Site - Specific Crop Monitoring System through Wireless Technology

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Abstract: ***India being an agricultural country needs some innovation in the field of agriculture. Now a day's the demand for farm products increasing due to population growth and limited resources for irrigation. The water has made the irrigation management system an important element of agricultural activity. Traditional methods of irrigation not only require water in quantity but the percentage of water wastage is also high. This paper describes the wireless technology - based design and implementation of a site - specific crop management system (SSCMS). The SSCMS involves the installation of customized sensor nodes at multiple sites within the farming land, each node incorporates very useful features such as multi - layer soil moisture content sensing, soil temperature, PH levels sensing, and ambient temperature, humidity, ambient light intensity monitoring. Monitoring these parameters is the most vital aspects of agricultural productivity and maintenance of field crops. Various diseases caused improper maintenance of some climatological conditions. Moreover, monitoring appropriate environmental parameters required for the high yield of crop production on given farmland among different technology for crop monitoring wireless sensor network processes the data in the agriculture domain with low cost and low energy power. This cost - effective technology improves its production and enhances agricultural yield.***

Keywords: Internet of Things (IoT), Mobile App, Soil Moisture & Temperature sensor, Site - Specific Crop Management, RF Wireless Module

1. Introduction

According to the United Nations Global Environment Outlook, water withdrawals in developing countries are expected to increase by 50% by 2025, and if this trend persists, approximately 1.8 billion individuals will be residing in areas with absolute water scarcity. However, not only developing countries, which are facing severe health problems due to limited access to fresh water but also the world's wealthiest industrial nations are increasingly suffering from water shortages. Groundwater is being depleted faster than it is being replenished in over 60% of the European cities with a population of over 100, 000. The severe impact of water scarcity hinders socio - economic development, because industrial and manufacturing activities require adequate water supplies. Consequently, the nations' economies face significant implications such as increasing prices of water, food, and energy, as well as reduced agricultural productivity. For instance, in the United States, water prices are growing at a rate of approximately 10 - 15% per year. The main reasons for the global water crisis – besides population growth, urbanization, and climate change – are excessive water use, poor management, and inadequate irrigation. As per United Nations World Water Development Report, irrigation accounts for 70% of the global freshwater usage [6].

Conventional farming methods usually involve untimely or random supply of water to the lands. This leads to a situation where the applied amount of water for irrigation often does not align with the crop's requirements, resulting in either over - irrigation or under - irrigation. Recent studies have revealed that the irrigated crop utilizes less than 40% of the applied water efficiently. Furthermore, it is well known that poorly managed irrigation systems not only contribute to water scarcity, but can also lead to significant soil damage caused by draining (due to water shortage) or leaching (due to excessive water application) entailing a further reduction in crop yield. To overcome the problems caused by inadequate and expensive irrigation, the current work proposes "Site - Specific Crop Management" [1]. Here, we proposed two self - powered sensor nodes and a coordinator integrated with multiple Agri - sensors, where each node will be connected to one or more sensors. By using mesh technology communication between different nodes is also possible which helps for long - distance monitoring. Each sensor in a node has several parts like a microcontroller unit, an electronic circuit for interfacing with sensors, energy source.

1.1 Need of Site - Specific Crop Management (SSCM)

The farming management concept based on Site - Specific Crop Management (SSCM) relies on the observation, measurement, and response to inter or intra - field variability in crops. Soil often falls short of providing the necessary water and nutrients for high and profitable crop yields, requiring farmers to manually supply the necessary supplements. The growth and requirements of a crop for additional resources can significantly differ among fields, seasons, and years due to variations in crop - growing conditions, soil and crop management, and climate. Hence, the management of soil condition requires an approach that assists variations in supplying necessary resources to accommodate the field - specific needs of the crop. SSCM offers farmers a set of guidelines, tools, and strategies to help them determine the precise timing and amount of water and nutrients they should apply to their fields, taking into account the actual growing conditions of a specific location and season. With the SSCM, farmers can take a better yield, the soil will also least disturbed and there will not be depletion of resources or minerals. Here large fields are divided into small patches so that no misapplication of products occurs. Hence, the adoption of SSCM will result in improved crop and farm efficiency.

2. Literature Review

Smart irrigation controllers [4], such as weather - or soil moisture - based devices, are able to automatically trigger irrigation events depending on actual site conditions. Controllers based on soil moisture content, such as soil moisture - based controllers, initiate irrigation events based on the moisture level present in the crop's root zone. Ensuring a soil moisture level between the field capacity of the soil and the wilting point of the crop, soil moisture - based controllers typically determine the water requirements by comparing the soil moisture measurements with pre - defined threshold values [2]. While smart irrigation controllers are capable of initiating irrigation events at appropriate times, there are several limitations associated with those currently available in the market. For instance, many smart irrigation controllers lack the ability to adjust the amount of water applied in real - time based on soil moisture measurements. Instead, they apply a fixed amount of water for each irrigation event regardless of the actual soil conditions. Consequently, even well - designed and managed sprinkler irrigation systems can achieve maximum irrigation application efficiencies ranging between 20% and 75%.

Chavez et al. reported that, to enhance the efficiency of remote irrigation systems, control and monitoring systems are installed on two distinct pipelines. The accuracy of precision irrigation systems is validated using a set of wireless sensor networks placed both in - field and onboard. The nozzle regulators are installed separately based on the approval maps [18]. A wireless control system for irrigation was created and assessed for controlling and monitoring variable - rate irrigation in real - time [17]. Additionally, a distributed wireless sensor network was designed for in field sensing of soil water conditions [12]. To avoid issues with salinity sensitivity and corrosion over time, a resistive - based sensor was utilized instead of a conductivity sensor. The chosen sensor is compact, durable, and energy - efficient. Specifically, the VH400 soil moisture sensor produced by Vegetronix [19] was employed for soil monitoring. This sensor uses transmission line techniques to gauge the soil's dielectric constant, making it immune to water salinity and resistant to corrosion. Additionally, compared to other low - cost sensors like gypsum block sensors, the VH400 has a quicker response time. In an automated irrigation system that employs a wireless sensor network, valves are utilizedto turn the motor on and off [7]. Controllers may beutilized to automate these valves with ease. The automation of irrigation in farms or nurseries enables farmers to accurately apply the appropriate amount of water at the optimal time, regardless of the availability of labor to manually operate the valves. Data acquisition, data analysis, data aggregation, and decision - makingare performed directly on the sensor nodes, and real - time soil moisture measurements, as well as actual weather data, are used to schedule irrigation events autonomously [14].

3. Materials and Methods

Implementation of site - specific crop management (SSCM) through wireless technology involves the design of wireless sensing nodes consisting of various sensors, wireless network module, internet of things, and user - friendly mobile application.

3.1 Hardware Implementation

The overview of the planned system contains two sensor nodes powered by solar energy. These sensor nodes are installed within the communication range of each other. These nodes are built with soil moisture sensor array, soil temperature sensor, ambient temperature and humidity sensor, light sensor, and PH sensor. Here, node - 1 and node - 2 will communicate each other using NRF communication protocol. The overview of the SSCM system is shown in fig 1.

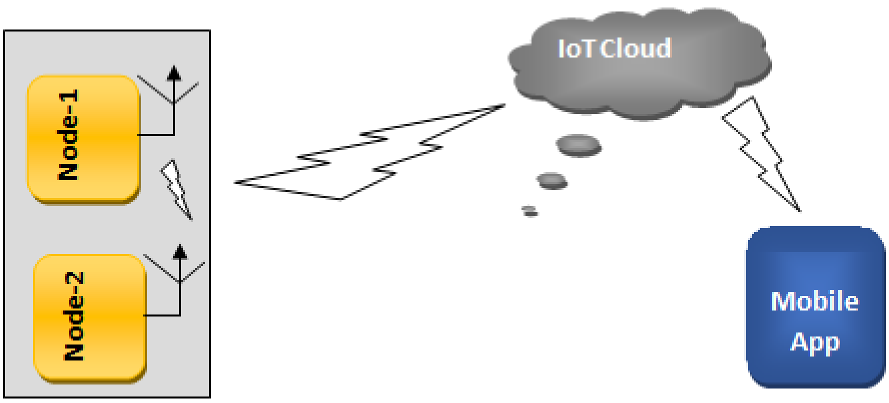

Figure 1: Overview of the site - specific crop management system

3.1.1 Implementation of Sensor Node - 1

The Sensor Node - 1 installed at specific site in the agricultural land consists of soil moisture sensor array, soil temperature sensor, ambient temperature and humidity sensor, light sensor, NRF comunication module, and solar power supply unit, and solar power supply unit as shown figure 2.

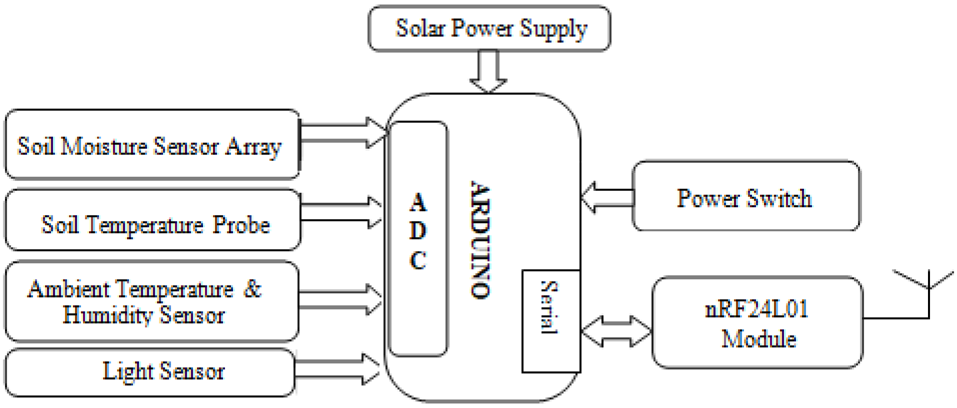

Figure 2: Implementation diagram of Sensor Node - 1

3.2 Implementation of Sensor Node - 2

The Sensor Node - 2 incorporates soil moisture sensor array, ambient temperature and humidity sensor, PH sensor, NRF comunication module, ESP8266 Wi - Fi Module, and solar power supply unit shown in figure 3.

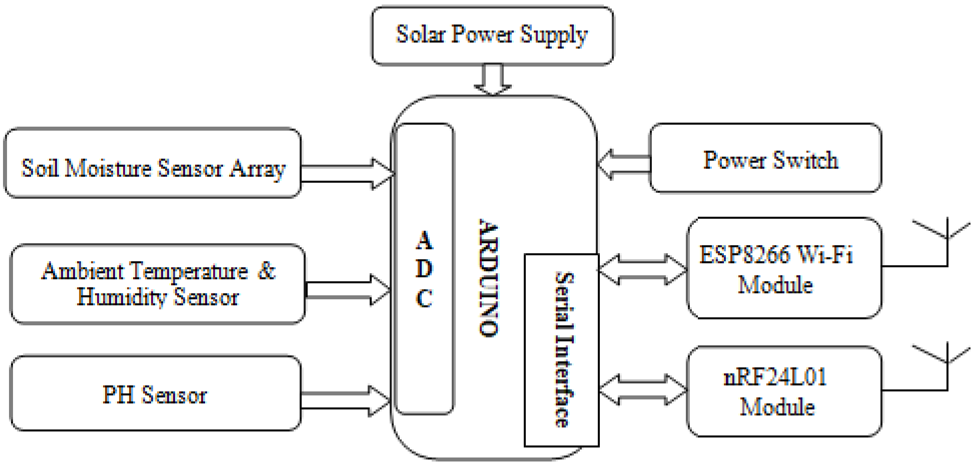

Figure 3: Implementation diagram of Sensor Node – 2

3.3 Software Implementation of SSCM

Software implementation plays a vital role in every real - time application design, using hardware resources and architectural features to perform desired operations more effectively. Programming the hardware module enables the users to perform various functions like; measuring or reading input data, processing, and communicating with networked devices. Rapid advancements in IoT technology connect an enormous amount of input and output devices on a cloud platform.

3.3.1 SSCM Sensor Node - 1

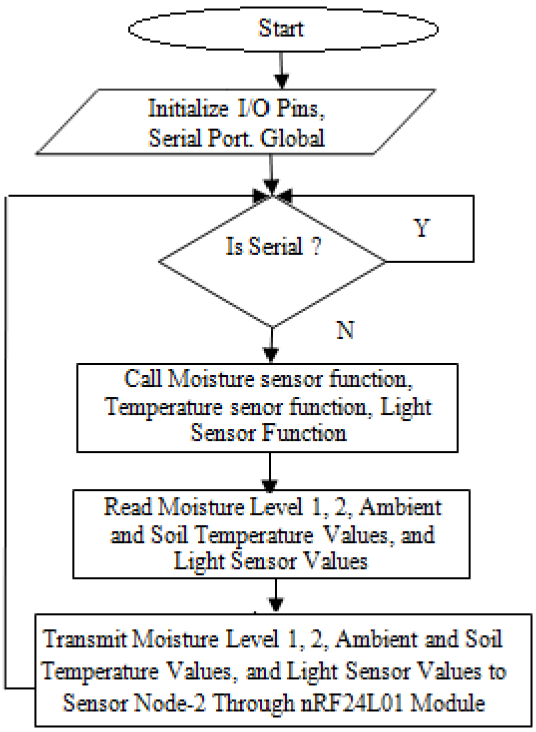

Figure 4: Flowchart of SSCM Sensor Node – 1

Flowchart of SSCM Sensor Node - 1, shown in figure 4, highlights the internal working in the sequential data flow. It explains the complete working of sensor node - 1, starting from the initialization of necessary functions, processing, and decision - making up to communication over the network device

3.3.2 SSCM Sensor Node - 2

Flowchart of SSCM Sensor Node - 2, shown in figure 5, highlights the internal working in the sequential data flow. It explains the complete working of sensor node - 2, starting from the initialization of necessary functions, processing, and decision - making up to communication over the network device, and finally uploads two sensor nodes data onto the thing speak IoT cloud.

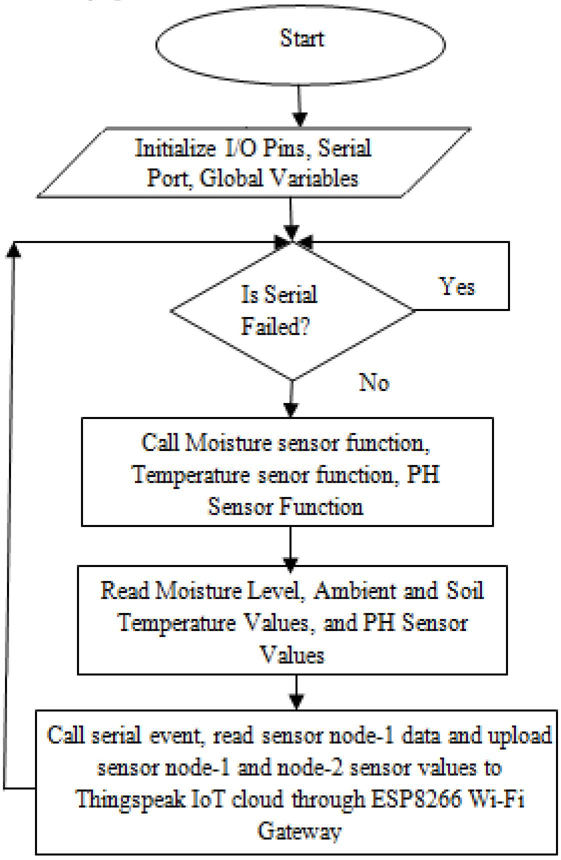

Figure 5: Flowchart of SSCM Sensor Node – 2

3.3.3 IoT Cloud Configuration for Data Upload, Storage and retrieval

The information generated by SSCM sensor node - 1 and sensor node - 2, have been uploaded to thingspeak IoT cloud platform for storage and remote access available for the authorized farmer using mobile applications. To upload the data to IoT Cloud, create a math account in the Thingspeak IoT Platform; every user will be assigned many channels with corresponding channel ID for uploading onto and retrieving the data from the IoT cloud. WRITE API key should be usedTo upload the sensor data to thingspeak IoT, and READ API key for accessing data from the cloud.

3.3.4. User - Friendly Mobile Application for SSCM

We have developed a user - friendly android mobile application using MIT App Inventor 2, as it offers graphical programming rather than textual programming environments. The App was designed for accessing Sensor Node - 1 and Sensor Node - 2 data

Streams stored on the Thingspeak IoT cloud using READ API keys. The main functionality of application as follows;

- When the application opens, it first initializes many tasks like; screen with static texts, a location sensor, global variables, Text to speech modules etc.
- The Main window contains wireless sensor node - 1 and sensor node - 2 selection options buttons, so all the windows are set with the selected names.
- By default, the main window consists of the normal flow of wireless sensor node - 1; if none of the windows is selected in step 2, then the execution flow proceeds with setting IoT read clock timer1 for WSN - 1 with 5 seconds read cycle.
- If WSN - 1 read time expires, then IoT read web page with URL query will be sent to thing speak IoT with reading API key.
- After sending an IoT read query for WSN - 1 and WSN - 2, when the IoT server responds with Sensor nodes data in JSON format, the application decodes the data, extracts each nodes parameter values in separate variables and then displays it onto the dashboard.

4. Results and Discussions

The presented concept of agriculture parameter measuring and monitoring system is more advantageous when the agriculture land is far away or the farmer is in remote places. The site - specific crop management system consists of two wireless sensor nodes integrated with various sensors and wireless network modules such as array moisture sensors, temperature, humidity, soil temperature, PH sensor, lux sensors, and nRF2401 wireless modules shown in figure 6.

The SSCM contains two wireless sensor nodes; wireless sensor node - 1 consists of humidity and ambient temperature sensor (DHT11), array of two soil moisture sensors, soil temperature sensor, nRF24L01 radio frequency wireless module, and solar power supply unitdisplayed in figure 6.

Figure 6: Complete setup of SSCM Hardware Modules

Similarly, wireless sensor node - 2 consists of a soil moisture sensors, PH sensor, Lux sensor (light intensity sensor), nRF24L01 radio frequency wireless module, and solar power supply module. The two wireless sensor nodes communicate each other through nRF24L01 RF wireless module.

The sensor node measures soil PH values, soil moisture content as well as ambient light intensity, apart from the measurements it continously receives the WSN - 1 sensor data at every 5 secods. Finally, WSN - 2 transmits the two node data to network module (NodeMCU) for uploading the whole data to IoT. Figure 7 shows the data frame consisting of all the sensor data from WSN - 1 and WSN - 2.

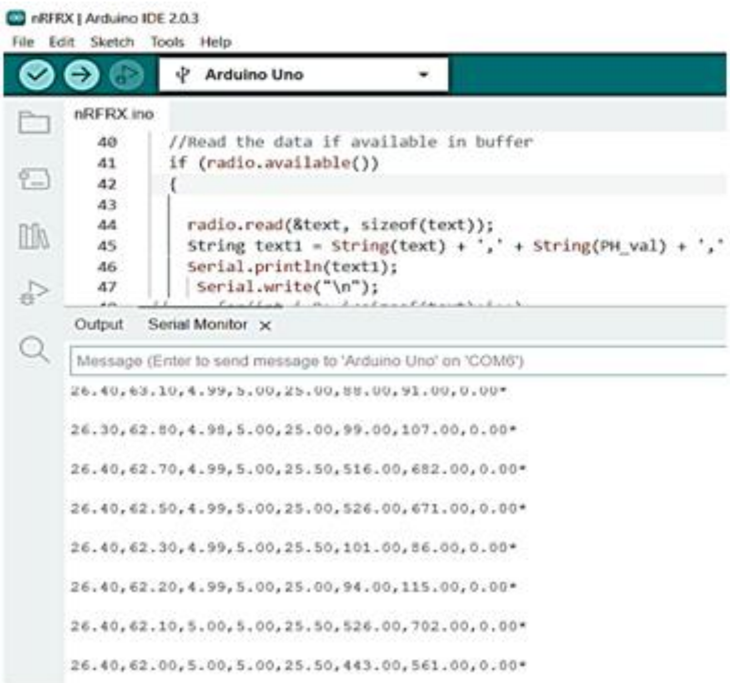

Figure 7: Data frame of WSN - 1 and WSN – 2

The complete data frame containing sensor informations of WSN - 1 and WSN - 2 will be uploaded to the thingspeak IoT cloud platform using WRITE API Key. The sensor data received from the client device will be updated to the respective field charts in the thingspeak channel. Various field charts displaying different sensor data are as shown in figures 8 and 9.

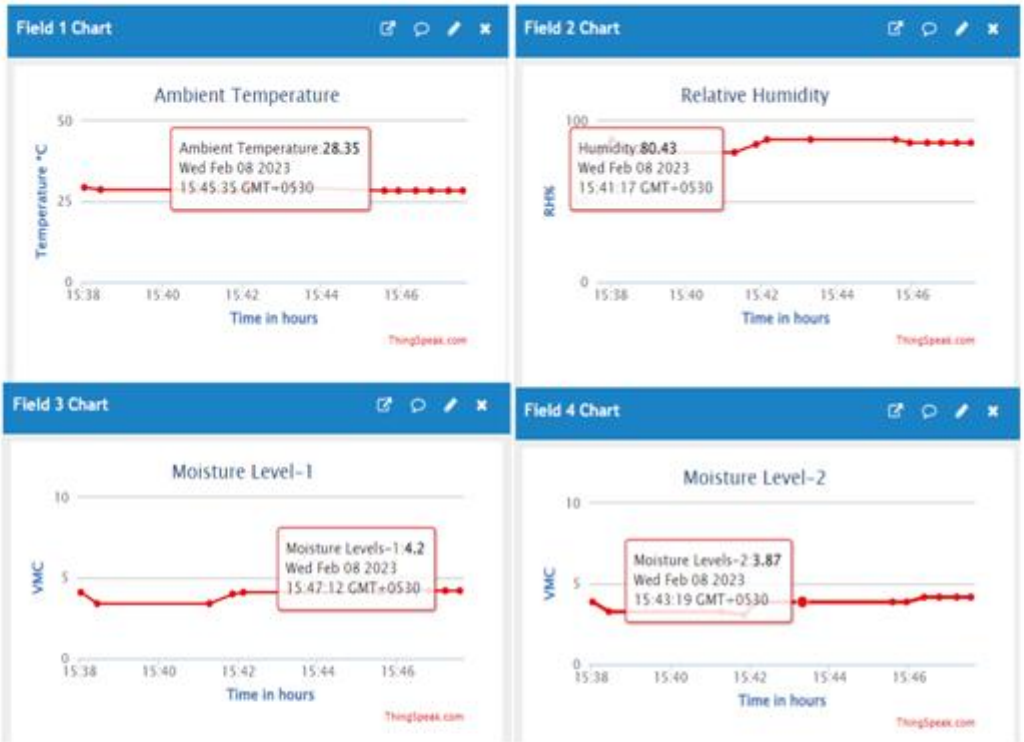

Figure 8: WSN - 1 and 2 sensor data field charts on thingspeak IoT

The sensor data stored on the thingspeak IoT cloud would be accessed using user - friendly mobile applications developed on MIT AI2 tool. The application fetches the sensor data from IoT cloud using READ API Key assigned to a created channel on the thingspeak IoT platform. The application displays the WSN - 1 and WSN - 2 sensor datas on the dashboard as shown in figure 10.

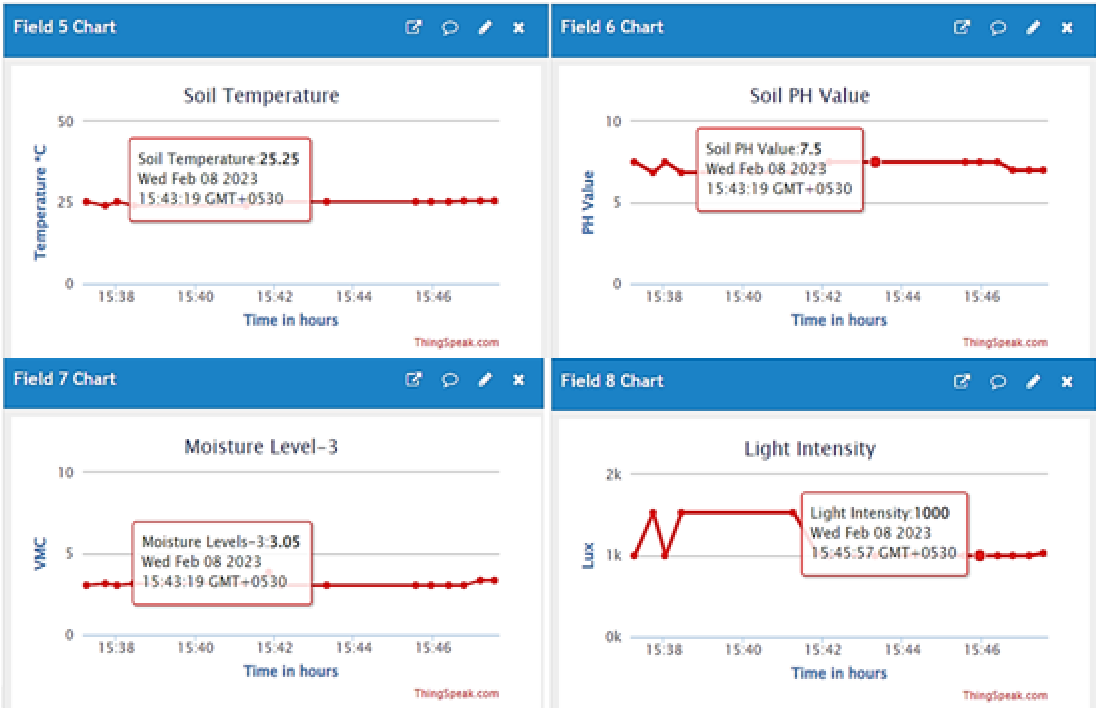

Figure 9: WSN - 1and 2 sensor data field charts on thingspeak IoT

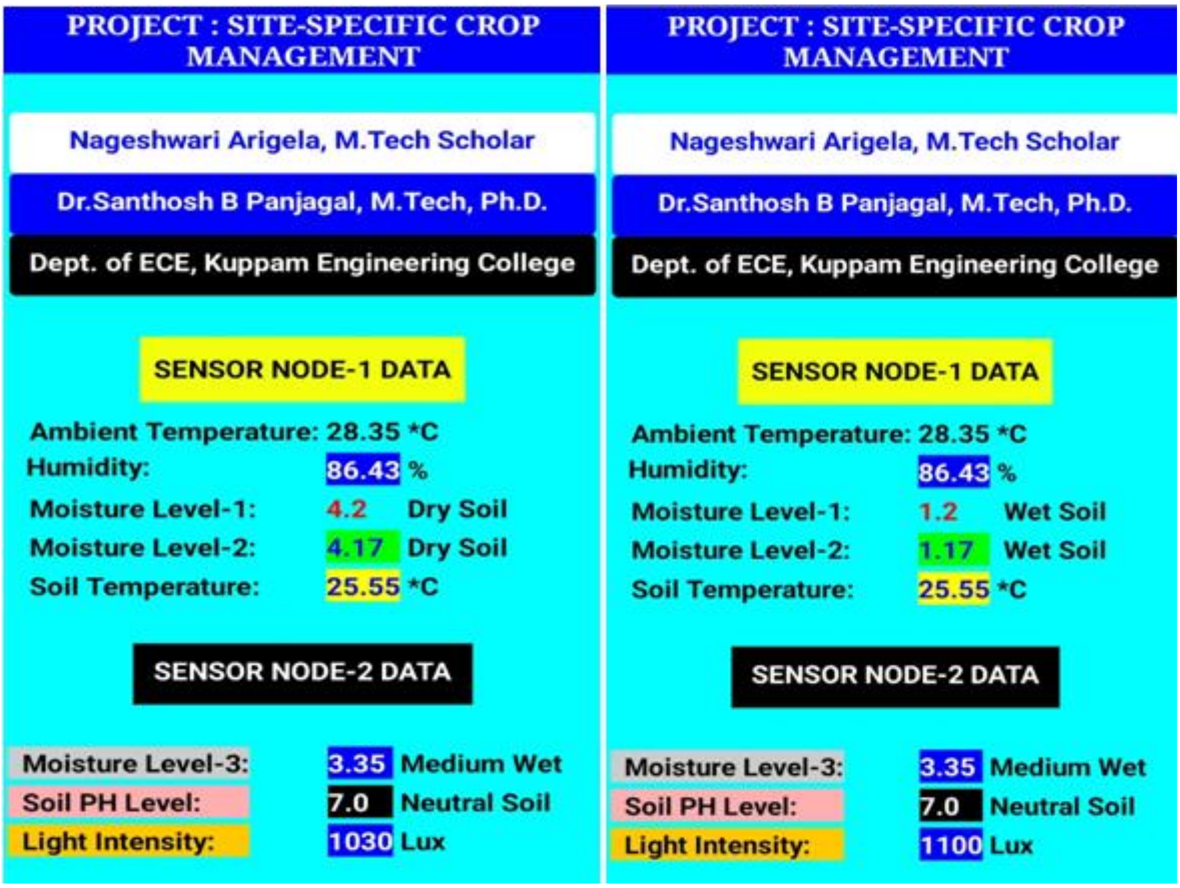

Figure 10: Mobile Application displaying WSN - 1 and WSN - 2 Sensor Data

5. Conclusion

Agriculture Management system is expected to play key role in improving farming activities. In recent years, advanced farm management systems have surfaced, replacing obsolete and cumbersome farm systems and software tools. The current trend is to facilitate management by acquiring knowledge of all parameters without being physically present in the field.

The proposed work describes about the design and implementation of wireless sensor nodes for the measurement of soil moisture condition at various sections, soil and ambient temperatures, soil PH values at the large acres of land areas. The system incorporates the low power, cost effective wireless sensing nodes to acquire the different conditions of soil and atmosphere. The wireless sensor node - 1 and node - 2 installed at different areas in a land and communicate each other in the private mesh networks using nRF2401 RF module to overcome the limited range coverage. The system shows the satisfactory results to monitor the agricultural land parameters. The master controller interprets measured soil parameters and then transfers the processed information to thingspeak IoT cloud for storage, future analysis and crop management. The user - friendly mobile application provides the land parameter information in real - time. It fetches the sensor nodes data stored on the IoT cloud using READ API key assigned to the dedicated channel, displays the sensor values on the dashboard for real - time monitoring. Alerts the farmers with varying land parameter conditions such as soil moisture contents, soil temperature and soil PH values.

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