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Experimental performance of smart IoT-enabled drip irrigation system using and controlled through web-based applications

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ABSTRACT

The water requirements in irrigation have been growing and the accurate quantity of water can be produced by a smart irrigation system. Considering this kind of need, this paper aims to develop an Internet of Things (IoT) enabled smart drip irrigation system by applying Web/Android applications that will provide a solution for continuous monitoring and controlling the drip irrigation system to avoid the problems of constant human vigilance and waste of water. It also facilitates prevention by giving automatic water to plants relying on water necessities. It can also convince be capable in Agricultural fields, Parks, Lawns, etc. With the advancement of technology, there are always reducing risks and making work simpler. The embedded system provides a solution for solving this kind of problem. In this paper, a smart drip irrigation system is established which is driven by IoT and web-based applications. The web application is also designed for taking appropriate action for the user during drip irrigation. This application provides the appropriate amount of water from the pump for gardening. It can be accomplished by incorporating different sensors within the system to observe the humidity, temperature, and soil moisture conditions which transmit the data to the micro-controller for proper estimating the water needs of the plants. This kind of system can be controlled and visualized in the android mobile phone through a web application anywhere.

1. Introduction

With an increasing population in the world, the requirement of the food production rate has been increased specially in India where agriculture is a major livelihood source [1]. To obtain a healthier quality and sustainable production rate of foods, the requirement of freshwater is also increased for irrigation. Currently, agriculture accounts hold total the water consumption of 83% in India [2]. Considering this aspect, the water for various applications has not been using in a planned manner consequently, the water is wastage in different places. Therefore, this shows that there is a demand to develop such systems for solving the problem without the wastage of water. Plant health management is a major science to overcome the succession of botanical parameters by setting up the boundary for plants towards achieving their full genetic potentials conditions. In this area, plant health monitoring is an important branch for crop health monitoring [3]. The majority of the farmers follow the manually operated pump method for irrigation and it gets a lot of time to do irrigation in a big land. Considering these contexts, some researchers have been studied automated/semi-automated methods for irrigation where they have shown the potential towards substitution of traditional/conventional ways of irrigation methods [4, 5]. Such irrigation systems can easily be rectified by using the automated system rather than the conventional systems but nowadays, Internet-of-thing (IoT) is acting a essential part in precision agriculture area where an IoT technology has the capability for establishing the communication between different things/device/objects using a shared/wireless network system. This technology provides a solution for communication within the available networks using the Internet. With help of IoT, precision agriculture attempts the reduction of wastage of different usages like labor, time, and other resources to enhance crop cultivation and their productivity. In this paper, an IoT based smart drip irrigation system is proposed for monitoring and controlling the crop-yielding parameters using data fusion method where the soil moisture condition is found using soil moisture sensors, and humidity

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and temperature sensors. Whenever there is a change in humidity and temperature by changing environment. These sensors update the data for activation of pumps for water flow in the plantation. An interrupt communication signal is sent to the microcontroller and NodeMCU. This smart drip irrigation system is connected with a web/android application so that the users/farmers can be monitored and controlled the process/data remotely on their mobile phones and the controlled data is accommodated in a web server database using IoT cloud platform which can be retired in any time. An IoT-based smart drip irrigation system can be applied for finding the plantation/crop health data in real-time. Using such a system, the major advantage is to provide the solution as a remotely operated, energy-efficient, and low-cost IoT-based control system for different drip irrigation applications.

The objective of this paper is focused on the development of a novel IoT-enabled smart drip irrigation system using a sensor fusion method which helps in the reduction of excess water and electricity in an effective and efficient manner. This also helps in the prevention of excess water loss and minimization of labor by controlling using android mobile. The major emphasis of this paper is as under.

(a) To develop a smart drip irrigation system using the sensor fusion method.
(b) To design web/android applications using IoT for monitoring and controlling the different sensor data and plant condition.
(c) To monitor and control the sensor fusion data using an Android mobile phone.

This paper is presented as under: a brief report state-of-art on IoT-related development for irrigation applications is discussed in Section 2. In Section 3, a novel concept on IoT-enabled drip irrigation system is proposed where the major focus on soil sensing, monitoring, and control system. In Section 4, a system architecture for IoT-based drip irrigation is described. In Section 5, a process flow of IoT based smart irrigation systems is also described. A testing setup is also developed for implementation purpose as discussed in the result and discussions in Section 6. The conclusion is written in Section 7.

2. Brief report of literature survey on IoT related development for irrigation applications

In the past, IoT-related development activities for irrigation applications have been carried out by some researchers. Kansara et al. [6] have presented the sensor-based automated irrigation system to provide an automation in irrigation which can save the money, time and effort for the farmer as compared to manual irrigations. Bedekar and Mechkul [7,8] have provided a solution for controlling the process of the irrigation system using IoT whereas Siddagangaiah [9] has attempted a plant health monitoring system using IoT technique where atmosphere parameters like light intensity temperature, humidity etc., and can be found using IoT cloud platform and further an alert message is mailed to the mobile phone. Umair and Usman [10] have also attempted an automated irrigation system where an intelligent control system is implemented using an artificial neural network (ANN) for effective irrigation scheduling. Touati et al. [11] have attempted on the fuzzy logic control system and the rules table is created for a particular crop and this provides the information about the irrigation timing. Arif et al. [12] have estimated the soil moisture data using the ANN model with the limited meteorological data and the proposed model has also been verified with observed data. Giri and Wavhal [13] have provides a solution for utilizing the more accurate way facility in the agriculture field using WSN along with linear programming where an application of wireless sensor network (WSN) has provided a low-cost wireless control system and irrigation can be monitored effective way. Salazar et al. [14] have attempted an intelligent multi-agents control architecture for irrigation systems where a fuzzy control system is implemented whereas Hussain et al. [15] have attempted the controlling the irrigation system using WSN for obtaining the sequenced data about the soil and moisture content of the particular area. Reddy et al. [16] have focused on an evapotranspiration model for getting parameters of soil condition, air humidity, radiation towards deciding the ecological conditions, and type of crop stage. Singh and Sharma [17] have attempted a fuzzy system and various experiments and applied research for collection of membership functions. A set of rules are used. Khamkar [18] has designed a knowledge-based expert system for the automatic drip irrigation system which is applied for enhancing the productivity of sugarcane. Parwatkar and Bhagat [19] have presented the Zigbee based wireless technology in an automated irrigation management system for WSN because Zigbee shows some potential such as low power, low cost, and wireless mesh topology networking standard. Darwin et al. [20] have attempted an efficient irrigation system where the automatic pump operation using solar energy has been carried out which reduces power consumption. Solar energy is sensitive to the environment where it does not require more maintenance. Anusha and Gouthami [21] have attempted a wireless network-based automatic irrigation system where a distributed WSN is applied for soil moisture and temperature data that is transmitted through the GSM module. Hellin et al. [22] have proposed a decision system to handle irrigation for plantation in agriculture where the soil moisture and climatic variables are acquired from the data based upon self-sufficient nodes provided in fields. Cruz and Marques [23] have conducted field experimentation on an efficient irrigation management system where the weather data are collected and compared with a trained embedded fuzzy inference system. Geng and Dong [24] have developed a classification model based on a deep learning algorithm for finding the soil condition and relative humidity of agricultural land so that the exact condition can be analyzed for the development of a better crop. Bagwan et al. [25] have focused on efficient water-saving management towards green farming using IoT where AI and NN algorithms are applied in the network gateway towards developing the smart wireless network system. Deshpande et al. [26] have also attempted an intelligent irrigation system that helps the farmers for irrigating land in a well-organized manner. The soil moisture sensor is exploited to get the soil moisture data. Villarrubi et al. [27] have built virtual organizations of agents for communication towards monitoring crops where a low-cost sensor architecture permits monitoring and optimization of the growth of the crops. Adeyemi et al. [28] have discussed how to incorporate adaptive decision support systems in an irrigation management system to increase the efficiency of the current irrigation approach. Sarojini et al. [29] have established an automated drip irrigation system using a programmable logic controller (PLC) and biosensors to monitor and control the drip irrigation system.

Vanitha et al. [30] have focused on finding the soil moisture condition using the Raspberry Pi microcontroller where crop field conditions can be found and visualized by using a web camera and it can be viewed in the remote server and send the SMS using GSM. Pooja et al. [31] have shown the potentials of the drip irrigation system where the acquired data from a sensor node is an updated centralized cloud server automatically whereas Swetha et al. [32] have tried to attempt an intelligent nutrition management system to acquire appropriate information about the required quantity of water towards irrigation. Shekhar et al. [33] have applied an AI-based classification method using K-Nearest Neighbor (KNN) for predicting the soil conditions towards irrigation. Singh and Vitkar [34] have focused on an intelligent artificial neural network control system for drip irrigation in paddy fields whereas Kwok and Sun [35] have attempted on a drip irrigation system where a deep learning method of artificial intelligence is applied for providing the water in each plant. Loubna and Bouchaib [36] have focused on WSN technology for intelligent irrigation methods where ZigBee based wireless communication is used for saving water and rising the effectiveness of irrigation systems. Adeyemi et al. [37] have applied a dynamic neural network method for modeling of sequential soil moisture conditions towards smart irrigation. This model is developed using a training set to create the prediction of the volumetric soil moisture content pattern based on environmental measurements. Seenu et al. [38] have developed an irrigation controller which is controlled through a mobile app and according to climatic conditions, the crop can get the amount of water. The moisture condition is also controlled. Jain and Vani [39] have presented a survey report of the automated irrigation systems and further, the AI technique has proposed for continuous monitoring of crops to find any diseases and any changes in the health of the crops. Sengottuvel and Hameed Hussain [40] have attempted an automatic plant irrigation system where the water is acquired from a reservoir kept at a height to provide high potential energy for the water. This automated irrigation system will decrease human labor and water consumption may be increased productivity. Ranjan et al. [41] have attempted AI-based algorithms namely logistic regression and naive Bayes for estimating amounts of water and nutrients on the land where the logistic regression algorithm is used for estimating amounts of water and naive Bayes is applied to estimate the number of nutrients.

Sharmila et al. [42] have focused on the development of AN model for an automatic irrigation system towards providing temperature, humidity, wetness, and pH. Deekshithulu et al. [43] have attempted on development of software for automated drip irrigation where performance evaluation of sweet corn crop has been carried out and it is found that yielding response and use of water efficiency is maximum in single row drip method. Goapa et al. [44] have discussed the machine learning and open source technologies for the collection of data over clouding web service standard to execute IoT based smart irrigation decision management system. Dharmaraj and Vijayanand [45] have thrown an idea on how to use AI in agriculture and challenge projected in the future whereas Kumbar et al. [46] have reviewed the different methodologies for smart irrigation and farming techniques to overcome the crisis of water. Kharat and Jawandhiya [47] have done the review on intelligent IoT-based automated irrigation systems whereby applying machine learning in the agricultural system and the machine-to-machine communication method is focused on allowing devices to objects for communicating to each other using wireless network system.

Jha et al. [48] have done a comprehensive review of the use of automation in agriculture where farming practices can be increased by applying them to strengthen the soil condition of the agriculture field. Anitha et al. [49] have focused on the hybrid method for selecting the irrigation method automatically sprinkler or dripper based on the climate condition changes and soil moisture level which enhances the productivity of the crop field. Janani and Jebakumar [50] have modeled for optimization of water usage to maintain a proper irrigation system using the machine learning method. Adenugba et al. [51] have attempted the collection of data to predict environmental conditions where the weather forecast, water level, temperature, humidity and irrigation data have been predicted and controlled through a web platform. Nataraj et al. [52] have attempted an automatic irrigation system where a NN machine learning algorithm is applied for predicting the sensor data. Aydin et al. [53] have attempted on automatic retrieval of data via e-mails which can be provided to the farmers and intimating them for making the decisions accordingly. Choudhary et al. [54] have developed artificial intelligence-based algorithms for the prediction of weather data, rainfall patterns, and climate changes and according to change an intelligent system that irrigates the crop fields. Prasanna and Rani [55] have highlighted the research work on the monitoring of soil properties remotely using IoT and machine learning that predict the soil properties for enhancing the high yield productivity. Ponraj and Vigneswaran [56] have analyzed various methods of machine learning. The data are implemented in the agricultural field and compared the techniques in terms of accuracy and confusion matrix which helps in decision making and production improvement. Mehanna et al. [57] have developed an expert system for finding the appropriate mechanism of the head controlling unit for a drip irrigation networking system based on the accessibility in the Egyptian market. This expert system has combined the scientific research and data base for technical specifications towards finding the control head. Aggarwal and Kumar [58] have developed the smart device for collecting the moisture data in the soil at different places, pH, and temperatures where the ANN model is applied for the analysis of this data. Amalraj et al. [59] have attempted an automated irrigation system for giving an appropriate solution to cultivate agricultural crop activity. Parthasarathy et al. [60] have developed an experimental prototype of an automated irrigation system for monitoring the soil moisture content and the corresponding relative humidity can be found using node MCU. Monisha et al. [61] have presented the review of many different techniques for irrigation and controlling the system and further, a design of a green agriculture system is also discussed where the image processing technique is applied. Madhav and Sandeep [62] have explored the machine learning approach for agriculture IoT. These help in farmer management systems to achieve the data. Alreshidi [63] has reviewed the development of smart IoT devices for agriculture applications whereas Upadhya and Mathew [64] have focused on the estimation of crop yielding parameters using a fuzzy-logic control system for vegetable crops. The input data of humidity, temperature and soil moisture are considered and the output parameters are the crisp value of crop yielding. Dasgupta et al. [65] have carried out work on a combination of IoT devices, WSN, and AI techniques for detecting the unwanted plants on crops. The capturing of data has been carried out using a drone, and deep learning methods. Sharma and Kumar [66] have focused on an IoT based irrigation system for monitoring the paddy crop field using different sensors which gives the concept of intelligent irrigation system.

Based on the brief literature report, it is understood that the research work on smart drip irrigation systems driven by IoT and web-based applications is not carried out. Therefore, the proposed work is an extended version of [67] where the sensor fusion method is applied for plant health conditions. Using different soil sensors, The condition of different plants are observed towards monitoring their health conditions. The data is stored cloud using different IoT devices which provides the novelty of this paper.

3. Design of IoT driven by smart drip irrigation system using sensor fusion method

A novel design of IoT-enabled drip Irrigation is proposed and the elemental layout is shown in Fig. 1. This sensing control system is designed using a sensor fusion method where two or more sensors are integrated in one process plant. The different moisture sensors are associated to IoT devices and these IoT devices are sending the communication system through wi-fi mode. Further, this data is stored to the cloud server which is connected to the central unit. This also provides feedback through the pump for getting the precise data. The detail of the central unit and IoT devices are shown in Fig. 2.

In this control system, the different moistures are connected to the microcontroller and nodeMCU (micro control unit). These sensors respond according to soil moisture conditions and send the data to the microcontroller and node MCU. According to the requirement, the pump will be automatically run depend upon the requirement of water through the solenoid where the threshold value of moisture condition is set in the microcontroller. The sensed values from the sensors are displayed on the computer. If the sensed value goes beyond the threshold values, the pump will be automatically switched Off/On depending upon plant requirement either 1 or 2. This will send the information of the water condition during plantation and the data will also be updated on the web page and this web data will be stored to the cloud. A mobile app is also developed for monitoring data. Therefore, the user can easily access the details about the condition of the crop field at any point in time anyplace.

4. Development of system architecture for IoT-enabled drip irrigation system

To develop the system architecture for enabling the drip irrigation

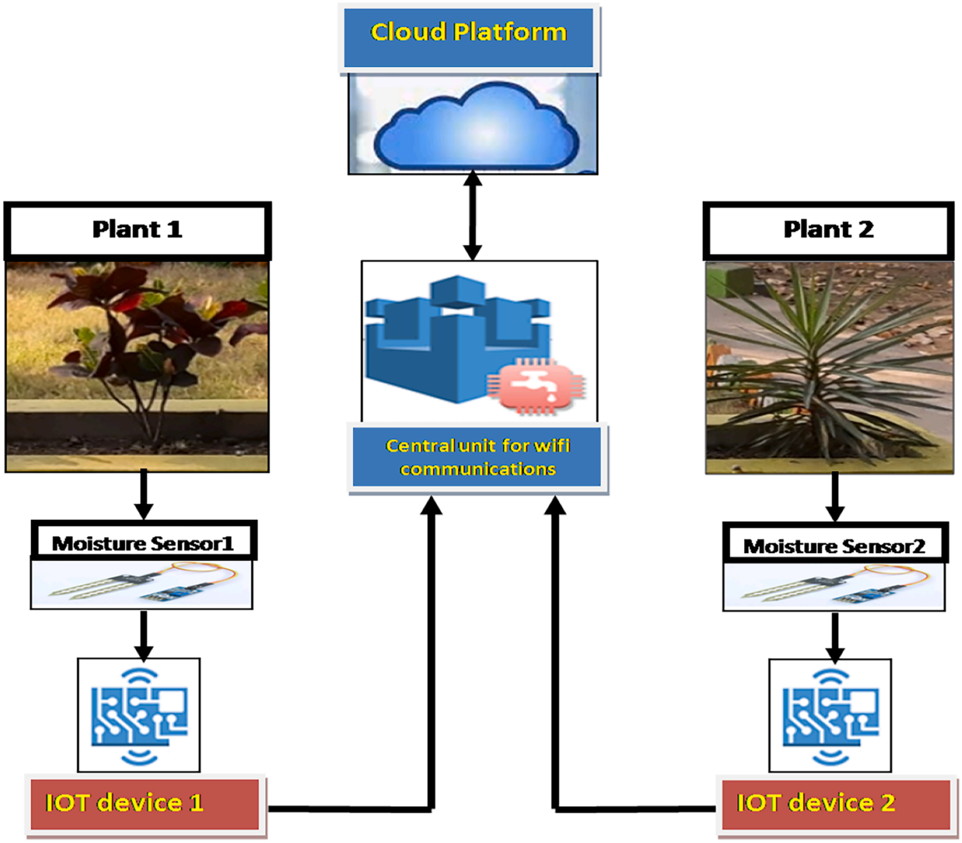

Fig. 1. Design of sensing and control system for IoT enabled drip irrigation system towards the smart plantation.

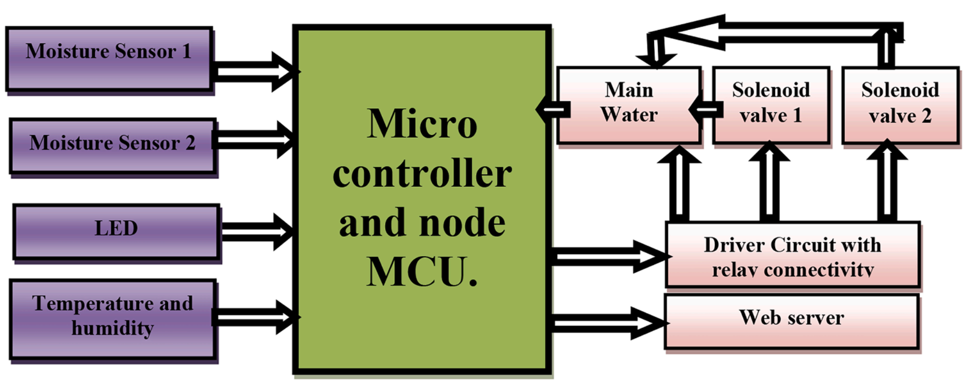

Fig. 2. Detailed schematic diagram of the control system for IoT enabled smart drip irrigation system.

system using the android/web application, the following hardware modules are used as under

4.1. Soil moisture sensor (FC-28)

The soil moisture sensorsareexploited for measuring the volumetric amount of water during insertion in the soil conditions which give the output level of moisture. For activation, the input voltage is 5 V, and the desired output voltage range within 0- 4.2 V which depends upon the moisture contents.

4.2. humidity and temperature sensor (DHT22)

Humidity and temperature sensors are utilized for measuring the relative humidity and temperature of the environment. For activation, the input voltage is 5 V.

4.3. DC submerged water pump

A DC submerged pump is implemented for supplying the water to the plantations properly.

4.4. Solenoid valve

The solenoid valves are also used for controlling the flow or direction of water where the poppet design is applied.

4.5. Micro controller (Arduino YUN)

A microcontroller board (**Arduino YUN**) is used which has inbuilt an

ATmega32u4 microcontroller and the atheros ar9331 with Wi-Fi and Ethernet ports. The speed of the ATmega is around 16 MHz. This board is used to realize the controlling the system/ mechanism and the communication data can be sent within the network. This board can be run at 5 V DC.

4.6. Node MCU (ESP8266)

NodeMCU (ESP8266) is used which has a wifi chip that interacts with an open-source platform during an interface with hardware during the designing of the system. This has the same capability as ESP8266.

4.7. Double channel relay

The double channel relay switches are utilized for the proper operation of the motors during opening and closing. These have three contactors (i) Open (NO) (ii) Closed (NC) (iii) common (COM). During operation, when the COM is connected to NC then it is an ON input condition, and COM is connected to NO then it is an OFF input condition.

4.8. Power supply (5-12VDC)

A multi channel power supply is also utilized for providing power to sensors, DC motors, microcontrollers, and its drivers upto 5–12 VDC.

4.9. Router

A router is used for networking connections with the robotic system. This forwards the data in the small package to computer networks for getting command action properly. The router also performs the traffic direct utility within the Internet system so that the robotic system can be connected using the IoT technique.

4.10. IoT cloud platform

IoT Cloud platform is used for processing and storing the data. This can be illustrated as a "massively scalable real-time event processing engine". In this system, the thing speaks is used as an IoT cloud platform during controlling the entire process.

4.11. Android studio

To developthe Android/Web application, Android Studio with an integrated developmental environment (IDE) is used where a Java integrated script is applied for the development of software using developer tools. This has editable code features.

For designing the system architecture, the communication system is designed using three layers as shown in Fig. 3. These detail of each layer are given below;

(i) Sensing layer,
(ii) Internet layer,
(iii) Application/User Interface (UI) layer.

In the design of the first layer, all soil moistures, humidity, and temperature sensors are integrated with an Arduino microcontroller. A DC power supply is used for providing voltage during data

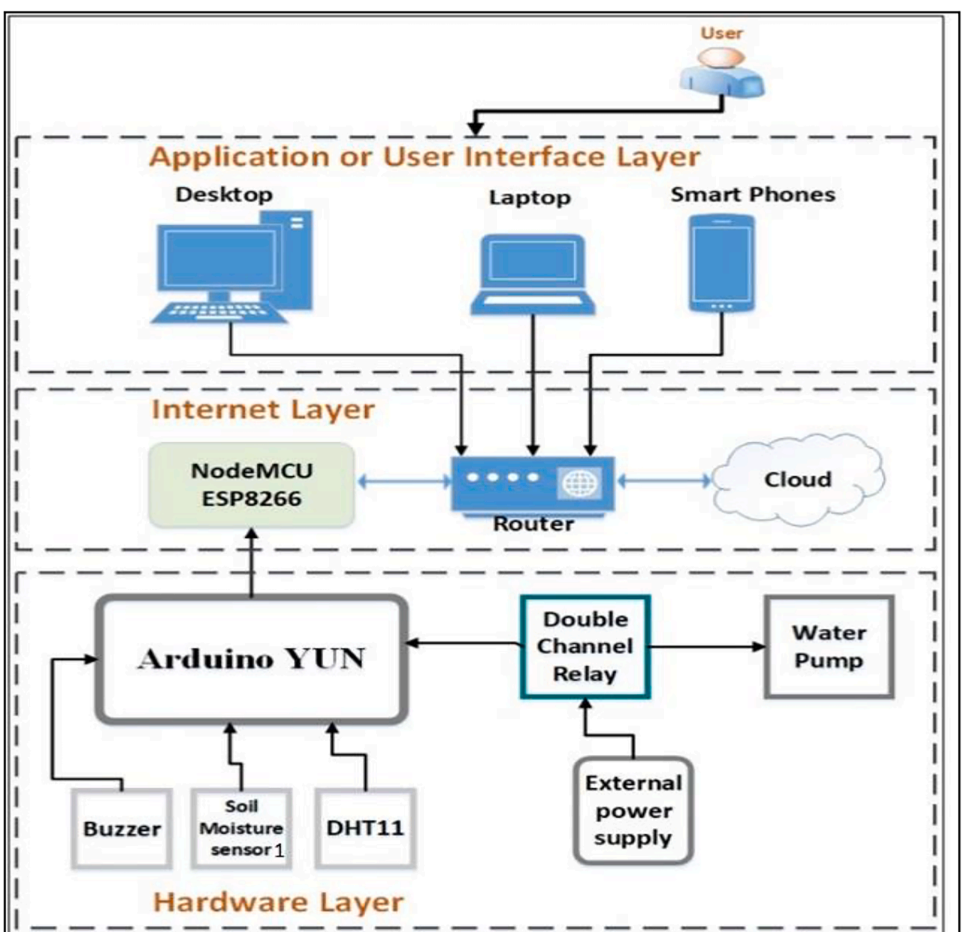

Fig. 3. Overall Block diagram for IoT enabled smart irrigation.

communications. The different moisture sensors are linked with the microcontroller to sense the moisture percentage level inside the particular area where the soil moisture is digging inside the soil. This soil moisture sensor is connected with the main pump through the solenoid valve and will on and off according to the condition applied in the microcontroller and other sensors will also operate as per the requirement of water through the solenoid valve. Through the pump, the feedback will also be sent to the microcontroller for desired operations. The solenoid valve will also work with the condition applied in the microcontroller.

This system performs manifold operations where the centralized microcontroller unit is placed. This is programmed to receive the input signals of the different multiple sensors (fusion data) of the field which is connected along with the different solenoid valves. A web application is interfaced with the microcontroller to control the parameter of the system field. The automatic smart drip irrigation system includes hardware and software sections interfaced together with the software serial communication between the Arduino and the NodeMCU to send out data from one system to another via wireless communication in the second layer. The main element of the design consists of a web application, interfacing peripherals, and the wi-fi connectivity inbuilt in it and the controls. The web application will generate the control command signals which are supposed to be used in the system. NodeMCU ESP8266 also used for providing the wireless connection between the internet layer and application/UI layer using an open-source platform. For this purpose, a router is also installed. The NodeMCU also developed communication between Android Application and IoT cloud via the application/UI layer. This application/UI system is used for monitoring and the controlling system through the automation process. Using this Android/Web-based communication system, the smart IoT enabled drip irrigation system is controlled using an Android mobile phone from anywhere.

5. Development of flow process

The schematic diagram for controlling different sensors using a microcontroller is drawn in Fig. 4. The commands are sent to all sensors using the Arduino YUN microcontroller. Arduino detects all the sensors and the sensors follows instruction as given by command control system. The desired values from the sensors send out to the configured network system. The pump is operated as per instruction using an Arduino microcontroller. The process flow for controlling the pump is shown in Fig. 5. This is designed for the smart drip irrigation system towards the plantation. During operation, all sensors are configured at first with a microcontroller then it will also configure with the network for exchanging the communication data. After configuring the network, a critical check operation will be carried out for finding any critical problem during execution of tasks. If critical problem arises, the buzzer will be on until the problem will not be solved of program. During operation, if the water for the plant is required then the pump is started

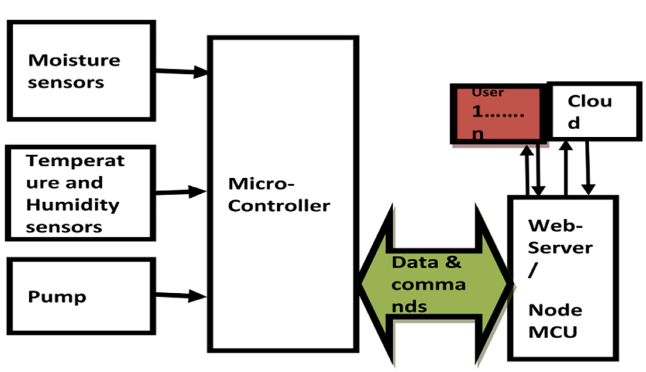

Fig. 4. Layout for controlling different sensors using a microcontroller.

and it will be maintained at the identical condition upto reaching the moisture level. It will be observed using a soil moisture sensor. Then, if the moisture level is sufficient, then the pump will be Off automatically. This process will be followed continuously when the soil moisture level is less than the required level. Further, this process is integrated with NodeMCU for sending the information to the android mobile phone for user notifications. Using NodeMCU, the data will be sent to the IoT cloud using the Think speak IoT cloud platform where data are also stored. A web application is established for monitoring and controlling the system. For authentication purposes, the user login and password are provided in the web application. Therefore, the smart drip irrigation system is controlled using an android mobile phone towards the plantation.

Therefore, the process is like when the system starts after switching on the power all sensors will be in an active mode and started their tasks. The system includes soil moisture sensors, fusion, temperature, humidity, and LED, and this hardware is connected with the microcontroller. Here, the microcontrollers are Arduino and NodeMCU Esp8266 with wi-fi SOC (System on chip) inbuilt in it. The Arduino and NodeMCU are connected with two jumper wires for serial communication to transfer the sensor's data to the microcontroller and the cloud via the microcontroller web server. The NodeMCU acts as a web server that is web-server is created inside the NodeMCU microcontroller with the help of Esp8266 library from the Esp8266 official website. Here web-server is created within the NodeMCU that can be able to communicate to the user and view the data from the cloud.

6. Result and discussions

For developing the smart drip irrigation system, the pilot project plant for plantation is developed as shown in Fig. 6. All said sensors are installed in different plantations and microcontroller and support items are installed in the control unit box and connected to each other. During operation, the sensors sense the data and process this, and sends these data to the IoT cloud using web-server. All this process is connected using the nodeMCU and IoT Think Speak Cloud. A web application is designed for controlling and visualization of the smart drip irrigation system.

A submerged pump is fitting with a storage tank for sending the water from the tank. The pump will start and send water to the plantation as per the soil conditions requirement. This is detected through a soil moisture sensor which is dug in soil nearer to plants. The threshold value of soil condition is set in microcontroller programming so that the pump will operate as per requirement accordingly. This system performs multiple operations for different plantation where a centralized microcontroller is used for receiving the input signals from the multiple sensors (fusion data). Once the microcontroller gets signals, the output signals drive a relay for further operations like a water pump. A web application is connected with the microcontroller for calculating the parameter of the system. The soil moisture sensing is built with the help of two aluminum-coated metal rods inserted into the field at a distance. The relations from the metallic rods are made to the controller. These signals are detected with help of the mobile phone which provides the user interface. The automatic Smart Drip Irrigation System includes hardware and software sections interfaced together with the software serial communication between the Arduino and the NodeMCU to send out data from one system to another via wireless communication. The web application will generate the control command signals.

For developing the Android/web application app, a web page is designed using an IoT cloud platform (Thinkspeak™) as revealed in Fig. 7. The Thinkspeak™is a commercial IoT cloud platform that is used for processing, visualize, storage, and analyze the live data in the cloud which provides alertness and massaging through their web server. In web-server, the data is uploaded using NodeMCU. A login page is also integrated with the URL and it will open by assigning the credentials. After assigning the credentials, the home page will open and then see the

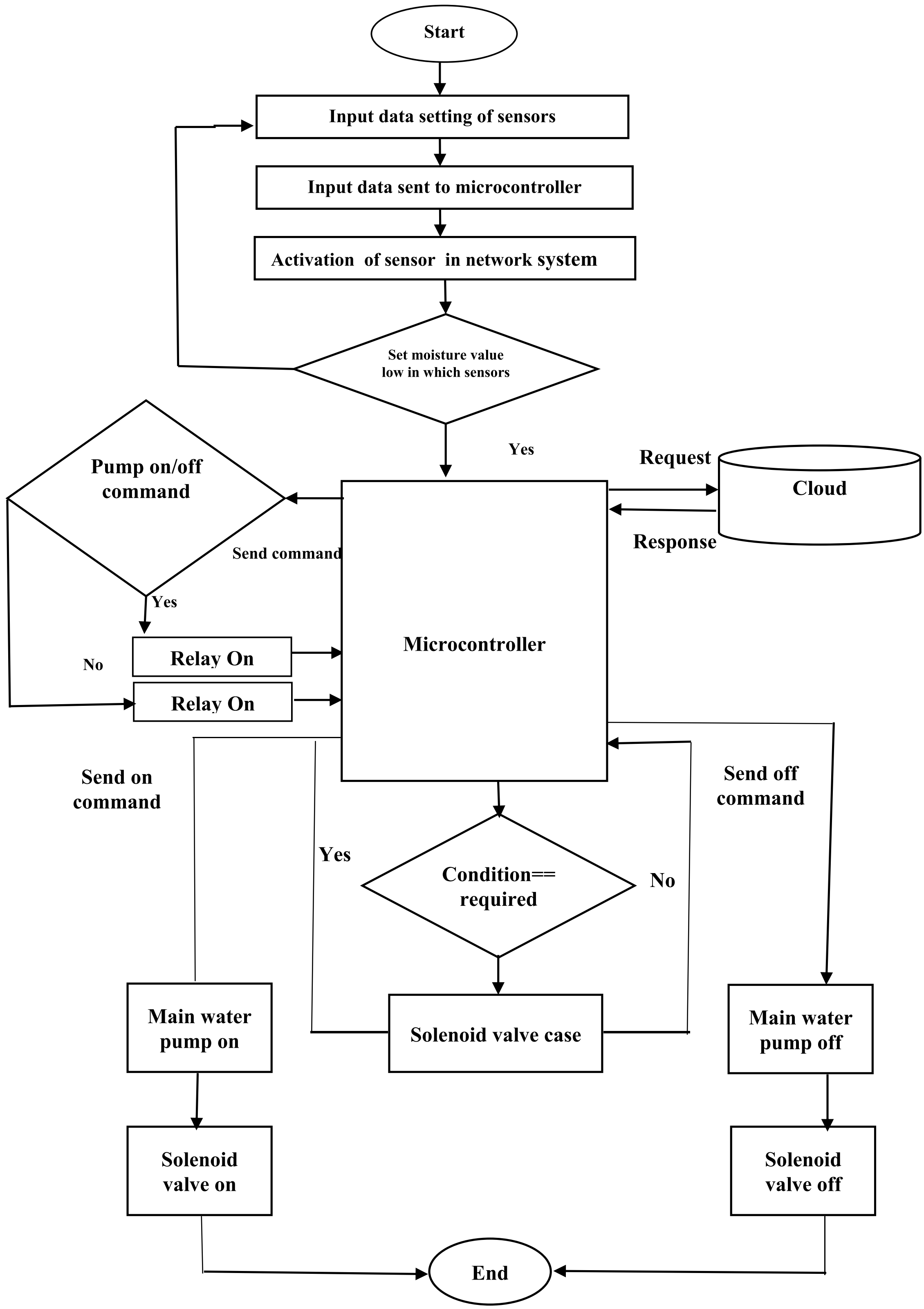

Fig. 5. Process flowchart for controlling the pump.

sensor data which are sent using nodeMCU and gateways. According to user instruction, an Android app will be operated where the user can control the pump operation and manage the smart drip irrigation system. The narrative of the codes is shown in Fig. 8. Therefore, smart drip irrigation can be remotely controlled through an android mobile phone at any point in time anyplace.

For measuring the soil moisture condition of each plant, the experimental data for three months have been collected as summarized at different tables. These data are collected in a time interval of 15 s. Every 15 s, the data is updated and stored in the cloud via web-server

Fig. 6. Development of smart irrigation system.

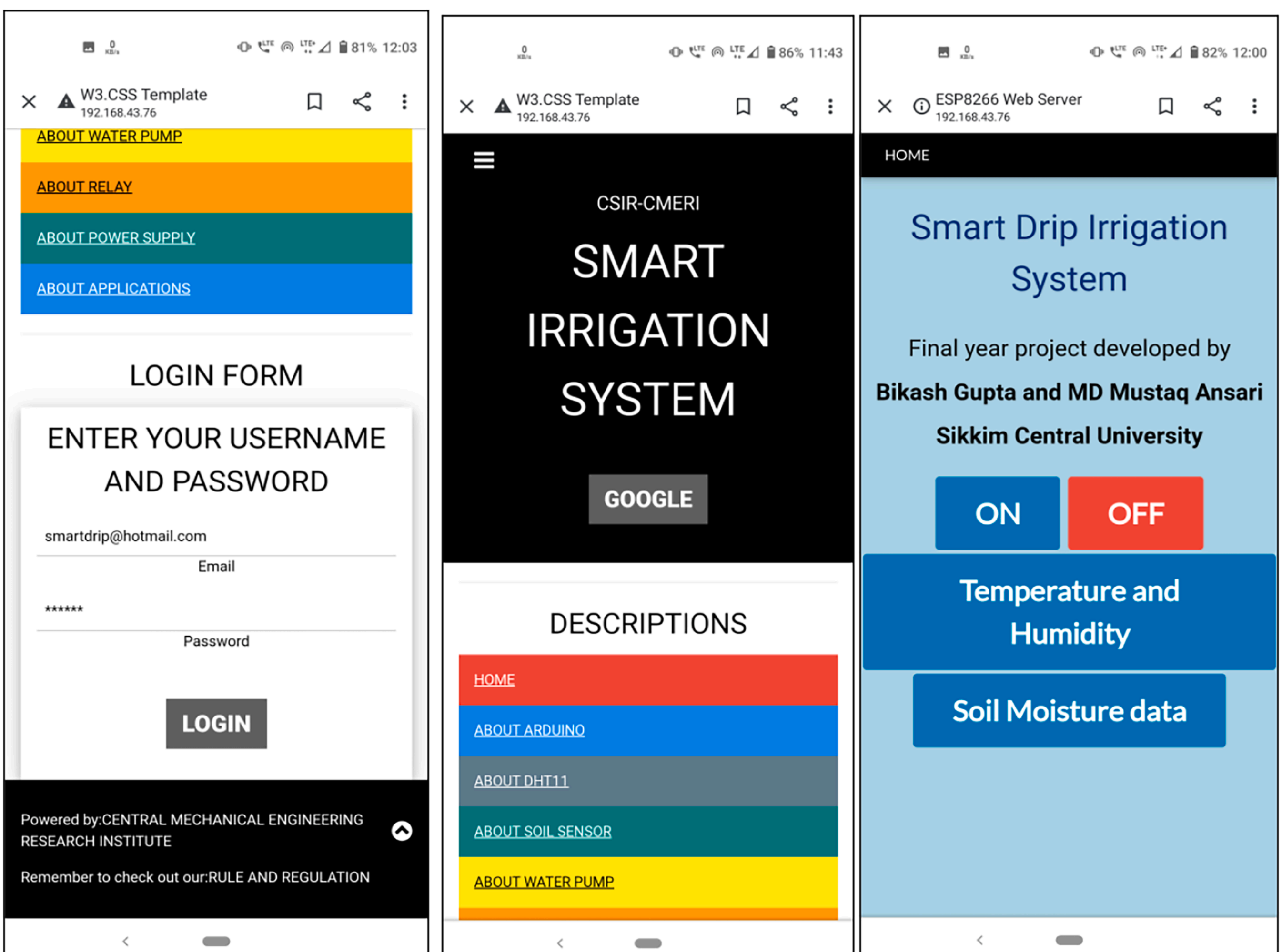

Fig. 7. Development of Android app.

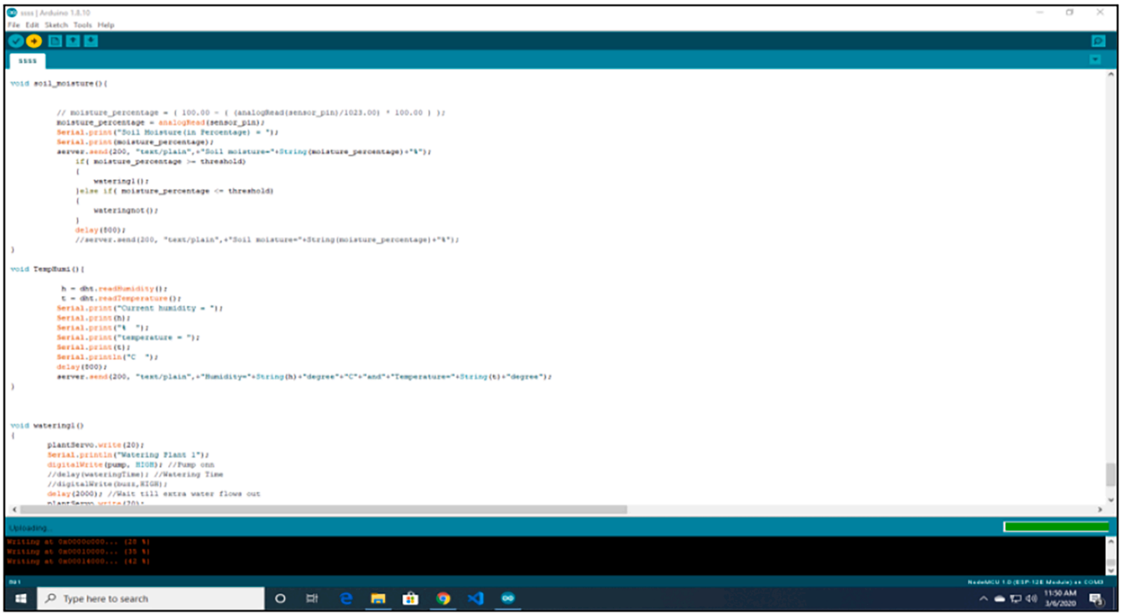

Fig. 8. Description of codes for developing the android applications.

automatically. During operation, the moisture sensor is controlled by setting up a threshold value (1024) where the soil moisture level nearer the plant is less than 40%, the water pump will operate immediately using drip automation to continue/retain the soil moisture level of the plant and this can be uploaded in the mobile phone in IoT ThingSpeak™ cloud platform. Using this, each plant condition can be analyzed immediately when the user is connected with the server.

For analyzing the experimental performance, the experimental data of the four months (February, March, April, May) are collected. The following cases for each month are analyzed as given below;

I When the soil moisture sensors are in an off state but the temperature sensor and relative humidity are active.
II When all soil sensors are on in dry and wet conditions and the temperature sensor and relative humidity are active.

The experiments experimental data for February in the morning, afternoon, and evening at a particular date are given in Tables 2–6. When the soil moisture sensors are in off/on states whereas the temperature/humidity sensors are active and capable of sending data to the microcontroller and ThingSpeak. These data can be displayed on an Android mobile phone. After data analysis, the experimental data are plotted as shown in Figs. 9–11.

From these experimental data, it is understood that when the soil moisture sensors are active and receive the data into the microcontroller and ThingSpeak, the updated information has sent to the mobile phone. The soil conditions are required more amount of water in the morning time for proper plantation at particular places.

The experimental data for March in the morning, afternoon, and evening on the same date are collected given in Tables 7–11. The experiments are conducted in a similar way that when the soil moisture sensors are in off/on states but the temperature/humidity sensors are active and data are sent to the microcontroller and the ThingSpeak cloud. After data investigation, the experimental data are plotted as shown in Figs. 12–14.

From these experimental data, it is found that when the soil moisture sensors are active and receive the data into the microcontroller and ThingSpeak, the data are updated in the mobile phone automatically. The soil conditions are required more amount of water in the afternoon time because the humidity level in the afternoon is high as compared to morning and evening. These experimental studies show that when the humidity level is high then the proper amount of water can be provided for proper plantation.

The experiments experimental data for April in the morning, afternoon, and evening on the same date are collected given in Tables 12–16. The experiment data are collected in the same way that when the soil moisture sensors are in off/on states but the temperature/humidity sensors are active and data are updated to the microcontroller and the ThingSpeak. After data analysis, the experimental data are plotted as shown in Figs. 15–17.

From these experimental data, the data are analyzed similarly and the information has been updated. The soil conditions are required more amount of water in the afternoon time for proper plantation because the humidity level in the afternoon is high as compared to morning and evening. During this period, the summer season has started.

The experiments experimental data for May in the morning, afternoon, and evening at the same date are collected given in Tables 17–21. The experiment data are collected similarly in the summer season that when the soil moisture sensors are in off/on states but the temperature/humidity sensors are active and data are updated to the microcontroller and the ThingSpeak. After data analysis, the experimental data are plotted as shown in Figs. 18–20.

For studying the soil characteristics, the mathematical correlations (polynomial equation) of soil conditions with time are obtained using the curve tool in Mat lab software so that the soil characteristics are a good impact on acquiring the water from the pump. These are summarized below;

In the month of February, the soil sensors characteristics in term of polynomial equation are given below;

(a) **Dry condition**

Soil Sensor 1: $y = - 4.4e^{-14}x + 1e^{+03}$

Soil Sensor 2: $y = - 2.8e^{-14}x + 1e^{+03}$ where x is time (seconds), y is sensor (in mu)

Both sensors shows linear behavior, there is no requirement of water in dry condition.

(b) **Wet condition**

Morning

Soil Sensor 1: 5th polynomial equation

$y = - 0.0028\times^5 + 0.15\times^4 - 2.6\times^3 + 18\times^2 - 32x + 4.4e^{+02}$

Soil Sensor 2: 5th polynomial equation

Table 1
Summary of state-of-art review along with advantages and their demerits.

Authors/ Citations	Objective/ methodology	Advantages	Demerits
Kansara et al. [6]	A review on the automated irrigation system is presented to run irrigation system automatically.	Saving of money, effort and time of the farmer	The manual irrigation takes lot-of-time.
Siddagangaiah [9]	A plant health monitoring system using IoT technique is developed where environment parameters such as light intensity, humidity temperature etc. and can be found using IoT cloud platform	An alert message can be mailed to the mobile phone.	Lab level experimental test setup is shown.
Arif et al. [12]	The soil moisture condition are analyzed using the ANN model.	The linear correlations are found and the soil moisture conditions are estimated using ANN model.	This is applied for the limited meteorological data.
Hussain et al. [15]	The controlling the irrigation automatically is carried out using wireless sensor network (WSN) for getting the sequenced data about the soil and moisture content of the particular area.	WSN method is applied for controlling the irrigation	Microprocessor (8085) is applied for automatic plant irrigator.
Parwatkar and Bhagat [19]	A Zigbee wireless technology is applied for an automated irrigation management system	Zigbee WSN shows the potential of the low power, low cost, and wireless mesh topology networking standard.	This method is applied in limit area.
Hellin et al. [22]	A support system for taking decision is developed to run irrigation for plantation where the soil moisture and climatic data are collected using intelligent nodes.	An autonomous nodes are developed.	The rainfall information did not attempt in the system.
Bagwan et al. [25]	An efficient water-saving management is developed towards green farming using IOT where embedded system is used for the network gateway.	Embedded system is used for the network gateway towards developing the smart and autonomous wireless system.	Time is dependent on input data for autonomous wireless system.
Adeyemi et al. [28]	An adaptive support systems is integrated in the irrigation management system for increasing the efficiency of the current irrigation approach.	The self-learning AI method is applied for the evaluation of decision strategies related to irrigation.	Time-varying parameter is an operational limitations for soil plant atmosphere system

Table 1 (*continued*)

Authors/ Citations	Objective/ methodology	Advantages	Demerits
Vanitha et al. [30]	An automatic drip irrigation system is developed for finding the temperature, humidity, and soil condition with the help of the Raspberry Pi microcontroller.	The crop field conditions can be visualized by using a web camera and it can be viewed in the remote server and send the SMS using GSM.	SMS can be reached when the communication is arranged properly only.
Kwok and Sun [35]	A smart IoT-based drip irrigation system is established where a deep learning method is applied for providing the water in each plant.	This can regulate amounts of water in each plant for plants recognition.	The operation and amount of water can get a specific time.
Sengottuvel and Hameed Hussain [40]	A design of an automatic plant irrigation system is implementation where the water is acquired from a reservoir kept at a height to provide high potential energy for the water.	This automated irrigation system will decrease human labor and water consumption may be increased productivity.	This type of automated irrigation system is applicable for vertical agriculture towards indoor gardening etc.
Goapa et al. [44].	A ML based model is applied for IoT based smart irrigation decision management system where open source programming is applied for the collection of data over clouding web service.	Open source technologies helps in the collection of data over clouding web service.	The model predication results are shown only.
Adenugba et al. [51]	An IoT approach has been attempted for the collection of data from the environment.	Irrigation data have been predicted and controlled through a web platform.	This method is applied in remote rural area of Saharan Africa.
Prasanna and Rani [55]	The research work is highlighted on the remote monitoring system for measuring the soil properties using IoT and ML.	This predict the soil properties for enhancing the high yield productivity.	The system needs to implement in the practical environment.
Monisha et al. [61]	A review of many different methods for irrigation and controlling the system are presented. A design of a green agriculture system is also discussed using the image processing technique.	This image processing technique helps in finding soil indicators or water balance condition.	The image processing technique needs to apply in the practical environment.
Upadhya and Mathew [64]	The estimation of crop yielding parameters have carried out using a fuzzy logic controller for vegetable crops. The input data of humidity,	This method helps in developing irrigation and optimal yielding methods.	The methods needs to implement in the practical environment.

(*continued on next page*)

Table 1 (*continued*)

Authors/ Citations	Objective/ methodology	Advantages	Demerits
	temperature and soil moisture are considered and the output parameters are the crisp value of crop yielding.		
Sharma and Kumar [66]	An IoT based irrigation system is established using WSN for monitoring the paddy crop fields.	This system helps in controlling from dashboard by the users.	The system needs to implement in the large scale in different environment.

Table 2
Data collection in February at morning time when the temperature and humidity sensor is active but the soil sensors are in the off state.

Interval (Second)	**Temperature (°C)**	**Humidity (%)**	**Sensor1 (Moisture unit mu)**	**Sensor2 (mu)**
0	23.2	50	1024	1020
15	23.2	50	1024	1020
30	23.2	50	1024	1020
45	23.2	50	1024	1020
60	23.2	51	1024	1020
75	23.2	51	1024	1020
90	23.2	51	1024	1020
105	23.2	51	1024	1020
120	23.5	51	1024	1020
135	23.5	51	1024	1020
150	23.5	51	1024	1020
165	23.5	52	1024	1020
180	23.5	52	1024	1020
195	23.5	52	1024	1020
210	23.5	52	1024	1020

Table 3
Data collection in February in the afternoon when the temperature and humidity sensors are active but the soil sensors are in an off state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	28.0	61	1024	1020
15	28.0	61	1024	1020
30	28.0	61	1024	1020
45	28.2	61	1024	1020
60	28.2	61	1024	1020
75	28.2	61	1024	1020
100	28.2	62	1024	1020
115	28.2	62	1024	1020
130	29.2	62	1024	1020
145	29.2	62	1024	1020
160	29.2	62	1024	1020
175	29.2	62	1024	1020
190	29.2	62	1024	1020
210	29.2	64	1024	1020
225	29.2	64	1024	1020

$y = - 0.0052\times^5 + 0.16\times^4 - 1.6\times^3 + 5.5\times^2 + 8x + 4.2e^{+02}$

Both sensors shows 5th degree of polynomial behavior, there is a water requirement.

Afternoon

Soil Sensor 1: 4th polynomial equation

$y = - 0.0084\times^4 + 0.21\times^3 - 1.2\times^2 + 14x + 5.9e^{+02}$

Soil Sensor 2: 4th polynomial equation

$y = 0.006\times^4 - 0.17\times^3 + 1.6\times^2 + 6.4x + 6e^{+02}$

Both sensors shows 4th degree of polynomial behavior, there is a water requirement.

Table 4
Data collection in February at morning time when all sensors are in on state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	23.2	50	425	430
15	23.2	50	430	440
30	23.2	50	450	466
45	23.2	50	480	470
60	23.2	51	500	480
75	23.2	51	515	509
100	23.2	51	533	512
115	23.2	51	550	535
130	23.5	51	560	550
145	23.5	51	570	600
160	23.5	51	590	650
175	23.5	52	600	700
190	23.5	52	650	750
210	23.5	52	700	780
225	23.5	52	766	810

Table 5
Data collection in February at afternoon time when all sensors are in on state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	28.0	61	610	601
15	28.0	61	623	611
30	28.0	61	635	615
45	28.2	61	640	650
60	28.2	61	650	668
75	28.2	61	655	670
100	28.2	62	658	683
115	28.2	62	669	700
130	29.2	62	708	705
145	29.2	62	712	755
160	29.2	62	720	769
175	29.2	62	735	780
190	29.2	62	750	799
210	29.2	64	759	810
225	29.2	64	790	824

Table 6
Data collection in February at evening time when all sensors were in on state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	20.0	40	810	801
15	20.0	40	823	811
30	20.0	40	835	815
45	20.0	40	840	850
60	20.0	40	850	868
75	20.0	40	855	870
100	19.8	38	858	883
115	19.8	38	869	890
130	19.8	38	908	905
145	19.8	38	912	955
160	19.8	38	920	969
175	19.8	38	935	980
190	19.8	38	950	999
210	19.8	37	959	1010
225	19.7	37	990	1024

In the month of March, the soil sensors characteristics in term of polynomial equation are given below;

(a) **Dry condition**

Soil Sensor 1: $y = - 4.4e^{-14}x + 1e^{+03}$

Soil Sensor 2: $y = - 2.8e^{-14}x + 1e^{+03}$

Both sensors shows similar linear behavior as in the month of February, there is no requirement of water in dry condition.

(b) **Wet condition**

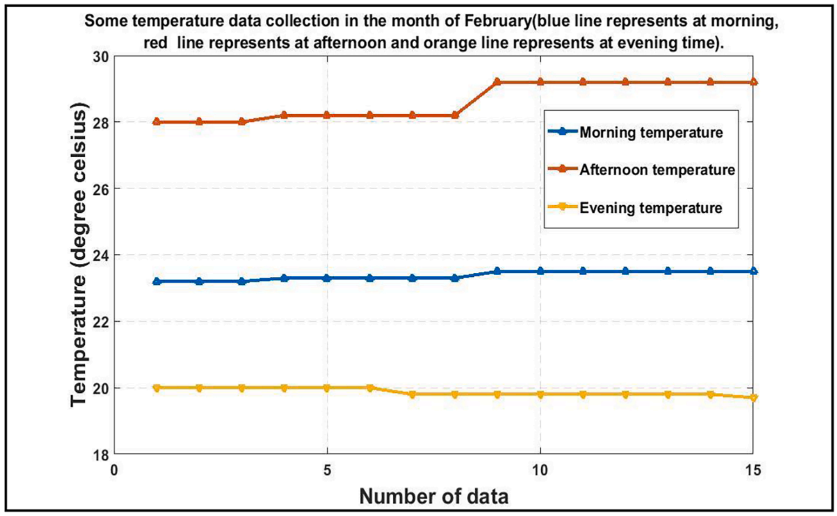

Fig. 9. Temperature data on the given date in February.

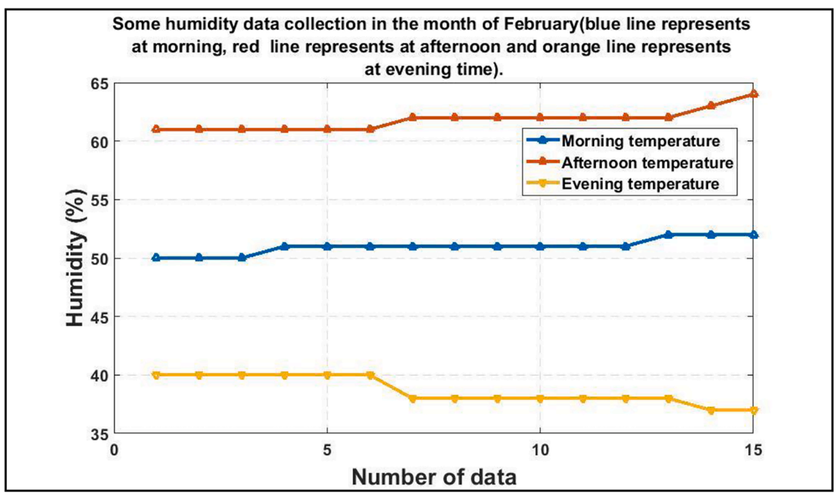

Fig. 10. Humidity on the given date in February.

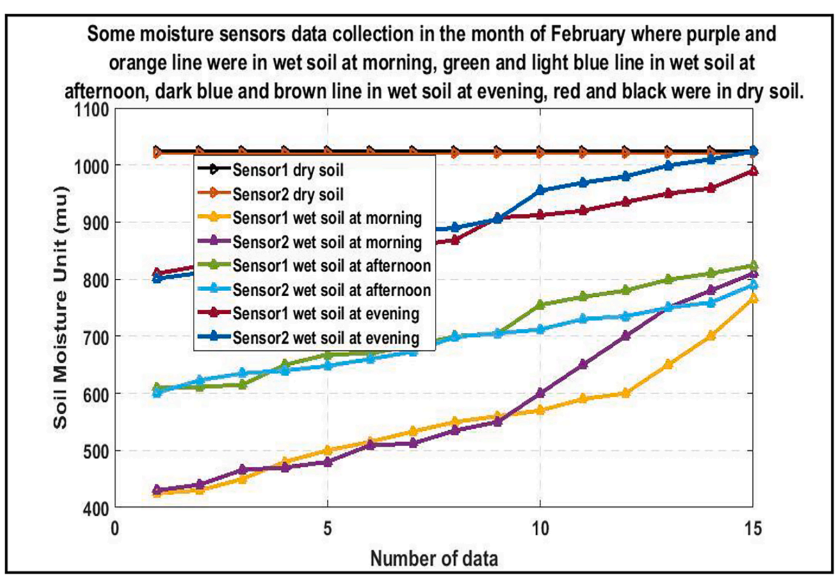

Fig. 11. Moisture value of different soil sensors in February at dry and wet conditions.

Table 7
Data collection in March at morning time when the temperature and humidity sensors are active but soil sensors are in an off state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	25.2	62	1024	1020
15	25.2	62	1024	1020
30	25.2	62	1024	1020
45	25.2	62	1024	1020
60	25.2	62	1024	1020
75	25.2	62	1024	1020
100	25.7	62	1024	1020
115	25.7	62	1024	1020
130	25.7	62	1024	1020
145	26.2	62	1024	1020
160	26.2	62	1024	1020
175	26.2	62	1024	1020
190	26.2	62	1024	1020
210	26.2	62	1024	1020
225	26.2	62	1024	1020

Table 8
Data collection in the month of March at afternoon time when the temperature and humidity sensors are active but soil sensors are in off state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	32.5	59	1024	1020
15	32.5	59	1024	1020
30	32.5	59	1024	1020
45	32.5	59	1024	1020
60	32.5	59	1024	1020
75	32.5	59	1024	1020
100	32.5	59	1024	1020
115	32.6	59	1024	1020
130	32.6	59	1024	1020
145	32.6	59	1024	1020
160	32.8	60	1024	1020
175	32.8	60	1024	1020
190	32.8	60	1024	1020
210	32.8	60	1024	1020
225	32.8	60	1024	1020

Table 9
Data collection in the month of March at morning time when all sensors were in on state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	25.2	62	510	520
15	25.2	62	520	530
30	25.2	62	550	550
45	25.2	62	559	559
60	25.2	62	570	600
75	25.2	62	590	690
100	26.2	62	610	710
115	26.2	62	630	730
130	26.2	62	665	765
145	26.2	62	670	790
160	26.2	62	697	799
175	26.2	62	700	809
190	26.2	64	730	810
210	27.8	64	770	850
225	27.8	64	830	860

Morning
Soil Sensor 1: 5th polynomial equation
$y = - 0.0028\times^5 + 0.15\times^4 - 2.6\times^3 + 18\times^2 - 32x + 5.4e^{+02}$
Soil Sensor 2: 5th polynomial equation
$y = - 0.0052\times^5 + 0.16\times^4 - 1.6\times^3 + 5.5\times^2 + 8x + 5.2e^{+02}$
Both sensors shows 5th degree of polynomial behavior, there is a water requirement.

Table 10
Data collection in the month of March at afternoon time when all sensors was is on state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	32.5	59	610	610
15	32.5	59	623	623
30	32.5	59	635	615
45	32.5	59	640	620
60	32.5	59	650	650
75	32.5	59	655	715
100	32.5	59	658	758
115	32.5	59	669	799
130	32.5	59	708	808
145	32.5	59	712	812
160	32.5	59	720	820
175	32.5	59	835	835
190	32.5	59	850	850
210	32.5	59	859	859
225	32.5	59	990	875

Table 11
Data collection in March at evening time when all sensors are in on state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	22.0	45	815	801
15	22.0	45	820	815
30	22.0	45	835	817
45	22.0	45	849	830
60	22.0	45	850	850
75	22.0	45	855	860
100	21.8	45	866	873
115	21.8	45	869	899
130	21.8	45	908	905
145	21.8	45	912	955
160	21.8	45	920	969
175	21.8	45	935	980
190	21.8	44	950	985
210	21.8	44	959	1010
225	20.7	44	960	1024

Afternoon
Soil Sensor 1: 4th polynomial equation
$y = - 0.0084\times^4 + 0.21\times^3 - 1.2\times^2 + 14x + 5.9e^{+02}$
Soil Sensor 2: 4th polynomial equation
$y = - 0.0075\times^4 + 0.2\times^3 - 1.8\times^2 + 18x + 5.9e^{+02}$
Both sensors shows 4th degree of polynomial behavior, there is a water requirement.

In the month of April, the soil sensors characteristics in term of polynomial equation are given below;

(a) **Dry condition**
Soil Sensor 1: $y = - 4.4e^{-14}x + 1e^{+03}$
Soil Sensor 2: $y = - 2.8e^{-14}x + 1e^{+03}$
Both sensors shows similar linear behavior as in the month of March, there is no requirement of water in dry condition.

(b) **Wet condition**

Morning
Soil Sensor 1: 5th polynomial equation
$y = - 0.0014\times^5 + 0.091\times^4 - 1.8\times^3 + 14\times^2 + 0.94x + 3e^{+02}$
Soil Sensor 2: 5th polynomial equation
$y = - 0.0052\times^5 + 0.16\times^4 - 1.6\times^3 + 5.5\times^2 + 8x + 5.2e^{+02}$
Both sensors shows 5th degree of polynomial behavior, there is a water requirement.
Afternoon
Soil Sensor 1: 4th polynomial equation

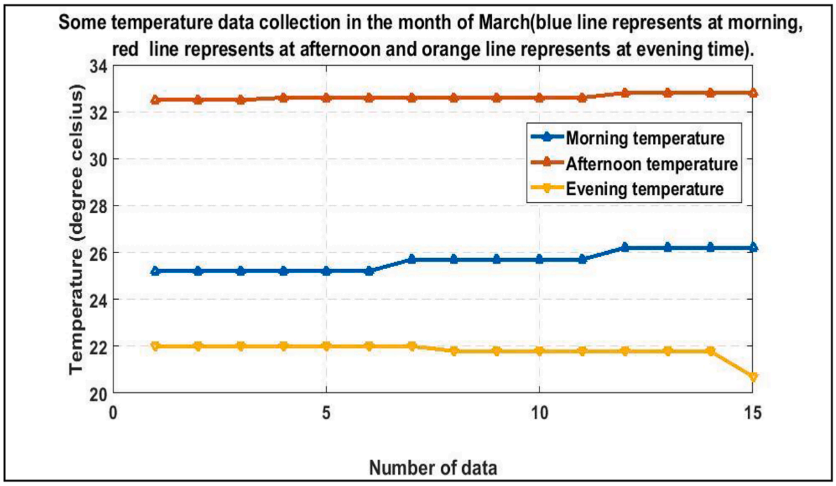

Fig. 12. Temperature data on the given date in the month of March.

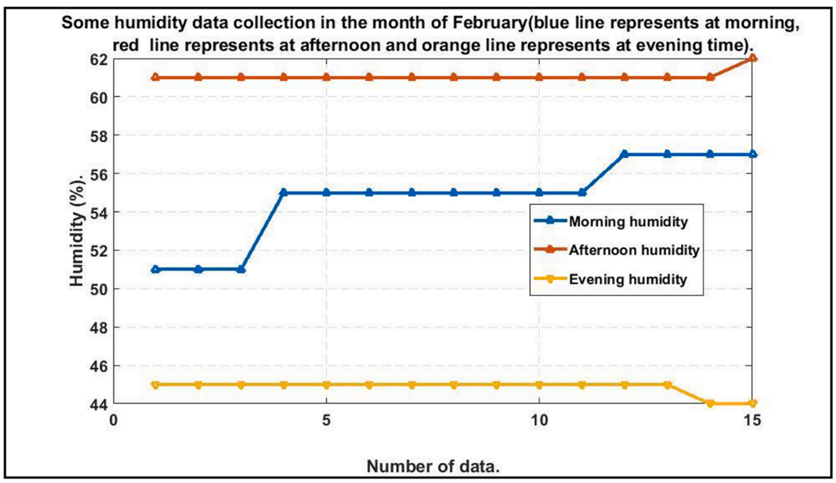

Fig. 13. Humidity on the given date in the month of March.

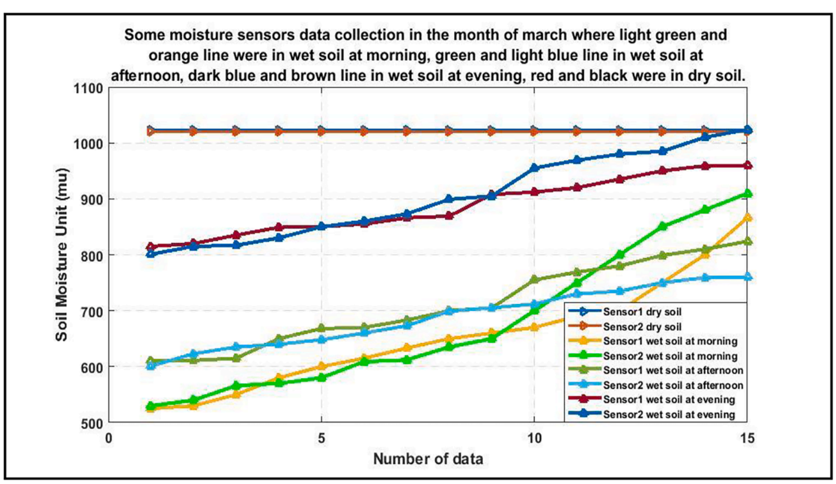

Fig. 14. Moisture value of different soil sensors in March at the dry and wet conditions.

$y = 0.037\times^4 - 1.2\times^3 + 12\times^2 - 12x + 5e^{+02}$
Soil Sensor 2: 4th polynomial equation
$y = - 0.0075\times^4 + 0.2\times^3 - 1.8\times^2 + 18x + 5.9e^{+02}$

Both sensors shows 4th degree of polynomial behavior, there is a water requirement.

In the month of May, the soil sensors characteristics in term of

Table 12
Data collection in April at morning time when the temperature, humidity sensor was active but soil sensor was in the off state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	25.2	62	1024	1019
15	25.2	62	1024	1019
30	25.2	62	1024	1019
45	25.2	62	1024	1019
60	25.4	62	1024	1019
75	25.4	63	1024	1019
100	25.4	63	1024	1019
115	25.4	63	1024	1019
130	25.6	63	1024	1019
145	25.6	63	1024	1019
160	25.6	63	1024	1019
175	25.8	63	1024	1019
190	25.8	64	1024	1019
210	25.8	64	1024	1019
225	25.8	64	1024	1019

Table 13
Data collection in April at afternoon time when the temperature, humidity sensor was active but soil sensor was in the off state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	35.2	62	1024	1019
15	35.2	62	1024	1019
30	35.2	62	1024	1019
45	35.2	62	1024	1019
60	35.2	62	1024	1019
75	35.2	62	1024	1019
100	35.2	62	1024	1019
115	35.2	62	1024	1019
130	35.2	62	1024	1019
145	35.2	62	1024	1019
160	35.2	62	1024	1019
175	35.2	62	1024	1019
190	35.2	62	1024	1019
210	35.2	62	1024	1019
225	35.2	62	1024	1019

Table 14
Data collection in April at morning time when the sensors were in on state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	25.2	62	610	1019
15	25.2	62	615	1019
30	25.2	62	630	1019
45	25.2	62	650	1019
60	25.2	62	660	1019
75	26.2	62	677	690
100	26.2	62	690	700
115	26.2	62	700	740
130	26.2	62	750	750
145	26.3	62	760	770
160	26.3	63	789	790
175	26.3	63	792	799
190	26.3	63	807	805
210	26.3	63	820	817
225	26.3	63	825	820

polynomial equations are given below;

(a) **Dry condition**
Soil Sensor 1: $y = - 4.4e\text{-}14x + 1e^{+03}$
Soil Sensor 2: $y = - 4.4e\text{-}14x + 1e^{+03}$
Both sensors shows similar linear behavior as in the month of April, there is no requirement of water in dry condition.

(b) **Wet condition**

Table 15
Data collection in April at afternoon time when all sensors are in on state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	35.9	64	410	509
15	35.9	64	415	509
30	35.9	64	430	515
45	35.9	64	450	520
60	35.9	64	560	550
75	35.9	64	577	590
100	35.9	64	590	600
115	35.9	64	600	640
130	35.9	64	650	650
145	35.9	64	660	670
160	35.9	64	689	720
175	35.9	64	792	759
190	35.9	64	807	798`
210	35.9	64	810	817
225	35.9	64	820	820

Table 16
Data collection in April at evening time when all sensors are in on state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	28.0	45	855	815
15	28.0	45	860	820
30	28.0	45	865	835
45	28.0	45	877	849
60	28.0	45	885	850
75	28.0	45	890	855
100	27.8	45	899	866
115	27.8	45	905	869
130	27.8	45	908	908
145	27.8	45	912	912
160	27.8	45	929	920
175	27.8	45	935	935
190	27.8	44	959	950
210	27.8	44	979	959
225	27.5	44	998	960

Morning
Soil Sensor 1: 5th polynomial equation
$y = 0.0044\times^5 - 0.19\times^4 + 2.8\times^3 - 16\times^2 + 50x + 3.8e^{+02}$
Soil Sensor 2: 5th polynomial equation
$y = - 0.0052\times^5 + 0.16\times^4 - 1.4\times^3 + 4.5 \times 2 + 12x + 5.1e^{+02}$
Both sensors shows 5th degree of polynomial behavior, there is a water requirement.

Afternoon
Soil Sensor 1: 4th polynomial equation
$y = 0.037\times^4 - 1.2\times^3 + 12\times^2 - 12x + 5e^{+02}$
Soil Sensor 2: 4th polynomial equation
$y = 0.018 \times 4 - 0.39\times^3 + 2.7\times^2 + 5.5x + 6e^{+02}$
Both sensors shows 4th degree of polynomial behavior, there is a water requirement.

From these experimental data, it is observed that the humidity and temperature affect the soil moisture conditions for proper plants. During experimentation, all plants are cultivated in an open environment. It is envisaged that IoT based system also helps in the reduction of crop damage and it is monitored by soil moisture conditions. This also reduces over-irrigation or under irrigation of soil. During uploading the data to the cloud, the computation time depends upon the sensor data and condition of activation of the sensors because when the pump is in "off" condition and there is no processing of the data whereas the pump is in "on" condition and the computations time takes the condition of soil accordingly. It may be varied according to the condition of the soil. By demonstration, it is observed that the variety of small land, open gardens, nurseries, and household plantation can be cultivated and

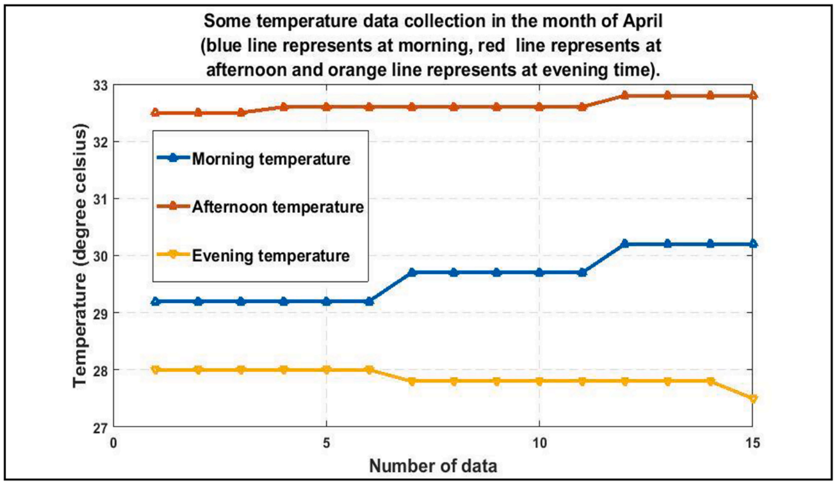

Fig. 15. Temperature data on the given date in April.

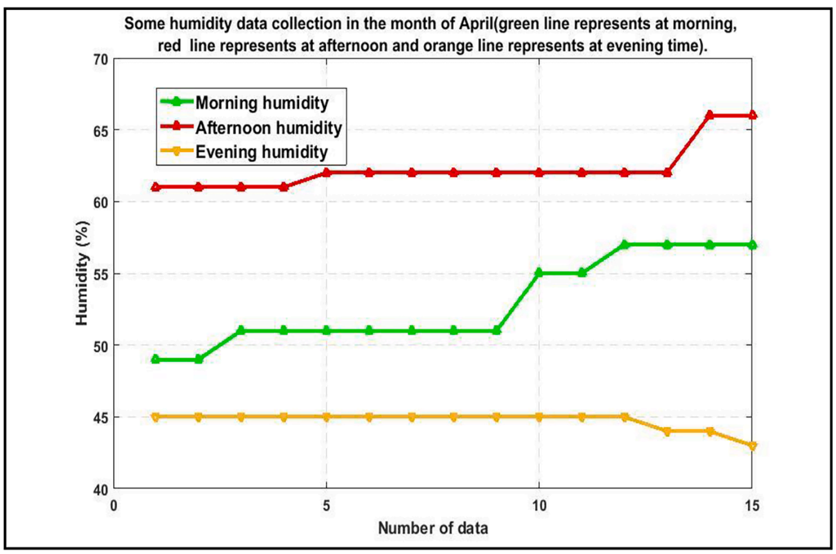

Fig. 16. Humidity data on the given date in April month.

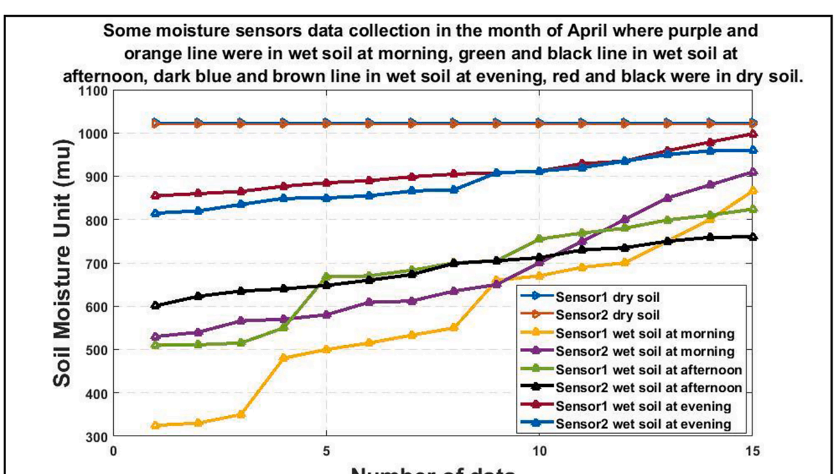

Fig. 17. Moisture value of different soil sensor in April at dry and wet condition.

Table 17
Data collection in May at morning time when the temperature and humidity sensors are active but soil sensors are in the off state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	23.7	62	1024	1019
15	23.7	62	1024	1019
30	23.7	62	1024	1019
45	23.8	62	1024	1019
60	23.8	62	1024	1019
75	23.8	62	1024	1019
100	23.8	62	1024	1019
115	23.8	62	1024	1019
130	23.8	61	1024	1019
145	23.8	61	1024	1019
160	23.8	61	1024	1019
175	23.8	61	1024	1019
190	23.9	61	1024	1019
210	23.9	61	1024	1019
225	23.9	61	1024	1019

Table 18
Data collection in May at afternoon time when the temperature and humidity sensors are active but soil sensors are in the off state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	38.9	66	1024	1019
15	38.9	66	1024	1019
30	38.9	66	1024	1019
45	38.9	66	1024	1019
60	38.9	66	1024	1019
75	38.9	66	1024	1019
100	38.9	66	1024	1019
115	38.9	66	1024	1019
130	38.9	66	1024	1019
145	38.9	65	1024	1019
160	39.1	65	1024	1019
175	39.1	65	1024	1019
190	39.1	65	1024	1019
210	39.3	66	1024	1019
225	39.3	66	1024	1019

Table 19
Data collection in May at morning time when sensors are in on state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1 (mu)	Sensor2 (mu)
0	23.7	62	**510**	**620**
15	23.7	62	**515**	**633**
30	23.7	62	**530**	**650**
45	23.8	62	**550**	**660**
60	23.8	62	**560**	**680**
75	23.8	61	**577**	**690**
100	23.8	61	**590**	**700**
115	23.8	61	**600**	**740**
130	23.8	61	**650**	**750**
145	23.9	61	**660**	**770**
160	23.9	61	**689**	**790**
175	23.9	61	**692**	**799**
190	23.9	61	**707**	**855**
210	24.7	63	**720**	**890**
225	24.7	63	**725**	**900**

enhanced productivity by using IoT and automation technologies. The major advantage of this kind of system is to effective consumption of water for irrigation purposes which reduces the problem of the existing manual and traditional process of irrigation by small landholder farmers.

The novelty of this work are highlighted point-wise as given below;

Table 20
Data collection in May at afternoon time when all sensors were in on state.

Interval (Second)	Temperature (°C)	Humidity (%)	Sensor1	Sensor2
0	35.9	68	440	509
15	35.9	68	455	509
30	35.9	68	460	515
45	35.9	68	480	520
60	35.9	68	510	550
75	36.0	68	537	590
100	36.0	68	550	600
115	36.0	68	580	640
130	36.0	68	600	650
145	36.0	68	630	670
160	36.0	68	659	720
175	36.0	68	712	759
190	36.2	68	757	798`
210	36.2	68	770	817
225	36.2	68	798	820

Table 21
Data collection in May at evening time when all sensors are in on state.

Interval(Second)	Temperature(°C)	Humidity (%)	Sensor1	Sensor2
0	32.0	54	755	815
15	32.0	54	760	820
30	32.0	54	765	835
45	32.0	54	777	849
60	31.9	54	785	850
75	31.9	54	790	855
100	31.9	54	799	866
115	31.9	54	805	869
130	31.9	54	808	908
145	31.9	53	812	912
160	31.9	53	829	935
175	31.8	53	835	955
190	31.8	53	859	967
210	31.8	52	879	979
225	31.8	52	898	1019

i A novel sensor fusion method is applied for developing a smart drip irrigation system.
ii A novel web/android application is established using IoT for monitoring and controlling the sensor data and plant condition.
iii The sensor fusion data is uploaded in IoT cloud platform using an Android mobile phone and stored data in the cloud for analytics.
iv The experimental performance of humidity, temperature and soil moisture are carried out using stored data in the cloud.

7. Conclusion

In this paper, a novel system architecture for an IoT-enabled drip irrigation system is designed which is controlled using an Android/web application. This is interfaced with a nodeMCU with the cloud network system using wireless communications. The experimental data is successfully uploaded in the IoT cloud and is remotely accessed using web applications. The appropriate amount of water is provided using the pump automation process. This improves plant health which can be monitored anywhere using an Android mobile phone. This provides a solution for an appropriate and price adequate for accessing water sources of supply for agricultural management. This method of irrigation allows for farming without a shortage of water. Making the testing plant step up and experimental performance demonstrates that this kind of system is conformed that use of such application can help an assortment of particular plant harvesting. This kind of system can be implemented in various nurseries, small land, open gardens, household plantations, etc. Hence, it is proved that a smart IoT-enabled drip irrigation system is driven by IoT and web-based application which is an emerging approach in the precision agriculture area.

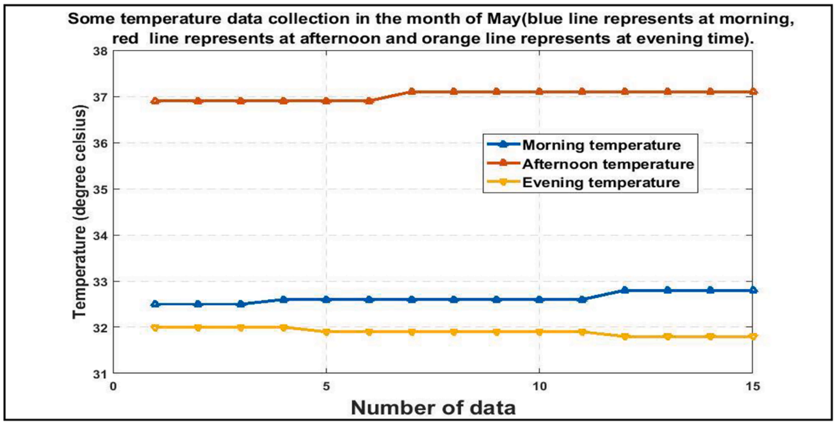

Fig. 18. Temperature data on the given date in May.

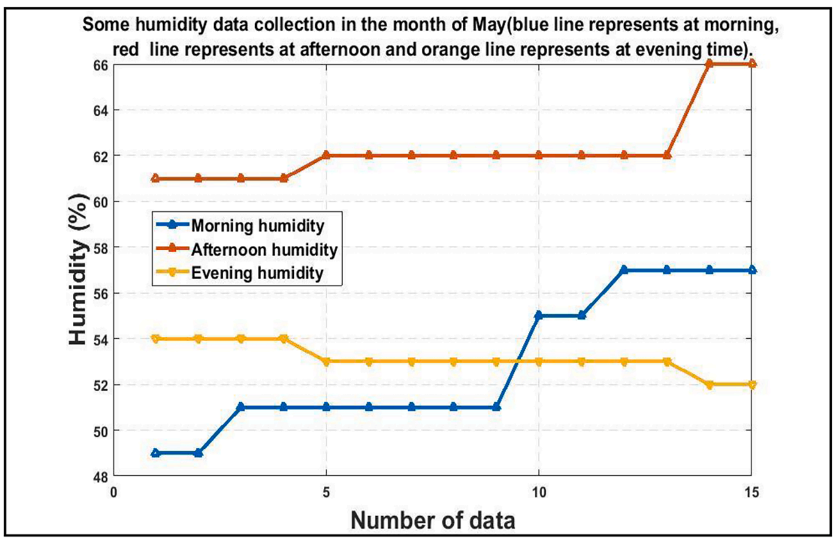

Fig. 19. Humidity data on the given date in May.

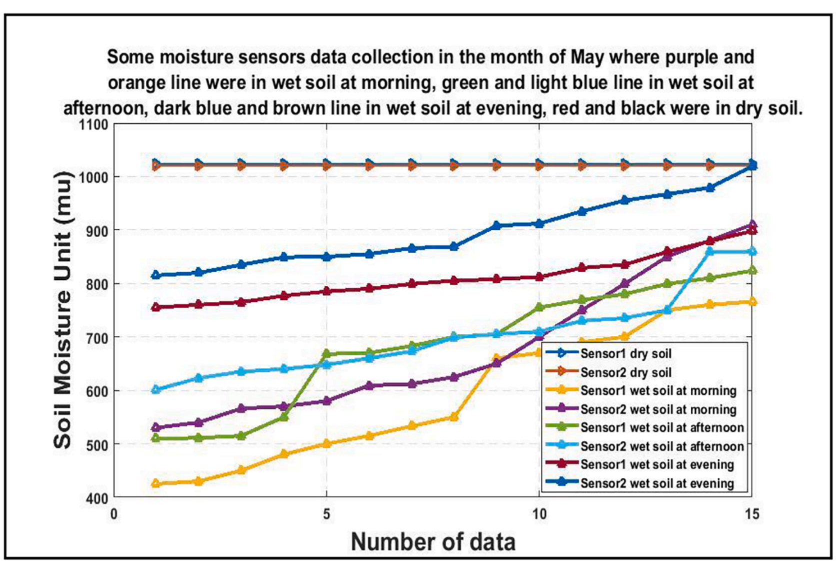

Fig. 20. Moisture value of different soil sensors in May atdry and wet condition.

Data availability

The data that has been used is confidential.

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