visual Implementation

An information system is a webpage that converts different values to be shown in graphical form. ThingSpeak is an application that gathers data from client nodes to analyze the findings and display them on a webpage. The ThingSpeak is an open-source IoT platform for data collecting, processing, visualization, and device management. Figure 9 depicts a dashboard panel that displays the environment values as a consequence. The graph indicates the serial monitoring of the parameters as time and date variants. Farmers can evaluate the environment in the cultivation plot based on the values collected and look at various values to make knowledgeable and ideal judgments for the growth and maintenance of crops. The test request performance package from the test data and the graph demonstrate that distance impacts the network connection request; the longer the distance, the more times the connection request will need to be made before the data

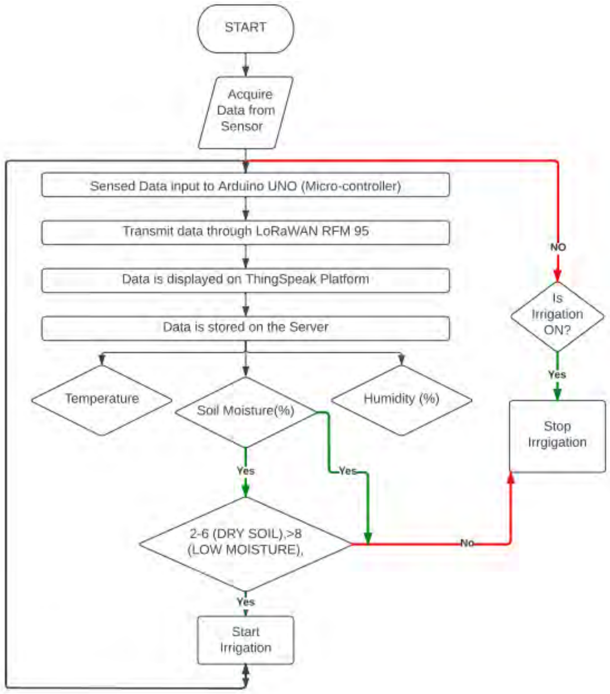

Fig. 11. Flow Chart of IOT Sytem for Smart Agriculture

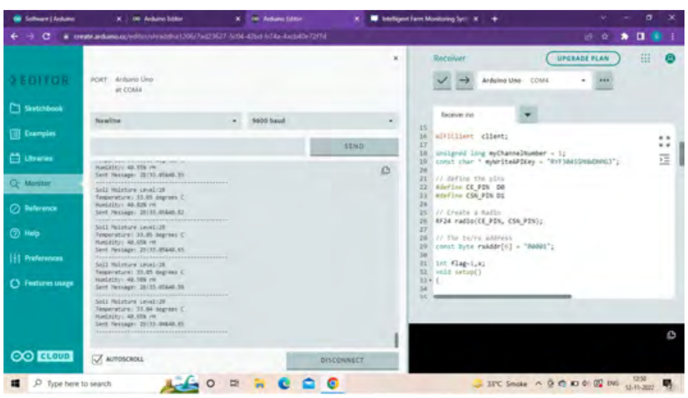

Fig. 12. Transmitter Node data with Serial Monitoring

is sent, resulting in delays.

CONCLUSION

This paper proposes a model for agriculture improvement based on LoRaWAN technology with an IoT platform. The data is collected through sensors and is processed. LoRa has become a suitable technology for agriculture since it can increase scalability to put IoT devices in farm areas. These end devices of LoRa can overcome bandwidth limitations and are economical and energy efficient. Temperature, humidity, and soil moisture are collected and monitored variables. A user (farmer) can evaluate the data on a cloud platform after the sensors have collected the data.

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