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LIST OF ABBEREVIATIONS

IoT	Internet of Things
NODE MCU	NODE Microcontroller Unit
LORA	Long Range Radio
USB	Universal Serial Bus
AC	Alternating Current
DC	Direct Current
LED	Light Emitting Diode
LAN	Local Area Network

CHAPTER-1

INTRODUCTION

1.1 General

Agriculture is a science and art of cultivating plants. Around 42% workforces are employed in agriculture but still it contributes to 17% to our GDP. For improving the agricultural production with minimum resources and less manual labour, essential innovations have been made since past. Sadly, only a minimum land of the earth's surface is suitable for agricultural use due to number of limitations, climate, temperature, soil quality and topography, and even much of the essential areas are not homogenous. Further, many reports showed that every crop possess different characteristic which can be measured separately in both qualitatively and quantitatively.

Soil characteristics like presence of nutrients, type of soil, irrigation flow, pest control etc. define its suitability and essentiality for a specific crop. Farmers need modern sensor technology-based methods to generate more production on limited land. Different of agricultural harvesters, automated tractors, drones, robots operated weeders and satellites are currently in trend agricultural equipment. Sensors collect the data in minimum time and it can be stored for further analysis.

There are reasonable efforts that highlight the role of the IoT in the agriculture industry, but most of the published report focuses only on applications, the use of IoT for better food quality, and other future problems considering the latest facts, figures and data.

In our project, various steps have been implemented which includes plantation of five different crops in the field, assembling of the sensors and deployment of the sensor. Sensors collect data of five different crops and sends data to cloud computing/ website through wireless protocols. After that it compares the collected data with the standard data through wireless protocol and checks the deficiency. Now, the farmers can add the supplements (pesticides, fertilizers, insecticides, nitrogen, phosphorous, potassium) to remove the deficiency. This will help in increase of total production of crops.

There are four main components of IoT:

i. **Low power embedded system:** High performance and less battery consumption are the inverse factors that play an important role in design of electronic system.
ii. **Cloud computing:** Data collected from devices is stored on reliable storage servers so here cloud computing comes into action.
iii. **Availability of Big Data:** As IoT is highly dependent on sensors that are real time. So the usage of electronic devices is spread throughout every field that is going to trigger a massive flux of data.
iv. **Network connection:** For communication, internet connectivity is necessary where each physical object is assigned by an IP address. A network connection is built between the devices with the help of these addresses.

1.2. Needs of IoT in Agriculture

The key advantages of using IoT in enhancing farming are as follows:

i. Soil management such as PH level, moisture content. Soil NPK etc. can be identified easily.
ii. It increases productivity with less labour and time
iii. Growth of crops can be easily monitored.

1.3 Advantages of IoT

- Efficient operation management
- Utilization of Resources Efficiently
- Cost effective operation
- Minimization of Human Efforts
- Time-saving
- Increase Data Collection

1.4 Disadvantages of IoT

- Too much dependency of technology
- Security
- Lose life control
- Privacy
- Complexity

1.5 Smart Agriculture

Smart agriculture is an emerging concept that refers to managing farms using technologies like IoT, robotics, drones and AI to increase the quantity and quality of products while optimizing the human labour required by production**.**

Smart farming refers to managing farms using modern information and communication technologies to increase the quantity and quality of produce while optimizing the human labour required. Various types of technologies used in smart agriculture are as follows:

Sensor:

A sensor is a device which produces an output signal after sensing physical characteristics. It detects the events or changes happening in the environment and sends the response.

Sensor have a wide range and are of many types but fundamentally sensor are devices that detect the physical quantity of measurement object and convert this into readable signal which is displayed on an instrument. The characteristics which are sensed by a sensor are of physical chemical biological properties. There is wide variety of sensors available for practical and industrial use. For demanding mission-critical industrial applications, sensor can help improve processes and offer unmatched asset production.

We hope that you gained a better understanding of what sensors are, how they work, and how they can be applied across a truly mind-boggling range of monitoring and testing applications.

Sensor Node:

A Sensor node is a small and inexpensive device with limited resources which include the battery and computation power which are deployed in a region to monitor the environment. A Sensor node is a devices that possess the capacity to gather sensor information from the environment, process the information and communicate with other nodes.

A sensor node is a type of transducer that uses one type of energy. A signal of some sort and convert it into a reading for a purpose information transfer. Furthermore it possesses the capacity of performing some process, gathering sensor information and communicating with other connected sensor in the network.

1.6 Architecture of Smart Farming

Primarily, this structure of system includes 3 layers that are sensor layer, transport layer and application layer. The functions of these layers are given below:

1.6.1 Sensor layer

One of the challenges of this sensor layer is to obtain automation and real time change of the figures of agriculture manufactured into digital changes or information that could be processed in virtual world through different or other means. The data that they are collect:

1.6.2 Sensor information:

1. Humidity, temperature, gas concentrations, pressure etc.
2. Products information- name, model, price and features.
3. Working condition - operating parameters of different equipment, apparatus etc.

The most challenging for information layer is to mark different kind of information or data and collecting the information and marking that information in the present world by different of techniques of sensing, after then remodelling it for further processing into digital information. The sensor layer consists of different strategies-RFID tags, cameras, two dimension code labels, sensor networks.

1) **Transport layer-** The task for this layer is to collect and summarize the data of farm acquired from the above layer for further processing. It is assumed as the

nerve centre of IoT. The layer consist the telecommunication combination management centre and network of internet, information centre and smart processing centres.

2) **Application layer-** The main function of this layer is the analysis and summarising and processing the information collected for the agriculture harvesting to digitally aware of actual world. It is basically the combination of IoT and agricultural market intelligence.

1.7 Benefits of IoT in Agriculture

1. IoT empowers simple collection and the execution of large amount of information which is collected from different sensors used and with the help of integration of segregated evaluating administrations such as cloud storage, farming field maps and much information that can be regain from any place and any location which does live monitoring and connectivity end to end.
2. IoT is viewed as an important segment for smart farming because with precise use of sensors and also the smart gadgets, farmers could expand the output by 72% up to year 2050 as delineated by specialists.
3. With the help of IoT creations, cost can be reducing to an outstanding that can further increase productivity and sustainability.
4. By the use of IoT efficiency level would be further expanded as far as utilization of water, soil, fertilizers, pesticides etc.

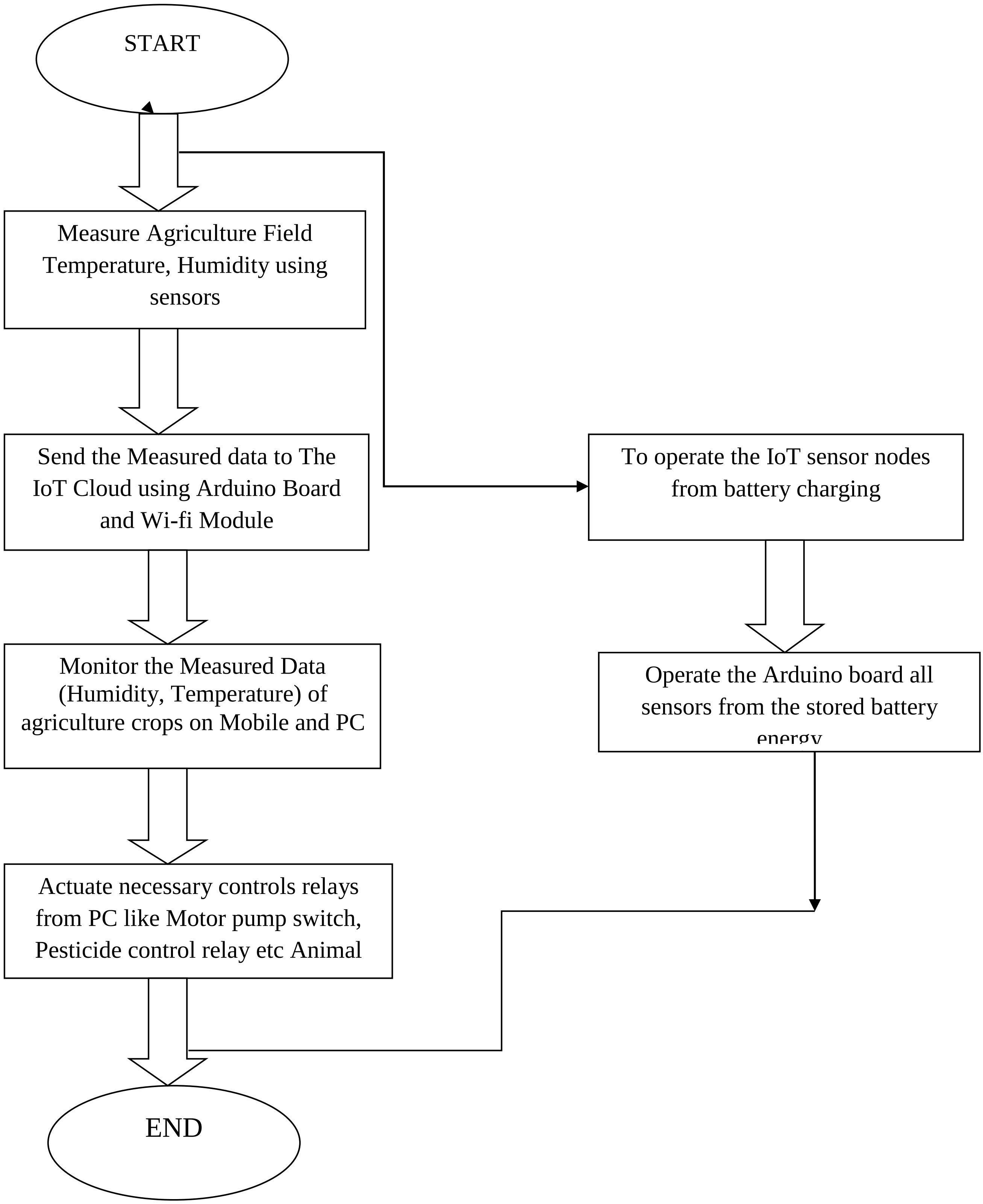
1.8 Applications of IoT in Agriculture

a) Precision farming
b) Agricultural drones
c) Livestock monitoring
d) Smart greenhouses

1.9 Flow Chart

Under this flow chart, information of the system components is discussed which is represented in the Figure 3.2. Firstly, we have collected all the components of NODE MCU (Sensors, Arduino, Raspberry pi etc.). Then we have deployed NODE MCU in agriculture field which will collect data of soil humidity, soil temperature, air temperature and air moisture of all the crops and transfer this data on cloud/website through wireless protocol. We have compared the collected data with the standard data and identify the defects/ deficiency. If there is any defect in the crop it will send the notification on the respected mobile/pc. After getting the notification the farmers can add supplements (fertilizers, urea, nitrogen, phosphorous and potassium) and will get high yield of production.

Figure 1.1: Flow chart



CHAPTER 2

LITERATURE SURVEY

In this chapter, literature survey about the available technology has been performed. As the world is trending into new technologies and implementations it is a necessary goal to trend up in agriculture also. Many researches are done in the field of agriculture.

Mohamed Amine Ferrag and Lei Shu, in year 2021 have studied a survey on Smart Agriculture: Development Modes, Technologies, and Security and Privacy Challenges. The technology used the security challenges of smart agriculture are analysed and agriculture information technology is the major outcome of their research paper.

Mohamed Amine Ferrag, Lei Shu and Xing Yang, in year 2020 have studied Security and privacy for green IoT based agriculture. They used 3S technology, including Remote Sensing (RS) and Geographic Information. The major outcome of their research paper is research challenges on security and privacy issues in the field of green IoT based agriculture. They reviewed the security and privacy solutions for IoT applications and how it will be adapted for green IoT based agriculture.

Junhu Ruan, in year 2019 has studied the life cycle framework of green IoT based agriculture and monitoring system operation. They used technology Radio Frequency Identification (RFID) technique. The major outcome of his research paper is that increasing population in the world forces humans to improve farm yields using advanced technologies.

Olakunle Elijah and tharek Abdul Rahaman, in year 2018 have studied an overview of Internet of things and data analytics in agriculture. They used WiFi and wireless sensor nodes technology. The major outcome of their research paper is to enhance crop productivity from minimum resources.

Muhammd Ayaz, in year 2019 has studied Internet of Thing (IoT) based Smart Agriculture monitoring. They used technology of the operating vehicles which are equipped with WiFi and GIS facilities so that they can work precisely. The major outcome of his research paper is IoT technologies in agriculture practices, every aspect of traditional farming methods can be fundamentally changed.

Arvind Prasad Dwived, in year 2017 has studied Analysis of Physico-chemical Characteristics of Soil from Various Locations of Banda City, Uttar Pradesh, India. The technology used atomic absorption spectrometer and the major outcome of his research paper is Physico - chemical analysis of soil samples under study showed variable concentration of various parameters.

Mohammad Halim Khan, Sunil Kumar, Atul Kumar and B Mehra, in year 2017 have studied Remote sensing and GIS based analysis of land use, land cover and soil fertility status at inter block level in Banda district of Uttar Pradesh. The technology used is remote sensing in Geographic Information System (GIS) and the major outcome of their research paper is Land utilisation on different categories of land.

M. Amini, in year 2020 has studied a Survey of Smart Agriculture development modes, technology and security and privacy challenges. The technology used IoT based smart agriculture monitoring system. The major outcome of his research paper is agriculture automation in Banda district.

Mohamed Amine Ferrag, Lei Shu and Xing Yang, in year 2020 have studied Security and Privacy for green IoT based agriculture; Review, Block chain solutions and challenges. The technology used is green internet of things. The major outcome of their research paper is to transform traditional farming into intelligent farming by using green internet of things.

Mhammd Ayaz, in year 2019 has studied Internet of Things (IoT) based smart agriculture: towards making the fields talk. The technology used is wireless sensor and IoT in agriculture. The major outcome of his research paper is traditional farming methods that can bring change for effective growth.

Olakunle Elijah tharek, Abdul Rahaman, in year 2018 have studied IoT based Smart Agriculture M.S an overview of internet of things and data analytics in agriculture. The technology used Wifi, wireless sensor node. The major outcome of their research paper is traditional farming methods that can bring change for effective growth.

CHAPTER-3

DESCRIPTION OF SYSTEM COMPONENTS

3.1 Configuration of proposed System

Main components of the proposed system include Arduino Uno, Raspberry pi, air humidity sensor, temperature sensor, soil moisture, soil pH sensor and soil NPK as shown in Figure 3.1. We have integrated all the sensors and further, these sensors have been deployed in the field to collect the data from soil and atmosphere. Finally, we have compared the monitored data with standard value to investigate whether the soil data is sufficient or not. Accordingly, remedial action such as fertilizer combination, water and lime solution can be added in the field.

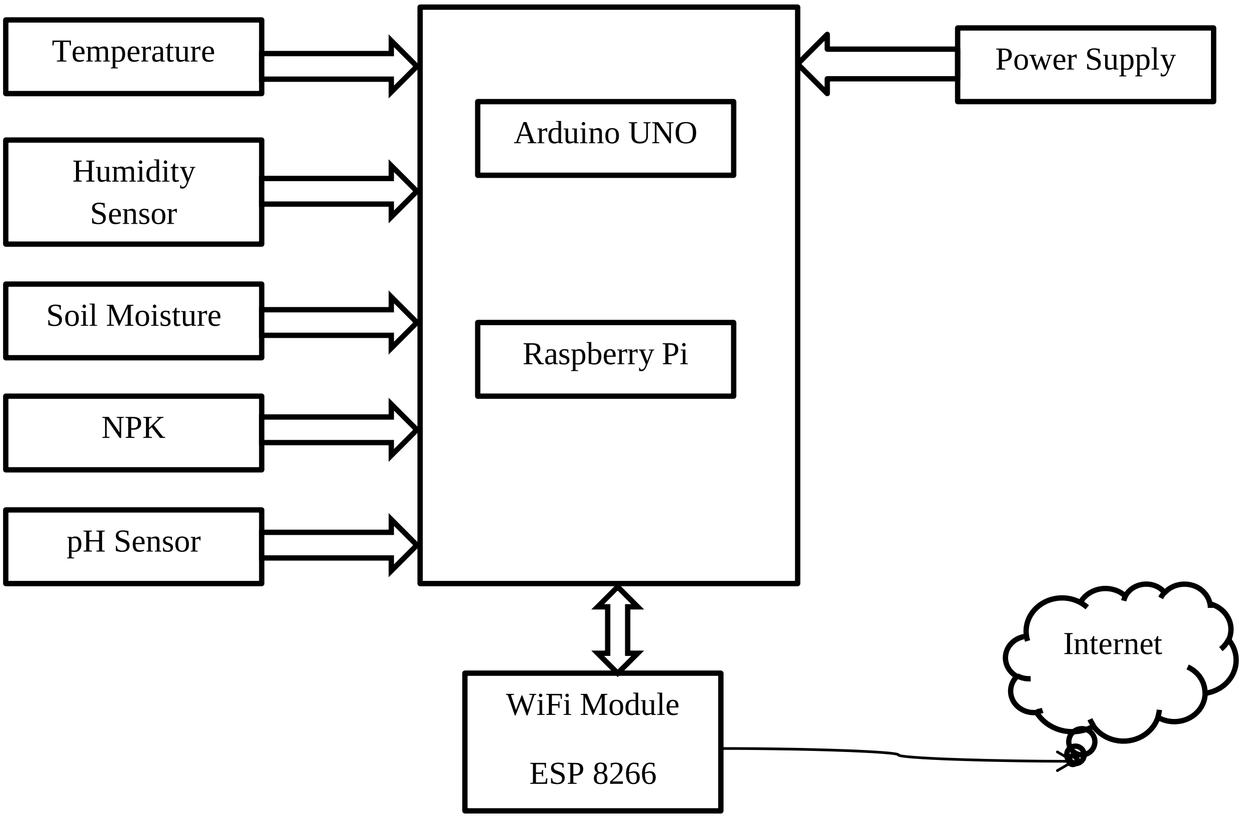


Fig 3.1 Block diagram of proposed system

This project is aided with many hardware components. The proposed technology is an amalgamation of different sensors, microcontroller and communication medium to help the farmers to work on their farms.

3.2 Description of System Components

The various components used in our project are shown in the Table 3.1.

Table 3.1: List of Components

Sr. No.	Name of component
1.	Node MCU
2.	Casing
3.	Jumper Wires
4.	Socket Connector
5.	Lora Shield
6.	Adapter
7.	Arduino UNO
8.	Raspberry Pi

3.2.1 Node MCU

Node MCU is basically a hardware component which includes various components. The components are Arduino UNO, LoRa Shield, Socket Connector, Temperature Sensor, Capacitive Soil Moisture Sensor, DHT11 Sensor, pH Sensor, DS18B20 and NPK Sensor. The various components are integrated together and are assembled in casing. The power supply is provided through an external source 5V supply is normally given to operate the Node MCU which is connected through a socket connector. Later, the Node MCU deployed in agriculture field to measure the data of soil temperature, soil moisture, air temperature, air humidity, soil pH and soil NPK.

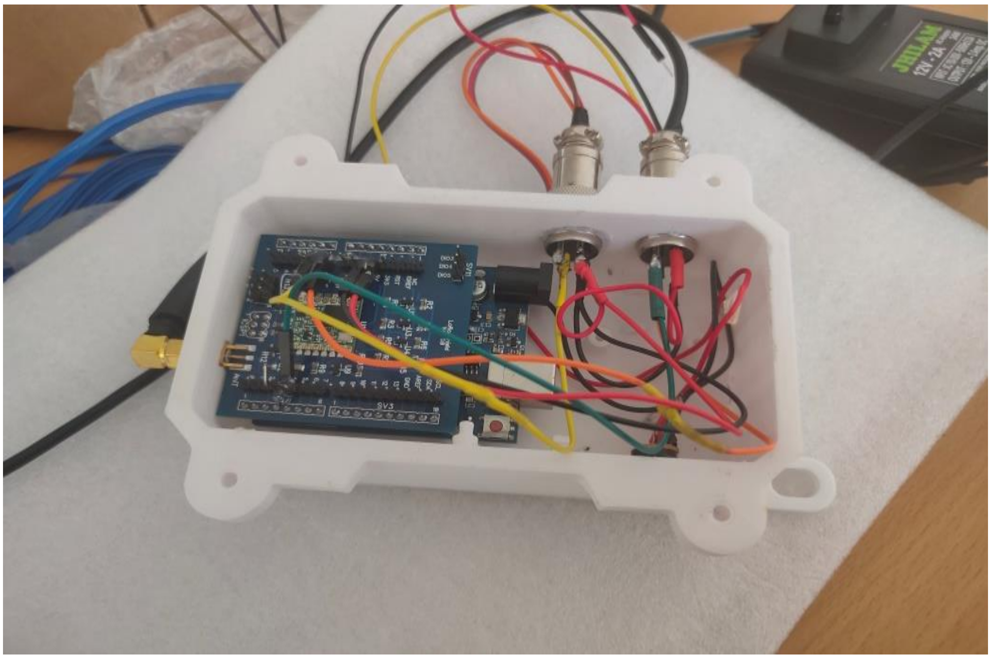


Fig 3.2: Node MCU

3.2.2 Casing

System cases protect the computer chassis, hardware, motherboard, and other internal components for advanced blade servers, computer networks, or small desktop units. It protects the system from atmospheric dust, humidity, temperature and thus prevents of circuit from getting damaged. Its length is 12 cm, breadth 5 cm and height is 4 cm.

The casing is made up of poly lactic acid (PLA) material. It is basically a polyester made up of thermoplastic which is formally obtained by condensation of lactic acid CHCOOH with lose of water. It can be prepare by ring opening polymerization of lactide, the cyclic dimer of basic repeating unit.

Fig 3.3: Casing

3.2.3 Jumper Wires

We have used jumper wire in our project to connect different components together. A jumper wire (also known as jumper, jumper wire, DuPont wire) is an electrical wire, or group of them in a cable, with a connector or pin at each end, which is normally used to interconnect the components of a breadboard or other prototype or test circuit, internally or with other equipment or components, without soldering. Individual jump wires are fitted by inserting their "end connectors" into the slots provided in a breadboard, the header connector of a circuit board, or a piece of test equipment.

Fig 3.4: Jumper Wires

3.2.4 Socket Connector

We have used socket connector in our project to connect external components with Node MCU. A connector is the unique end of a plug, jack, or the edge of a card that connects to a port. For example, all desktop computer expansion cards have a connector that allows them to connect in a slot on the motherboard. When referring to cables, the connector is the end of the cable that connects into a port. Once a peer-to-peer connection is established, a socket descriptor is used to uniquely identify the connection. It establishes a connection to a remote host, the host which is specified by an array of IP address and port number.

Fig 3.5: Socket Connector

3.2.5 Lora Shield

We have used Lora Shield in our project to provide easy connection .It allows the user to send data and reach extremely long range at low data rate. Lora Shield is a long-range transceiver on an Arduino shield form factor and based on open source library. The shield allows the user to send data and reach extremely long ranges at low data-rates. It provides ultra-long range spread spectrum communication and high interference immunity whilst minimizing current consumption. Lora Shield is based on chip, it targets professional wireless sensor network applications such as irrigation systems, smart metering, smart cities, smartphone detection, building automation, and so on. It also provides significant advantages in both blocking and selectivity over conventional modulation techniques, solving the traditional design compromise between range, interference in immunity and energy consumption. Its dimensions are:

i. Device Dimension: 62*43*23mm
ii. Device Weight: 22g
iii. Package Dimension: 111*70*36mm
iv. Package Weight: 53g

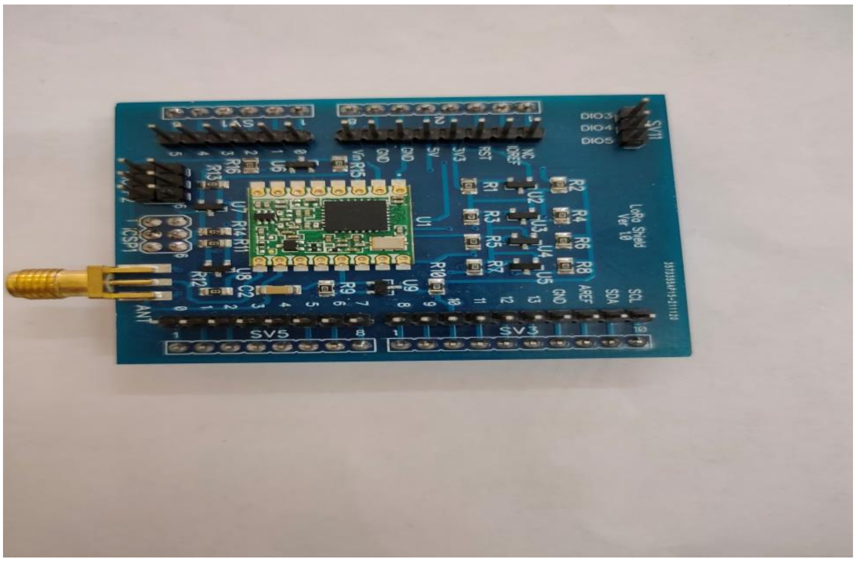


Fig 3.6: Lora Shield

3.2.6 Adapter 12 V

We have used a 12V adapter is used in our project to provide power supply to NPK sensor as NPK sensor operate only at 9V to 12V adapter. Adapter for battery powered equipment may be described as chargers or rechargers (also battery charger). AC adapters are used with electrical device that require power but do not contain internal component to derive the required voltage in power from mains power.

External power supplies are used both with equipment with no other source of power and with battery powered equipment, where the supply, when plugged in can sometimes charge the battery in addition to powering the equipment. Originally, most AC/DC Adapters were linear power supplies, containing a transformer to convert the mains electricity voltage to a lower voltage, a rectifier to convert it to pulsating DC, and a filter to smooth and pulsating waveform to DC, with residual ripple variations small enough to leave the powered device unaffected.

Fig 3.7: Adapter

3.2.7 Arduino UNO

The Arduino UNO is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with AC to DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter. Revision 2 of the Uno board has a resistor pulling the 8U2 HWB line to ground, making it easier to put into DFU mode. Revision 3 of the board has the following new features:

1. Pinout added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible both with the board that use the AVR, which operate with 5V and

with the Arduino due to that operate with 3.3V. The second one is a not connected pin that is reserved for future purposes.

2. Stronger RESET circuit.
3. Atmega 16U2 replace the 8U2

Fig 3.8: Arduino UNO

"UNO" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The UNO and version 1.0 will be the reference versions of Arduino, moving forward. The UNO is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino boards.

Pins Description

In addition, some pins have specialized functions:

1. **Serial: 0 (RX) and 1 (TX):** Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attach Interrupt () function for details.

2. **PWM**: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analogWrite() function.
3. **SPI:** 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication using the SPI library.
4. **LED**: 13. There is a built-in LED driven by digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.
5. **TWI:** A4 or SDA pin and A5 or SCL pin. Support TWI communication using the Wire library.

The UNO has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). There are a couple of other pins on the board:

1. Voltage for the analog inputs. Used with analog reference ().
2. Reset brings this line LOW to reset the microcontroller. Typically used to add a reset button to shield which block the one on the board.

The technical specification of Arduino UNO has been shown in the given table 3.2.

Table 3.2: Specifications of Arduino

Sr. No.	Parameters	Range
1.	Microcontroller	ATmega328P
2.	Operating voltage	5V
3.	Input voltage(Recommended)	7V-12V
4.	Input voltage(Limit)	6V-20V
5.	Digital input /output Pins	14(of which 6 provide PWM output)
6.	PWM digital input /output Pins	6
7.	Analog input pins	6
8.	DC current per input /output pins	20 mA
9.	DC current for 3.3V Pin	50mA
10.	Flash memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
11.	SRAM	2 KB (ATmega328P)
12.	Clock speed	16 MHz
13.	LED Builtin	13
14.	Length	68.6mm
15.	Width	53.4mm
16.	Weight	25 g
17.	EEPROM	1 KB(ATmega328P)

3.2.8 Raspberry Pi

Raspberry pi is a series of small single-board computers (SBCs) developed in the United Kingdom by the Raspberry Pi foundation .It works on the operating system window. It consumes 5V and 3A (for full power delivery to USB devices). It is used by millions of people to learn programming skills, build hardware projects, do home automation and industrial applications.

Raspberry pi is:-

1. Low cost
2. Credit card sized computer
3. Works as standard keyboard and mouse

We are using Raspberry pi 3 Model B+ in our project it is the latest product in the raspberry pi 3 range, which boast a 64 bit quad core processor which runs at 1.4Ghz, dual band 2.4GHz and 5GHz wireless LAN, Bluetooth 4.2 / BLE, faster Ethernet and PoE capability via a separate PoE HAT.

The dual band wireless LAN comes with modular compliance certification , allowing the board to be design into end product with significantly reduce the wireless LAN compliance testing , improving both cost and time to market. The raspberry Pi 3 model B+ maintains the same mechanical foot print as both the raspberry Pi 2 Model B and the raspberry Pi 3 Model B. The features are as follows:

1. Dual HDMI connectors
2. Dual MIPI display connectors
3. Dual MIPI camera connectors
4. CM 4 socket: Suitable for all variants of Compute Module 4
5. Standard Raspberry Pi HAT connectors with PoE support
6. Standard PCle Gen 2*1 socket
7. Real –time clock (RTC) with battery backup
8. On-board USB 2.0 hub with 2 USB 2.0 connectors
9. Gigabit Ethernet socket supporting PoE HAT
10. Support for programming eMMC variants of compute Module 4
11. SD card socket for Compute Module 4 variants without eMMC
12. PWM fan controller with tachometer feedback

The specifications of raspberry pi are comprehensively displayed in the table 3.3.

Table 3.3: Specification of Raspberry Pi

Sr. No.	Parameters	Range
1.	Processor	Broadcom BCM2837B0, Cortex-A53 64-bit SoC @ 1.4 GHz
2.	Memory	1GB LPDDR2 SDRAM
3.	Connectivity	• 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN , Bluetooth 4.2, BLE • Gigabit Ethernet over USB 2.0 (maximum throughput 300 Mbps) • 4*USB 2.0 ports
4.	Access	Extended 40-pin GPIO header
5.	Video and sound	• 1*full size HDMI • MIPI DSI display port

		• MIPI CSI camera port • 4 pole stereo output and composite video port
6.	Multimedia	H.264, MPEG-4 decode (1080p30); H.264 encode (1080p30);OpenGL ES 1.1 ,2.0 graphics
7.	SD card support	Micro SD format for loading operating system and data storage
8.	Input power	• 5V/2.5A DC via micro USB connector • 5V DC via GPIO header • Power over Ethernet(PoE)-enabled(requires separate Poe HAT)
9.	Environment	Operating temperature, 0-50 degree celcius
10.	Production Lifetime	The Raspberry Pi 3 Model B+ will remain in production until at least January 2023.

To avoid mal functions of or damaged to this product please follow the following instruction:-

1. Avoid exposure to water or moisture and don't place it on a conductor surface while it is performing operation.
2. Do not expose the heat from any source; the raspberry Pi 3 Model b+ is designed for reliable operation at normal ambient temperature.
3. Handle it properly to avoid mechanical and electrical damage to the printed circuit board and connectors.
4. Avoid handling the printed circuit board, whilst it is powered or handle it by edges to minimize the risk of electrostatic discharge damage.

Fig 3.9: Raspberry Pi

The various sensors used in our project are shown in the figure below:-

Table 3.4: List of Sensors

S. No.	Name of sensors
1.	DHT11
2.	Capacitive soil moisture sensor V2.0
3.	pH Sensor
4.	NPK
5.	DS18B20

3.2.9 DHT11 Temperature and Humidity Sensor

The DHT11 Temperature and Humidity sensor is used to sense temperature and humidity present in the atmosphere. It has 3 pins generally. One pin is used for transmitting signals, the next pin is used to receive signals and the last pin is data transfer. It can be used for prolonged time period. It gives approximate results. It regularly sends information to Arduino UNO. The information consist the signals which contain the values gathered about temperature and humidity. It is reliable on nature. It gives a very fast response.

DHT11 Temperature & Humidity Sensor features a temperature & humidity sensor complex with a calibrated digital signal output. By using the exclusive digital-signal-acquisition technique and temperature & humidity sensing technology, it ensures high reliability and excellent long-term stability. This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component, and connects to a high performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost- effectiveness.

The DHT11 measures relative humidity. The relative humidity is the amount of water vapour in air Vs the saturation point of water vapour in the air. At the saturation point, water vapour starts to condense and accumulate on surface forming dew.

The saturation point changes with air temperature. Cold air can hold less water vapour before it becomes saturated, and hot air can hold more water vapour before it becomes saturated.

The formula to calculate relative humidity is:-

$$RH = (\rho w / \rho s) \times 100\%$$

RH: Relative humidity

ρw: Density of water vapour

ρs : Density of water vapour at saturation

The relative humidity is expressed as a percentage. At 100% RH, condensation occurs, and at 0% RH, the air is completely dry. Measurement of Humidity and Temperature through DHT11 is as follows

The DHT11 detects water vapour by measuring the electrical resistance between two electrodes. The humidity sensing component is a moisture holding substrate with electrodes applied to the surface. When water vapour is absorbed by the substrate, ions are released by the substrate, which increase the conductivity between the electrodes. The change in resistance between the two electrodes is proportional to the relative humidity. Higher relative humidity decreases the resistance between the electrodes, while lower relative humidity increase the resistance between the electrodes.

The DHT11 measures temperature with a surface mounted NTC temperature sensor (thermistor) built into the unit .An IC mounted on the back of the unit converts the resistance measurement to relative humidity. It also stores the calibration coefficients, and controls the data signal transmission between the DHT11and the Arduino. The DHT11 uses one signal wire to transmit data to the Arduino. Power comes from separate 5V and ground wire. A 10 k ohm pull –up resistor is needed between the signal line and 5V line to make sure the signal level stays high by default.

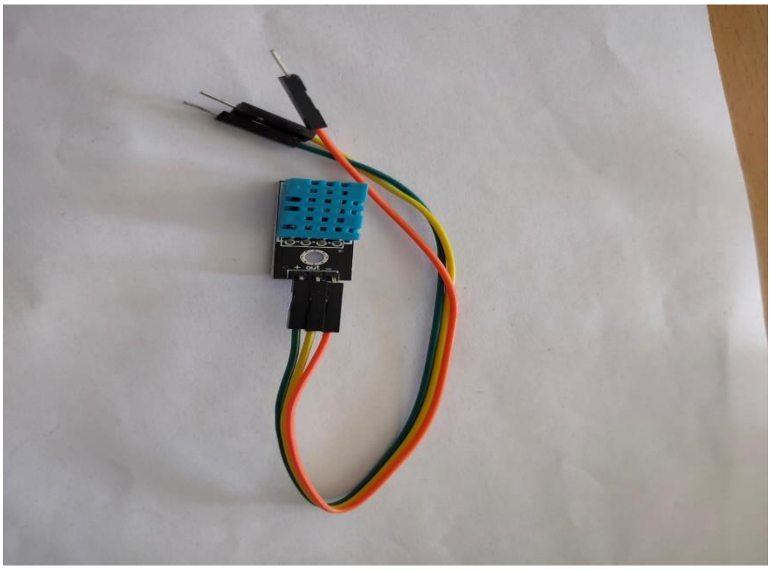


Fig 3.10: DHT11

The features of DHT11 are as follows:

1. Low cost
2. 3 to 5V power and input / output
3. 2.5mA current use during conversion (while requesting data)
4. Good for 20 -80% humidity readings with 5% accuracy
5. Good for 0-50% C temperature readings (-2 to +2 C) accuracy.
6. No more than 1Hz sampling rate (once every second)
7. Body size 15.5 mm *12 mm* 5.5 mm
8. 4 pins with 0.1 spacing.

We can setup the DHT11 on an Arduino by following the given steps. Wiring the DHT11 to the Arduino is really easy but the connections are different depending on which type you have.

1. VCC – red wire connect to 3.3-5V power. Sometimes 3.3V power is not enough in which case try 5V power.
2. Data out – white or yellow wire not connected
3. Ground – black wire

Simply ignore pin 3, its not used. You will want to place a 10 k ohm resister between VCC and Data pin, to act as a medium – strength pull up on the data line. The Arduino has built-in pull–ups you can turn on but they are very weak, about 20-50k.

Each DHT11 element is strictly calibrated in the laboratory that is extremely accurate on humidity calibration. The calibration coefficients are stored as programmes in the OTP memory, which are used by the sensor's internal signal detecting process. The single-wire serial interface makes system integration quick and easy. Its small size, low power consumption and up-to-20 meter signal transmission making it the best choice for various applications, including those most demanding ones. The component is 4-pin single row pin package. It is convenient to connect and special packages can be provided according to user's request.

Table 3.5: Overview

Item	Measurement Range	Humidity Accuracy	Temperature Accuracy	Resolution	Package
DHT11	20-90%RH 0-50℃	±5%RH	±2℃	1	4 pin single row

Table 3.6: Specifications of DHT11

Parameters	Conditions	Minimum	Typical	Maximum
Humidity				
Resolution		1%RH	1%RH	1%RH
			8%RH	
Repeatability			±1%RH	
Accuracy	25℃		±4%RH	
	0-50℃			±5%RH
Interchangeability	Fully Interchangeable			
Measurement Range	1℃	30%RH		90%RH
	25℃	20%RH		90%RH
	50℃	20%RH		80%RH
Response Time (Seconds)	1/e(63%)25℃, 1m/s Air	6 S	10 S	15 S
Hysteresis			±1%RH	
Long-Term Stability	Typical		±1%RH/year	
Temperature				
Resolution		1℃	1℃	1℃
		8 Bit	8 Bit	8 Bit
Repeatability		±1℃		±2℃
Accuracy				
Measurement Range		±0℃		±50℃

3.2.10 Capacitive Soil Moisture Sensor V2.0

The Soil Moisture sensor is used to sense moisture content in the soil and it measure soil moisture levels by capacitive sensing rather than resistive sensing like other sensors .It is made of corrosion-resistant material which gives it excellent service life .Insert it into the soil around your plants and get the real time soil moisture data. It checks the volume of water content or moisture present in the soil. The calculations are done in the soil moisture sensor through coefficients. It estimates the volume of water content in the soil. It detects the water content in the soil and gets and sends the Analog signals which are shown digitally. It transmits the signals containing information or data or values of the condition of soil to Arduino to further process it and display.

This soil moisture sensor module is used to detect the moisture of the soil. It measures the volumetric content of water inside the soil and gives us the moisture level as output. The module has both digital and Analog outputs and a potentiometer to adjust the threshold level. This module includes an on board voltage range of 3.3~5V.

We are using capacitive type instead of resistive. The major issue with the resistive soil moisture sensor is the corrosion of the sensor probes, not just because it is in contact with the soil but also because there is a DC current flowing which cause electrolysis of the sensors. Capacitive measuring has some advantages; it not only avoids corrosion of the probe but also give a better reading of the moisture content of the soil as opposed to resistance measuring.

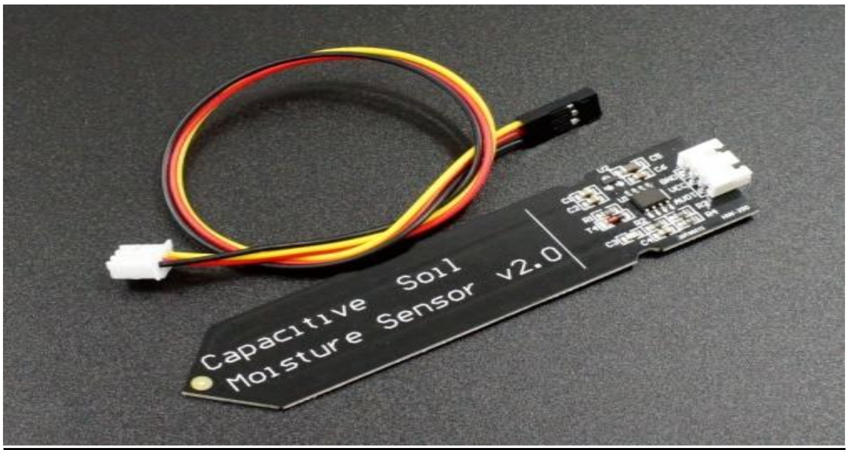


Fig. 3.11: Capacitive Soil Moisture Sensor V2.0

Table 3.7: Moisture Sensor Module Pin out Configuration

Pin name	Description
VCC	The VCC pin powers the module, typically with +5V
GND	Power Supply Ground
DO	Digital Out Pin for Digital Output
AO	Analog Out Pin for Analog Output

Table 3.8: Specifications Moisture Sensor

Sr.no.	Parameters	Range
1.	Operating Voltage	3.3V to %V DC
2.	Operating Current	15mA
3.	Digital Output	0V to 5V, Adjustable trigger level from preset
4.	Analog Output	0V to 5V based on infrared radiation from fire flame falling on the sensor
5.	LEDs	indicating output and power
6.	PCB Size	3.2cm*1.4cm
7.	Design	LM393

It is easy to use Microcontrollers or even with normal Digital/Analog IC small, cheap and easily available.

3.2.11 pH Sensor

A pH sensor helps to measure the acidity or alkalinity of the water with a value between 0 -14 .When the pH value dips below seven, the water starts to become more acidic. Any number above seven equates to more alkaline. pH meter, electric device used to measure hydrogen ions activity (acidity or alkalinity) in solution. Seven pH is for neutral components which are neither acidic nor basic.

Soil pH is a key parameter for crop productivity therefore its spatial variation should be adequately addressed to improve precision agriculture management system. Soil pH affects the soil's physical, chemical, and biological properties and processes, and thus plant growth. Soil pH, a measure of hydronium ion (H+) concentration traditionally tested in labs to decide how much fertilizer to apply to a field.

Recently, with increased emphasis on precision agriculture, economics, and the environment, soil tests are also a logical tool to determine areas where adequate or excessive fertilization has taken place. In addition, they are used to monitor the impact of past fertility practices on changes in a field's nutrient status. Therefore, developing rapid tools which can detect pH variations on a site-specific basis has become pressing need of the hour because laboratory based methods are inadequate, time consuming, laborious and expensive.

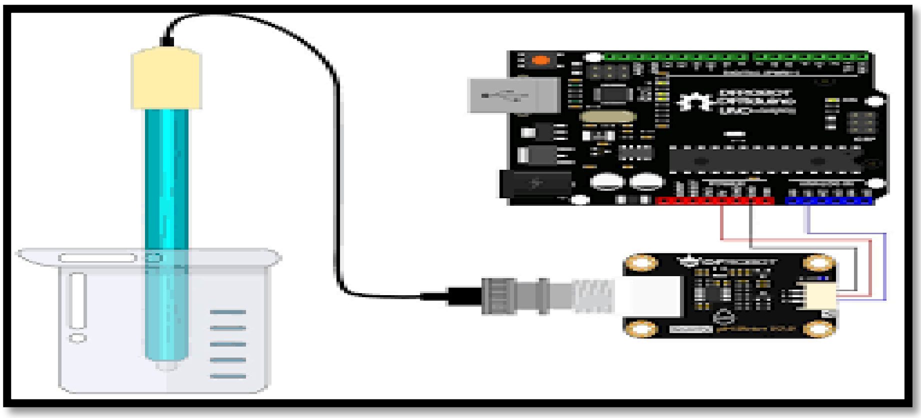


Fig 3.12: pH Sensor

Analog pH sensor is used to measure the pH value of a solution and shows the acidity or alkalinity of the substance. It is commonly used in various applications such as agriculture, wastewater treatment, industries, environmental monitoring, etc.

pH is a representation of hydrogen ion activity in a liquid . It is the negative logarithm of the amount of hydrogen ions (in moles) per litre of liquid .Thus 10-11 moles of hydrogen ions in 1 litre of liquid = 11 pH 10-5.3 moles of hydrogen ions in 1 litre of liquid =5.3 pH. The basic pH scale extend from 0 (Strong Acid) to 7 (Neutral, Pure water) to 14 (Strong caustic). Chemical solutions with pH levels below zero and above 14 are possible but rare.

pH can be measure by the measuring the voltage produce between the special electrodes immersed in the liquid solution. One electrode, made of a special glass, is called a measurement electrode. Its job is to generate a small voltage proportional to pH (ideally 59.16 mV per pH unit).

The other electrode (called the reference electrode) uses a porous junction between the measured liquid and a stable, neutral pH buffer solution (usually potassium chloride) to create a zero-voltage electrical connection to the liquid. This provides a point of continuity for a complete circuit so that the voltage produced across the thickness of the glass in the measurement electrode can be measured by an external voltmeter.

Here is the general procedure to follow when using the pH Sensor:

1. Connect the pH Sensor to the interface.
2. Start the data-collection software.
3. The software will identify the pH Sensor and load a default data-collection setup. You are now ready to collect data.

Important: Do not fully submerge the sensor. The handle is not waterproof. Calibration of pH sensor: Calibration of the pH electrode is very important in this project. For this, we need to have a solution whose value is known to us. This can be taken as the reference solution for the calibration of the sensor.

Suppose, we have a solution whose pH value is 7 (Distilled water). Now when the electrode is dipped in the reference solution and the pH value is 6.5. Then to calibrate it, just add 7-6.5=0.5 in the calibration variable “calibration _value” in the code, i.e. make the value 21.34+0.5=21.84. After making these changes, again upload the code to Arduino and recheck the pH by dipping electrode in the reference solution. Now the correct pH value i.e. 7 (Little variations are considerable). Similarly, adjust this variable to calibrate the sensors. Then check for all other solution to get the exact output.

Working of pH sensor: The overall working principle of pH sensor and pH meter depends upon the exchange of ions from sample solution to the inner solution (pH 7 buffer) of glass electrodes through the glass membrane. The porosity of the glass membrane decreases with the continuous use that decreases the performance of the probe.

The pH amplifier inside the handle is a circuit which allows the standard combination pH electrode to be monitored by a lab interface. The cable from the pH amplifier ends in a BTA plug. The pH Sensor will produce a voltage of approximately 1.75 volts in a pH 7 buffer. The voltage will increase by about 0.25 volts for every pH number decrease. The voltage will decrease by about 0.25 volts/pH number as the pH increases. The Vernier gel-filled pH Sensor is designed to make measurements in the pH range from 0 to 14. The gel-filled reference in half cell is sealed; it cannot be refilled.

Table 3.9: Technical Specifications

Sr.no.	Parameters	Range
1.	Supply Voltage	3.3 ~5.5V
2.	Type	BNC Probe connector
3.	High Accuracy	+0.1,-0.1@25^{0}C
4.	Detection Range	0~14

Electrode of pH is given below

1. Operating Temperature Range :5~60^{0}C
2. Zero (Neutral) Point :7+0.5 , 7-0.5
3. Easy calibration
4. Internal Resistance: < 250Mohm

3.2.12 RS-485 NPK Sensor

The soil NPK sensor is suitable for detecting the component of nitrogen, phosphorous and potassium in the soil. It helps in determining the fertility of the soil there by facilitating the systematic assessment of the soil condition. The sensor can be buried in the soil for a long time. Resistant is the long term electrolysis, corrosion resistance vacuum potting and completely waterproof. This sensor is widely used in precision agriculture, forestry, soil research geological prospective.

NPK help plants- phosphorous promote the formation of roots and development of flowers and fruits. K- Potassium helps move water and nutrients around in your plants. NPK fertilizer is usually used to increase the growth of a plant. The N element in NPK fertilizer has the function of preparing amino acids (protein), nucleic acid, nucleotides and chlorophyll in plants. The element P in the NPK sensor is used as a function of storage and energy transfer. You need to know why NPK is important to your plants. All plants need nitrogen, phosphorous and potassium to grow. Without enough of any one of these nutrients, a plant will fail.

Fig 3.13: RS-485 NPK Sensor

3.2.12.1 Sign of Nitrogen Deficiency

1. Slow and stunted growth.
2. Smaller than average leaves.
3. The lower leaves start to turn yellow first and might fall of from the stem.
4. The upper leaves appear the usual green, but overtime, the yellowing creeps up the plant.

3.2.12.2 Fixing Nitrogen Deficiency in the Soil

1. Adding composted manure to the soil.
2. Planting a green manure crop, such as borage.
3. Planting nitrogen fixing plants like peas or beans.
4. Adding coffee grounds to the soil.

3.2.12.3 Sign of Nitrogen Toxicity

1. Extremely dark green leaves.
2. “Burning” of leaf tips, causing them to turn brown.
3. Some leaves turning yellow due to abundance of nitrogen but lack of other nutrients.

3.2.12.4 Sign of Phosphorous Deficiency

1. Phosphorous deficiency tends to inhabit growth. Leaves turn dark, dull, blue-green and may become pale severe deficiency. Reddish, Reddish- Violet, or Violet color developed from increased anthocyanin synthesis. Symptoms appear first on older parts of the planet.
2. Reduced shoot and increase root growth result in a low shoot/ root ratio.

3.2.12.5 Deficiency of Phosphorous Corrected in Plants

1. Provide plants with the correct nutrient ratio.
2. Do not over water plants.
3. Ensure the temperature is correct.
4. Bone meal is an excellent high phosphorous fertilizer with an average N:P:K ratio of 3:15:0.

3.2.12.6 Sign of Potassium Deficiency

The most common symptoms of a potassium deficiency are brown or burn – looking leaf adjust and tips, coupled with chlorosis between leaf veins. Also see purple spot on the underside of your leaves. To fix a potassium deficiency, you can try:

1. Potassium-rich additives such as sulphate of potash.
2. Tomato feed or organic sources such as Seaweed or Kelp treatments.
3. Apply potassium fertilizers.

Table 3.10: Soil NPK Sensor Specification

Sr. no.	Parameters	Range
1.	Power supply	5-30VDC
2.	Maximum power consumption	<0.15W
3.	Operating temperature	-40~80 ^{0}C
4.	NPK parameters	Range: 0-1999 mg/kg(mg/L) Resolution:1 mg/kg(mg/L) Precision: +-2%FS
5.	Response time	<1S
6.	Protection grade	IP68
7.	Probe material	Black flame-retardant epoxy resin

8.	Default cable length	2 meters, cable length can be customized
9.	Dimension	45*15*123mm
10.	Output signal	RS485/4-20ma/0-5V/0-10V

3.2.13 DS18B20

DS18B20 is 1-wire interface temperature sensor manufactured by Dallas semiconductor corp. The unique 1-wire interface requires only one digital pin for two way communication with a microcontroller. The core functionality of the DS18B20 is its direct-to-digital temperature sensor. The resolution of the temperature sensor is user configurable to 9,10,11 or12 bits corresponding to increments of 0.5℃ 0.25 ℃, 0.125℃ and 0.0625℃ respectively.

One wire temperature sensors like the DS18B20 are devices that can measure temperature with a minimal amount of hardware and wiring. These sensors use a digital protocol to send accurate temperature reading directly to your development board without the need of an analog to digital converter or other extra hardware. This sensor can measure temperature between temperature ranges of -55 ℃ to +125 ℃ and is accurate to +- 0.5℃, over the range of -10℃ to +85℃.

This sealed digital temperature probe let you precisely measure temperature in wet environments with a simple one wire interface. The DS18B20 provides 9 to 12 bits temperature readings over a one wire interface, so that only one wire needs to be connected from a central microprocessor.

Fig 3.14: DS18B20

The Benefits and features of DS18B20 are as given below:

1. Unique one wire interface requires only one port pin for communication.
2. Simplifies distributed temperature sensing.

Application with multi drop capability each devices has a unique 64 bits serial code stored in one on board ROM.

Connection of DS18B20 with arduino UNO

1. Connect the ground pin of the sensor to the ground.
2. Connect the VCC pin of the sensor to the 5volt supply.
3. Connect the signal pin of the sensor to the 5volt through a 4.7kohm resistor and also connect this signal pin to the digital pin number 12 of Arduino.

CHAPTER-4

STUDY AREA AND CROP SELECTION

4.1 Information of Study Area

Under this project, an area of 5000 square feet located in Atarra Tehsil of Banda district has been taken for the development of proposed IoT based agriculture monitoring system as shown in Figure4.1. Banda district is one of the Eastern most district of Bundelkhand, Uttar Pradesh state in northen India. It is a part of Chitrakoot division.
Its geographic location is:

Latitude – 24^{o}58’29” N to 25^{0}54’43” N
Longitude – 80^{o}06’38” E to 81^{0}02’06” E

The total geographical area is 4456.802 Km square and the altitude varies between 3 to 427m. It extends around 104.60 km from north to south and around 94.50 km from west to east. There are four Tehsil namely Banda, Naraini, Baberu, Palani and Atarra. It consists of eight blocks Badokhar – Khurd, Pailani, Jaspura, Tinwari, Naraini, Mahua, Baberu, Bisanda and Kamasin.

The Yamuna River departed from Fatehpur district and Banda distric and it flows in the direction from west to east bordering Banda district. The confluence of Ken river and Yamuna river is at Chilla in north direction. River Baghain also depart Banda district from Chitrakoot district in south east. Our study area for the project includes the area of Naraini and Atarra region of Banda district.

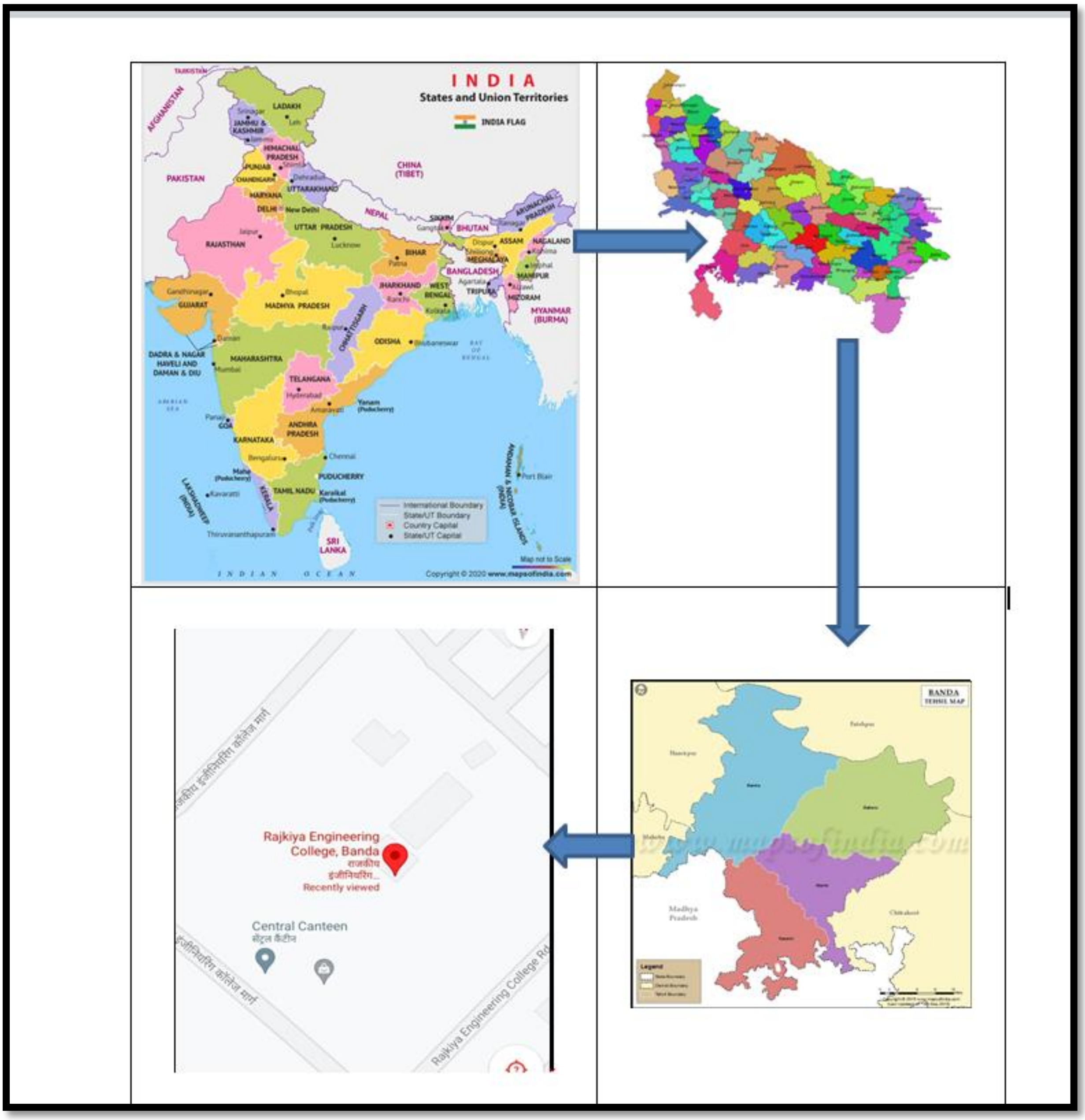


Fig. 4.1: Location of Study Area

4.2 Soil and Climatic Conditions

The soils of Banda district broadly falls into two categories:

1. Red soil
2. Black soil

The basic association of soil varies from:

1. Coarse grained reddish brown soil
2. Coarse grained grey to greyish brown soil
3. Two types of clayey loamy black soil

Locally these soils are called as:

1. Rakar (belongs to Alfisol soil order)
2. Parua (belongs to Inceptisol soil order)
3. Kabar(belongs to Vertisol soil order)
4. Mar (belongs to Vertisol soil order)

The soils are slightly acidic to neutral in nature with presence of calcium carbonate and magnesium carbonate granules in lower depth. Most of the soils of Banda district are low in organic matter /carbon content, available nitrogen and phosphorus and medium availability of potassium and sulphur. The status of available micronutrients contents such as Zinc, iron, copper and manganese are ranged from medium to high value. Mar is Bundelkhand most prized soil, wheat; gram, lentil, pea, flax and mustard etc. are successfully cropped on it under rain fed condition. This soil is relatively high organic matter content, very good water holding capacity and hence can be cropped without use of fertilizers .

The climate of Bundelkhand region including Banda district is semi added in characteristic it is typically monsonic with the year devisable into three seasons namely rainy \ Kharif (Mid june to and of October), winter\ Rabi (Mid October to Mid Feb) and summer \ Zaid (Mid Feb to Mid June) the average rainfall receive in this region is 900 mm of which more than 80% occur during July to September. The distribution of rainfall is also erratic. The annual temperature is uniformly high. The summer, rainy and winter temperature vary 30-44 ℃, 20-24 ℃ and 14-21℃ respectively. The May and June are the hottest months and sometimes temperature crosses 45℃ and reaches up to 50℃. The minimal temperature falls around 2°C during December-January. Hot breezes locally known as loo are commonly experienced during summer season.

4.3 Major concerns of the Area

The various challenges of Bundelkhand region are discussed below in detail:

4.3.1 Barren Land

The area which is not under any agriculture use and has sparse vegetation and stunted growth of trees called barren land. The area is no futile use and is totally a waste land .The like Jaspura, Tindwari, Badokhar khurd, Baberu, Mahuva and Naraini of Banda district have more than 5% barren land. The main reason for land being barren is unavailability of water as the rainfall in the area is very less thus making the land infertile.

4.3.2 Forest

In Banda district forest is found only 1.9% area which varies from one block to another blocks Tindwari, Mahuva and Naraini are the blocks where 2.48%, 2.58%and 6.61% area is found under forest covered besides this all the block have less than 1% forest covered besides this all the block have less than 1% forest cover land. Mainly in southern part of the district where some ranges of Vindhyan mountain range passes that is why some patches of forest found there.

4.3.3 Rainfall

The climate of Banda district in summer is mostly rainier than the winter. **G**enerally the winters are drier and the precipitation here is about 959mm. November is the driest month. The precipitation in this month goes down up to 3mm in 0.1 inch of land July is the month which receives the greatest amount of precipitation with an average of about 305mm in 12 inches of land.

The month with the highest relative humidity is August (79.88%) and the lowest relative humidity is in month of April (25.54%). Due to low amount of precipitation received by Banda district makes it driest, the moisture content falls down thus making it less suitable for agriculture hence the crop grown in this area are those crops which require less amount of water for agriculture as the external source of water is not easily available.

4.3.4 Waste land

The land resultant of the terrain deformation due to water erosion which occurs widely in the area associated with stream courses. Gullies are formed as a result of localized surface run-off affecting the unconsolidated material resulting in the formation of perceptible channels causing undulating terrain. After some time this land convert into degraded land. In Banda district about 1.75% area found in this type of land, which is mostly found in the blocks associated with river courses in Baberu where about 12.0% area found independently in this land. Jaspura, Tindwari, Badokhar khurd and kamasin blocks are falls 0.75, 0.90, 0.38, 0.40 percentage areas in these categories respectively.

4.4 Application of smart agriculture

Smart agriculture has various applications in today world. Some of them are as follows:

4.4.1 Water management

By 2050 the world’s population will reach 9.1 billion, a 50% increase compared to 2000. Agriculture must provide this increase against the decreasing availability of and competition for land and water from other uses, whether non-food crop, urbanization or industrial development. Most of the crop land is in fact rain fed and this is where remains the largest yield gap in crop productivity among the different Regions of the World.

According to the comprehensive assessment on water management in agriculture (2007), improving rain fed farming could double or quadruple yield. One main reason why yield gaps exist is that farmers do not have sufficient economic incentives to adopt yield enhancing seeds or cropping techniques. Other reasons include lack of access to information, extension services and technical skills. Poor infrastructure, weak institutions and discouraging farm policies can also create huge obstacles to the adoption of improved technologies at farm-level. Other factors can be that available technologies have not been adapted to local conditions.

Solutions lie with public sector investments in infrastructure and institutions, and sound policies to stimulate adoption of technologies that reduce costs as well as improving productivity, thus increasing agricultural incomes. Changes in crop management techniques can also help closing yield gaps. Plant breeding plays an important role in closing yield gaps by adapting varieties to local conditions and by making them more resilient to biotic (e.g. insects, diseases, viruses) and abiotic stresses. The first step is to target water as without water people face crop failure and hunger.

4.4.2 Crop Monitoring

a) Monitoring thermal radiation

This is useful in determining crop water stress since most plant leaves temperature is strongly mediated by water availability in the soil and their effect on crop evapotranspiration.

b) Evaluating Power plant stress

Remote sensors determine whether the plants are meeting inspirational demands of the atmosphere and reducing plant water status from that measurement.

c) Measuring salinity stress

Salts in soils and water are key factors in producing many plants; thus, remote sensors identify soils that are contaminated by detecting changes in spectral properties of crops growing in affected areas.

d) Nutrient Management

Managing nutrients efficiently is a challenge to production in agriculture. However, Remote sensors can detect the nutrient deficiencies early, avoiding yield and quality loss.

e) Monitoring soil properties

Remote sensors can display more soil features that are crucial in the soil management of crops.

f) Disease management

Remote sensors can detect crop diseases and assess their impact on crop production.

g) Assessment of crop condition

Changes in a plant may occur due to stress that results in changes in the spectral reflectance characteristics. Monitoring a crop at regular intervals during its growth cycle is necessary so that appropriate measures may be taken and a formation on probable loss of production.

CHAPTER -5

WORK METHODOLOGY

5.1 Project Objectives

1. To collect the information from the Agriculture field for soil monitoring. (Soil moisture and Soil pH).
2. To collect the information such as Humidity Measure, temperature Measurement from the Agriculture field for environmental condition monitoring.
3. To develop a system for monitoring the requirement of fertilizers and water in various crops such as tomato, green pea and banana etc.

5.2 Scope

Smart farming based on IOT technologies enables growers and farmers to reduce waste and enhance productivity ranging from the quantity of fertilizer utilised to the number of journeys the farm vehicles have made, and enabling efficient utilization of resources such as water, electricity, etc. According to a new market intelligence report by BIS research, the global smart farming market is expected, to reach $23.14 billionsby2022.

Wireless Sensor Networks (WSNs), Internet of things (IoT) and aerial mapping are nowadays being used very much in agriculture. The challenge of joining those technologies requires a new and smart wireless network topology for devices communication. Problems like scalability and manageability are important challenges when there are many devices. The field parameters, the index vegetation (estimated using aerial images) and the irrigation events, such as flow level, pressure level or wind speed, are periodically sampled. Data is processed in a smart cloud service based on the Drools Guvnor (a Business Rules Manager). The developed multimedia platform can be controlled remotely by a mobile phone.

5.3 Methodology

The basic building blocks of an IoT system are sensors, processors and applications. So the block diagram below is the proposed model of our project which shows the interconnection of these blocks. The sensors are interfaced with microcontroller and data from the sensor is displayed on the mobile app of the user. Mobile app provides an access to the continuous data from sensors and accordingly helps farmer to take action to fulfil the requirements of the soil and crop.

First assemble all NODE MCU components

⇩

Integration of NODE MCU component

⇩

Deployed in agriculture field in campus

⇩

Send, measured data on cloud

⇩

Remedial actions taken as per data

⇩

End

Fig 5.1: Process of Node MCU

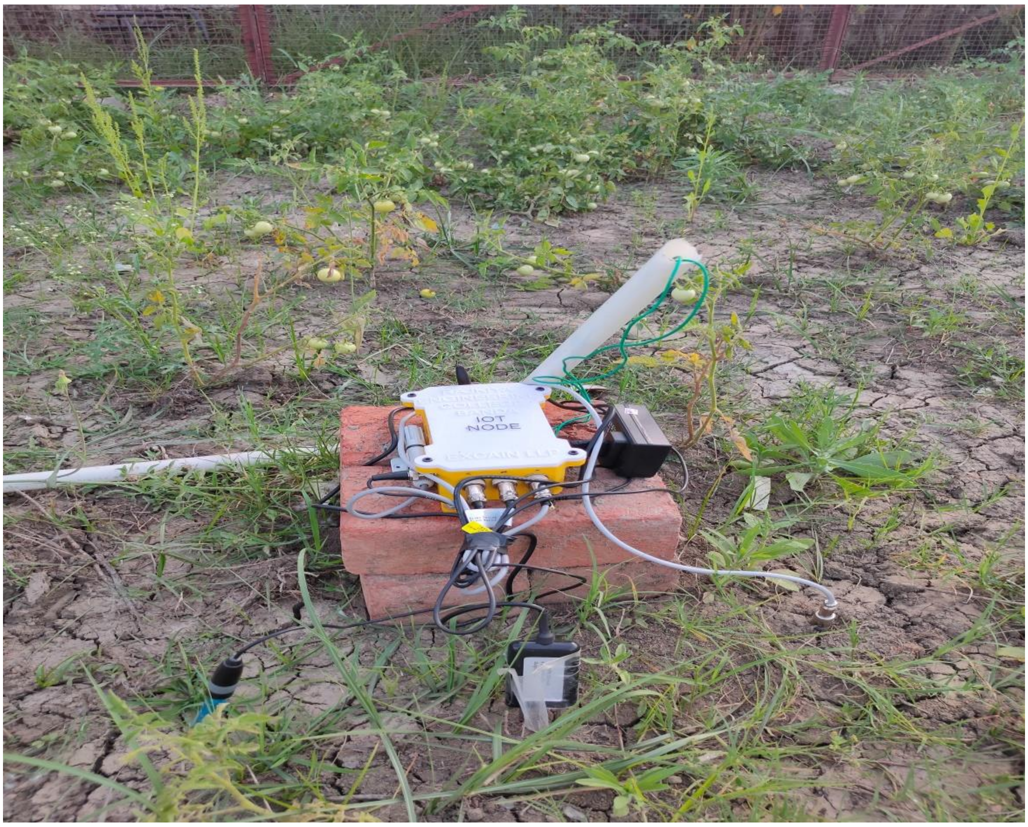


Fig 5.2 Block diagram of proposed work

In our project, various steps have been implemented which includes plantation of five different crops in the field, assembling of the sensors and deployment of the sensor. Sensors collect data of five different crops and sends data to cloud computing/ website through wireless protocols. Now this whole process is connected to ESP8266WiFi module is a self-contained with integrated TCP/IP protocol stack that can give any microcontroller access to your WiFi network.

Now this whole data is collected is used and accessed through internet and we display or use it through application like PC or Mobile web .After that it compares the collected data with the standard data through wireless protocol and checks the deficiency. Now, the farmers can add the supplements (pesticides, fertilizers, insecticides, nitrogen, phosphorous, potassium) to remove the deficiency. This will help in increase of total production of crops

Fig 5.3: Pea Planting

CHAPTER – 6

RESULTS AND DISCUSSIONS

Firstly, we have integrated NODE MCU for IoT based smart agriculture monitoring for which we have assembled various sensors. The setup contains microcontroller i.e. Arduino UNO and the sensors which are connected through it. The Arduino UNO gives base for live streaming of temperature, humidity, soil moisture and soil PH and sending the sensor information to the server using ESP8266 WiFi module and also the data of these sensors are send to the mobile app or PC. The sensors are interface with the microcontroller (Arduino UNO) and are given power supply.

Value from the sensors is read by Arduino UNO and this microcontroller sends the information to the cloud server. When the value of the moisture of the soil reaches below a certain standard value which results in display required water and whenever the moisture values reaches the standard data results in display required soil weeding. When the value of the soil temperature reaches below certain standard value it results in display of requirement of light irrigation and if the value reaches the standard value it will result in required compost.

We have compared the collected data with the standard data and identified the defects deficiency like Nitrogen, Phosphorous and Potassium deficiency. If there is any defects and deficiency in the crops it will send notification on the respected mobile and PC. After getting the notification the farmers can add supplements (fertilizers, urea, nitrogen, phosphorous, potassium) can get high yield variety of crops qualitatively and quantitatively. This system helps the farmer to increase the average crop yield production and plant quality through smart farming.

Banda is one of the challenging districts of India for practicing agriculture. The main reason for this soil, climatic conditions and precipitation received. The land here is barren and rocky. We have collected the sample of soil and data of atmospheric conditions to study the area for our project. We have further given the description of soil and climatic conditions below.

Table 6.1: Comparison of Sensor Data with Standard Value for Tomato crop

Sr. No.	Parameters	Standard Value	Comparison Sensor Data With Standard Value	Display Output
1.	Temperature	21-24°C	1. Sensor output data <21°C 2. 21°C< Sensor output data <24°C 3. Sensor output data >24°C	Required Light Irrigation OK Required Compost
2.	Humidity	80-90%	1. Sensor output data < 80% 2. 80% < Sensor output data < 90% 3. Sensor output data >90%	Required Insecticide Ok Required Water Discharge
3.	Soil Moisture	65-75%	1. Sensor output data <65% 2. 65% < Sensor output data < 75% 3. Sensor output data > 75%	Required Soil Weeding Ok Required Water
4.	pH Value	6.2-6.8	1. Sensor output data < 6.2 2. 6.2 < Sensor output data < 6.8 3. Sensor output data > 6.8	Required Oxide Ok Required Gypsum
5.	Rain	Low Or High	1.If Low 2.If High	No Rain Rain

The table 6.2 show some crops parameters with Standard Value. These are parameter soil parameter (soil moisture and pH value) and environment parameter (temperature and humidity).

Table 6.2: Standard Value

Sr. No.	Crop	Temperature	Humidity	Soil Moisture	pH value
1.	Tomato	21℃ to 24℃	80% to 90%	65% to 75%	6.2 to 6.8
2.	Egg Plant	15℃to 32℃	85% to 95%	70% to 75%	5.5 to 6.5
3.	Banana	25℃ to 30℃	85% to 95%	60% to 80%	6.5 to 7.5
4.	Green Peas	10℃ to 30℃	90% to 98%	18% to 20%	6 to 6.8
5.	Green Chilli	22℃ to 25℃	85% to 95%	60% to 75%	6 to 7.5

Table 6.3: Real Values before adding any supplement

Sr. No.	Crop	Air Temperature (in°C)	Air Humidity (in%)	Soil Temperature (in °C)	Soil Moisture (in%)	pH value
1.	Tomato	37.75	23.29	40.81	56	7.2
2.	Egg Plant	37.75	27.02	40.88	60	7.1
3.	Banana	37.75	25.04	40.9	65	7.3
4.	Green pea	37.75	25	40.01	62	7.1
5.	Green Chilli	37.75	27	40.03	59	7.4

6.1 Ways to fix deficient contents in soil

We have collected the data and compared that data with the standard value as shown in the table 6.4. As per requirement, we can add supplement to increase crop productivity. As to decrease pH for Tomato crop to make it more acidic, we can add acidifying fertilizers (limestone and phosphoric acid) and lime juice to it or we can add an inch or two (2.5-5cm) of peat to the topsoil in and around plants, or during planting. For another quick fix, water plants several times with a solution of 2 tablespoons vinegar to a gallon water. This is a great way to adjust pH in container plants. To make soil more moisten as it very dry for Banda district we can water plants regularly in frequent intervals of time. To reduce soil temperature we can water plants regularly which make the soil moisten and hence soil moisture is increased.

Table 6.4: Real Values after adding supplement

Sr. No.	Crop	Air Temperature (in°C)	Air Humidity (in%)	Soil Temperature (in°C)	Soil Moisture (in%)	pH value
1.	Tomato	37.75	23.29	27 C	70	6.5
2.	Egg plant	37.75	27.02	30 C	69	6
3.	Gram	37.75	25.04	30 C	65	7.4
4.	Green pea	37.75	25	28 C	18	7
5.	Green Chilli	37.75	27	30 C	68	7

6.2 Soil condition of Banda district during summer

The soil of Banda district broadly falls into two categories:

1. Red soil
2. Black soil

The basic association of soil varies from coarse grained radish brown soil to coarse grey to greyish brown soil. The climate of Bundelkhand region including Banda district is semi-arid in characteristics. The distribution of rainfall is also erratic.

6.2.1 Soil Temperature

The soil temperature of Bundelkhand region including Banda district has high temperature. The temperature ranges from 38°C to 55°C. We need to water plants regularly to grow effective crop. The maximum soil temperature recorded is 44°C which is around 2PM. The minimum temperature recorded is 30°C which is around 12AM. The average soil temperature throughout the day is around 40.81°C.

The graph shown Figure 6.1 is of summer basically of May month for soil temperature. We have recorded the data of 13 May 2022 and timing is around 12AM to 12PM.

Date: 13 May 2022

Timing: 12AM to 12PM

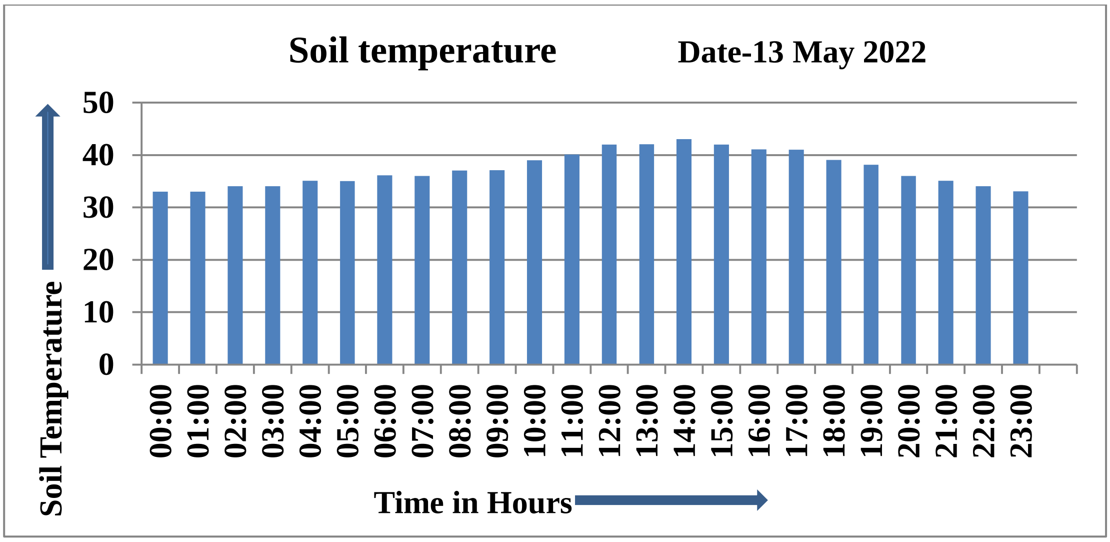


Fig 6.1: Hourly distribution of Soil Temperature during summer

6.2.2 Soil Moisture

The soil moisture of Bundelkhand region including Banda district has low humidity. The relative humidity of the district ranges from 56% to 77%. We need to water plants regularly to increase moisture in the soil for effective crop growth. The maximum soil humidity is 77% which is around 11PM. The minimum soil humidity is 56% which is around 9AM. The average soil moisture throughout the day is around 63.80%.

The graph shown Figure 6.2 is of summer basically of May month for soil moisture. We have recorded the data of 13 May 2022 and timing is around 12AM to 12PM.

Date: 13 May 2022

Timing: 12AM to 12PM

Before watering plant

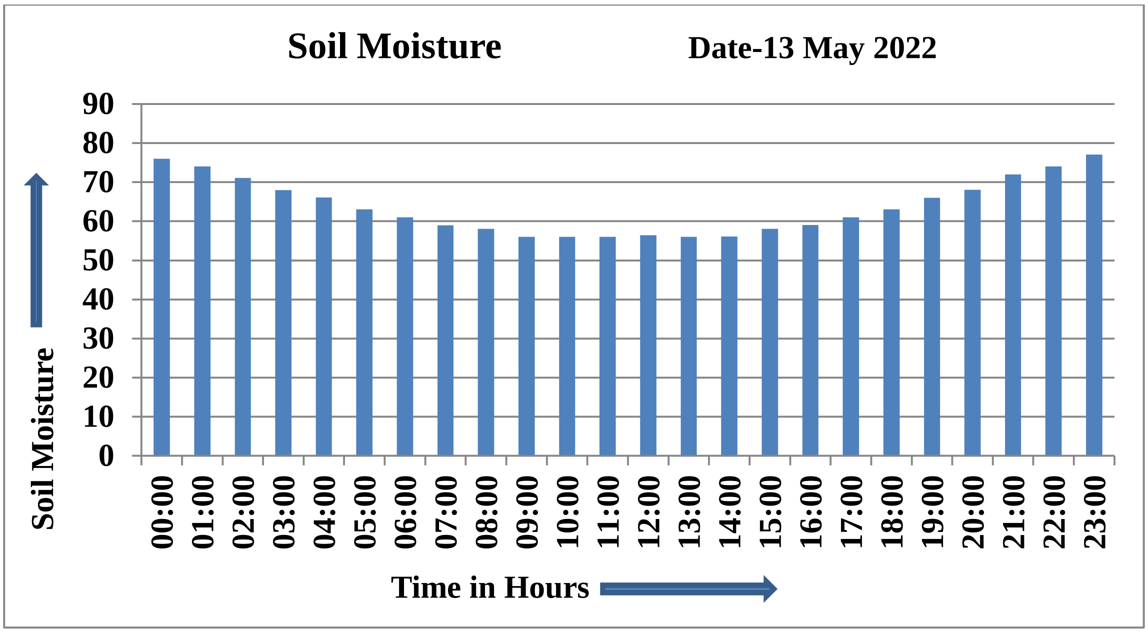


Fig 6.2: Hourly distribution of Soil Moisture of summer before watering plants

The maximum soil moisture after watering plants is 97% which is around 12AM. The minimum soil moisture after watering plants is 80% which is around 12PM. The average soil moisture throughout the day is around 89.04%.

The graph shown Figure 6.3 is of summer basically of May month for soil moisture. We have recorded the data of 14 May 2022 and timing is around 12AM to 12PM.

Date: 14 May 2022

Timing: 12AM to 12PM

After watering plants

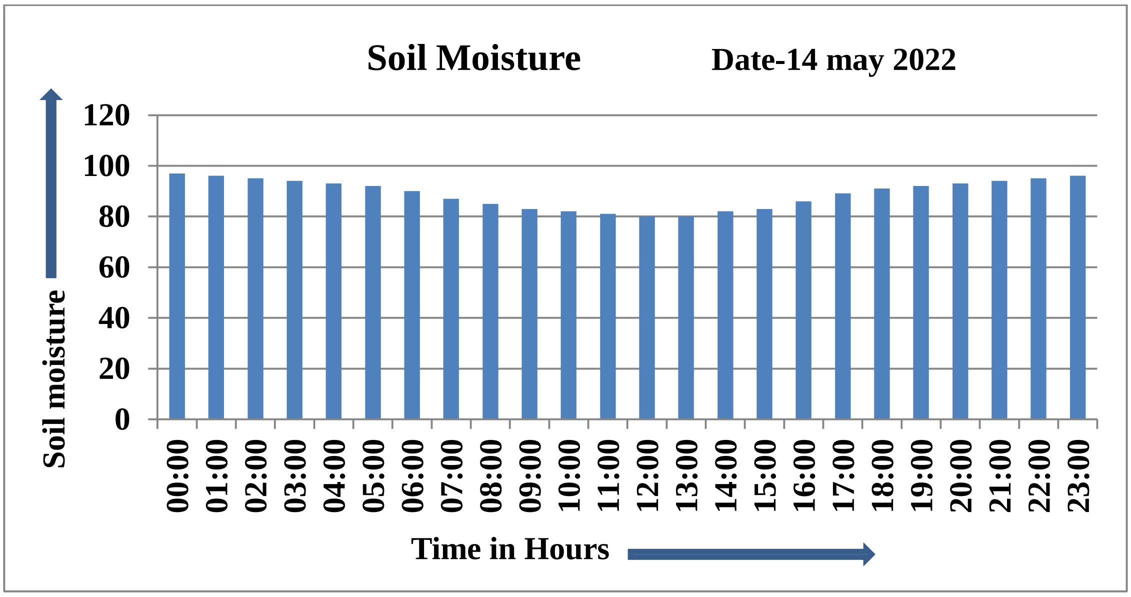


Fig 6.3: Hourly temperature distribution of Soil Moisture during summer

6.2.3 Air Temperature

The air temperature of Bundelkhand region including Banda district is generally dry and semiarid. The air temperature of the district ranges from 30℃ to 47℃. The maximum air temperature is 47℃ which is around 2PM. The minimum air temperature is 30℃ which is around 12AM. The average air temperature throughout the day is around 37.75℃.

The graph shown Figure 6.4 is of summer basically of May month for air temperature. We have recorded the data of 13 May 2022 and timing is around 12AM to 12PM.

Date: 13 May 2022

Timing: 12AM to 12PM

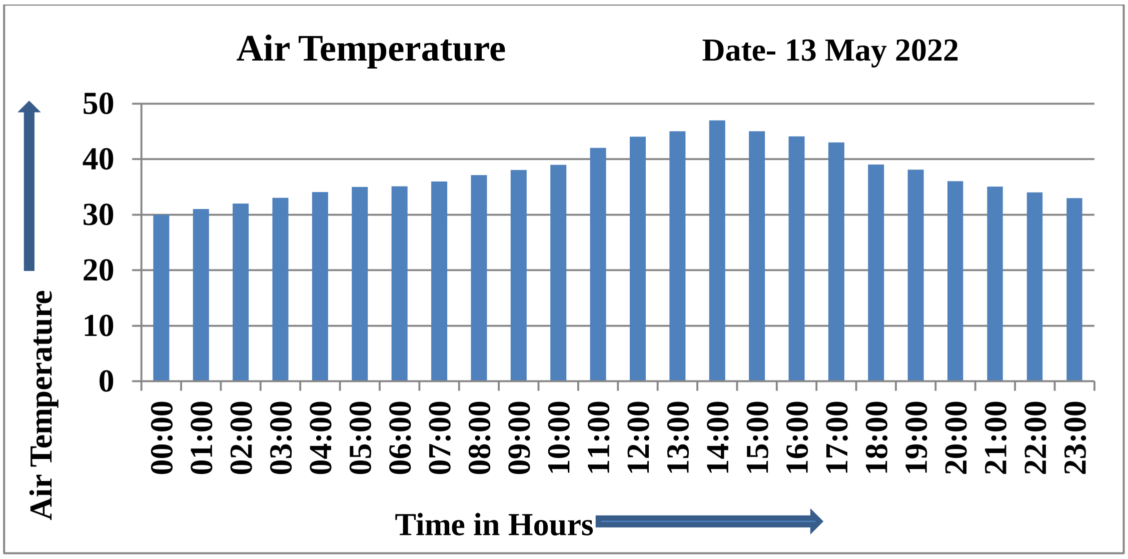


Fig 6.4: Hourly distribution of Air Temperature during summer

6.2.4 Soil pH

The pH of Bundelkhand region including Banda district is slightly acidic to neutral in nature. pH concentration of all the soil samples varied from 6.38 to 7.8. We can increase pH by adding alkaline substance like sodium bicarbonate and decrease pH by adding lime juice.

The graph shown Figure 6.5 is of summer basically of May month for soil moisture. We have recorded the data of 13 May 2022 and timing is around 12AM to 12PM.

Date: 13 May 2022

Timing: 12AM to 12PM

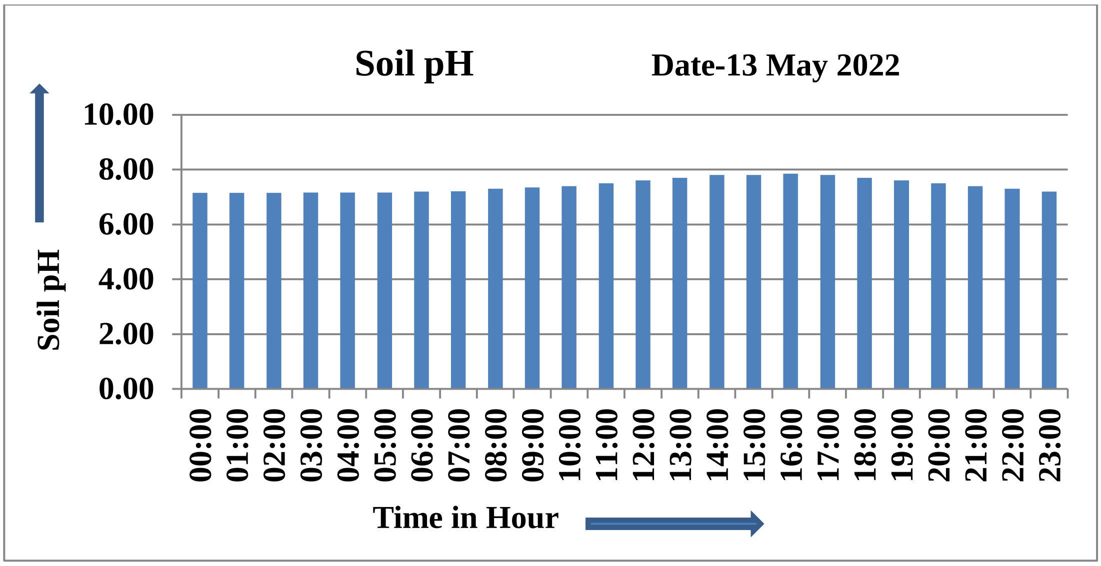


Fig 6.5: Hourly temperature distribution of Soil pH during summer

6.2.5 Air Humidity

The air humidity of Bundelkhand region including Banda district is generally less moist. The air humidity of the district ranges from 7% to 40%. The maximum air humidity is 41% which is around 3AM. The minimum air humidity is 6% which is around 3PM. The average air humidity throughout the day is around 23.29%.

The graph shown Figure 6.6 is of summer basically of May month for air humidity. We have recorded the data of 13 May 2022 and timing is around 12AM to 12PM.

Date: 13 May 2022

Timing: 12AM to 12PM

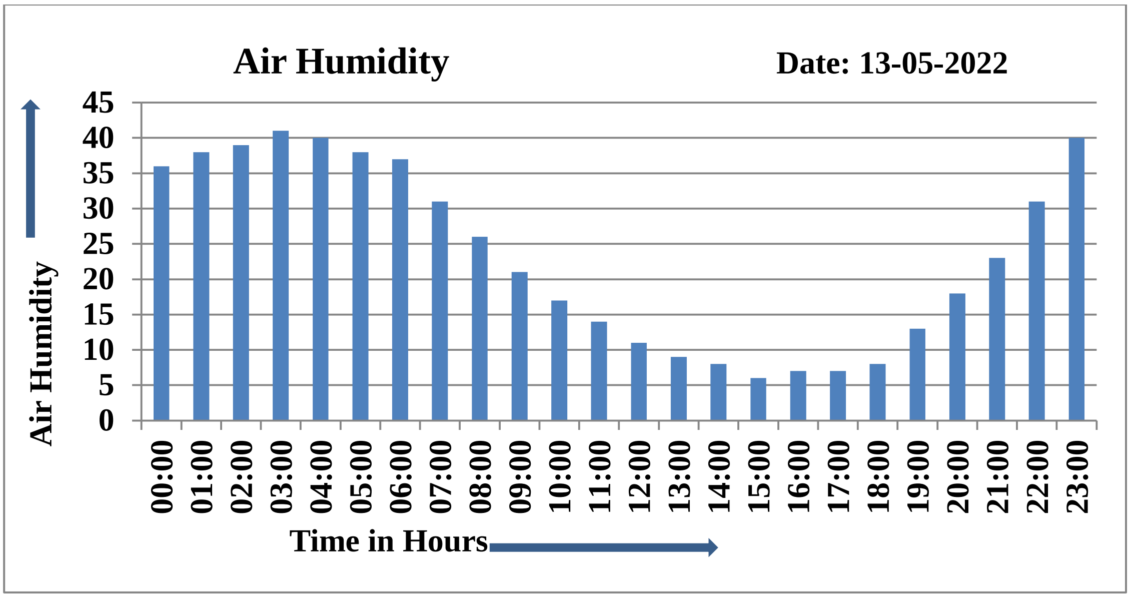


Fig 6.6: Hourly distribution of Atmospheric Humidity during summer

6.3 Soil condition of Banda district during winter

In Banda, the temperature falls very low during winter. The winter last for 2.7 months from mid-November to mid-February with and average daily high temperature below 81 F. The coldest month in the Banda district is January.

6.3.1 Soil Temperature

The soil temperature during winter in Banda district is generally cold and chilled. The soil temperature generally is very less. The maximum soil temperature recorded during winter is 20.98℃ which is around 2PM. The minimum soil temperature recorded during winter is 6.05℃ which is around 4AM. The average soil temperature throughout the day is 14.09℃.

The graph shown Figure 6.7 is of winter basically of January month for soil temperature. We have recorded the data of 08 Jan 2022 and timing is around 12AM to 12PM.

Date: 08 January 2022
Timing: 12AM to 12PM

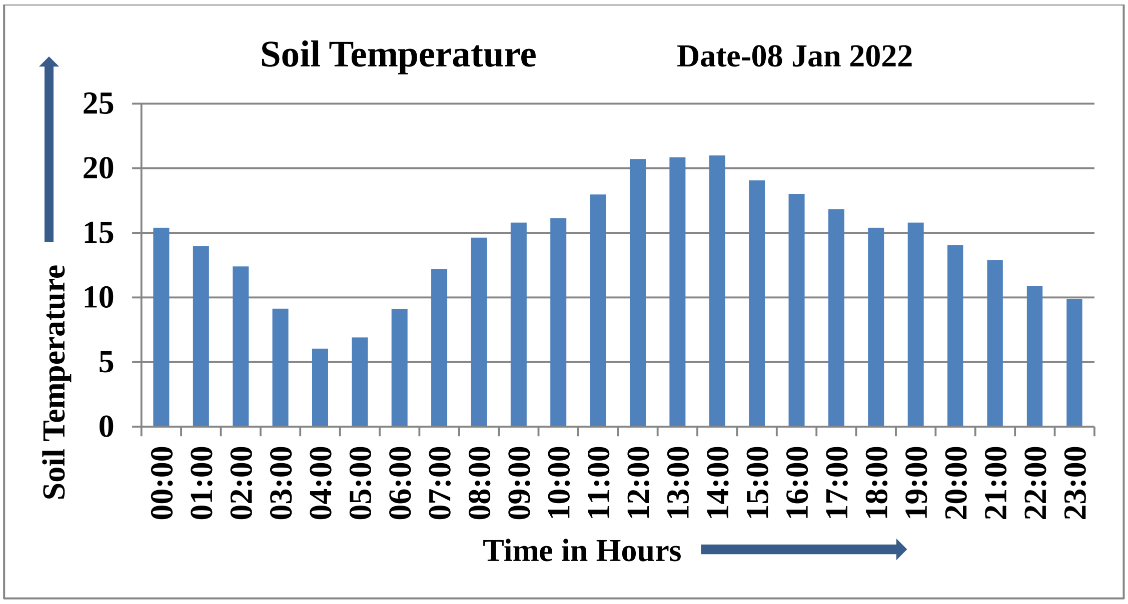


Fig 6.7: Hourly distribution of Soil Temperature during winter

6.3.2 Soil Moisture

The soil moisture of Bundelkhand region including Banda district has low humidity. The relative humidity of the district ranges from 70% to 92%. We need to water plants regularly to increase moisture in the soil for effective crop growth. The maximum soil moisture is 91.09% which is around 2PM. The minimum soil moisture is 77% which is around 11AM. The average soil moisture throughout the day is around 80.37%.

The graph shown Figure 6.8 is of winter basically of January month for soil moisture. We have recorded the data of 08 Jan 2022 and timing is around 12AM to 12PM.

Date: 08 January 2022

Timing: 12am to 12pm

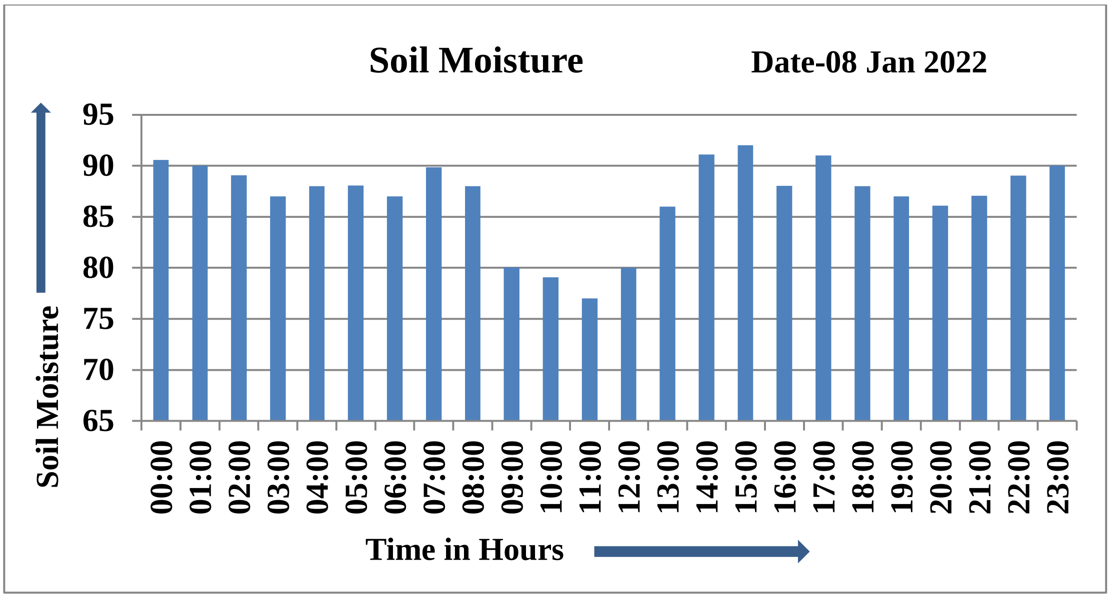


Fig 6.8: Hourly distribution of Soil Moisture during winter

6.3.3 Air Temperature

The air temperature of Bundelkhand region including Banda district is generally dry and semi-arid. The air temperature of the district ranges from 5℃ to 24℃. The maximum air temperature is 23.85℃ which is around 1PM. The minimum air temperature is 6.05℃ which is around 4AM. The average air temperature throughout the day is around 15.29℃.

The graph shown Figure 6.9 is of winter basically of January month for air temperature. We have recorded the data of 08 Jan 2022 and timing is around 12AM to 12PM.

Date: 08 January 2022

Timing: 12AM to 12PM

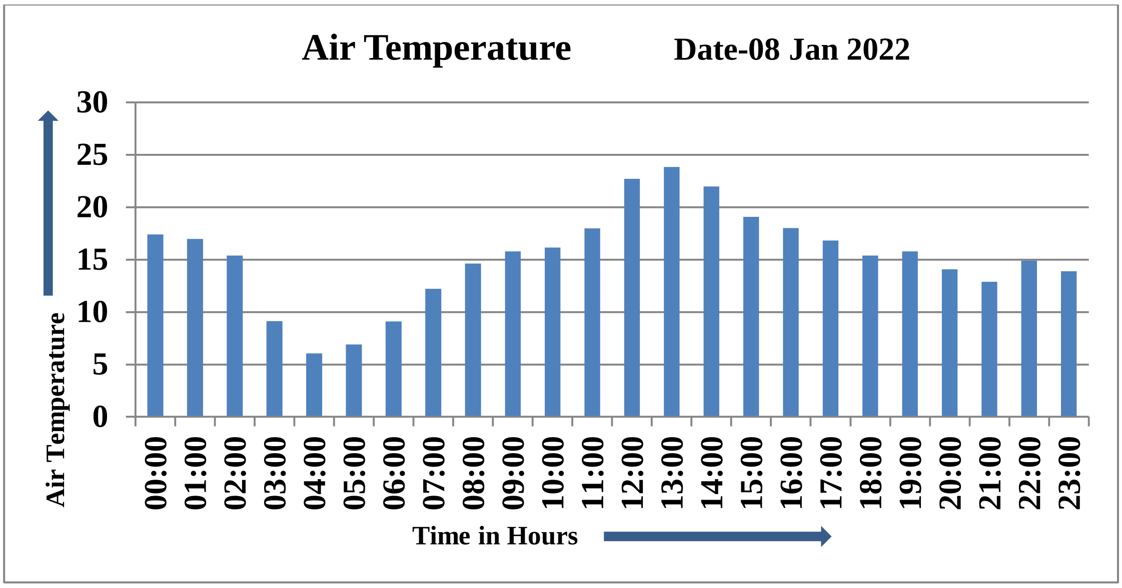


Fig 6.9: Hourly distribution of Air Temperature during winter

6.3.4 Soil pH

The pH of Bundelkhand region including Banda district is slightly acidic to neutral in nature. pH concentration of all the soil samples varied from 10 to 13. We can increase pH by adding alkaine substance like sodium bicarbonate and decrease pH by adding lime juice.

The graph shown Figure 6.10 is of winter basically of January month for soil pH. We have recorded the data of 08 Jan 2022 and timing is around 12AM to 12PM.

Date: 08 January 2022

Timing: 12AM to 12PM

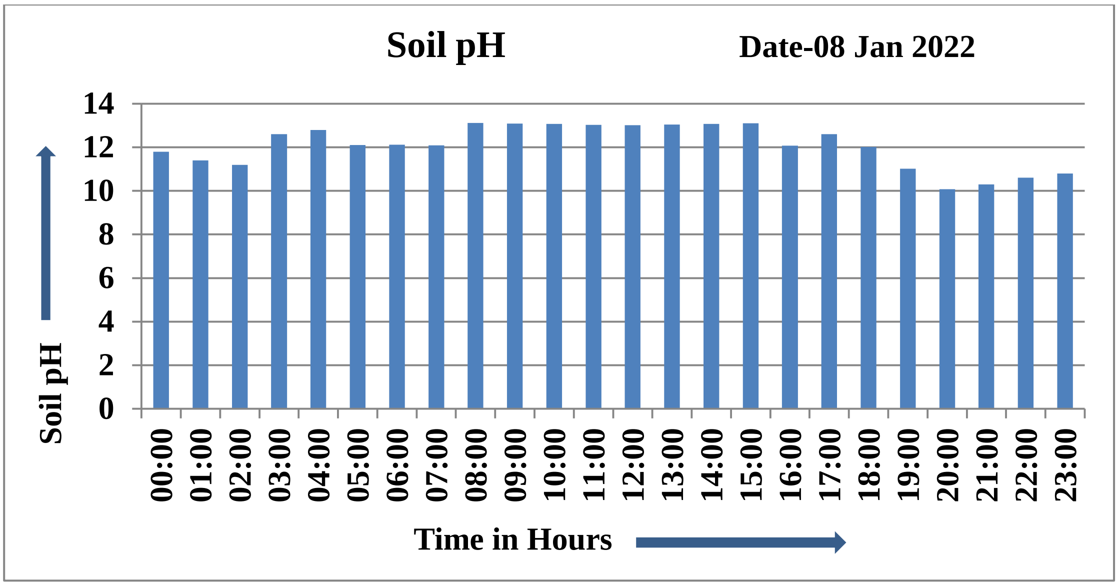


Fig 6.10: Hourly distribution of Soil pH during winter

6.3.5 Air Humidity

The air humidity of Bundelkhand region including Banda district is generally less moist. The air humidity of the district ranges from 80% to 95%. The maximum air humidity is 99% which is around 1AM. The minimum air humidity is 77% which is around 11AM. The average air humidity throughout the day is around 90.97%.

The graph shown Figure 6.11 is of winter basically of January month for air humidity. We have recorded the data of 08 Jan 2022 and timing is around 12AM to 12PM.

Date: 08 January 2022

Timing: 12AM to 12PM

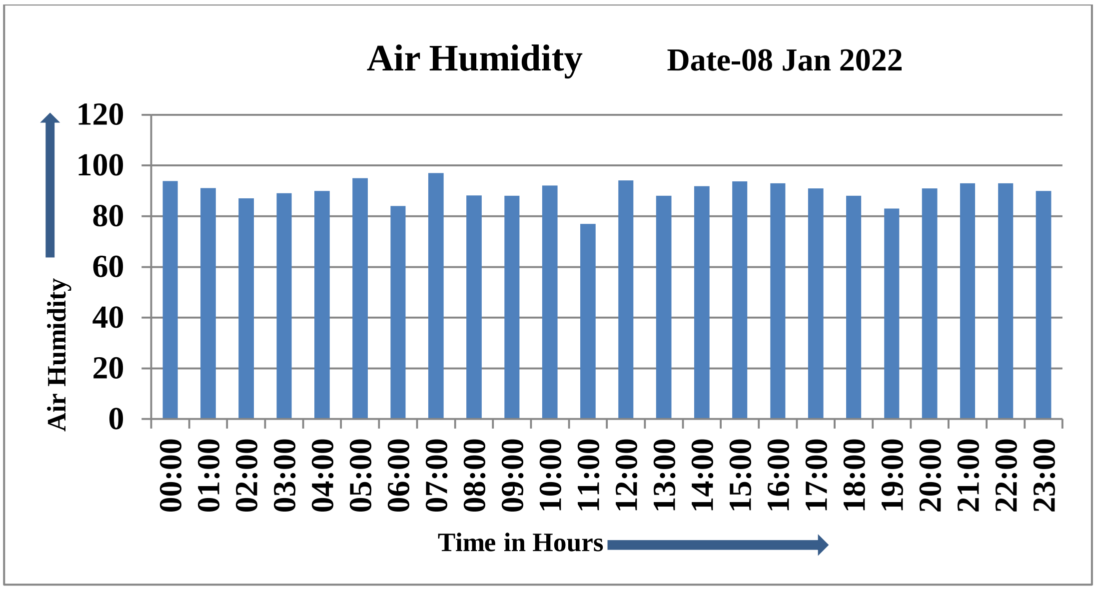


Fig 6.11: Hourly distribution of Air Humidity during winter

6.4 Soil Health Card

Department of agriculture and farmers welfare has provided facility of soil health card which gives nutrients suggestion of various crops. It is an advisory based on the soil nutrients status of a farmers holding. It will show recommendations on dosage of different nutrients. So, we have taken five crops (gram, peas, paddy, wheat and mustard) to compute its required data for effective growth.

Table 6.5: Collected Data of Soil

Sr.No.	Parameters	Collected Data	Unit
1.	pH	7	unit
2.	EC	0.526	dS/m
3.	Organic Matter (OC)	48	%
4.	Available Nitrogen (N)	108	Kg/Ha
5.	Available Phosphorous (P)	18	Kg/Ha
6.	Available Potassium (K)	234	Kg/Ha
7.	Available Sulphur (S)	10.261	ppm
8.	Available Zinc (Zn)	0.726	ppm
9.	Available Boron (B)	0.384	ppm
10.	Available Iron (Fe)	2.25	ppm
11.	Available Manganese (Mn)	0.98	ppm
12.	Available Copper (Co)	0.765	ppm

Soil health card is a government scheme in which government plans to issue soil cards to farmers which will carry crop wise recommendation of nutrients and fertilizers required for the individual farms to help farmers to improve productivity through judicious use of inputs. Therefore, we have analysed the strength and weakness (micronutrients deficiency) of soil suggested method to deal with it. After putting the collected data in the soil health card we have got the recommendation of nutrients of five different crops. The result of five different crops as follows.

Table 6.6: Soil Testing Report

Test Name	Test Value	Unit	Rating	Suggestion (Spray)	Suggestion (Soil)
pH	7		Neutral		
EC	0.53	dS/m	Normal		
Organic Matter (OC)	48	%	Very High		
Sulphur (S)	10.26	ppm	Sufficient		
Zinc (Zn)	0.73	ppm	Sufficient		
Boron (B)	0.38	ppm	Deficient	0.25% Borax	Borax (5-10Kg/Ha)
Iron (Fe)	2.25	ppm	Deficient	1% Ferrous Sulphate (Spray thrice)+ 0.5% lime	Ferrous Sulphate (25-50Kg/Ha) (Soil application is preferred)
Manganese (Mn)	0.98	ppm	Deficient	1% Manganese Sulphate + 0.25% Lime or 0.5% Manganese	Manganese sulphate (10-25Kg/Ha)
Copper (Co)	0.77	ppm	Sufficient		

Table 6.7: Micronutrient Value

Sr. No.	Micronutrient	Critical Limits
1.	Sulphur	10ppm (0.15% $CaCl_2$ extractable sulphur)
2.	Zinc	0.6ppm (DTPA extractable Zn)
3.	Boron	0.5ppm (Hot water soluble Boron)
4.	Iron	4.5ppm (DTPA extractable Fe)
5.	Manganese	2.0ppm (DTPA extractable Mn)
6.	Copper	0.2ppm (DTPA extractable Cu)

The various crops chosen in our project to monitor soil deficiency and to discuss its nutrient recommendation are discussed below in detail. The crops are mustard, paddy, Bengal gram, wheat and pea:

6.4.1 Crop 1

Mustard is one of the main crops of Banda district. It belongs to Oil seeds group of crop. It is basically a Rabi crop which needs irrigation on time.

Crop: Mustard

Crop Group: Oil Seeds

Season: Rabi

Irrigation: Irrigated

The table shown below represents the fertilizer combination which can be added in crop as per required to grow high yield of mustard crop. Fertilizers used Neem coated urea, Single superphosphate and Potassium chloride.

Table 6.8: Fertilizer Combination 1

Sr. No.	Fertilizer Name	Unit	Amount
1.	Neem coated urea	Kg/Ha	195.65
2.	Single Superphosphate (16% P_2O_5 Granulated)	Kg/Ha	281.25
3.	Potassium Chloride (Muriate of potash)	Kg/Ha	50.00

Another fertilizer combination which can be used to grow crop effectively is represented in table below. Fertilizers used Neem coated urea, Diammonium phosphate and Potassium chloride.

Table 6.9: Fertilizer Combination 2

Sr. No.	Fertilizer Name	Unit	Amount
1.	Neem Coated Urea	Kg/Ha	160.08
2.	Diammonium Phosphate (16:44:0)	Kg/Ha	102.27
3.	Potassium Chloride (Muriate of potash)	Kg/Ha	50.00

6.4.2 Crop 2

Bengal gram is one of the main crops of Banda district. It belongs to Pulses group of crop. It basically a rabi crop which needs irrigation on time.

Crop: Bengal Gram (Gram)

Crop Group: Pulses

Season: Rabi

Irrigation: Irrigated

The table shown below represents the fertilizer combination which can be added in crop as per required to grow high yield of Bengal gram. Fertilizers used Neem coated urea, single superphosphate and potassium chloride.

Table 6.10: Fertilizer Combination 1

Sr. No.	Fertilizer Name	Unit	Amount
1.	Neem Coated Urea	Kg/Ha	21.74
2.	Single Superphosphate (16% P2O5 Granulated)	Kg/Ha	312.50
3.	Potassium Chloride (Muriate of potash)	Kg/Ha	0.00

Another fertilizer combination which can be used to grow crop effectively is represented in table below. Fertilizers used Neem coated urea, Diammonium phosphate and Potassium chloride.

Table 6.11: Fertilizer Combination 2

Sr. No.	Fertilizer Name	Unit	Amount
1.	Neem Coated Urea	Kg/Ha	0.00
2.	Diammonium Phosphate (16:44:0)	Kg/Ha	62.50
3.	Potassium Chloride (Muriate of potash)	Kg/Ha	0.00

6.4.3 Crop 3

Paddy is the main crops of Banda district. It belongs to Cereals group of crop. It is basically a Kharif crop which needs irrigation on time.

Crop: Paddy (Dhan)

Crop Group: Cereals

Season: Kharif

Irrigation: Irrigated

The table shown below represents the fertilizer combination which can be added in crop as per required to grow high yield of Paddy crop. Fertilizers used Neem coated urea, single superphosphate and potassium chloride.

Table 6.12: Fertilizer Combination 1

Sr. No.	Fertilizer Name	Unit	Amount
1.	Neem Coated Urea	Kg/Ha	293.48
2.	Single Superphosphate (16% P2O5 Granulated)	Kg/Ha	250.00
3.	Potassium Chloride (Muriate of potash)	Kg/Ha	33.33

Another fertilizer combination which can be used to grow crop effectively is represented in table below. Fertilizers used Neem coated urea, Diammonium phosphate and Potassium chloride.

Table 6.13: Fertilizer Combination 2

Sr. No.	Fertilizer Name	Unit	Amount
1.	Neem Coated Urea	Kg/Ha	261.86
2.	Diammonium Phosphate (16:44:0)	Kg/Ha	90.91
3.	Potassium Chloride (Muriate of potash)	Kg/Ha	33.33

6.4.4 Crop 4

Wheat is one of the main crops of Banda district. It belongs to Cereals group of crop. It is basically a Kharif crop which needs irrigation on time.

Crop: Wheat

Crop Group: Cereals

Season: Kharif

Irrigation: Irrigated

The table shown below represents the fertilizer combination which can be added in crop as per required to grow high yield of wheat crop. Fertilizers used Neem coated urea, single superphosphate and potassium chloride.

Table 6.14: Fertilizer Combination 1

Sr. No.	Fertilizer Name	Unit	Amount
1.	Neem Coated Urea	Kg/Ha	326.09
2.	Single Superphosphate (16% P2O5 Granulated)	Kg/Ha	250.00
3.	Potassium Chloride (Muriate of potash)	Kg/Ha	41.67

Another fertilizer combination which can be used to grow crop effectively is represented in table below. Fertilizers used Neem coated urea, Diammonium phosphate and Potassium chloride.

Table 6.15: Fertilizer Combination 2

Sr. No.	Fertilizer Name	Unit	Amount
1.	Neem Coated Urea	Kg/Ha	294.47
2.	Diammonium Phosphate (16:44:0)	Kg/Ha	90.91
3.	Potassium Chloride (Muriate of potash)	Kg/Ha	41.67

6.4.5 Crop 5

Peas are the main crops of Banda district. It belongs to Cereals group of crop. It is basically a Rabi crop which needs irrigation on time.

Crop: Peas (Dry)

Crop Group: Pulses

Season: Rabi

Irrigation: Rain fed

The table shown below represents the fertilizer combination which can be added in crop as per required to grow high yield of Paddy crop. Fertilizers used Neem coated urea, single superphosphate and potassium chloride.

Table 6.16: Fertilizer Combination 1

Sr.No.	Fertilizer Name	Unit	Amount
1.	Neem Coated Urea	Kg/Ha	21.74
2.	Single Superphosphate (16% P2O5 Granulated)	Kg/Ha	312.50
3.	Potassium Chloride (Muriate of potash)	Kg/Ha	0.00

Another fertilizer combination which can be used to grow crop effectively is represented in table below. Fertilizers used Neem coated urea, Diammonium phosphate and Potassium chloride.

Table 6.17: Fertilizer Combination 2

Sr. No.	Fertilizer Name	Unit	Amount
1.	Neem Coated Urea	Kg/Ha	0.00
2.	Diammonium Phosphate (16:44:0)	Kg/Ha	62.50
3.	Potassium Chloride (Muriate of potash)	Kg/Ha	0.00

6.5 Comparison of NPK with standard data

We have collected the nitrogen, phosphorous and potassium from NPK sensor. Later we have compared that data with the standard data. The table given below shows the comparison of NPK measured data with the standard data.

Table 6.18: Comparison of NPK with standard data

Sr. No.	Parameters	Measured Value (kg/hectare)	Standard Value (kg/hectare)
1.	Nitrogen	108	120
2.	Phosphorous	18	25
3.	Potassium	234	255

CHAPTER 7

CONCLUSION

IoT is used to enhance Smart farming using IoT in our project we are able to predict the soil moisture level and humidity, soil pH, the nutrient content of Nitrogen, Phosphorous, Potassium in soil, so that the irrigation system can be monitored and controlled IoT works in different aspects of farming which improves quality, time, efficiency, water management, crop monitoring, soil management and control of insecticides and pesticides. This reduces human efforts, Simplifies techniques of farming and helps to gain smart farming. Smart agriculture can help to grow the market for farmers with single touch and minimum effort.

To increase productivity of crop we have analysed the strength and weakness (micronutrients deficiency) of soil suggested method to deal with it. We have added nutrients and fertilizers as per requirements in farms to help farmers to improve productivity through judicious use of inputs. The fertilizers are used Neem coated urea, single superphosphate and potassium chloride.

The Smart Agriculture Monitoring System can be used as destiny factors of agriculture. This would be a relief for farmers since it decreases the load of manual efforts. A gadget to screen moisture levels within the soil changed into constructed and the assignment furnishes a possibility to take a look at the prevailing structures, at the side of their features and downsides. Agriculture is one of the most effort-consuming hobbies. The device makes use of statistics from soil moisture sensors to irrigate soil. Similarly, live knowledge (Temperature, Moisture, Humidity and pH value of soil) of farm readings are experimented. The system helps the farmers to increase the average crop yield ratings, and plant quality through smart farming.

FUTURE SCOPE

This project has vast scope in developing the system and making it more users friendly. We can install webcam in the system, photos of the crop can be captured and the data can be sending to the data base. Implementation of speech based option can be done in the system for the people who are less literate and for the people who are not much aware about technology. GPS (Global positioning system) can be integrated to provide specific location of the farmer and more accurate weather reports of agriculture field. We can also implement regional language feature to make it easy to the farmers who are not aware of any other language.

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APPENDICES

```
/*##########################################################CONNECTIONS###########
##############################################

 * NOTE: Do not use Pins: DIGITAL 2,9,10,11,12, and 13 as they are used by LoRa shield.

 * DHT22 :-: Air temperature and humidity

 * DHT22 :: BY DHT Header, Pins - 3.3VDC:RED, GND:BLACK, YELLOW:DIGITAL4

 *          10K resistor from pin DIGITAL4 (data) to pin 3.3VDC (power)

 * CAPACITIVE_SOIL_SENSOR :-: Soil humidity

 * CAPACITIVE_SOIL_SENSOR :: NO HEADER, Pins - 3.3VDC:RED, GND:BLACK,
YELLOW:ANALOG0

 * DS18B20 :-: Soil temperature (thermometer sensor)

 * DS18B20 :: BY OneWire and DallasTemperature Header, Pins - 5VDC:RED, GND:BLACK,
YELLOW:DIGITAL3

 *          4K7 (4.7K) resistor from pin DIGITAL3 (data) to pin 3.3VDC (power)

 */


// ---------------------------------------------------------------------------------------------------------------------


// send next/each value after/with delay of 1 second

int const DELAY4=5000;                    // milliseconds (NOTE: Can't be less than 1000
milliseconds)

char const NODENAME='3';                  // node name


// ---------------------------------------------------------------------------------------------------------------------


// load header files

#include<DHT.h>                           // for AM2105A (Temperature and Humidity)

#include<OneWire.h>                       // for DS18B20 soil thermometer sensor (soil temperature)

#include<DallasTemperature.h>             // for DS18B20 soil thermometer sensor (soil
temperature)
```

```
#include<RH_RF95.h>                              // for LoRa sending and receiving


// -----------------------------------------------------------------------------------------------------------------


// PIN DEFINATIONS

#define DHT22PIN 4                               // of DHT22 sensor

#define SOILCAPPIN A0                            // of capacitive soil sensor

#define SOILTHMPIN 3                             // of soil thermometer sensor


// -----------------------------------------------------------------------------------------------------------------
-


// other definations

#define DHT22TYPE DHT22                          // DHT sensor type


// -----------------------------------------------------------------------------------------------------------------
-


// Initialize sensor

DHT DHT22SENSOR(DHT22PIN,DHT22TYPE);             // setup AM2105A (DHT22) sensor

// Setup a oneWire instance to communicate with any One Wire devices (not just Maxim/Dallas
temperature ICs)

OneWire oneWire(SOILTHMPIN);                     // for soil thermometer sensor (soil temperature)

// Pass our oneWire reference to Dallas Temperature.

DallasTemperature DS18B20(&oneWire);             // for soil thermometer sensor (soil temperature)

// make LoRa connection object

RH_RF95 LoRaConnection;                          // for send data by LoRa module


// -----------------------------------------------------------------------------------------------------------------
```

```
// variable to controll detailed printing on serial monitor
bool detailed=false;
// variables to store sensor values ------------------------------
// DHT22 sensor
int DHT22_ARRAY_SIZE=5;
float DHT22_VALUES[]={-1.0,-1.0,-1.0,-1.0,-1.0};    // to store humidity, temperature(°C),
temperature(°F), heat index (°C and °F)
// set values for capacitive soil sensor at pin A0 ---------------
const int max_CAPACITOR_VALUE=600;                // maximum capacitor value (3.3VDC) (in dry
air)
const int min_CAPACITOR_VALUE=240;                // minimum capacitor value (3.3VDC) (in
water)
int CURRENT_CAPACITOR_VALUE=0;                    // capacitor value (soil humidity)
// soil thermometer sensor (soil temperature) --------------------
float CURRENT_SOIL_TEM_VALUE=0;                   // soil temperature value

// ---------------------------------------------------------------------------------------------------------------
-

// setup function
void setup() {
  // open serial port, set the baud rate to 9600 bps
  Serial.begin(9600);
  // start communication with DHT22 temperature and humidity sensor
  DHT22SENSOR.begin();
  // start communication with DS18B20 thermometer sensor
  DS18B20.begin();
  // start connection with LoRa
  while (!LoRaConnection.init()) {
    Serial.println("LoRa initialization failed!");
```

```
    delay(500);
  }
  // Wait a few seconds before starting measurements.
  delay(2000);
  }

// -----------------------------------------------------------------------------------------------------------------------
---


// loop function
void loop(){
  // read temeperature and humidity
  callDHT22(detailed=false);
  // read soil moisture capacitive value by capacitive soil sensor
  callSOILCAP(detailed=false);
  // read soil temeperature by DS18B20
  callDS18B20(detailed=false);
  // make wait for a while before start sending
  delay(500);
  // make send message
  callLoRaSender(detailed=true);
  // make await before next value
  delay(DELAY4-500);
}



// -----------------------------------------------------------------------------------------------------------------------
----
```

```
// function to read temeperature and humidity
float callDHT22(bool detailed){
  // Reading temperature or humidity takes about 250 milliseconds!
  // Sensor readings may also be up to 2 seconds 'old' (its a very slow sensor)
  DHT22_VALUES[0]=DHT22SENSOR.readHumidity();
  // Read temperature as Celsius (the default)
  DHT22_VALUES[1]=DHT22SENSOR.readTemperature();
  // Read temperature as Fahrenheit (isFahrenheit = true)
  DHT22_VALUES[2]=DHT22SENSOR.readTemperature(true);
  // Check if any reads failed and exit early (to try again).
  if (isnan(DHT22_VALUES[0])||isnan(DHT22_VALUES[2])||isnan(DHT22_VALUES[3])){
    // print notification if value fail to read
    Serial.println("Failed to read from DHT22 sensor!");
    // make all values to -1
    DHT22_VALUES[0]=-1;
    DHT22_VALUES[1]=-1;
    DHT22_VALUES[2]=-1;
    DHT22_VALUES[3]=-1;
    DHT22_VALUES[4]=-1;
    // make return that reading failed
    return -1;
  }
  // Compute heat index in Fahrenheit (the default)
DHT22_VALUES[3]=DHT22SENSOR.computeHeatIndex(DHT22_VALUES[2],DHT22_VALUES
[0]);
  // Compute heat index in Celsius (isFahreheit = false)
DHT22_VALUES[4]=DHT22SENSOR.computeHeatIndex(DHT22_VALUES[1],DHT22_VALUES
[0],false);
```

```
  // if value have to be printed on serial monitor
  if (detailed) {
    // make print all values
    Serial.print("Humidity: ");Serial.print(DHT22_VALUES[0]);
    Serial.print("%  Temperature: ");Serial.print(DHT22_VALUES[1]);
    Serial.print("°C ");Serial.print(DHT22_VALUES[2]);Serial.print("°F  Heat index: ");
    Serial.print(DHT22_VALUES[4]);Serial.print("°C
");Serial.print(DHT22_VALUES[3]);Serial.println("°F");
  }
  // make return
  return 0;
}

// function to read soil moisture capacitive value by capacitive soil sensor
float callSOILCAP(bool detailed){
  // read soil moisture capacitive value by capacitive soil sensor

CURRENT_CAPACITOR_VALUE=map(analogRead(SOILCAPPIN),min_CAPACITOR_VALUE,
max_CAPACITOR_VALUE,100,0);
  // if value have to be printed on serial monitor
  if (detailed) {
    // make print soil capacitor (humidity) value values
    Serial.print("Soil capacitor value (Soil humidity):
");Serial.println(CURRENT_CAPACITOR_VALUE);
  }
  // make return
  return 0;
}

// function to read soil temeprature by soil thermometer sensor (soil temperature)
```

```
float callDS18B20(bool detailed){
  // read soil temperature value by DS18B20 thermometer sensor
  DS18B20.requestTemperatures();                    // call for temperature value
  CURRENT_SOIL_TEM_VALUE=DS18B20.getTempCByIndex(0);
  // if value have to be printed on serial monitor
  if (detailed) {
    // make print soil temperature value values
    Serial.print("Soil temperature: ");Serial.println(CURRENT_SOIL_TEM_VALUE);
  }
  // make return
  return 0;
}

// function to send data to LoRa reciver
float callLoRaSender(bool detailed){
  // make string to send to reciver
  String sensorData="Node"+String(NODENAME)+"::";
  // add dht22 all values to data
  sensorData+="H,Tc,Tf,HIc,HIf:";          // to sending humidity, temperature(°C),
temperature(°F), heat index (°C and °F)
  for(int i=0;i<DHT22_ARRAY_SIZE;i++){
    // add data
    sensorData+=String(DHT22_VALUES[i])+",";
  }
  // mark end of the value for dht22
  sensorData+=";";
  // add values for soil Humidity
  sensorData+="SH:"+String(CURRENT_CAPACITOR_VALUE)+";";
  // add values  for soil temperature
```

```
  sensorData+="ST:"+String(CURRENT_SOIL_TEM_VALUE)+";";
  // sending data - convert data to character array
  char dataArray[sensorData.length()+1];
  sensorData.toCharArray(dataArray,sensorData.length()+1);
  // if value have to be printed on serial monitor
  if (detailed) {
    // print array to send
    Serial.print("Sending: "); Serial.println(dataArray);
  }
  // Sending data to reciver
  LoRaConnection.send(dataArray,sizeof(dataArray));
  LoRaConnection.waitPacketSent();
}
```