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Smart monitoring of soil parameters based on IoT

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Abstract
Monitoring of soil parameters is one of the major concerns in agricultural practices. Monitoring of these parameters leads to increase in yield as well as quality. Soil moisture and soil temperature are two basic soil parameters to characterize soil. Depending on these parameters, decisions can be taken up for optimum use of input resources. In this paper, the development of basic soil parameter monitoring system and its testing is demonstrated. Here, YL-69 soil moisture sensor is used for soil moisture measurement. The determination of soil temperature is done using K-Type thermocouple. MAX6675, a cold junction compensated K-type thermocouple to digital converter chip is taken for its signal conditioning counterpart. The system is integrated with Arduino UNO and ESP8266 Wi-Fi module to make the system Internet of things (IoT) enabled. The data are transferred to ThingSpeak platform for visualization and processing. The developed system is calibrated and tested in the laboratory environment. Calibration is done with 0% soil moisture and 100% soil moisture. Testing of the developed system is done with the different water content.

Keywords
Soil moisture, Soil temperature, Thermocouple, IoT.

1.Introduction
The Indian economy in general and rural households in particular depends on the agricultural produce. Around 58% of total rural households primarily have agriculture as their means of livelihood. The research Council in 1997 stated that monitoring soil conditions is one of the pivotal parameters on which agricultural development and yield within a field depends. The production and maintenance of crop are directly influenced by the soil parameters and monitoring of these parameters is an important aspect of agriculture. Providing real time information on soil parameters like moisture content, temperature etc. to the framers seems to be the need of the hour. This is accomplished by using appropriate sensors connected to the internet using Wi-Fi connectivity. Internet of things (IoT) is an ongoing concept which deals with the interaction among various objects.

This is widely used in different fields of science and technology. Agriculture is one of the budding fields where newer technologies are implemented for its growth.

For precision agriculture, it is necessary to collect data from the field and to make it available to access in IoT environment which enable easy access of the data. To maximize the yield, the farmers need to optimize the application of input resources like fertilizers, water etc. and to reduce the risk of crop failure and costs. Effective management of input resources is the key to success of the farmer. Lack of awareness among the farmers compels them to use the conventional methods like crop investigation, soil analysis etc. However, now-a-days, newer technologies like IoT based system for collection of data online and implementing different predictive models for optimizing the use of input resources are being used. This results in better productivity. To assist farmers to maximize their yield at minimum cost, this IoT based system works effectively. The world is changing and trending into newer models of science and technology. And, with other sectors reaping the benefits of newer technologies, it is necessary to step up the game for agriculture as well, which supports almost half of the population of the country [1−3].

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Developing a smart soil parameter monitoring system is utmost important for proper farming. IoT based instruments are best suited for the stated purpose. Improving agricultural sector can be done by implementing IoT based instruments [4]. Soil water content and soil temperature are two most important parameters for proper monitoring of soil physical health [4−6]. Optimizing these two parameters can lead to proper irrigation scheduling. Some other parameters including pH, nutrients, salinity are also important, but there is no direct relationship found in between these parameters and irrigation. For soil classification also the parameters like moisture, temperature, and pH play a pivotal role [7]. Therefore, a system capable of monitoring soil moisture and temperature is required for proper irrigation management. Also, the system should be budget friendly as it will be used mostly by the rural farmers.

This paper describes the development of a cost effective, easy to handle IoT based soil moisture and soil temperature monitoring system and its testing in the laboratory environment. YL-69 soil moisture sensor and K-type thermocouple are taken for the purpose. Required signal conditioning and system calibration is done. All data are available on ThingSpeak platform. This system helps farmers with a little technical knowledge in precision irrigation management. The objective and complete working mechanism are depicted in *Figure 1*. The paper is organized in such a way that, section 1 presents the introduction, section 2 deals with the related literature review, section 3 deals with the methods and materials, section 4 describes the results and section 5 deals with the discussion of the research work. Conclusion and future prospects are presented in section 6.

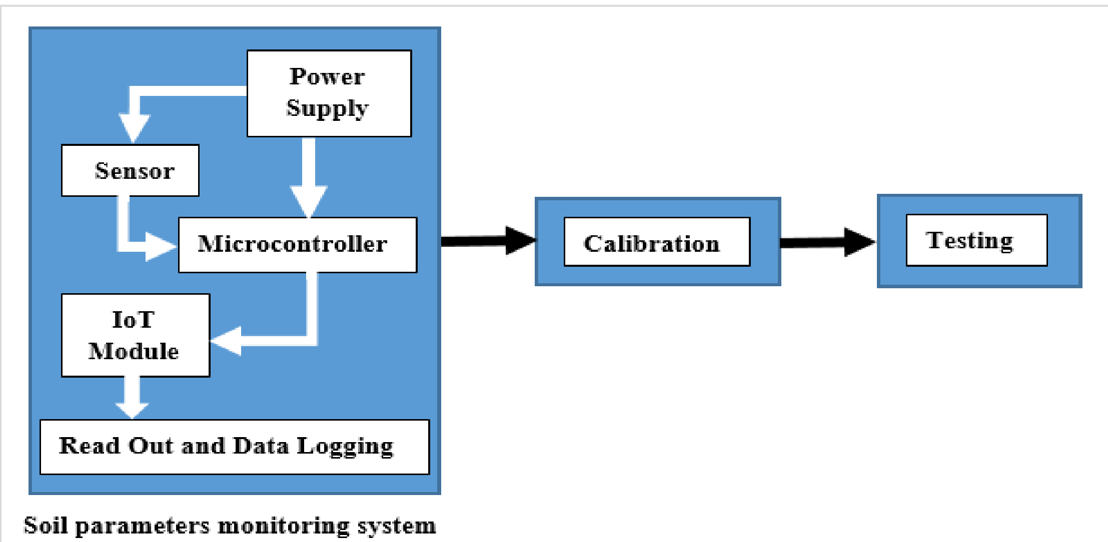

Figure 1 Objective of the proposed work

2.Literature review

One of the existing methods which is manual in nature is used to check the parameters required for agricultural practices. In this method, collection of soil and verification of parameters is done by the farmers and the readings are calculated. In [8], development of wireless sensor network-based system was illustrated which was used to manage, display and alert users. Another low-cost soil moisture and soil temperature collection system was developed and discussed in [9]. The advantages of IoT and cloud computing are merged to manage and handle the enormous data involved in agricultural practices. It helps to solve problems efficiently and fast development of agricultural modernization [10]. In [11] wireless communication technology based smart farming methods using smart sensor and smart irrigation system was described. Wireless sensor network based smart irrigation module to optimize input water supply is described in [12].

In [13], the development of wireless sensor network to monitor different parameters such as temperature, humidity, soil moisture and light intensity for the agricultural site is developed. The developed wireless sensor network is based on the IEEE 802.15.4 pattern and it is made IoT enabled by using ESP826612E. The acquired data is stored using ThingSpeak server.

In [14] an IoT enabled soil moisture measurement system have been developed and management of soil parameters is done for farmers by predicting the seasonal rainfall using neural network in north Karnataka, India. Bhanu et al. [15] discussed the design, implementation and validation of a wireless sensor network-based soil parameter monitoring system. This system comprised of a number of smart sensor nodes connected to an on-site computer system with internet connectivity which was remotely accessed. Field installation and validation of the instrument was also done and it was used to disseminate soil information remotely. Precise scheduling of the irrigation was also a prime interest of this system. Different studies have been carried out [16] by creating a monitoring network for the measurement of atmospheric and soil climate parameters at the southern boundary of the permafrost area of Buryatia, Russian Foundation.

A green internet of things (G-IoT) based real time precision agriculture monitoring system is developed and reported in [17]. Several parameters have been incorporated in the system such as weather, water, soil, fire etc. which are vital in precision agriculture monitoring. For this, different sensors DHT-22, passive infrared (PIR) sensor, MQ-2 gas sensor, raindrop sensor, YL-38 and YL-69 soil moisture sensor, colour detection sensor (TCS230), water level sensor has been used. The system helps farmer to take a decision and appropriate action for precision agriculture. Development of soil fertility parameter monitoring system has been reported in [18]. Real time monitoring of soil pH and soil parameters in a web-based platform has been discussed. For this ETP-110 pH sensor and FC-28 soil moisture sensor has been taken. ESP8266 has been taken for data communication. A wireless sensor network based real time monitoring of soil moisture on a web server-based system has been discussed and reported in [19]. Libelium Waspmote is the microcontroller used in the system for measuring soil moisture. The wireless multimedia sensor network based agricultural, environmental monitoring system is also reported in [20]. In that study, the system is used for three different purposes viz. soil nutrients, analysis of leaves disease and agriculture environments monitoring. A review of recent trends for precision agriculture and irrigation management using different sensors and IoT enabled systems is also published [21].

In one more experiment, by capturing the temporal variability of soil moisture, a new soil moisture index has been developed where temporal variability of soil moisture is independent of cloud cover and solar illumination [22]. In [23], soil salinity level and environment condition to recommend water requirement which is determined by an IoT assisted solution is discussed. Machine learning based approach has been adopted to estimate water requirements for saline soils by using an in-situ monitoring system for salinity level and crop field temperature. In this case naïve Bayes classifier is used to predict the leaching requirement. In a study [24], the application of IoT and big data technology supported practical monitoring system for sustainable use of soil and land resources has been studied. A reliable, adaptable, scalable and accurate system has been constructed by optimizing the traditional construction method.

For smart farming, IoT networks-based soil monitoring with low energy consumption has been discussed in [4]. Soil permittivity and electrical conductivity are the key parameters taken for this study. IoT network is self-organizing in nature in this case. For precision agriculture applications, long range wide area network (LoRaWAN) based energy efficient wireless sensor network for greenhouse sensing and actuation has been designed and implemented [25]. Water content and temperature are two important parameters taken into account in this study. Physical sensor deployed in agricultural field is replaced by neural sensor which increases the reliability of smart irrigation system [26]. This neural sensor is designed based on deep learning techniques and used LM 35 for temperature measurement, DHT-22 for humidity measurement and a customized soil moisture sensor. The neural sensor predicts the temperature value with high accuracy and humidity along with soil moisture values in an acceptable accuracy range. This experiment is done in a lemon field near the Ghadap Sindh province of Pakistan. In [27], a model is developed to determine crop water consumption and optimizing irrigation scheduling depending on shallow ground water depth. Two irrigation scheduling methods were tested and compared in this study. The first method deals with the management of irrigation based on soil water content while the second method is based on crop water demand. Comparison of these two methods reveals that the first method is more rational and crop water consumption can be better estimated.

3.Methods and materials

The objective is to design the proposed system for measuring soil moisture percentage and temperature remotely in real-time through smart phones or personal computer. Further, the developed system helps the farmers for precision agricultural practice and irrigation management. The block diagram of the proposed system is shown in the *Figure 2*.

To develop this system, processing unit such as micro- controller is required for controlling and communicating with different components necessary for this purpose. In this work, Arduino UNO is used as a microcontroller unit. The sensing unit comprises of soil moisture sensor and a thermocouple to get the value of soil temperature. Required signal conditioning is done using inbuilt signal conditioning circuit of YL-69 sensor and MAX6675 is used for the K-type thermocouple. The sensor characteristics are shown in *Table 1*. These sensor outputs are interfaced with a 10-bit analog to digital converter (ADC) of Arduino UNO. The acquired data are displayed using IoT on ThingSpeak platform using ESP8266.

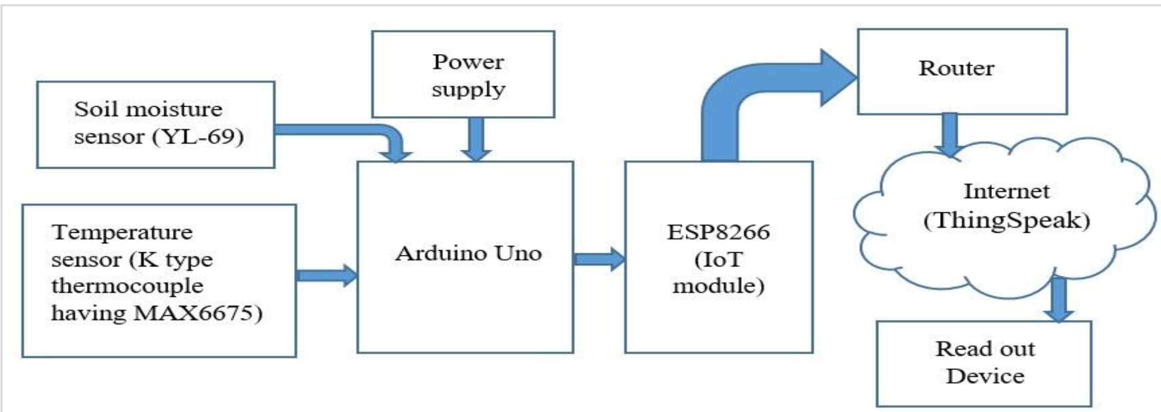

Figure 2 Block diagram of IoT based soil parameter monitoring system

Table 1 Selected sensor characteristics

Sensor	Characteristics
YL-69 (Soil moisture sensor)	More accurate analog output, dual output mode
	Having a stable LM393 comparator chip
	Operating Voltage = 3.3 ~ 5 Volt DC
K-type thermocouple with signal conditioning (Temperature sensor)	Temperature range of 0°C to 1024°C
	Cold junction compensation and digital conversion with 12 bit resolution
	Sensitivity of approximately 41 µV/°C of the thermocouple

3.1Hardware used

Soil moisture sensor: For measuring soil moisture YL-69 sensor with its inbuilt signal conditioning circuit was chosen. It consists of two probes and pads of the probes were used to measure the volumetric water content of the soil. The resistance value is measured which corresponds to the soil moisture value. To get the resistance value, the two probe pads allow the current to pass through the soil. Soil moisture sensor with signal conditioning circuit is shown in *Figure 3* [28].

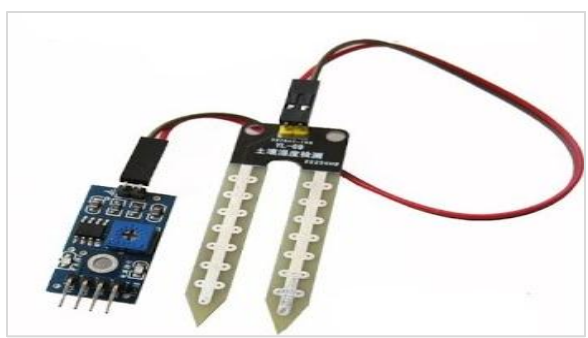

Figure 3 Soil moisture sensors (YL-69) with signal conditioning circuit

Soil temperature sensor: To monitor soil temperature, a K-type thermocouple was chosen. For signal conditioning and digital conversion purpose, MAX6675 chip was taken. MAX6675 is a cold junction compensated K-type thermocouple to digital converter and can measure from 0°C to 1024°C. The output is read only serial peripheral interface (SPI) compatible data and is of 12-bit resolution. Thermocouple and MAX6675 is shown in *Figure 4* [29].

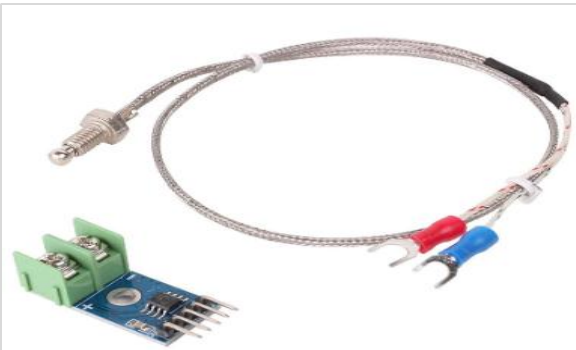

Figure 4 Soil temperature sensors (K-type thermocouple) with signal conditioning circuit using MAX6675

Processing Unit: For processing the data and sending the same through IoT, the following hardware units were taken-

Arduino UNO: It is an ATmega328P microcontroller based open-source microcontroller board developed by Arduino.cc. It comprises of sets of digital and analog input/ output pins required to interface different sensors and expansion boards and circuits. It is shown in *Figure 5* [30].

Figure 5 Arduino UNO

Wi-Fi/IoT module: To perform the IoT, the low-cost module ESP8266 was taken. It is a self-contained system on a chip (SoC) consisting of transmission control protocol/internet protocol (TCP/IP) protocol stack that enables the microcontroller to conjure its own Wi-Fi network. It is shown in *Figure 6* [13, 20, 31].

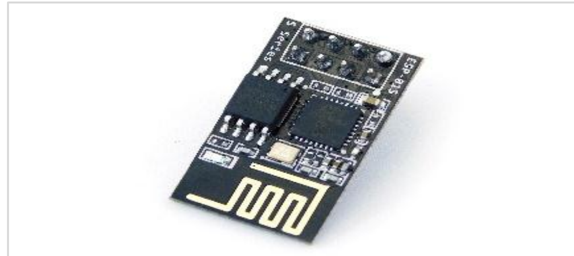

Figure 6 ESP8266 module

Software Used

Arduino IDE: The Arduino integrated development environment (IDE) is used to write and upload programs to Arduino compatible boards [30]. Here, it was used to develop the software embedded in the microcontroller to do the following task-

a) Initialize all ports and pins to read and write data, control signals etc.
b) Read the sensors data
c) Send the data to serial port for monitoring
d) Send the data through IoT for global monitoring

IoT and ThingSpeak: IoT refers to the system where anything which is measurable, such as any physical parameters like temperature, relative humidity, to biomedical signals like a heartbeat, electrocardiogram (ECG) etc. can be accessed through the internet. For this, a soft-platform is needed where these data can be monitored remotely. ThingSpeak is one of them. It is an open source IoT application. It enables the creation of sensor data logging applications, location tracking applications, and a social network of things with status updates. It uses hypertext transfer protocol (HTTP) over the Internet or via a local area network to store or retrieve information [13, 32].

3.2Experimental set-up and layout

The experimental setup is shown in *Figure 7* and *Figure 8*. The experimental system has been designed using three important parts- the microcontroller part, the sensing part and the information transfer (communication) part. The motive behind this proposed system is to collect different samples of soil and test for its two vital parameters moisture percentage and temperature. The microcontroller part is the brain and soul of this proposed system. It is responsible for keeping in control, the other organs, namely the sensing part and the information transfer part. It also sends the information received from the sensors to a read-out device via an ESP8266 Wi-Fi module. The microcontroller development board used in this system is ATmega328P based Arduino UNO. The sensing part or organ consists of YL-69 soil moisture sensors and K-type thermocouple temperature sensor with necessary signal conditioning. YL-69 is interfaced with the 10-bit ADC of the microcontroller and the K-type thermocouple is interfaced with MAX6675 which is connected with digital input pins of the microcontroller. Both the sensors are enclosed in an air tight desiccator. Inside the desiccator, there is a glass tube which holds the soil samples. The two sensors are dipped in the glass tube. The system is powered using a 9 Volt DC power supply.

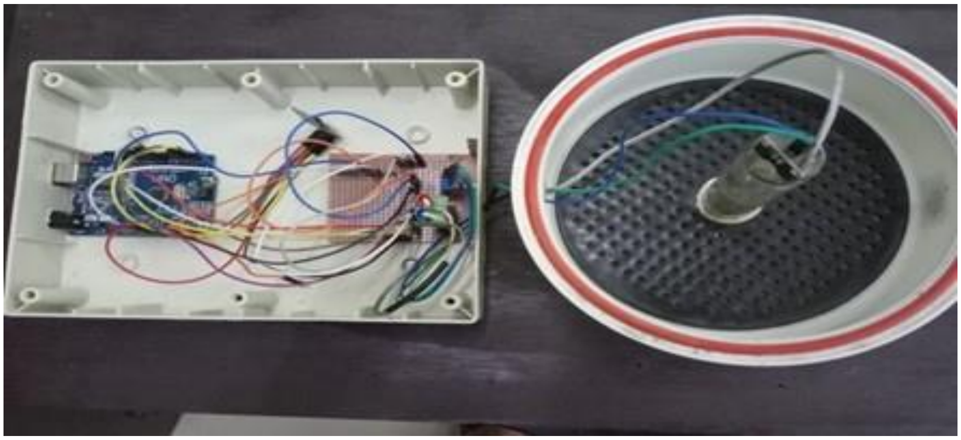

Figure 7 Layout of experimental setup

Figure 8 Complete experimental setup

4.Results

4.1System calibration

Calibration of the developed system is done under two conditions- (a) 0% soil moisture (b) 100% soil moisture. The used soil moisture sensors are capable of generating 5 Volt output for 100% moisture content and 0 Volt output for 0% moisture content. The output voltage is directly proportional to the soil moisture. The calibration equation found in this system is given in Equation 1.

$$SM\% = (V_{out} / 5) \times 100 \quad (1)$$

Where SM represents soil moisture in % and V_{out} represents the voltage output of the sensor. Calibration curve is shown in *Figure 9*. In the graph, the calibration equation is given as shown in Equation 2.

$$y = 20x \quad (2)$$

Where y signifies SM in % and x signifies V_{out}. Goodness of fit (R^2) found from the calibration curve is 1.

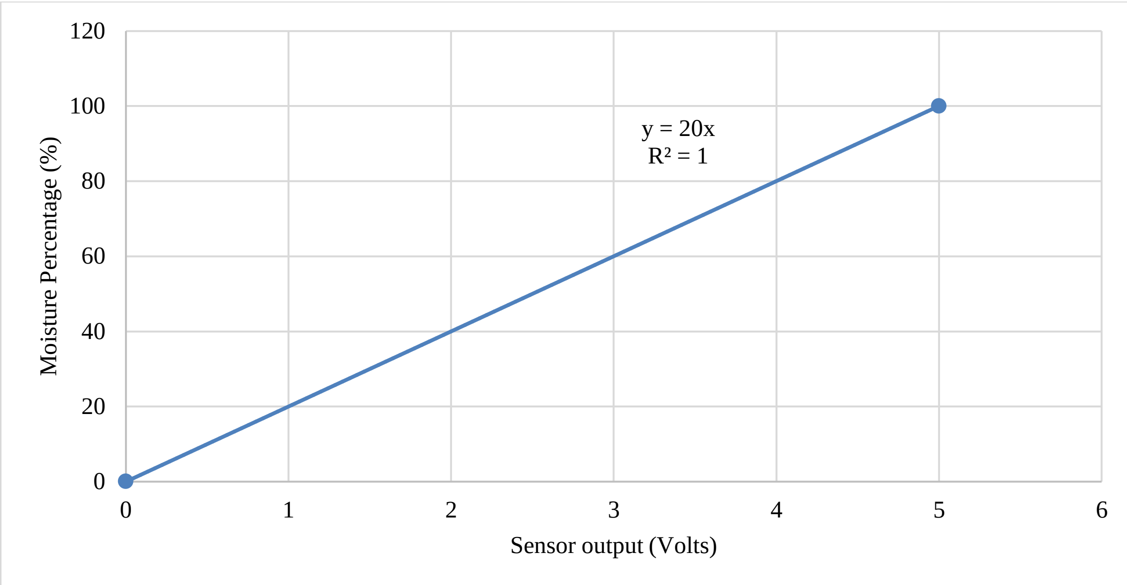

Figure 9 Calibration curve for soil moisture

4.2Testing in a laboratory under different conditions

a) A soil sample of 78 gm weight is taken.
b) Then, it is air-dried and subsequently oven-dried to a point where no change of weight is recorded.
c) Weight of sample after drying (no change of weight) recorded=54 gm
d) Subsequently, moisture and temperature values are recorded by adding 0 ml, 5 ml, 15 ml, 35 ml, and 50 ml of water.

Table 2 depicts the moisture and temperature values and corresponding standard deviations of the recorded data for dried soil as well as the subsequent addition of water. Graphical representation of the variation of moisture content and temperature values with respect to different amount of water added is shown in *Figure 10* and *Figure 11*. From these graphs, it is seen that moisture percentage increases with the increase in the amount of water added while the temperature decreases.

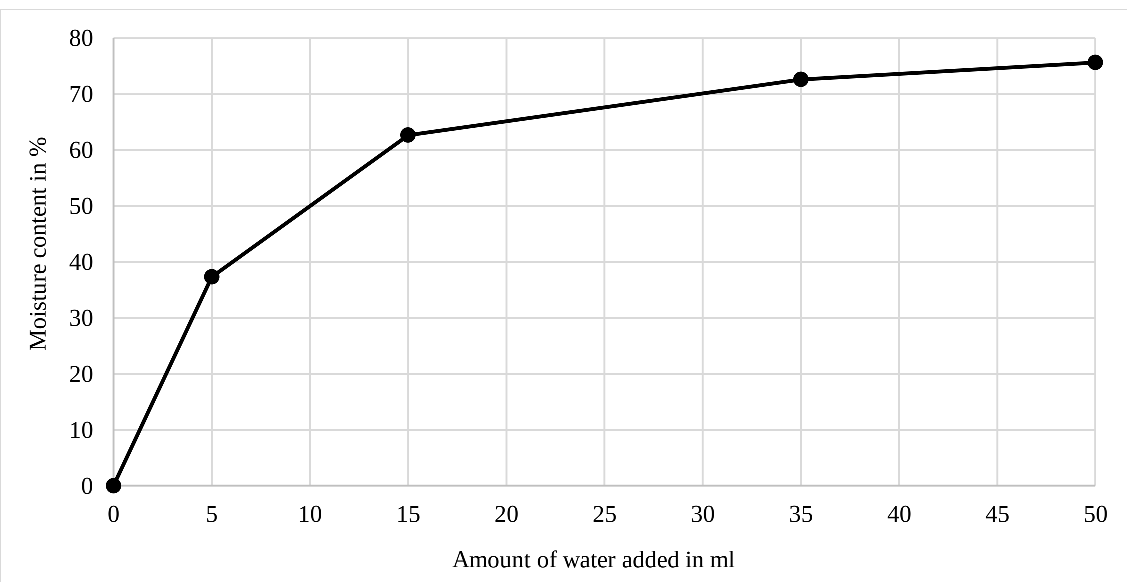

Figure 10 Variation of moisture values with respect to different amount of water added

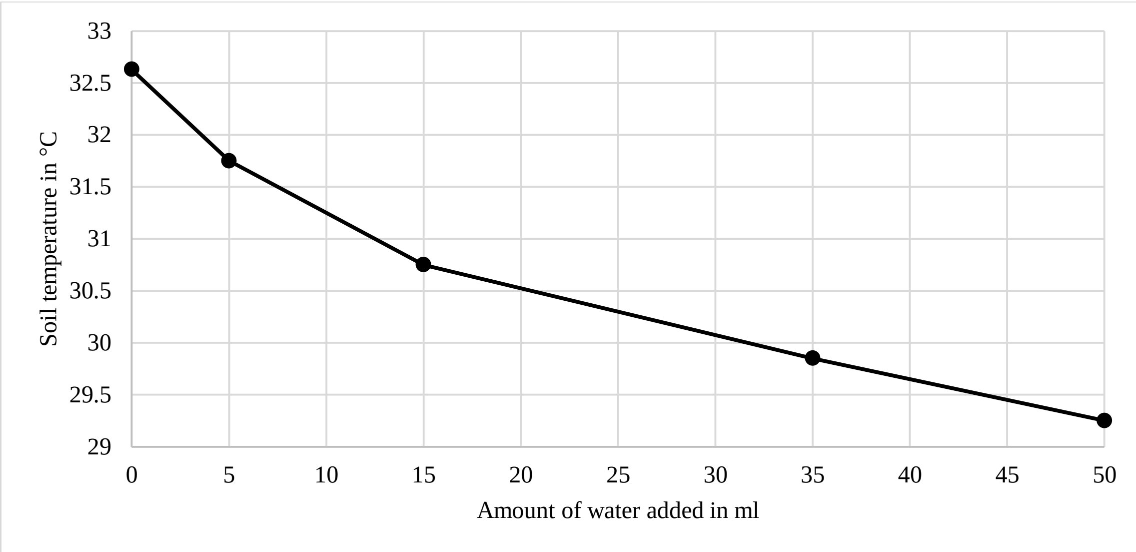

Figure 11 Variation of temperature values with respect to different amount of water added

Table 2 Testing of the developed system with different water content

Amount of water added in ml	Moisture content in %	Standard deviation for moisture content	Temperature in °C	Standard deviation for temperature
0	0	0	32.63	0
5	37.34	0	31.75	0.14
15	62.66	0.07	30.75	0
35	72.63	0.12	29.85	0.05
50	75.66	0.14	29.25	0

4.3Online monitoring of data using IoT on ThingSpeak Platform

Soil parameters are monitored online using IoT on ThingSpeak platform as shown in *Figure 12* and *Figure 13.*

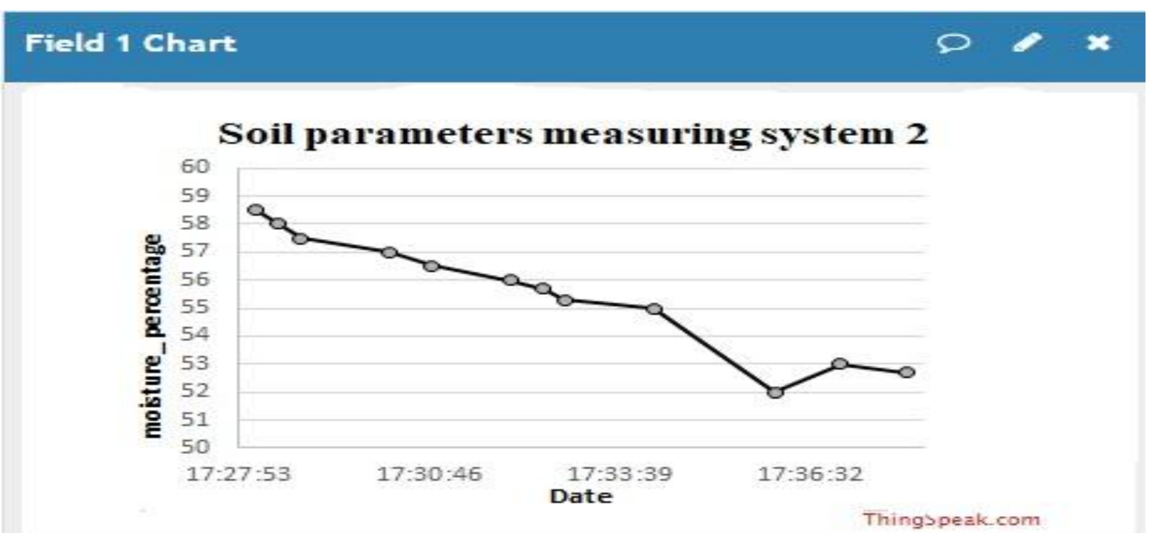

Figure 12 Online monitoring of soil moisture using IoT on ThingSpeak platform

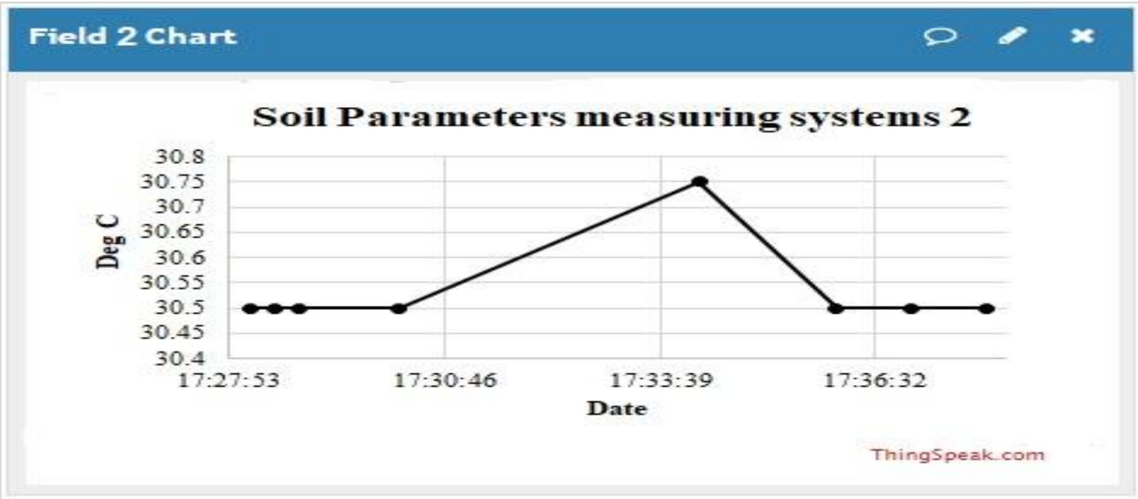

Figure 13 Online monitoring of soil temperature using IoT on ThingSpeak platform

5.Discussion

A handheld, low-cost soil parameters monitoring smart instrument based on IoT has been developed, calibrated and tested. Following are the key points need to be discussed.

1. Soil moisture and soil temperature are the key parameters incorporated in the said instrument. For soil moisture measurement, YL-69 soil moisture sensor with its associated signal conditioning circuit is taken while for soil temperature, K-type thermocouple with MAX6675 cold junction compensated thermocouple to digital converter is taken.
2. The processing part is done by Arduino UNO and IoT is achieved by ESP8266 module.
3. Data recording and monitoring is done with ThingSpeak platform. A Smart phone or personal computer is sufficient for this purpose.

At the time of this study, the approximate cost found in this instrument is given in *Table 3.*

Table 3 Detailed budget for approximate cost

S. No.	Item	Approximate cost in INR
1	YL-69 with signal conditioning module	200/-
2	K-type thermocouple with MAX6675 cold junction compensated K-type thermocouple to digital converter module	450/-
3	Arduino UNO	550/-
4	ESP8266 IoT module	200/-
5	Miscellaneous (includes wires, box etc.)	150/-
	Total	1550/-

5.1Comparison

The developed system is found to be cost effective and easy to handle with a little technical knowledge. For proper irrigation management, soil moisture and soil temperature are two vital parameters need to be measured, so that these two sensors are incorporated in this system. This system basically aims to precision irrigation management by measuring the aforementioned parameters. *Table 4* shows a comparison between some latest research works (2018-2021) cited in this article with the developed system in terms of parameters, technical complexity, cost etc. A complete list of abbreviations is shown in *Appendix I.*

Table 4 Comparison between different systems

Author	Parameters	Technical complexity	Cost (in INR)
Ali et al. [17]	weather, water, soil, pest detection, intrusion detection, fire detection	High	7996.00 Rs

Author	Parameters	Technical complexity	Cost (in INR)
Kamelia et al. [18]	Soil pH, soil humidity	Low	Not mentioned in the paper, however, it is MODERATE due to its hardware requirement.
Siregar et al. [19]	Soil moisture	High	Not mentioned in the paper, however, it is HIGH due to its hardware requirement.
Manjula [20]	Soil nutrients, analysis of leaves disease and agriculture environments monitoring	High	Not mentioned in the paper, however, it is HIGH due to its hardware requirement.
Proposed system	Soil moisture, soil temperature	Low	1550.0 s

5.2Limitations

The developed system is able to monitor soil parameters such as moisture and temperature in a laboratory by collecting the soil samples as well as in the agricultural field. However, this system is useful only for irrigation management purpose. Following are some limitations of the developed system.

a) Local display is not integrated with the system. Therefore, Internet facility is always required for measurement and monitoring.
b) The system is not tested in rugged environments.
c) The system aims only for irrigation management. Complete fertility and soil environment is not targeted.

6.Conclusion and future work

A system for monitoring soil parameters (soil moisture and soil temperature) is developed and calibrated. The system is tested in the laboratory and it works properly. The system enables the monitoring of data using IoT on ThingSpeak platform. For future developments, the following points need to be associated.

a) The instrument can be enhanced and used in the actual agricultural practices and the benefits of this system can be analyzed in terms of the yield of crops and overall production.
b) A website can be developed for uploading the sensor data instead of the ThingSpeak platform.
c) More parameters like soil pH and conductivity can also be added to enhance the system. So that the system can be used for complete fertility and soil environment monitoring.
d) Finally, impact of all these parameters can be analyzed for a specific region.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Author's contribution statement

Debashis Saikia: Conceptualization, investigation, analysis and interpretation of results, resources, writing – review and editing, Supervision. **Rehana Khatoon:** Methodology, software, data collection, writing–original draft, visualization.

References

[1] Vani PD, Rao KR. Measurement and monitoring of soil moisture using cloud IoT and android system. Indian Journal of Science and Technology. 2016; 9(31):1-8.

[2] Na A, Isaac W, Varshney S, Khan E. An IoT based system for remote monitoring of soil characteristics. In international conference on information technology (InCITe)-the next generation IT summit on the theme-internet of things: connect your worlds 2016 (pp. 316-20). IEEE.

[3] Suma N, Samson SR, Saranya S, Shanmugapriya G, Subhashri R. IOT based smart agriculture monitoring system. International Journal on Recent and Innovation Trends in Computing and Communication. 2017; 5(2):177-81.

[4] Slalmi A, Chaibi H, Saadane R, Chehri A, Jeon G, Aroussi HK. Energy-efficient and self-organizing internet of things networks for soil monitoring in smart farming. Computers & Electrical Engineering. 2021.

[5] Bünemann EK, Bongiorno G, Bai Z, Creamer RE, De DG, De GR, et al. Soil quality–a critical review. Soil Biology and Biochemistry. 2018; 120:105-25.

[6] Corstanje R, Mercer TG, Rickson JR, Deeks LK, Newell-price P, Holman I, et al. Physical soil quality indicators for monitoring British soils. Solid Earth. 2017; 8(5):1003-16.

[7] Seaton FM, Barrett G, Burden A, Creer S, Fitos E, Garbutt A, et al. Soil health cluster analysis based on national monitoring of soil indicators. European Journal of Soil Science. 2021; 72(6):2414-29.

[8] Lakshmisudha K, Hegde S, Kale N, Iyer S. Smart precision based agriculture using sensors. International Journal of Computer Applications. 2016; 146(11):36-8.

[9] Nandurkar SR, Thool VR, Thool RC. Design and development of precision agriculture system using wireless sensor network. In first international conference on automation, control, energy and systems 2014 (pp. 1-6). IEEE.

[10] Gayatri MK, Jayasakthi J, Mala GA. Providing smart agricultural solutions to farmers for better yielding using IoT. In technological innovation in ICT for agriculture and rural development 2015 (pp. 40-3). IEEE.

[11] Gutiérrez J, Villa-medina JF, Nieto-garibay A, Porta-gándara MÁ. Automated irrigation system using a wireless sensor network and GPRS module. IEEE Transactions on Instrumentation and Measurement. 2013; 63(1):166-76.

[12] Jagannathan S, Priyatharshini R. Smart farming system using sensors for agricultural task automation. In technological innovation in ICT for agriculture and rural development 2015 (pp. 49-53). IEEE.

[13] Bachuwar VD, Shligram AD, Deshmukh LP. Monitoring the soil parameters using IoT and Android based application for smart agriculture. In AIP conference proceedings 2018. AIP Publishing LLC.

[14] Athani S, Tejeshwar CH, Patil MM, Patil P, Kulkarni R. Soil moisture monitoring using IoT enabled arduino sensors with neural networks for improving soil management for farmers and predict seasonal rainfall for planning future harvest in North Karnataka-India. In international conference on I-SMAC. 2017 (pp. 43-8). IEEE.

[15] Bhanu BB, Hussain MA, Ande P. Monitoring of soil parameters for effective irrigation using wireless sensor networks. In sixth international conference on advanced computing 2014 (pp. 211-5). IEEE.

[16] Badmaev N, Bazarov A. Monitoring network for atmospheric and soil parameters measurements in permafrost area of Buryatia, Russian federation. Geosciences. 2018; 9(1):1-10.

[17] Ali TA, Choksi V, Potdar MB. Precision agriculture monitoring system using green internet of things (G-IoT). In international conference on trends in electronics and informatics 2018 (pp. 481-7). IEEE.

[18] Kamelia L, Nugraha S, Effendi MR, Gumilar S. Real-time monitoring system for measurement of soil fertility parameters in smart farming applications. In 5th international conference on wireless and telematics 2019 (pp. 1-4). IEEE.

[19] Siregar B, Nasution AA, Adlin L, Andayani U, Fahmi F. Soil moisture monitoring system using wireless sensor network. In journal of physics: conference series 2018 (pp. 1-11). IOP Publishing.

[20] Manjula E. An agricultural soil environment monitoring using wireless multimedia sensor network. Turkish Journal of Computer and Mathematics Education. 2021; 12(10):5533-40.

[21] García L, Parra L, Jimenez JM, Lloret J, Lorenz P. IoT-based smart irrigation systems: an overview on the recent trends on sensors and IoT systems for irrigation in precision agriculture. Sensors. 2020; 20(4):1-48.

[22] Zeng J, Chen KS, Cui C, Bai X. A physically based soil moisture index from passive microwave brightness temperatures for soil moisture variation monitoring. IEEE Transactions on Geoscience and Remote Sensing. 2019; 58(4):2782-95.

[23] Bashir RN, Bajwa IS, Shahid MM. Internet of things and machine-learning-based leaching requirements estimation for saline soils. IEEE Internet of Things Journal. 2019; 7(5):4464-72.

[24] Chen Z, Wang D, Ma L, Chen Y. Internet of things technology in monitoring system of sustainable use of soil and land resources. IEEE Access. 2020; 8:152932-40.

[25] Placidi P, Morbidelli R, Fortunati D, Papini N, Gobbi F, Scorzoni A. Monitoring soil and ambient parameters in the IOT precision agriculture scenario: an original modeling approach dedicated to low-cost soil water content sensors. Sensors. 2021; 21(15):1-28.

[26] Sami M, Khan SQ, Khurram M, Farooq MU, Anjum R, Aziz S, et al. A deep learning-based sensor modeling for smart irrigation system. Agronomy. 2022; 12(1):1-14.

[27] Zhang G, Li X. Estimate cotton water consumption from shallow groundwater under different irrigation schedules. Agronomy. 2022; 12(1):1-15.

[28] Panigrahy A, Chavan SS, Patil RN, Vidyapeeth B. An effective method for soil moisture sensing using Arduino Uno and interfacing with GSM Sim900. International Journal for Scientific Research & Development (IJSRD). 2016.

[29] Abdullah MH, Ghani SC, Zaulkafilai Z, Tajuddin SN. Development open source microcontroller based temperature data logger. In IOP conference series: materials science and engineering 2017 (pp. 1-13). IOP Publishing.

[30] Patnaik P, Dinakar R. A comparative study of arduino, raspberry Pi and ESP8266 as IoT development board. International Journal of Advanced Research in Computer Science. 2017; 8(5): 2350-2.

[31] Mehta M. ESP 8266: a breakthrough in wireless sensor networks and internet of things. International Journal of Electronics and Communication Engineering & Technology. 2015; 6(8):7-11.

[32] Pasha S. ThingSpeak based sensing and monitoring system for IoT with matlab analysis. International Journal of New Technology and Research. 2016; 2(6):19-23.

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Appendix I

S. No.	Abbreviation	Description
1	ADC	Analog to Digital Converter
2	ECG	Electrocardiogram
3	G-IoT	Green Internet of Things
4	HTTP	Hypertext Transfer Protocol
5	IDE	Integrated Development Environment
6	IoT	Internet of Things
7	LoRaWAN	Long Range Wide Area Network
8	PIR	Passive Infrared
9	SoC	System on a Chip
10	SPI	Serial Peripheral Interface
11	TCP/IP	Transmission Control Protocol/Internet Protocol