

# **Smart IoT Based Agriculture Soil Nutrient and Fertilizer Monitoring System**

A project by  
**Md. Delwar Hossain**

Supervisor  
**Dr. Mohammod Abul Kashem**

**Computer Science and Engineering  
Dhaka University Of Engineering & Technology,  
Gazipur**

**December 2022**

The Project entitled “SMART IOT BASED AGRICULTURE SOIL NUTRIENT AND FERTILIZER MONITORING SYSTEM” submitted by Md. Delwar Hossain, Student No.: 142415-P has been accepted as satisfactory in partial fulfillment of the requirement for the Degree of Master of Engineering in Computer Science and Engineering on 05 December, 2022.

### **BOARD OF EXAMINERS**

- |    |                                                                                                                                                                                                                           |                          |
|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|
| 1. | <hr/> <div>Dr. Mohammad Abul Kashem<br/>Professor &amp; Director(IICT)<br/>Department of Computer Science and Engineering<br/>Dhaka University of Engineering and Technology, Gazipur<br/>Gazipur-1707, Bangladesh.</div> | Chairman<br>(Supervisor) |
| 2. | <hr/> <div>Head<br/><br/>Department of Computer Science and Engineering<br/>Dhaka University of Engineering and Technology, Gazipur<br/>Gazipur-1707, Bangladesh.</div>                                                   | Member<br>(Ex-Officio)   |
| 3. | <hr/> <div>(Dr. Md. Obaidur Rahman)<br/>Professor<br/>Department of Computer Science and Engineering<br/>Dhaka University of Engineering and Technology (DUET), Gazipur<br/>Gazipur-1707, Bangladesh.</div>               | Member                   |
| 4. | <hr/> <div>Dr. Momotaz Begum<br/>Professor<br/>Department of Computer Science and Engineering<br/>Dhaka University of Engineering and Technology, Gazipur<br/>Gazipur-1707, Bangladesh.</div>                             | Member                   |
| 5. | <hr/> <div>Dr. Mohammad Shamsul Arefin<br/>Professor<br/>Department of Computer Science and Engineering<br/>Chittagong University of Engineering and Technology, Chittagong<br/>Chittagong-4349, Bangladesh.</div>        | Member<br>(External)     |

## DECLARATION

This project is my own original work; it is hereby declared. The project presented here has not been submitted elsewhere for the award of a degree or diploma in whole or in part. Information that was taken from other people's works has been properly referenced.

Signature

.....

Md. Delwar Hossain

Student ID: 142415-P

Department of Computer Science and Engineering, DUET, Gazipur

Date:

Signature of Thesis Supervisor

.....

Dr. Mohammad Abul Kashem

Professor

Department of Computer Science and Engineering

Dhaka University of Engineering and Technology, Gazipur

Gazipur-1707, Bangladesh.

Date:

---

## LIST OF FIGURES

---

| S.L    | Figure Name                                                          | Pg |
|--------|----------------------------------------------------------------------|----|
| 2.3.1  | Arduino Nano .....                                                   | 11 |
| 2.3.2  | Arduino Nano pinout .....                                            | 12 |
| 2.3.3  | Soil NPK Sensor .....                                                | 12 |
| 2.3.4  | Modbus MAX485 TTL for RS-485 .....                                   | 13 |
| 2.3.5  | Capacitive (V1.2) Soil Moisture Sensor .....                         | 15 |
| 2.3.6  | Waterproof Temperature Sensor model DS18B20 .....                    | 16 |
| 2.3.7  | DS18B20 pinout .....                                                 | 16 |
| 2.3.8  | Wireless Transceiver Module and model NRF24L01.....                  | 17 |
| 2.3.9  | ESP32-D0WDQ6.....                                                    | 18 |
| 2.3.10 | ESP32 & NRF24L01 Wireless Transceiver Module connection .....        | 19 |
| 2.3.11 | Various sensor are connected with Arduino.....                       | 19 |
| 3.2.1  | Proposed System Methodology .....                                    | 25 |
| 3.2.2  | Overall design for IoT based soil fertilizer monitoring system ..... | 26 |
| 3.2.4  | Crop Recommendation Module Design .....                              | 28 |
| 3.2.5  | Sequence Process of Model building for Crop Recommendation .....     | 34 |
| 4.2.1  | Various Soil Sample .....                                            | 38 |
| 4.2.2  | Soil sample1 .....                                                   | 38 |
| 4.2.3  | Soil sample2 .....                                                   | 39 |
| 4.2.4  | Soil sample3 .....                                                   | 39 |
| 4.2.5  | Soil sample4 .....                                                   | 40 |
| 4.2.6  | Four Soil sample1 combine .....                                      | 40 |
| 4.2.7  | Percentage of soil moisture for different samples .....              | 41 |
| 4.2.8  | Feature importance basis on Crop growth .....                        | 43 |
| 4.2.9  | Nitrogen and Potassium attributes are dispersed. ....                | 43 |
| 4.2.10 | Table data from fertilizer monitoring module .....                   | 44 |
| 4.2.11 | Implementation of Soil fertilizer monitoring .....                   | 44 |
| 4.2.12 | Use of Implemented module .....                                      | 44 |
| 4.2.13 | Test data Accuracy comparison .....                                  | 46 |
| 4.2.14 | Calling recommendation model method .....                            | 47 |

---

## LIST OF TABLE

---

| <b>S.L</b> | <b>Table Name</b>                           | <b>Pg</b> |
|------------|---------------------------------------------|-----------|
| 3.1.1      | Nitrogen Inquiry frame .....                | 13        |
| 3.1.2      | Nitrogen Inquiry response frame .....       | 13        |
| 3.1.3      | Phosphorus Inquiry frame .....              | 14        |
| 3.1.4      | Phosphorus Inquiry response frame .....     | 14        |
| 3.1.5      | Potassium Inquiry frame .....               | 14        |
| 3.1.6      | Potassium Inquiry response frame .....      | 24        |
| 3.1.8      | Pin Description of ESP3 and NRF24L01 .....  | 28        |
| 3.2.1      | Details meaning of the Dataset .....        | 34        |
| 3.2.2      | Sample Instances of Dataset .....           | 34        |
| 3.2.3      | Crops Consideration .....                   | 35        |
| 4.2.1      | Nutrient Values for Different Samples ..... | 44        |
| 4.2.2      | Soil nitrogen Fertilizer Range .....        | 44        |
| 4.2.3      | Soil Phosphorous Fertilizer Range .....     | 45        |
| 4.2.4      | Potassium in Soil fertilizer Range .....    | 45        |
| 4.2.5      | Train and Test accuracy score .....         | 47        |

# Table of Contents

|                 |                                                 |       |                                                               |      |
|-----------------|-------------------------------------------------|-------|---------------------------------------------------------------|------|
| Acknowledgments |                                                 |       |                                                               | VII  |
| Abstract        |                                                 |       |                                                               | VIII |
| Chapter-1       | Introduction                                    |       |                                                               |      |
|                 | 1.1                                             |       | General Importance .....                                      | 02   |
|                 | 1.2                                             |       | Background .....                                              | 03   |
|                 | 1.3                                             |       | Problem Statement .....                                       | 04   |
|                 | 1.4                                             |       | Motivation .....                                              | 05   |
|                 | 1.5                                             |       | Objectives.....                                               | 05   |
|                 | 1.6                                             |       | Contributions.....                                            | 06   |
|                 | 1.7                                             |       | Summary .....                                                 | 06   |
| Chapter-2       | Background, Related Work and used components    |       |                                                               |      |
|                 | 2.1                                             |       | Background .....                                              | 08   |
|                 |                                                 | 2.1.1 | IoT-Based Agriculture for Soil Nutrients .....                | 08   |
|                 |                                                 | 2.1.2 | Significance of IoT-Based Soil Nutrient and Fertilizer        | 09   |
|                 | 2.2                                             |       | Related Work .....                                            | 10   |
|                 | 2.3                                             |       | Components used in the project .....                          |      |
|                 |                                                 | 2.3.1 | Arduino Nano .....                                            | 11   |
|                 |                                                 | 2.3.2 | Soil NPK Sensor .....                                         | 12   |
|                 |                                                 | 2.3.3 | Modbus MAX485 TTL for RS-485 Interface Module..               | 12   |
|                 |                                                 | 2.3.4 | NPK sensor for soil and Arduino connection .....              | 13   |
|                 |                                                 | 2.3.5 | Capacitive V 1.2 Soil Moisture Sensor .....                   | 14   |
|                 |                                                 | 2.3.6 | Waterproof Temperature Sensor model DS18B20.....              | 16   |
|                 |                                                 | 2.3.7 | Wireless Transceiver Module and model NRF24L0.....            | 16   |
|                 |                                                 | 2.3.8 | Chip ESP32-D0WDQ6 .....                                       | 17   |
|                 |                                                 | 2.3.9 | ESP32 & Wireless Transceiver Module Connection ....           | 18   |
|                 | 2.4                                             |       | Summary .....                                                 | 20   |
| Chapter-3       | Proposed methodology and implementation process |       |                                                               |      |
|                 | 3.1                                             |       | Collaboration and implementation using smart technology ..... | 22   |
|                 | 3.2                                             |       | Proposed System Methodology .....                             | 24   |
|                 |                                                 | 3.2.1 | Soil Nutrients Fertilizer Monitoring Module .....             | 25   |
|                 |                                                 | 3.2.2 | Crop Recommendation Module .....                              | 27   |
|                 | 3.3                                             |       | Summary .....                                                 | 35   |
| Chapter-4       | Experimental Result and Discussion              |       |                                                               |      |
|                 | 4.1                                             |       | Experimental setup .....                                      | 37   |
|                 | 4.2                                             |       | Experimental Result Analysis and Discussion .....             | 37   |
|                 | 4.3                                             |       | Summary .....                                                 | 48   |
| Chapter-5       | Conclusion                                      |       |                                                               |      |
|                 | 5.1                                             |       | Conclusion .....                                              | 50   |
|                 | 5.2                                             |       | Future work .....                                             | 50   |

---

## Acknowledgments

---

I end up owing a huge debt of gratitude to the All-Mighty Allah for His unending favors and blessings that have empowered me to finish this work.

I want to start by expressing my gratitude to my mentor, Prof. Dr. Mohammad Abul Kashem, for his invaluable guidance, ongoing support, and patience throughout my study. Throughout the course of my M. Eng. thesis/project research, he constantly guided and inspired me with his profound knowledge and broad experience.

My appreciation also goes out to my wife and my parents. It would have been incredibly challenging for me to finish my work without their ongoing encouragement and support over the past few years.

---

## Abstract

---

Agricultural yield is generally dependent on the degree of soil fertility. N (Nitrogen), P (Phosphorus), K (Potassium), soil temperature and moisture level as soil chemical components are very important parameters for the determination of soil fertility. By measuring their presence, the proper amount of fertilizer can be easily used to ensure a good yield. Due to insufficient technical knowledge of the farmers in our country, the farmers cannot apply fertilizers in the right amount and thus the crops of the land are not produced well. In the present scenario, the manual method of measuring soil nutrients is less accurate because after collecting soil in the field, taking it to the laboratory for testing as well as the whole thing requires a lot of time, moreover consequently being very costly. There is different system and techniques to measure the amount of fertilizer, especially soil components analytical technique, spectrum method, Colorimetry techniques can be used for measuring different soil elements but these measuring instruments are so expensive too. It becomes obligatory to implement a smarter Internet of Things (IoT) based Agriculture Soil nutrient and fertilizer Monitoring system which determine the soil nutrients from practical or real cropland and will send the processed data to the cloud using wireless sensor networks (WSN). Through this system, after determining soil fertility, the knowledgebase system will suggest to the farmer what kind of crops will grow well in the soil of this land. In this way, the farmer can choose to grow specific crops based on economic interest and soil quality which will be more productive. Overall, the smart Internet of Things (IoT) based agricultural soil nutrient and fertilizer monitoring system helps farmers collect real-time information about different soils, their fertility aspects of crops. Where all of the sensors will be controlled by interfacing with an Arduino Nano. Arduino Nano transmit data to NRF24L01 2.4GHz Wireless Transceiver (Transmitter) Module. And Transceiver (Transmitter) Module transmit data to NRF24L01 2.4GHz Wireless Transceiver (Receiver) Module where it controlled by ESP32 Board. ESP32 wireless Device send the data set to Cloud where data will be stored for future process or Graphical Presentation. Finally, this project effort will help the farmers to make the right decisions, and get better yields and economic benefits.

# Chapter-1

## **Introduction**

---

# Introduction

---

Choosing the appropriate crops for their cropland is one of the reasons why many farmers, despite devoting their lives to farming, are unable to improve their financial situation. When they can't choose the right crop, they typically lose money. The only way to take the necessary steps for profitable production is to assess the crop soil's nutritional quality. By adding the chemical nutrients of the soil from the outside, soil fertility can be significantly increased, but the biological characteristics of the soil cannot be changed much. Numerous plant disorders and low yields are caused by nutrient-deficient soils. If farmers are aware of which crops will thrive in which soil, they can increase their profits. Therefore, it is crucial to be aware of information pertaining to the farmer's soil's nutrient quality. The issue of selecting the best crop is more prevalent in rural areas, and using IoT techniques to solve it is absolutely necessary.

## 1.1 General Importance

The Internet of Things (IoT) and engineering have produced and will continue to produce enormous amounts of work as a result of the recent rapid advancements in computer and information technology. Because of this, the Internet of Things (IoT) and its applications are expanding daily, but the main obstacles to widespread use of this field are small integrated devices like the Arduino Nano, ESP32, Modbus Modules, etc.

Lack of IoT-based agricultural development prevents farmers from producing high-quality crops. Consequently, IoT-based agricultural research is essential to the production of crops. The level of soil fertility typically determines the yield of an agricultural crop. When determining soil fertility, N (nitrogen), P (phosphorus), K (potassium), soil temperature, and moisture content are crucial factors to consider. It is simple to use the right amount of fertilizer to ensure a good yield by measuring their presence. a more intelligent agriculture system based on the Internet of Things Monitoring system for soil nutrients and fertilizer that extracts data from actual cropland and uses wireless sensor networks to send the processed information to the cloud (WSN). The knowledgebase system will recommend to the farmer what kinds of crops will grow well in the soil of this land using this system, after determining soil fertility. The farmer can then decide

which crops to grow based on their economic viability and their ability to produce more due to better soil. In general, the IoT-based smart agricultural soil nutrient and fertilizer monitoring system aids farmers in gathering real-time data about various soil types and their effects on crop fertility.

## **1.2 Background**

The agricultural industry always provides a variety of food sources and also ensures nutritional deficiencies. Farmers in our nation were unable to apply various related resources that could have increased the yield from their cropland due to a lack of technological knowledge on their part. To measure the amount of fertilizer, particularly soil elements like nitrogen, phosphorus, and potassium, various systems and techniques are used. For measuring various soil components, nutrient analytical techniques, spectrum methods, and colorimetry techniques can be used. There are a few ways to measure the amount of nutrients in soil, including using optical sensors, spectrometers, and wireless sensor networks (WSNs), but these measuring tools are very expensive. On the other hand, spectral analysis techniques are inconvenient and provide less accurate data. Using NPK, moisture, and temperature sensors ensures faster, cheaper, and better performance while providing more accurate information. It is critical to deal with a new pattern that will be more expensive and effective when measuring soil nutrient content. Therefore, developing a strategy for intelligent agricultural fertilizer is crucial. Although in the current context only nutritional factors will be taken into account, the term a submitted soil sample may be subjected to any number of chemical, physical, and biological tests, collectively referred to as "soil testing." Chemical fertilizers, primarily nitrogen, phosphorus, and potassium (NPK), along with improved crop varieties, pesticides, and mechanization have been used to increase crop yields by 30 to 50% in agricultural soils that are generally fertile. However, to prevent encroachment into highly valuable ecosystems, there is a greater need to more effectively use Agriculture on less fertile, degraded lands due to the growing the growth in human population and the consequent relative and absolute increase in agricultural needs. Considering the significance of fertilizers in crop yield, it was argued for a paradigm change in fertilizer product development. Plant ecological and biological processes were used as a starting point for innovative nutrient wrapping and shipment to plants as well as re-tuning agronomic nutrient requirements to make them more precise to crop, soil, and agricultural production conditions within the socio-economic context of multiple farming

practices. Such re-tuning presupposes that diagnostic tools for determining soil reproductive capacity and plant nutrition would also need to be reevaluated in order to bring them closer to the realities of various types of farmers around the world.

### **1.3 Problem Statement**

Most of the farmers are unable to directly extract various soil parameters such as temperature, humidity and moisture due to lack of technical knowledge. So they have to be taken to the soil laboratory of that cropland to know or extract the various parameters of the soil. Transporting to the laboratory for laboratory testing is time-consuming as well as expensive. So what type of fertilizer should be applied to the crops depends on the knowledge of the various parameters of the soil at the right time. So the whole thing is very challenging. The soils of the Indian subcontinent are now less productive as a result of this and the insufficient, and frequently complete lack of, amendment of cultivated fields with mineral fertilizers. This demonstrates the need to supplement fertilizers with particular nutrients (micro and macro) to improve yield response. As a result, in the context of balanced fertilization, micronutrient depletion in continuously farmed soils aids in reevaluating the manure's composition, sustaining and increasing yield, and assisting in nutrient recovery for food, fruit, and vegetable crops. over the last few decades, in steady decline. Fertilizers ought to be productive for crop growth under these circumstances, and farmers' investments in them will pay off.

Few studies have attempted to evaluate the usefulness of efficacy of rapid soil-plant nutrient testing methods as parts of an inclusive nutrient management strategy, despite the fact that they have been around for a while. In reality, the scarcity of information in the research literature indicates that These product lines have very little in the way of objective assessments. Therefore, the aim of this review is to identify the range of commercial soil and plant nutrient testing methods that are currently available, to evaluate their basis for deployment as alternative soil and plant nutrient analysis techniques, and to reflect their efficacy for relevant production. To gather data for logical fertilizer recommendations. In areas where conventional wet lab capabilities are constrained, prohibitively expensive, or nonexistent, it is anticipated that this work will offer valuable information to support soil fertility and crop nutrition research and development activities.

## **1.4 Motivation**

One of the reasons why many farmers, despite devoting themselves to agricultural work, are not able to improve their economic condition is that they do not know the exact amount of soil elements in their crops. Only by determining the nutritional quality of the crop soil can the necessary measures be taken for profitable production. Especially, soil fertility can be increased by applying the chemical nutrients of the soil from outside, but the biological properties cannot be changed much. Low nutrient soils lead to multiple plant disorders and low yields. Farmers can be more profitable if they know which type of crop will grow well in which soil. Therefore, it is very important to know the information related to the nutrient quality of the soil of the farmer. The problem of choosing the right crop is more in rural area and for solving it is very necessary to use the techniques of IoT approach which works amazingly. In many cases, farmers without realizing it, apply excessive amounts of unwanted fertilizers, which leads to high costs and on the contrary, crop damage and production losses. Therefore, if all these soil nutrients can be accurately measured and monitored from a distance, it will be easy to produce better agricultural yields.

## **1.5 Objectives**

The following are some of the specific research goals of this project:

- a.** To deploy a smart IoT-based soil nutrient and fertilizer monitoring system using a wireless sensor network (WSN) so that different kinds of data of soil content data can be measured and collected from agricultural cropland. Then, for future use and development, these data are stored in the cloud.
- b.** To develop a system to implement the propose methodology for the project within low cost and minimum time.
- c.** To ensure real-time requirement of different properties or content of soil nutrient for proper cultivation.

## **1.6 Contribution**

The following original IoT Based Agriculture for Soil Nutrients as well as fertilizer monitoring research contributions are made by this study:

- a.** A framework facilitates to assessment and analysis of different content of the soil.
- b.** The data set can be seen from a remote area with different attributes of soil which are stored in the cloud for further process, future use and development.

## **1.7 Summary**

This section has presented the background and related work of Smart IoT Based Agriculture Soil Nutrient and Fertilizer Monitoring Systems. The next chapter will discuss the IoT Based Agriculture Soil Nutrients, Fertilizer Monitoring Systems, and implementation procedures.

## **Chapter -2**

### **Background and Literature Review**

---

## Background, Related work and used Components

---

An overview of the fundamentals of smart IoT-based agriculture soil nutrient and fertilizer monitoring systems is what this chapter aims to do. The history and related research of smart IoT-based agriculture for soil nutrient and fertilizer monitoring systems are explained in this chapter. Background is describing in section 2.1. The description of the IoT Based Agriculture for Soil Nutrients is provided in Section 2.1.1. The significance of IoT-Based Agriculture Soil Nutrient and Fertilizer Monitoring System and its branches are covered in Section 2.1.2. We give a brief overview and related work of IoT-based agriculture and fertilizer monitoring systems in section 2.2. In section 2.3 has been explain used components to implement the project. Finally, summary in section 2.4.

### 2.1 Background

Farmers' inability to accurately and timely determine the cropland's nutrient quality is one of the reasons they are unable to improve their financial situation, even if they devote their entire lives to farming. Nutrient deficiencies in the soil result in numerous plant diseases and low yield because it is difficult to accurately determine the nutrients in the soil. Or in many cases, applying too much fertilizer without understanding the effects results in crop damage and decreased yield. Additionally, in order to learn about or extract the various soil parameters of the cropland, the farmer traditionally needs to take the soil to an agricultural laboratory. Transporting samples to the lab for testing takes time and money. Because of this, the majority of farmers are not eager to send soil samples to a lab and wait for the results. Therefore, knowing the various soil parameters at the appropriate time will determine what kind of fertilizer should be applied to the crop.

#### 2.1.1 IoT Based Agriculture for Soil Nutrients

We are aware that over-fertilization is a major issue for farmers worldwide. Due to various environmental issues like leaching, water contamination, soil salinity, bio-magnification,

pollutants of ground water, and poor food quality, we may not have a clear understanding of the fertilizers for crops. We are aware that the current method for testing soil is chemical-based, which takes more time & expense, so our automated system can easily conquer those false results. It is crucial and essential that the system we use is quick, affordable, and easy to use. Farmers experienced time delays as a result of the use of subpar techniques, so we should employ cutting-edge technology. The automated fertilization system boosts crop production's sales and profits while potentially damaging environmental effects are lowered. In the modern world, if someone wanted to test their soil, they would have to take a sample to a lab for chemical analysis, then wait a couple of days for the results. This is a very time-consuming process. Finding out the quantity of nutrients in the soil is important for soil testing for formulated fertilization. Among all the nutrients necessary for crop growth, nitrogen, phosphorus, and potassium are three of the most crucial components. A few of the techniques used in conventional soil NPK testing include soil random samples, conductivity measurement, electrochemical method, and optical methods. Electrochemical sensors have been used up until this point to measure soil nutrient content. Although electrochemical methods are reliable, they take more time, are more difficult, and cost a lot more money per test. As a result, cheaper alternatives to the electrochemical method, such as the optical method, are being used. The optical methods are trustable, quicker, easier, and very inexpensive per test.

### **2.1.2 significance of IoT-Based Soil Nutrient and Fertilizer Monitoring System**

Automatic fertilization units increase the profitability of crop production and reduce potential negative environmental impacts. Currently, if someone wants to test their soil, they must take a sample to a soil testing lab where it will be chemically tested. After 2-3 days, they will return with the results, making the process very time-consuming. lengthy process. One of the reasons why many farmers are unable to improve their economic condition even if they engage in agriculture is because they cannot select the right crops for their crop land.

Due to poor crop yields, labor shortages, extremely high labor costs, a lack of knowledge of modern farming practices, and excessive use of chemical fertilizers and pesticides, the percentage of agricultural systems has been rapidly declining over the past few years. There are a few ways to measure soil nutrients, such as using optical sensors, spectrometers, or wireless sensor networks (WSNs), but these measuring tools are very expensive, and spectral analysis techniques are not practical and provide poor results. Therefore, it is very important to extract

the nutrients from the soil to produce the right amount of crops from the crop land. In that case it is possible to ensure nutrient extraction by using IoT-based agricultural soil nutrient and fertilizer monitoring system.

## **2.2 Related Work**

Due to their inability to choose the right crop, farmers frequently suffer financial loss. If farmers are aware of which crops will thrive in which soil, they can increase their profits [1]. Therefore, it is crucial to be aware of information pertaining to the farmer's soil's nutrient quality. The issue of selecting the best crop is more prevalent in rural areas, and using IoT techniques to solve it is absolutely necessary [2]. Many times, farmers apply large amounts of unnecessary fertilizers without realizing it, which results in high costs and, on the other hand, crop harm and manufacturing losses. To determine these nutrients, a variety of sensors (such as NPK, pH, temperature, moisture, and humidity sensors) are used [3]. These sensors continuously gather the required data from the crop field using IoT devices (Arduino, Raspberry pi), and these devices send the information to the cloud platform through wireless communication (Bluetooth , GSM, ZigBee, Radio or Wi-Fi, etc.) module using the Wireless network [4]. Low yield is always caused by choosing a crop that will not produce a high yield on a particular soil, planting during the incorrect season, and choosing the incorrect crop. When choosing these crops, farmers frequently make mistakes [5].

Due to poor crop yields, labor shortages, exorbitant labor costs, a lack of knowledge of modern farming, and extreme use of pesticides and chemical fertilizers the percentage of farming methods has been rapidly declining over the past few years [5, 6]. There are only a few ways to measure the amount of nutrients in soil, including using optical sensors, spectrometers, and wireless sensor networks (WSNs), but these measuring tools are very expensive. On the other hand, spectral analytical techniques are not practical and provide less accurate data [3-6].

Data analytics, servicing, mobility, infrastructural facilities, data protection, equipment, and privacy are the main challenges in automated nutrient monitoring systems, with the hardware portion focusing on the selection of IoT devices with sensors. These sensors and gadgets can occasionally be easily broken in the agricultural field [7].

Farmers must be aware of the quantity of soil nutrient content in their croplands before using chemical fertilizers. The traditional method for determining soil nutrients involves sending soil samples to agricultural testing labs, but the majority of farmers with less education are not interested in sending soil samples to the lab and waiting for the results [8]. System for monitoring

base fertilizer using smart IoT Encourage local farming, determine the quantity of nutrients present in soil without transporting soil samples to laboratories, and allow farmers to remotely test the nutrient content of their soil and receive results in a few minutes. This research aims to examine the current state of Bangladesh's agriculture monitoring deployment system. Through this project, we can concentrate on important factors that also impede the deployment of an agriculture monitoring system [9].

## 2.3 Components used in the project

There are various kinds of sensors and devices are used to implement the project. Short description of the components given below:

### 2.3.1 Arduino Nano

The Nano Board has a variety of communication ports that can be used to connect a computer, some other Arduino, or additional microcontrollers. The ATmega328P provides UART TTL (5V) sequential communication, which is reachable on input pin 0 (RX) and 1. (TX). An FTDI FT232RL is used on the board to route this sequential communiqué over USB, and the FTDI drivers (involved in the Arduino programming) provide access to a virtual com port for computers and software. 22 digital pins from (D0-D21). Operating voltage +5v. 2KB SRAM and 1 KB EEPROM. 32KB flash memory which is 2KB used for the bootloader. Clock speed 16MHz. Three protocols UART, SPI, I2C [10].

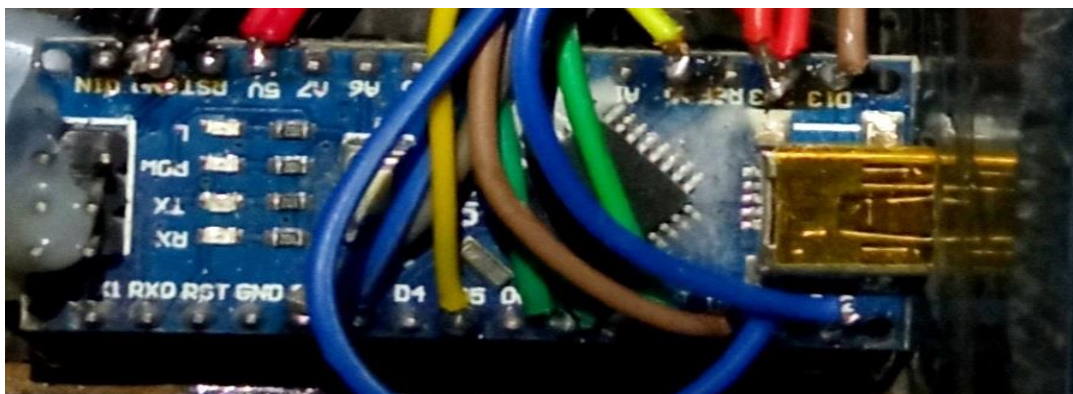


Figure 2.3.1 :Arduino Nano

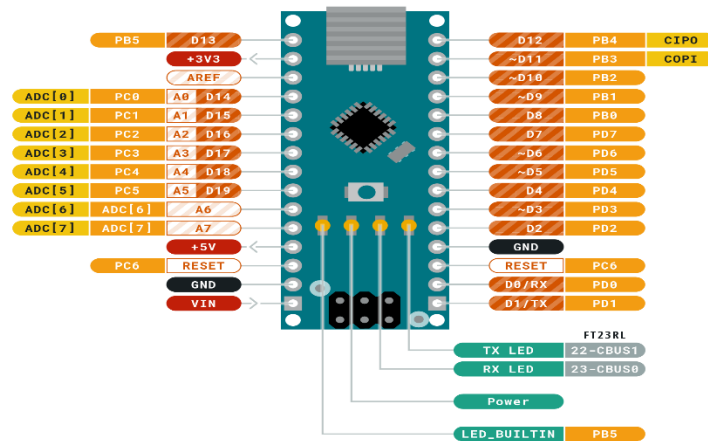


Figure 2.3.2 :Arduino Nano pinout

### 2.3.2 Soil NPK Sensor

The soil NPK device can be cast-off to quantity the soil's nitrogen, phosphorus, and potassium content. It facilitates the systematic evaluation of the soil condition by assisting in determining the soil's fertility. For a very long time, the sensor can be buried in the ground. To guarantee the long-term functionality of the enquiry part, it has a high-quality probe that is corrosion resistant to salt and alkali, rust, and electrolysis. It is therefore appropriate for all types of soil. Alkaline, acidic, substrate, plantlet bed, and coconut bran soil can all be perceived using this method [10][11].

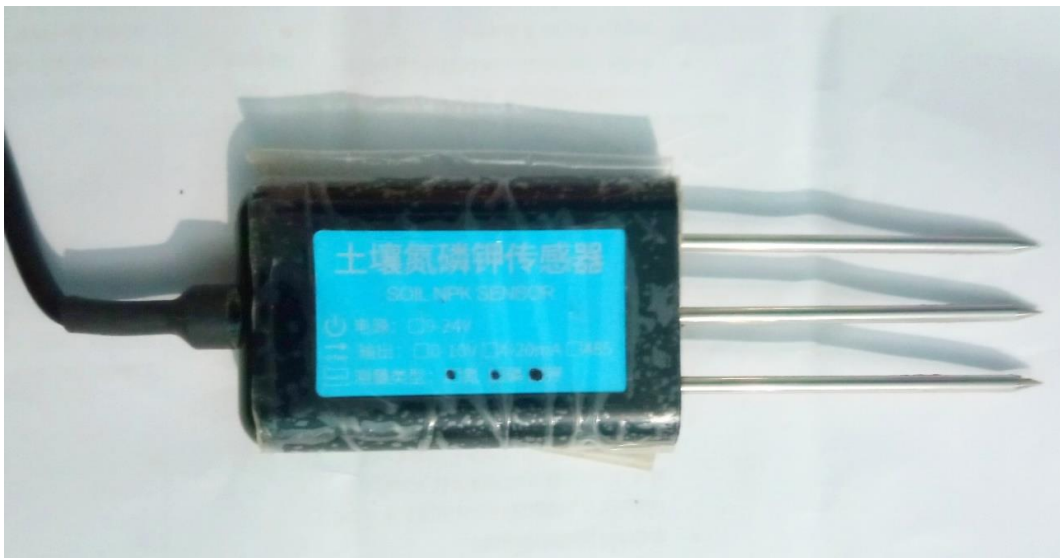


Figure 2.3.3 :Soil NPK Sensor

### 2.3.3 Modbus MAX485 TTL for RS-485 Interface Module

We can use RS-485 differences signaling for dependable long-distance sequential transportations up to 1200 meters or in electrically deafening surroundings thx to the widely used MAX485 TTL to RS-485 Ethernet Interface. It can support data rates of up to 2.5MBit/sec, but the extreme data rate that can be supported decreases with increased distance [11] [12].



Figure 2.3.4 : Modbus MAX485 TTL for RS-485

### 2.3.4 NPK sensor for soil and Arduino connection

Utilizing software serial, connect the D2 and D3 Arduino pins to the R0 and DI pins layout for the Modbus. In a similar manner, we must enable DE & RE high. Associate the Arduino's DE and RE pin for the D7 and D8 pins to accomplish this. There are 4 wires on the NPK Sensor. The brunet one is VCC and requires a control supply ranging from 9V to 24V. a black pin known as the GND pin. Connect it to Arduino's GND by doing so. The MAX485's B pin and A pin are connected by the yellow cable, which is the A pin, and the MAX485's B pin, which is the blue wire[13].

The microcontroller sends the following frame of inquiry to obtain the soil nitrogen value:

| Adr Code | Fun Code | Reg Start address | Reg Length | CRC_L | CRC_H |
|----------|----------|-------------------|------------|-------|-------|
| 0x01     | 0x03     | 0x00 0x1e         | 0x00 0x01  | 0XE4  | 0x0C  |

Table 3.1.1 : Nitrogen Inquiry frame

NPK sensor will give feedback or response to calculate the Soil Nitrogen

| Adr Code | Fun Code | Effective Number of bytes | Nitrogen Value | CRC_L | CRC_H |
|----------|----------|---------------------------|----------------|-------|-------|
| 0x01     | 0x03     | 0x02                      | 0x00 0x20      | 0Xb9  | 0x9C  |

Table 3.1.2 :Nitrogen Inquiry response frame

For instance, the Soil Nitrogen Value will be as follows if you receive the response 0020: 0020 H (hexadecimal) = 32 (decimal) = 32 mg/kg of nitrogen.

The following inquiry frame is sent by the microcontroller to obtain the soil phosphorus value:

| Adr Code | Fun Code | Regt Start address | Reg Length | CRC_L | CRC_H |
|----------|----------|--------------------|------------|-------|-------|
| 0x01     | 0x03     | 0x00 0x1f          | 0x00 0x01  | 0Xb5  | 0xCC  |

Table 3.1.3 : Phosphorus Inquiry frame

NPK sensor will give feedback or response to calculate the Soil Phosphorous

| Adr Code | Fun Code | Number of bytes | Phosphorous Value | CRC_L | CRC_H |
|----------|----------|-----------------|-------------------|-------|-------|
| 0x01     | 0x03     | 0x02            | 0x00 0x25         | 0X79  | 0x9F  |

Table 3.1.4 : Phosphorus Inquiry response frame

If the response code is 0025, for example, the soil phosphorus value will be as follows: 0025 H(hexadecimal) = 37 (Decimal) => 37mg/kg of phosphorus.

The following questions are used to determine the soil potassium value:

| Adr Code | Fun Code | Reg Start address | Reg Length | CRC_L | CRC_H |
|----------|----------|-------------------|------------|-------|-------|
| 0x01     | 0x03     | 0x00 0x20         | 0x00 0x01  | 0X85  | 0xC0  |

Table 3.1.5 : Potassium Inquiry frame

A response or feedback from the NPK sensor will be used to determine the soil potassium.

| Adr Code | Fun Code | Number of bytes | Potassium Value | CRC_L | CRC_H |
|----------|----------|-----------------|-----------------|-------|-------|
| 0x01     | 0x03     | 0x02            | 0x00 0x30       | 0X B8 | 0x50  |

Table 3.1.6 : Potassium Inquiry response frame

For instance, if you receive the response 0030, the value for the soil's potassium will be as follows: 0030 H(hexadecimal) = 48 (Decimal) => 48 mg/kg of Potassium.

### 2.3.5 Soil Moisture Sensor

We require a soil moisture sensor in direction to measure the soil moisture level. A capacitive type of soil moisture sensor is preferred for this application. To measure the amount of soil moisture, we will use an analog capacitive soil moisture sensor. This indicates that the capacitance varies according to the amount of water in the soil. The voltage level that the measured capacitance is converted to generally ranges from 1.2V to 3.0V at its highest. Because

they are made of a material that resists corrosion, capacitive soil moisture sensors have a long service life [14].

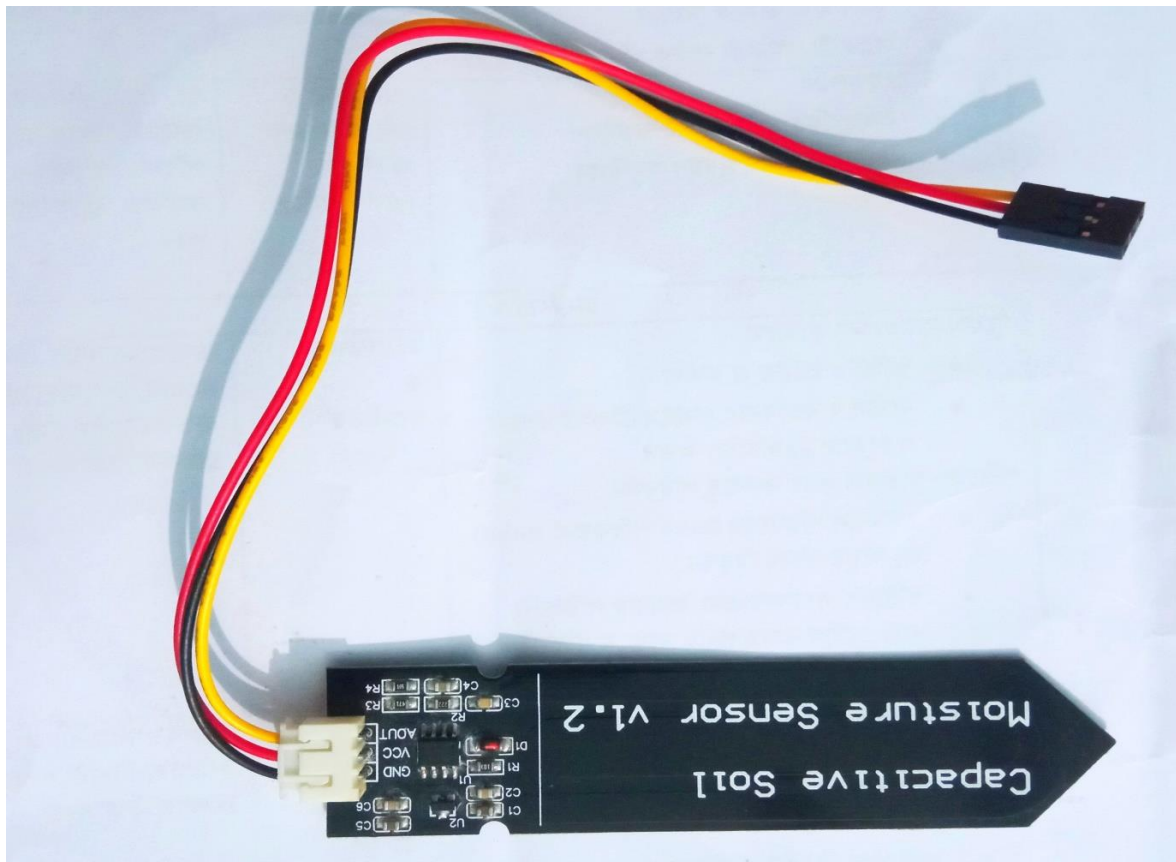


Figure 2.3.5 :Capacitive (v1.2) Soil Moisture Sensor

### 2.3.6 Waterproof Temperature Sensor model DS18B20

This pre-wired, waterproof variation of the DS18B20 Sensor is used to measure distant objects or things that are wet. The Sensor is capable of measuring temperatures in the range of -55 to 125°C (-67 to +257°F). PVC is used to jacket the cable. These 1-wire digital temperature sensors are fairly accurate, with an average range of 0.5°C. Any microcontroller with an individual digital pin can use them with great success [15].



Figure 2.3.6 :DS18B20 Waterproof Temperature Sensor

Two libraries, such as the One-Wire Library and the Dallas Temperature Sensor Library, are needed for the sensor. When using the sensor, it also needs a 4.7k resistor to act as a pull-up from the DATA to the VCC line [16].

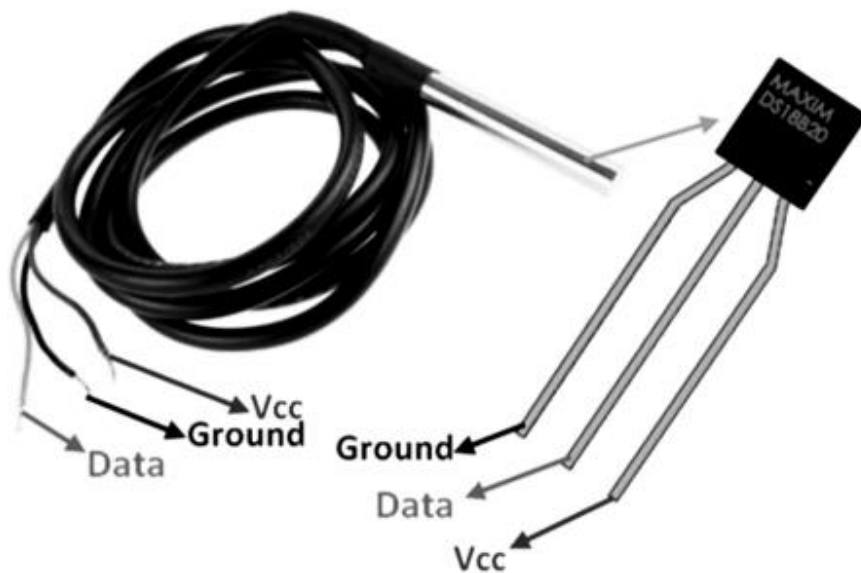


Figure 2.3.7 :DS18B20 pin out

### 2.3.7 Wireless Transceiver Module and model NRF24L01

Each NRF24L01 module can send and receive data because it is a wireless transceiver. It operates at 2.4GHz frequency range. If the modules are used effectively, they can travel 100

meters. The second iteration of this module, the nRF24L01 with PA+LNA, has a special RFX2401C chip that integrates the PA and LNA, a SMA connector, and a duck antenna. With the aid of a duck-antenna and this range extender chip, the module can transmit data over a distance of about 1000m [17].



Figure 2.3.8 : Wireless Transceiver Module and model NRF24L0

### **2.3.8 chip ESP32-D0WDQ6**

The ESP32 is a Microcontroller Board based, System on a chip (SoC) that can be used as a broad sense microcontroller device. It has a wide range of peripheral devices, such as Bluetooth and Wifi wireless capabilities.

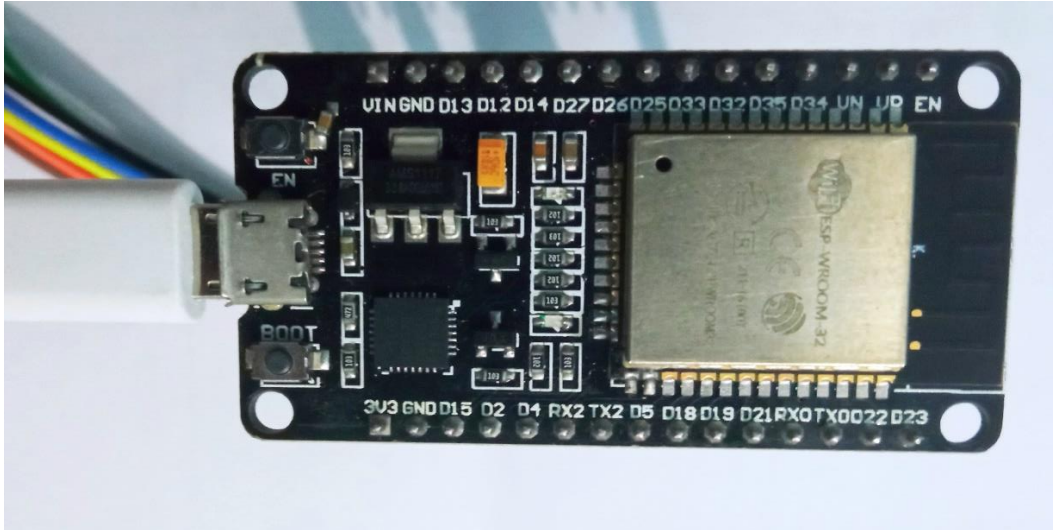


Figure 2.3.9 :ESP32-D0WDQ6

Espressif Systems, based in Shanghai, makes it. ESP32 is a SoC, but most users won't start out by using the chip by itself. The ESP32 SoC can be used to design products, but this is not a common practice. The main parts of the pre-made modules that are utilized in the majority of ESP32-based designs include a real ESP-32 SoC, extraneous flash memory, a crystal, a pre-tuned circuit board aerial or an IPEX aerial connector, and a pre-made module [18] [19].

### 2.3.9 NRF24L01 Wifi Transceiver Component and ESP32 Device Connection

The Gateway is also a part of the Smart IoT Based Agriculture Soil Nutrient and Fertilizer Monitoring System. The ESP32 WiFi device and NRF24L01 for WTD (Wireless Transceiver Module) were used in the design of the Gateway. Below is a diagram showing how the ESP32 Board and NRF24L01 Wireless Transceiver Module are attached [20] [21].

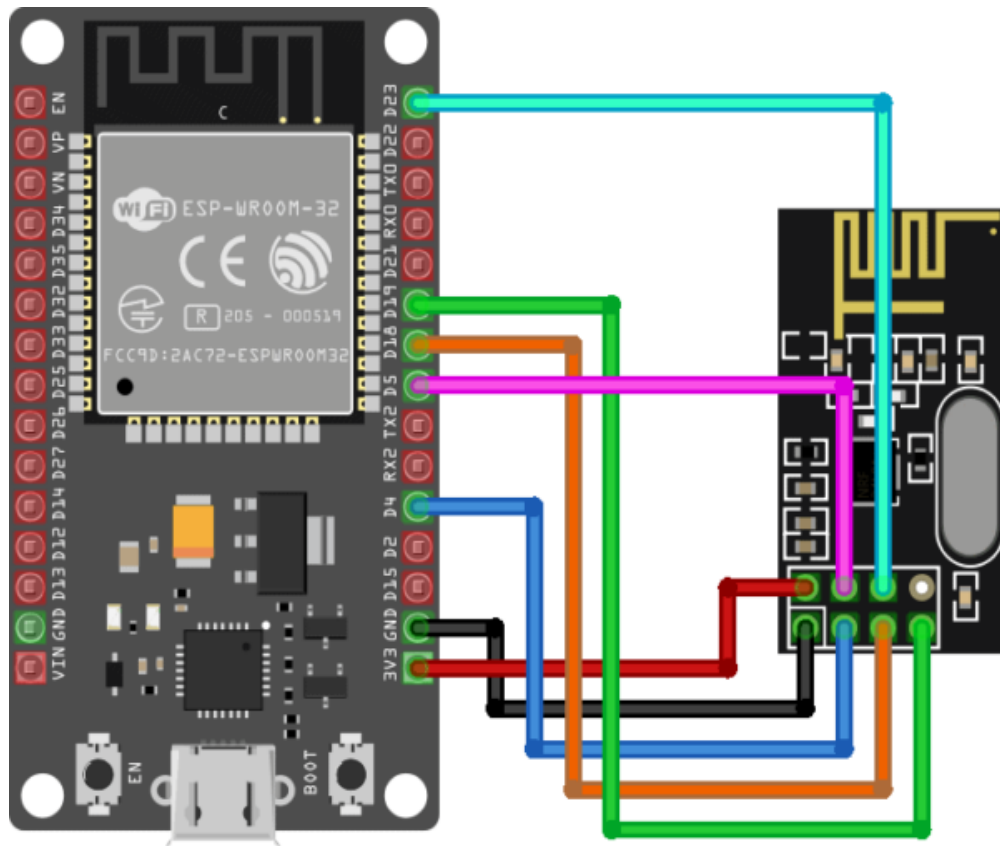


Figure 2.3.10 :ESP32 WiFi Module & NRF24L01 Wireless Transceiver Module connection

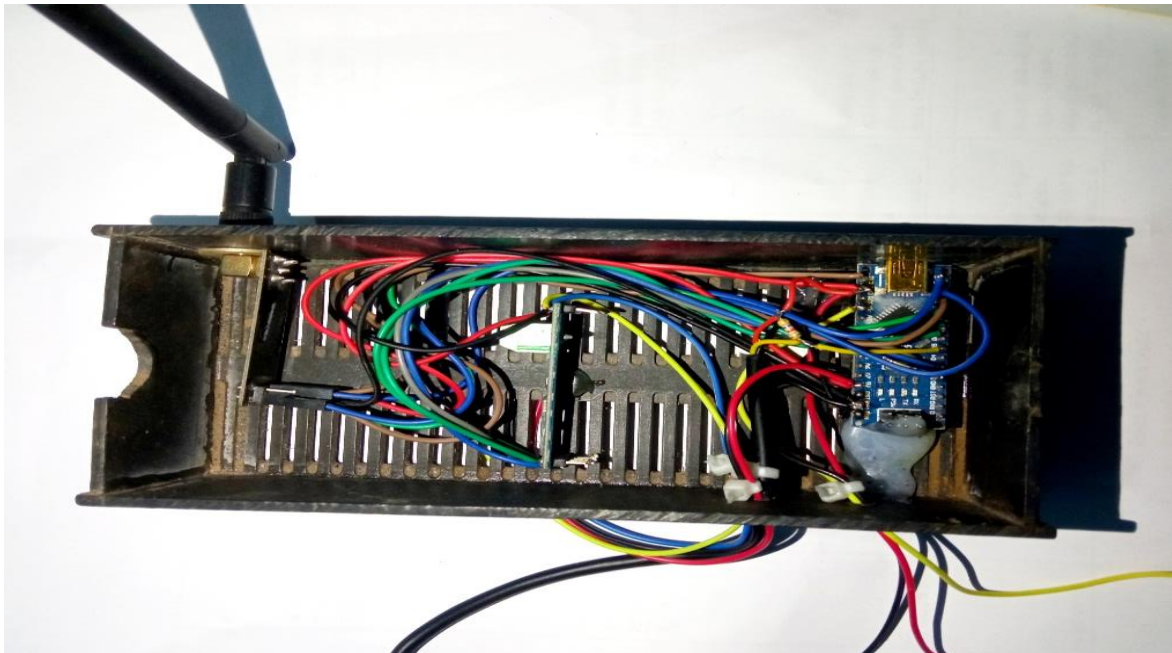


Figure 2.3.11 :Various sensor are connected with Arduino.

## **2.4 Summary**

This section has presented the background and related work of IoT-Based Agriculture for Soil Nutrients Fertilizer Monitoring Systems. In the next chapter, we will discuss the procedure of IoT Based Agriculture for Soil Nutrients Fertilizer Monitoring Systems.

## **Chapter-3**

### **Proposed method of the System and Implementation**

---

## Proposed method of the System and Implementation

---

It is critical to have a thorough understanding of soil nutrients in order to measure them. It is necessary to quantify the soil characteristics that primarily contribute to increased crop production. If an input is insufficient, it can be increased externally to ensure higher yields. In Section 3.1, it is discussed Collaboration of smart technology to measure soil nutrients. And Section 3.2 talks about Proposed System Methodology. Finally, In section 3.3, summary of this chapter.

### 3.1 Collaboration and implementation using smart technology

Farmers have recognized the importance of smart technologies, which is causing the agriculture sector to go through a digital transformation. The demand for food is rising globally, and the agriculture sector has been dealing with a labor shortage as well. This increased the need for clever solutions to raise productivity, efficiency, and overall yield. Robotics, drones, sensors, the Internet of Things (IoT), artificial intelligence, machine learning, cloud computing, and robotics are all able to provide real-time insights and assist farmers in taking quick decisions. Smart technology adoption boosts overall profitability while also working to improve farming practices' effectiveness. Technology companies, governments, universities, and other organizations have realized the value of creating and utilizing cutting-edge technologies to advance research, enhance farming practices, and address problems like greenhouse gas emissions[22]. As a result, they have adopted a variety of strategies including partnerships, collaborations, and others to jointly resolve problems and create new technologies.

#### Internet of Things (IoT)

It is clear that smart devices and the Internet of Things (IoT) have a significant impact on today's society. It is present in the majority of industries, and agriculture is no exception. IoT and connected devices can actually have a huge impact on farming techniques, allowing farmers to stop using horses and plows. After all, what use is it to rely on antiquated techniques in the era of self-driving cars, augmented reality, and virtual worlds. As a result, the idea of IoT is widely

accepted in agricultural production. Even though consumer connected devices are currently more popular than smart agriculture IoT, the market is still very dynamic. Basically, improve farming technology gives farmers more control over the process of raising livestock and growing crops [23]. In this manner, it creates enormous economies of scale, lowers expenses, and aids in the conservation of finite resources, such as water. From the amount of fertilizer used to the number of trips made by farm vehicles, farmers and growers are able to reduce waste and increase productivity.

### **Machine Learning (ML)**

Agricultural efficiencies are raised, crop yields are improved, and food production costs are decreased thanks to AI, machine learning (ML), and Internet of Things (IoT) sensors that would provide actual information for algorithms. Imagine managing, excelling at, and monitoring at least 40 crucial processes simultaneously over a sizable farming area, often measured in the hundreds of acres [24]. A perfect problem for machine learning is learning how yield is affected by the weather, seasonal sunlight, animal, bird, and insect migration patterns, crop use of specialized fertilizers and insecticides, planting and irrigation cycles, and various other factors. The importance of reliable data for crop cycles has never been greater. In order to increase agricultural yields and quality, farmers, co-ops, and agricultural development firms are stepping up their data-centric strategies and broadening the scope and scale of their use of AI and machine learning [25]. Using ML-driven image processing, it is possible to identify weed species and identify which crops are contaminated with fungi, bacteria, or viruses. Digital applications can also confirm the diagnosis diseases and suggest the most effective treatments.

### **Cloud computing**

One industry that has profited from applications of cloud computing is agriculture. This is a natural union of the most recent innovation and the most established industry. Because of the growing population, the scarcity of arable land, the fertility of the soil, and climate change, technology is essential in agriculture. To give farmers the insights that direct what to plant next, experts gather data on the crops that growers have been growing recently. Additionally, they receive regional weather information and forecasts for the coming days. Based on the data they receive from cloud computing; growers can make decisions regarding their crops.

Soil information from analysts includes soil profiles. To predict future trends, they look at past soil patterning. Experts in soil analysis assess changes in the soil's quality and composition, as well as its acidity and alkalinity. Thus, soil data is stored in the cloud and analyzed there. Soil information from analysts includes soil profiles. To predict future trends, they look at past soil patterning[26]. Experts in soil analysis assess changes in the soil's composition and quality, as well as its acidity and alkalinity. Thus, soil data is stored in the cloud and analyzed there.

### **3.2 Proposed System Methodology**

A large part of the problems of monitoring the soil and its constituents in cropland can be solved using Internet of Things technology and crop recommendations can be made using machine learning technology to determine which type of crop will grow well on this land. This system model is based on two modules to perform the complete task. Through Soil Fertilizer Monitoring Module, the real data of soil properties parameters Nitrogen (N), Phosphorous (P), Potassium (K), Humidity, Potential of hydrogen (pH), and Temperature are collected at run time and sent to the cloud. The crop Recommendation Module implements a machine learning-based model for crop recommendation where the dataset from the Soil Fertilizer Monitoring Module will be used to decide what type of crop will grow well on this land and recommend crops accordingly as shown in Figure 3.2.1

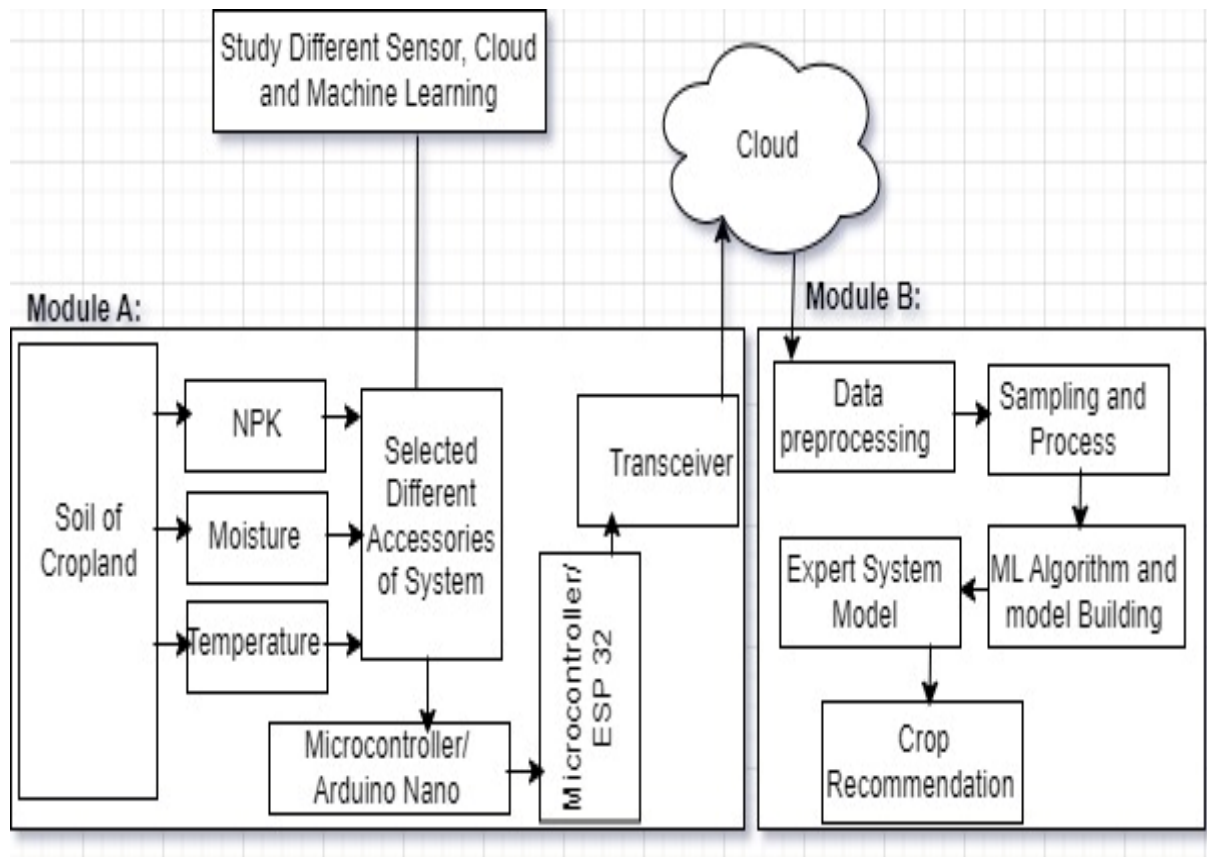


Figure 3.2.1 :Proposed System Methodology

### 3.2.1 Soil Nutrients Fertilizer Monitoring Module

Different sensors measure various parameters of the various soil constituents. For example, an NPK sensor collects the soil constituents' N (nitrogen), P (phosphorus), and K (potassium), while a moisture sensor measures the moisture content of the soil. An Arduino Nano will be used to interface with and control all of the sensors. The Arduino Nano and ESP32 Board will be connected, allowing for the transmission and reception of data. Because ESP is wireless, data can be sent or received by it without the use of any wired devices. Data can then be sent to a particular server or cloud for additional analysis after that. The soil element can be monitor by Cloud database.

To identify and use chemical fertilizers, farmers need to know the number of soil nutrients present in their croplands. To find out the number of nutrients present in the soil without carrying soil samples in the laboratory. Through these schemes and methods, farmers can remotely test the nutritional value of their soil and get results within minutes. The project will prevent the use of unnecessary chemical fertilizers and also limit environmental imbalances and improve crops without degrading the soil.

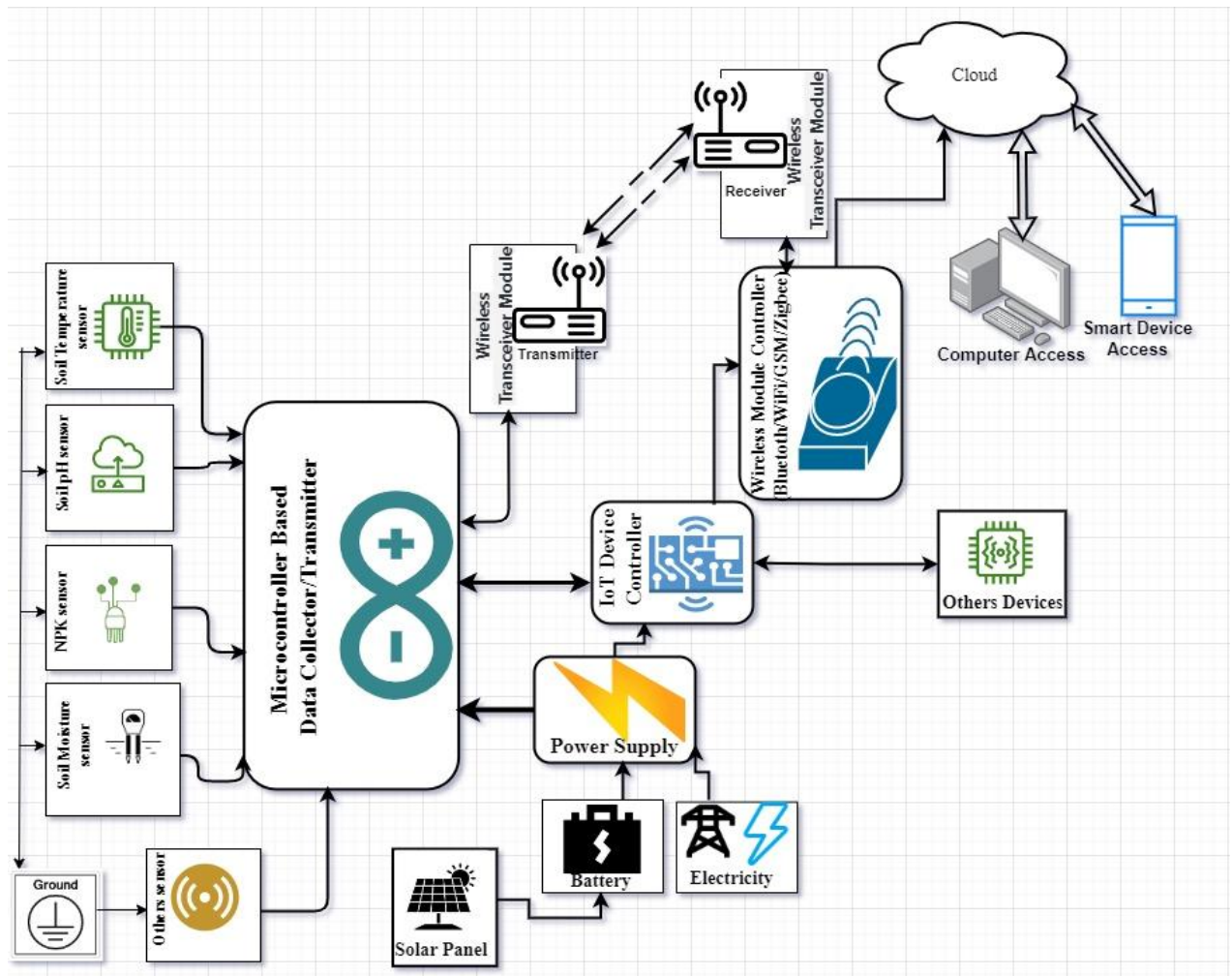


Figure 3.2.2 : Overall design for IoT based soil fertilizer monitoring system

If the nutrient quality of the soil of cropland can be determined, it is possible to ensure profitable production by applying proper fertilizers accordingly. The amount of additional fertilizer to be applied to cropland depends on the current soil quality. Infertile soils lead to multiple plant disorders and low yields. The parameters on which soil nutrition is determined are soil pH, temperature, moisture, humidity, nitrogen, phosphorus, and potassium. Sensors for soil moisture, soil temperature, temperature, and humidity are combined in this proposed Soil Fertilizer Monitoring Module system to create an efficient irrigation system. Above all Soil sensor send the data to Anchor or data collector device. Camera sensors are used to provide images of crops or plants. These images are then used through image processing to diagnose crop diseases and determine whether pesticides are needed. The collector device or Anchor device (Arduino, Raspberry pi) collects data from all sensors. The collector device will process the data received from the sensors and send it to the receiver End(ESP32) utilizing the transceiver and a wireless communication module, such as Bluetooth, Wi-Fi, ZigBee, Radio, or GSM. The receiver end

(ESP32) receives the data through the transceiver and sends it to the cloud database system using the wireless communication (Wi-Fi) method. The farmer can take necessary measures by analyzing the necessary information received. It is advised to use batteries in addition to a direct power source to power all electrical components included in this proposed system. It is also advised to use renewable solar energy, as shown on Figure 3.2.2 where the IoT-based soil monitoring system is covered. This system will have a platform where some stakeholders will be interfaced with the system according to their responsibilities. The proposed platform can be a web-based or mobile application to provide access to the system to the registered stakeholders of the system as per their needs.

After gathering real-time soil nutrient related data from cropland, it is also possible to recommend best crop for this cropland.

### **3.2.2 Crop Recommendation Module**

a crop recommendation model based on machine learning was implemented. Because supervised machine-learning provides better accuracy than unsupervised learning in recommendation problems, four different well-known supervised machine learning algorithms are used in the model's deployment. The crop recommendation model is designed using Linear Regression, Random Forest Regression, Decision Tree, and XGBoost machine learning algorithms. Nitrogen (N), Phosphorous (P), Potassium (K), Humidity, Potential of hydrogen (pH), Soil Temperature, and Average Rainfall in millimeters these seven (7) parameters have been taken into consideration for machine learning in implementing the crop recommendation model. The system model will suggest what type of crop will grow best if these parameters are in which amount.

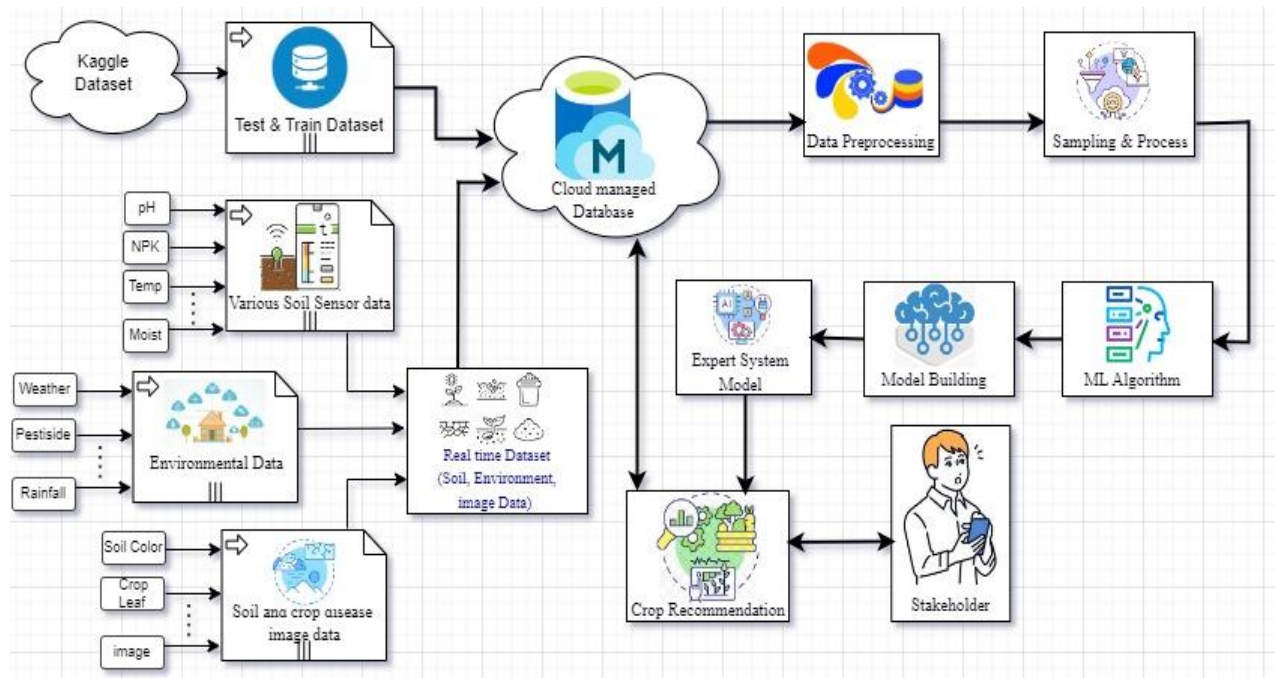


Figure 3.2.4 :Crop Recommendation Module Design

### Machine Learning with Linear Regression

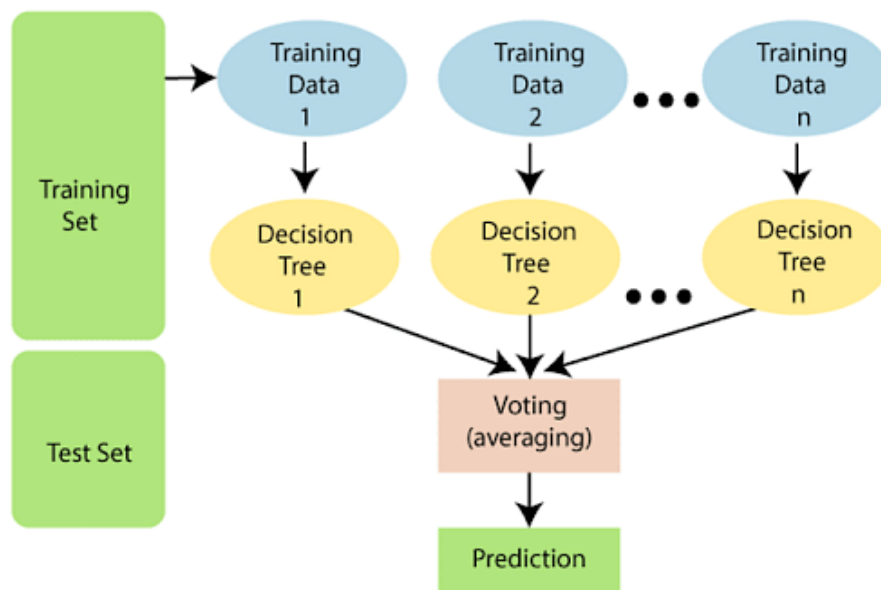
One of the simplest and most widely used Machine Learning algorithms is linear regression. It is a statistical technique for performing predictive analysis. For continuous data like selling, pay rate, age, and product price, among others, linear regression makes predictions.

The linear regression algorithm, also known as linear regression, illustrates a correlation between the dependent (y) and one or more independent (x) factors. Given that linear regression demonstrates a linear relationship, it can be used to evaluate how the dependent variable's value changes as a function of the individual variable's value.

### Machine Learning with Random Forest Regression

An extremely well-liked supervised machine learning algorithm called the Random Forest Algorithm is used to solve classification and regression issues. A forest is made up of many different types of trees, and the more trees there are, the more robust the forest will be. Similar to this, the accuracy and problem-solving capacity of a Random Forest Algorithm increase with the number of trees in the algorithm. In order to increase the dataset's predictive accuracy, a classifier called Random Forest uses multiple decision trees on different subsets of the input

data. It is based on the idea of ensemble learning, which is the process of combining various classifiers to solve a challenging problem and enhance the model's performance.



Random Forest working procedure

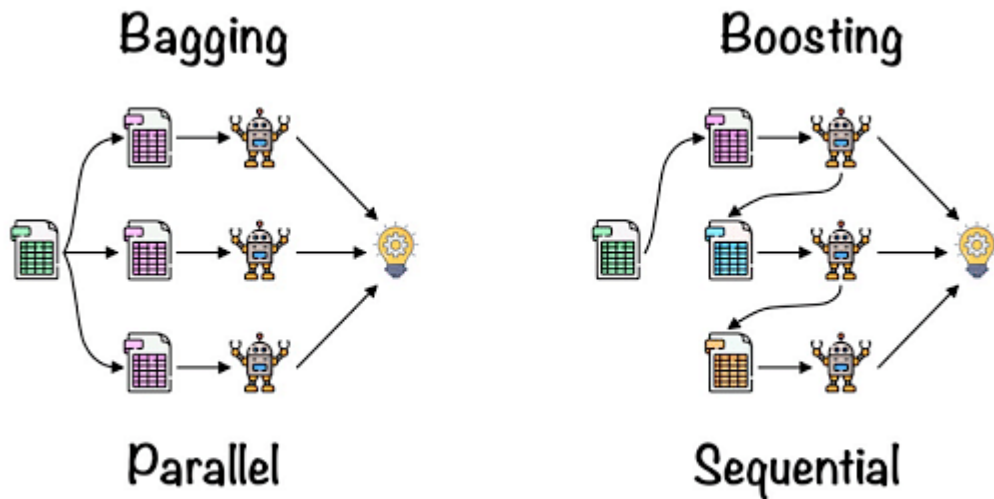
The Random Forest Algorithm's operation is described in the steps that follow:

- Choose random selection from a given collection of information or training set.
- For each training set of data, this algorithm will build a decision tree.
- Right to vote will be conducted using an average of the decision tree.
- Finally, choose the prediction result that received the most votes as the predicted result.

Ensemble is the name given to this fusion of various models. Ensemble employs two techniques:

1. Bagging: Bagging is the process of generating an alternative training subset using replacement from a sample training dataset. The outcome is decided by a majority vote.

2. Boosting: Boosting is the process of combining weak classifier into strong learners by building sequential models to make sure that the final model has the highest accuracy. For instance, ADA BOOST and XG BOOST[27].

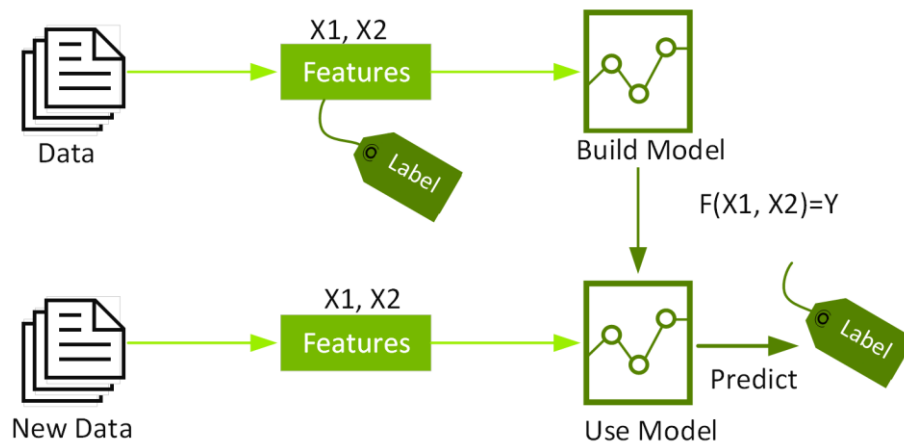


### Machine Learning with Decision Tree

A supervised learning method called a decision tree can be used to solve regression and classification problems, but it is typically preferred for doing so. It is a forest classifier, where internal nodes stand in for a dataset's features, branches for the decision-making process, and each leaf node for the classification result. The Decision Node and Leaf Node are the two nodes in a decision tree. While Leaf nodes are the results of decisions and do not have any additional branches, Decision nodes are used to make choices and have multiple branches. The given dataset's features are used to perform the test or make the decisions [28].

### Machine Learning with XGBoost

Extreme Gradient Boosting (XGBoost) is a distributed, scalable gradient-boosted decision tree (GBDT) machine learning library. The top machine learning library for regression, classification, and ranking issues, it offers parallel tree boosting. Understanding the machine learning ideas and techniques that supervised machine learning, decision trees, ensemble learning, and gradient boosting are built upon is essential to understanding XGBoost. In supervised machine learning, a model is trained using algorithms to find patterns in a dataset of features and labels, and the model is then used to predict the labels on the features of a new dataset.



By analyzing a tree of if-then-else true/false feature questions and estimating the bare minimum of questions required to assess the probability of making the right choice, decision trees produce a model that predicts the label. Regression to predict a continuous numeric value or classification to predict a category can both be done using decision trees[29]. The straightforward example below shows how to estimate a home's price (the label) using a decision tree and the size and number of bedrooms (the features).

Crop recommendation module work with few steps. Each step has been designated below one by one.

#### a. Importing Libraries and dataset

Data preprocessing tools, Machine learning Algorithms as well required Libraries need to be imported. The system is made productive and efficient to predict the best crop by these tools and libraries. Popular libraries were imported, including label encoder, train test split, pickle, pandas, seaborn, matplotlib, and numpy. The system also includes models like XGBoost, Decision Trees, Linear Regression, and Random Forest Regression. To train the system, the dataset collected from Kaggle is combined with some manual datasets collected from real fields to form a new reliable dataset. Most of the data in this dataset are used for machine learning and the remaining data is used for testing the system model. The dataset comprises 2,420 rows and eight columns (8 attributes). last column enlisted the crop list. 7 columns of attributes describe below:

| S.L | Attribute | Description               |
|-----|-----------|---------------------------|
| 1   | N         | Content of Nitrogen(s)    |
| 2   | P         | Content of Phosphorous(s) |

|   |      |                         |
|---|------|-------------------------|
| 3 | K    | Content of Potassium(s) |
| 4 | H    | Humidity ( %)           |
| 5 | T    | Temperature in Celsius  |
| 6 | PH   | Soil pH                 |
| 7 | RF   | Rainfall in millimeter  |
| 8 | Crop | Crop Grown              |

Table 3.2.1: Details meaning of the Dataset

| <b>N</b> | <b>P</b> | <b>K</b> | <b>H</b> | <b>T</b> | <b>PH</b> | <b>RF</b> | <b>Crop</b>  |
|----------|----------|----------|----------|----------|-----------|-----------|--------------|
| 79       | 51       | 16       | 68.4     | 25.3     | 6.5       | 96.4      | Maize        |
| 90       | 42       | 43       | 82.0     | 20.8     | 6.5       | 202.9     | Rice         |
| 43       | 79       | 79       | 18.9     | 19.4     | 7.8       | 80.2      | Chickpea     |
| 17       | 77       | 23       | 20.8     | 24.5     | 5.6       | 64.1      | Kidney Beans |
| 28       | 59       | 22       | 52.7     | 30.9     | 7.0       | 170.9     | Pigeon peas  |
| 99       | 15       | 27       | 56.6     | 27.4     | 6.0       | 127.9     | Coffee       |

Table 3.2.2: Sample Instances of Dataset

Table 6: Crops that are being suggested, and the number of examples in the dataset that Correspond to them.

| <b>Sl. No.</b> | <b>Name of Crop</b> | <b>Instances</b> |
|----------------|---------------------|------------------|
| 1              | Rice                | 110              |
| 2              | Maize               | 110              |
| 3              | Orange              | 110              |
| 4              | Pomegranate         | 110              |
| 5              | Muskmelon           | 110              |
| 6              | Blackgram           | 110              |
| 7              | Chickpea            | 110              |
| 8              | Mango               | 110              |

|    |             |     |
|----|-------------|-----|
| 9  | Watermelon  | 110 |
| 10 | Mungbean    | 110 |
| 11 | Grapes      | 110 |
| 12 | Papaya      | 110 |
| 13 | Pigeonpeas  | 110 |
| 14 | Apple       | 110 |
| 15 | Jute        | 110 |
| 16 | Kidneybeans | 110 |
| 17 | Coconut     | 110 |
| 18 | Cotton      | 110 |
| 19 | Lentil      | 110 |
| 20 | Coffee      | 110 |
| 21 | Mothbeans   | 110 |
| 22 | Banana      | 200 |

---

Table 3.2.3: Crops Consideration

### **b. Data Analysis and Visualization**

To obtain the best model, data analysis and visualization should be performed prior. It is very important to check for missing values per attribute as well as distinguish unique values of dependent and independent variables. Visualization is easy after getting the analyzed dataset. A table showing the correlations and coefficients between the characteristics shown in the presence matrix Fig.3.

### **c. Label encoding**

The label values for the dependent label variables must be converted into numeric values before being nourished into the predictive model for future prediction because they have categorical and non-numeric values. Because processing non-numeric values is quite complex and time-consuming, label encoding plays a major role.

### **d. Splitting the data into train and test sets**

Data sets are separated into training and testing sets for model building after data analysis and visualization. Initial data is required to train the machine. Machine learning algorithms are taught how to make precise predictions or carry out a desired action using training datasets. 60% of the data from this data set was used for machine learning and the remaining 40% of the data was used for testing the system model shown in Figure 3.2.5.

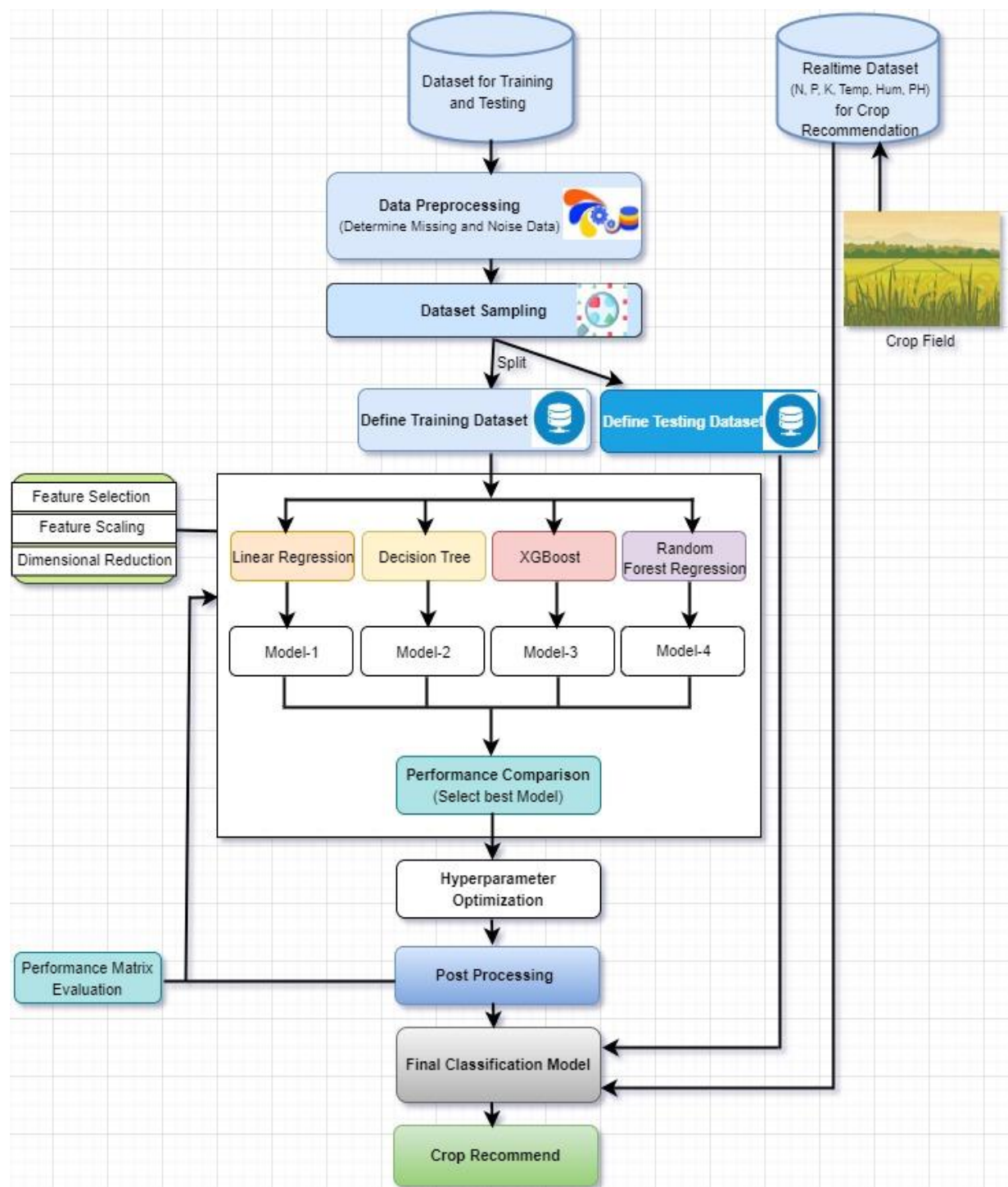


Figure 3.2.5 : Sequence Process of Model building for Crop Recommendation

#### **e. Model building**

The best crop recommendation model is found using four machine learning algorithms in the proposed work. Steps to build a model should be performed

- To build the model, the library has to be imported.
- Being formed is a model.
- The model is fitted with both training and testing data, and after training, the testing data set is used to test the model.
- Metrics for evaluation and confusion are computed.

Among these four machine learning algorithms namely Linear Regression, Decision Tree, Random Forest Regression, and XGBoost, the one with the best performance is used for model building. Random Forest Regression and XGBoost algorithm performs better than the two. Model building is done using the Random Forest Regression algorithm.

#### **f. Predicting the crop**

Choosing the best method for crop assumption based on comparison and performance assessment. The model needs inputs for N, P, K, temperature, moisture, pH, and rainfall in order to predict the best crops. According to the parameter values, the best-predicted crop name would be recommended.

### **3.3 Summary**

This section has presented the methodology of IoT-Based Agriculture for Soil Nutrients Fertilizer Monitoring Systems. Describe the Equipment needed to implement the soil nutrients Fertilizer Monitoring Systems as well as implementation procedure. In the next chapter, we will discuss the Result and discussion of the project.

## **Chapter-4**

### **Experiment and Result**

---

## Experimental Result and Discussion

---

The test method and analysis findings of the various soil nutrient measurement techniques are presented in this chapter. The implementation process for a fertilizer monitoring system and a soil nutrient measurement system is described. The methods for measuring soil nutrients and monitoring fertilizer use are compared.

### 4.1 Experimental setup

The proposed soil nutrient measurement and fertilizer monitoring system is implemented in flat C programming using Arduino.cc environment. In addition to a text editor for writing code, a message area, a text console, a toolbar with buttons for frequently used operations, and a number of menus, the Arduino Integrated Development Environment, also known as the Arduino Software (IDE), is also available. Graphical Overview is shown in Google colab as well as MS Excel and Power point. On a PC, the experiment is carried out. Intel Core i7 2.4GHz processor with 8GB RAM, and 500GB Hard Drive are the specifications for the PC.

### 4.2 Experimental Result Analysis and Discussion

Research/Project results are obtained by verifying the performance of the proposed method from different sensor outputs. The IoT-based smart soil fertilizer monitoring module was tested in garden tubs as well as agricultural crop fields and found satisfactory results. Over time various cycles of testing, multiple factors were considered and improvements were made according to satisfactory results.

In various types of soil, this project has been tested. However, by specifically testing four types of soil, the quality of soil properties has been examined.

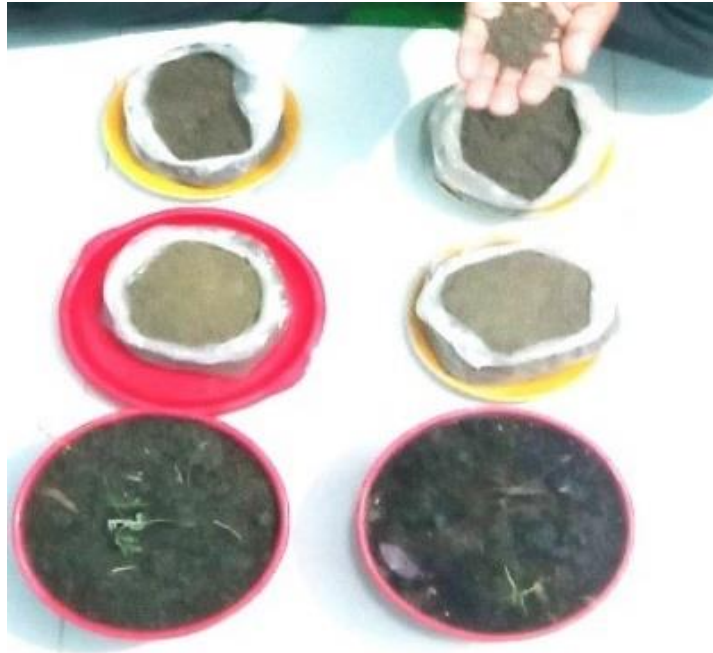


Figure 4.2.1 Various Soil Sample



Figure 4.2.2 :Soil sample1

Different soils have varying soil property values. The terms share a lot of similarities for some soil types.



Figure 4.2.3 :Soil sample2

A comparative analysis of the soils was conducted using samples from four different regions of Bangladesh.



Figure 4.2.4 :Soil sample3

Figures 2, 3, and 4 have better average soil nutrients than Figure 1, which has the opposite situation.



Figure 4.2.5 :Soil sample4

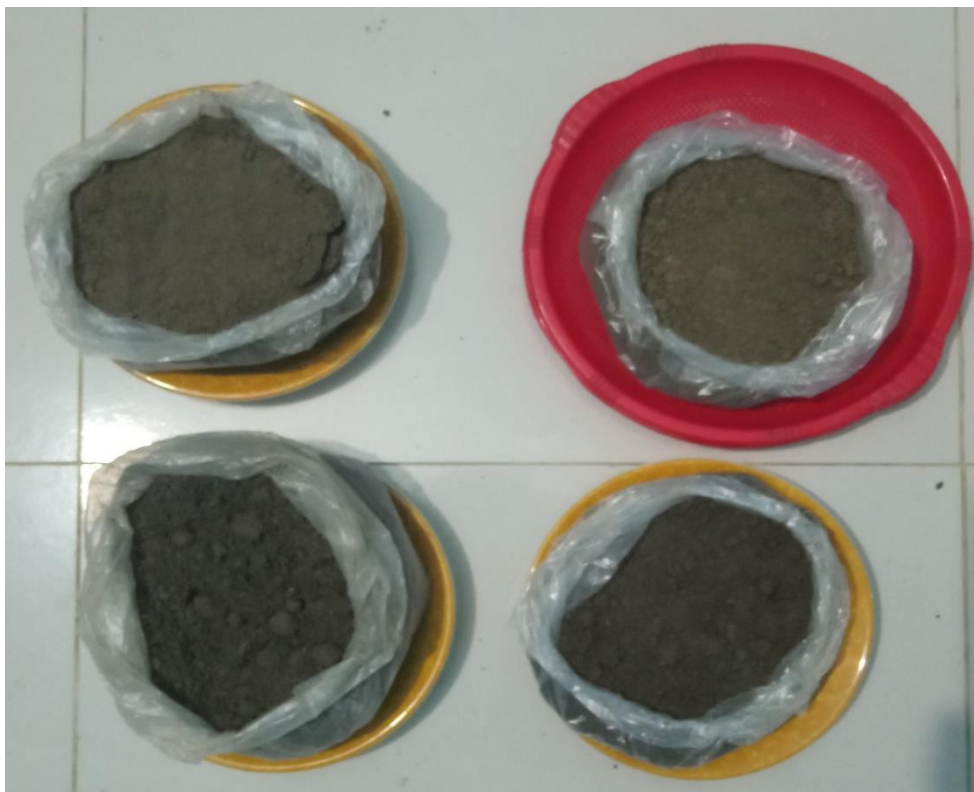


Figure 4.2.6 : Four Soil sample combine

Figure 4.2.7 displays a graphic representation of the percentage of moisture in the soil in the sample.

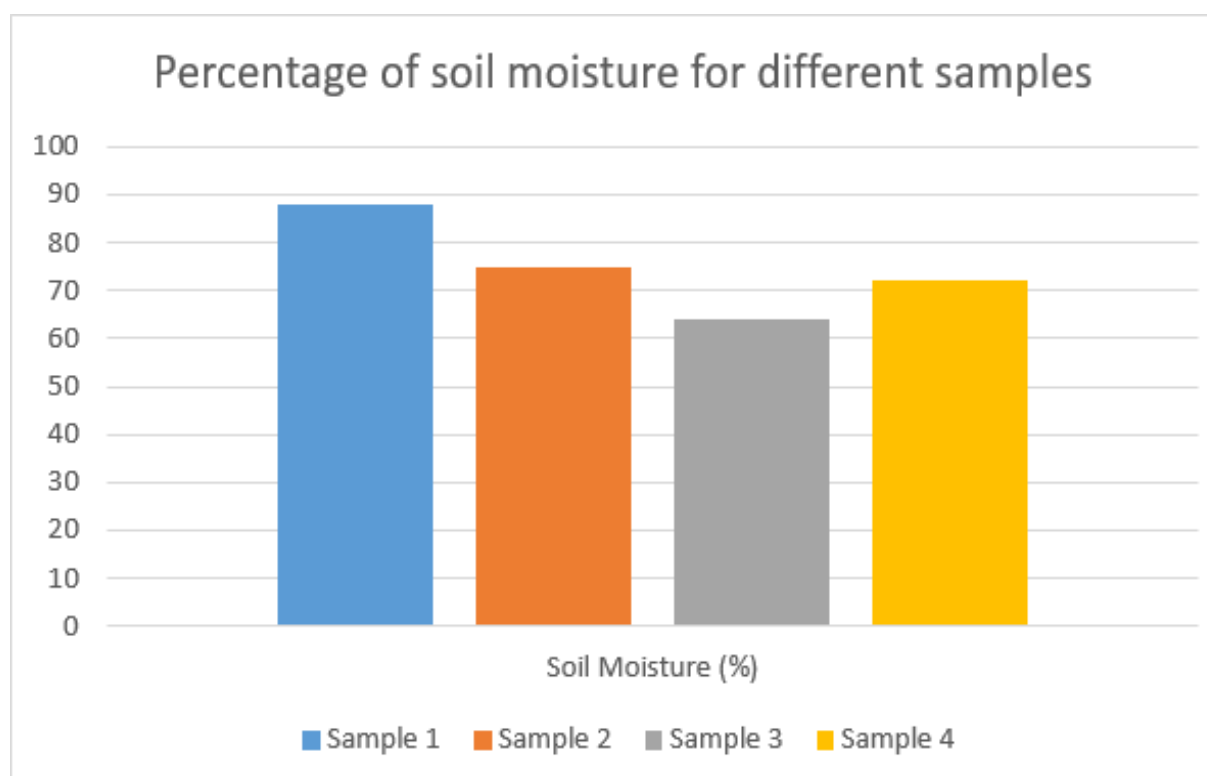


Figure 4.2.7 :Percentage of soil moisture for dissimilar samples

| Sample | Phosphorous (P) | Nitrogen (N) | Potassium (K) |
|--------|-----------------|--------------|---------------|
| 1      | Intermediate    | Little       | Little        |
| 2      | Little          | Intermediate | Little        |
| 3      | High            | Little       | Intermediate  |
| 4      | Intermediate    | High         | Intermediate  |

Table 4.2.1. Nutrient Values for Dissimilar Samples

Based on the nitrogen, phosphorus, and potassium levels of the four sample soils examined, a table was created.

| Rating of Fertility for Nitrogen |                 |
|----------------------------------|-----------------|
| Levels                           | Range           |
| High                             | >450 kg/ha      |
| Intermediate                     | 280 – 450 kg/ha |
| Little                           | 0 – 280Kg/ha    |

Table 4.2.2: Soil nitrogen Fertilizer Range

Constructed by the nitrogen fertility scores of four dissimilar soil samples, a table is displayed.

| Rating of Fertility for Phosphorus |                 |
|------------------------------------|-----------------|
| Levels                             | Range           |
| High                               | >22 kg P/ha     |
| Intermediate                       | 11 – 22 kg P/ha |
| Little                             | 0 – 11kg P/ha   |

Table 4.2.3: Soil Phosphorous Fertilizer Range

Based on the Phosphorus fertility scores of four different soil samples, a table is displayed.

| Rating of Fertility for Potassium |                   |
|-----------------------------------|-------------------|
| Levels                            | Range             |
| High                              | >280kg K/ha       |
| Medium                            | 118 – 280 kg K/ha |
| Low                               | 0 – 118kg K/ha    |

Table 4.2.4: Potassium in Soil Fertilizer Range

Based on the Potassium fertility scores of four different soil samples, a table is displayed. Tables 4.2.2, 3, and 4 show the varieties of NPK which guarantees farmers to cultivate suitable harvests and growth farming. Table 4 shows the nutrient values for various soil samples. A recommendation system helps farmers apply the proper amount of fertilizer to ensure maximum effectiveness.

Figure 4.2.10 shows the cloud database table content collected from the IoT-based smart soil fertilizer monitoring module. WiFi communication method was used to communicate with the server to send real-time data.

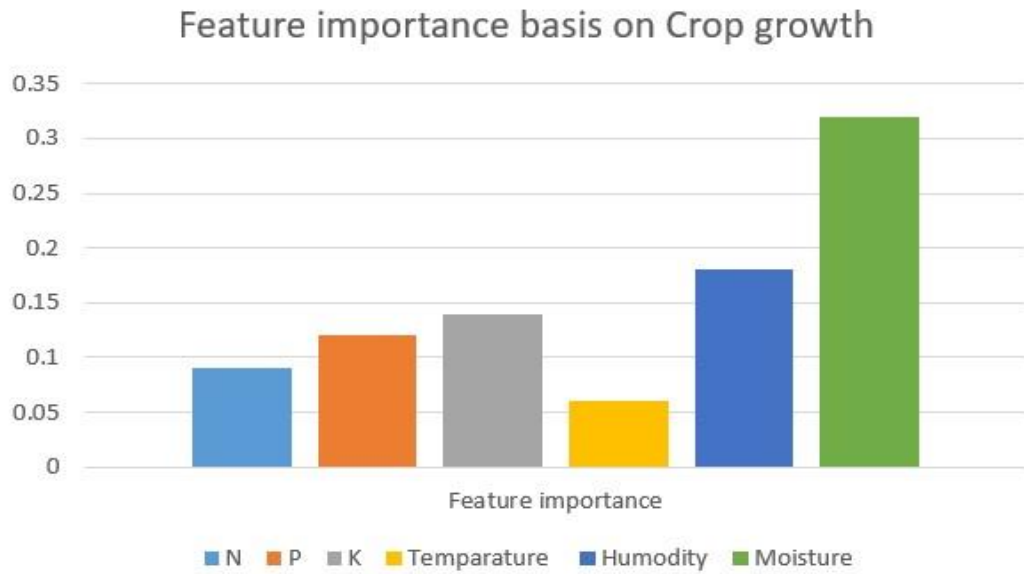


Figure 4.2.8 :Feature importance basis on Crop growth

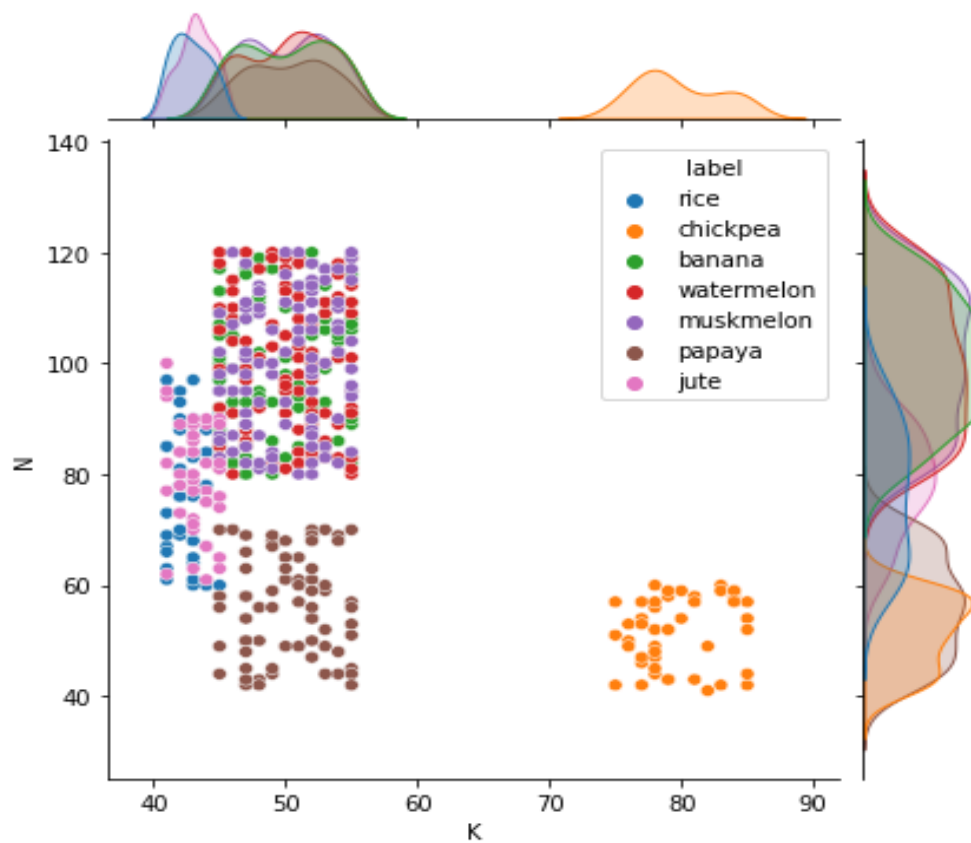


Figure 4.2.9 :Nitrogen and Potassium attributes are dispersed.

required crop property and the algorithmic model will recommend crops for that land. As seen in Figure 4.2.10, the regarded dataset.

| + Options |          |             |           |          |                        |     |                            |
|-----------|----------|-------------|-----------|----------|------------------------|-----|----------------------------|
| S.L       | Nitrogen | Phosphorous | Potassium | Humidity | Temperature in Celsius | PH  | Timestamp                  |
| 1         | 28       | 56          | 22        | 52       | 30                     | 7   | 2022-11-04 13:16:16.519138 |
| 2         | 23       | 48          | 23        | 58       | 33                     | 7.5 | 2022-11-04 13:36:16.519168 |
| 3         | 34       | 67          | 43        | 58       | 43                     | 6.5 | 2022-11-04 14:36:16.519158 |
| 4         | 54       | 57          | 65        | 63       | 54                     | 6.5 | 2022-11-04 15:36:16.519128 |
| 5         | 43       | 79          | 80        | 18.9     | 19.4                   | 7.8 | 2022-11-05 23:19:54.411323 |
| 6         | 45       | 34          | 76        | 34       | 24                     | 6.4 | 2022-11-05 23:32:16.519188 |
| 7         | 45       | 67          | 54        | 47       | 28                     | 6.7 | 2022-11-05 23:33:09.555397 |
| 8         | 28       | 34          | 54        | 45       | 24                     | 6.4 | 2022-11-05 23:34:16.240124 |
| 9         | 32       | 49          | 59        | 43       | 29                     | 5.9 | 2022-11-05 23:35:06.005177 |
| 10        | 54       | 67          | 59        | 47       | 31                     | 6.2 | 2022-11-05 23:35:54.172716 |
| 11        | 43       | 79          | 59        | 34       | 29                     | 6.4 | 2022-11-05 23:36:27.168105 |

Figure 4.2.10 :Table data from fertilizer monitoring module

Since consider various parameters of soil content In Figure 4.2.8, shown the Feature importance basis on Crop growth. Among the various content of soil, a comparison In Figure 4.2.9, shows the Nitrogen and Potassium attributes are dispersed.

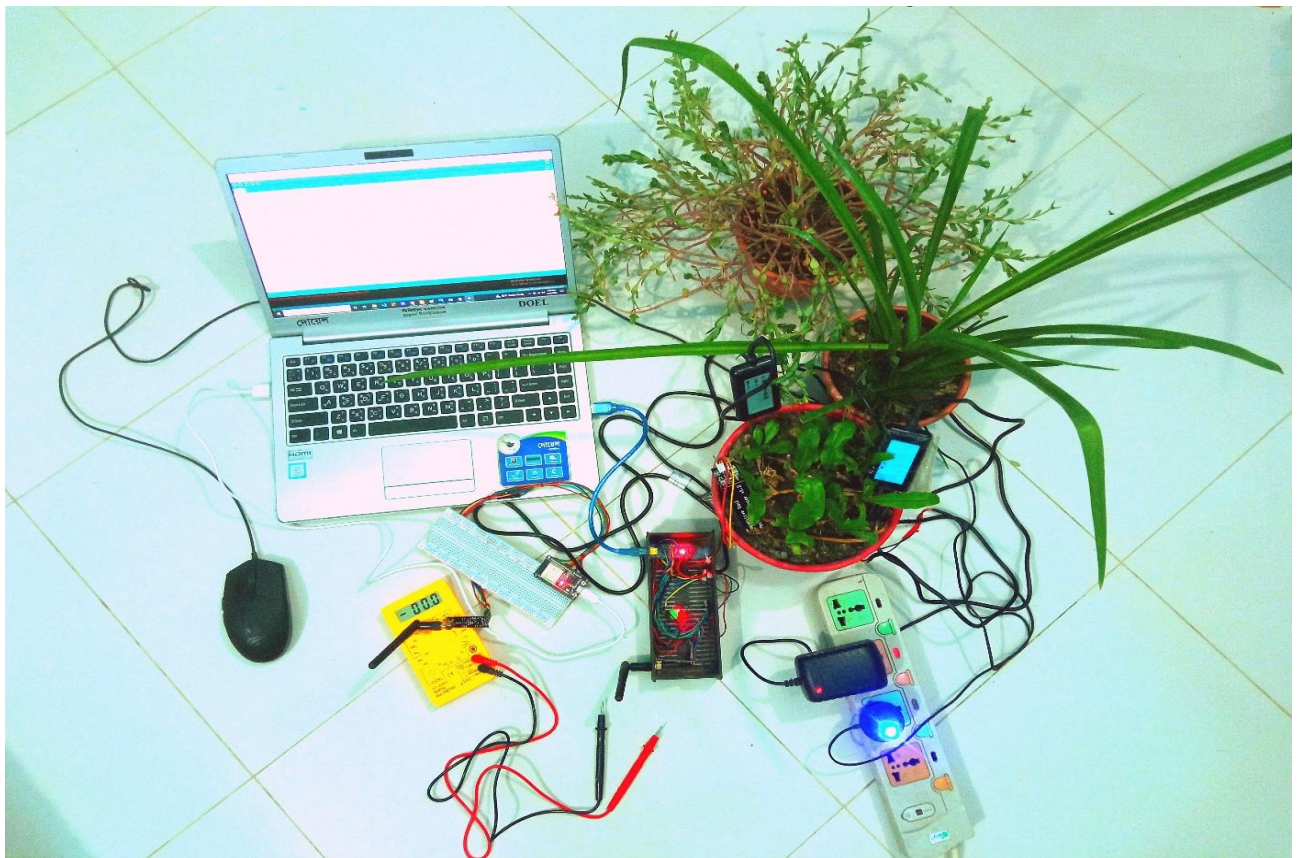


Figure 4.2.11: Implementation of Soil fertilizer monitoring

Use of Soil fertilizer monitoring implemented module in different environment with different soil sample which is shown in Figure 4.2.12. It also experimented in different locality soil like Brahmanbaria, Cumilla and Gazipur.

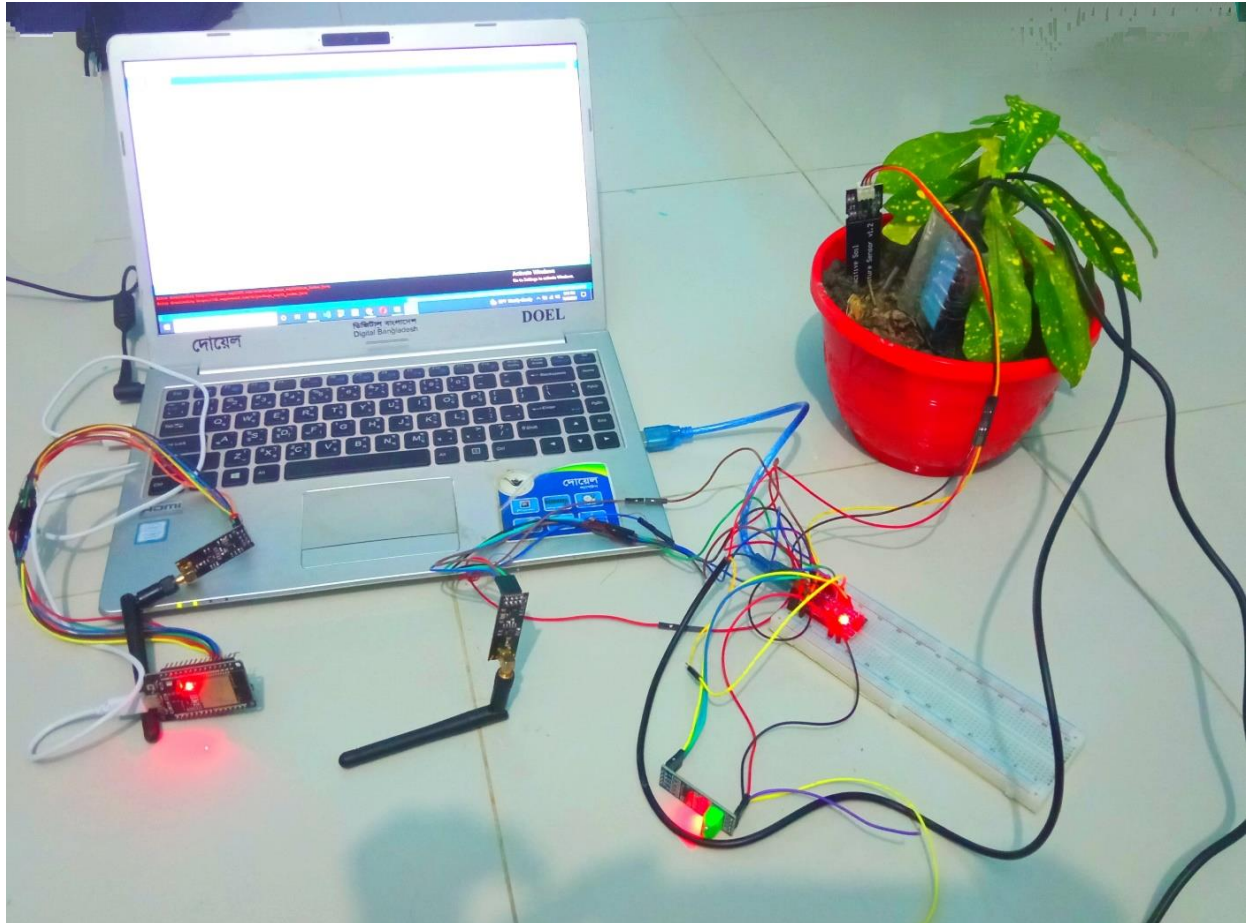


Figure 4.2.12 : Use of Implemented module

The Train accuracy of Linear Regression, Random Forest Regression, Decision tree, and XGBoost are 72.03%, 100%, 94.48%, and 100% respectively. Similarly, The Test accuracy of Linear Regression, Random Forest Regression, Decision tree, and XGBoost are 70.81%, 99.09%, 93.48% and 98.63% respectively Table Table 4.2.5. Test dataset accuracy has been shown on Figure Figure 4.2.13.

|   | model_name               | accuracy_train | accuracy_test |
|---|--------------------------|----------------|---------------|
| 0 | Linear Regression        | 72.025319      | 70.808524     |
| 1 | Random Forest Regression | 100.000000     | 99.090909     |
| 2 | Decision Tree            | 94.480519      | 93.484848     |
| 3 | XGBoost                  | 100.000000     | 98.636364     |

Table 4.2.5: Train and Test accuracy score

According to the Above table content a graphical overview has been shown on

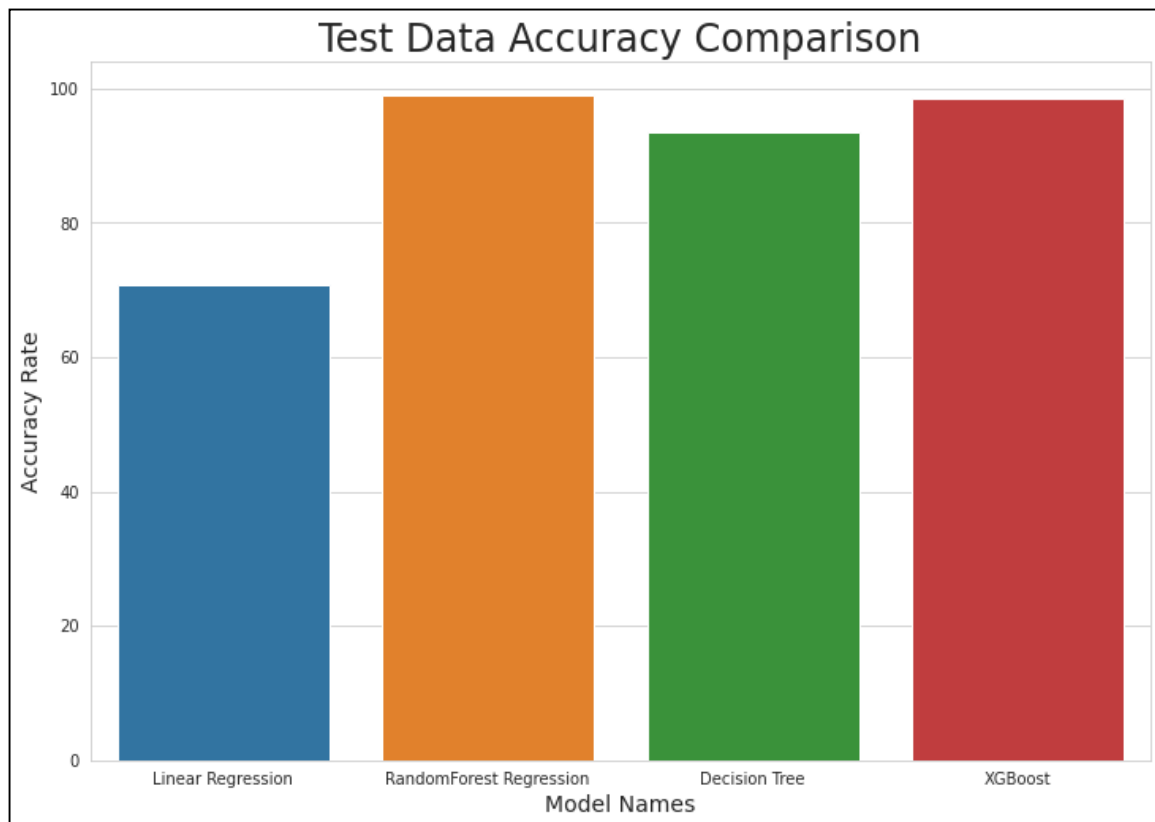


Figure 4.2.13: Test data Accuracy comparison

```

N = 90
P = 42
K = 43
temperature = 20.82312
humidity = 82.00284
ph = 6.50232
rainfall = 202.93536
sample = [N, P, K, temperature, humidity, ph, rainfall]
single_sample = np.array(sample).reshape(1,-1)
pred = model.predict(single_sample)
pred.item().title()

```

Fig. 4.2.14 :Calling recommendation model method

Output: Rice

List of the material cost for the Project work

| S.N.  | COMPONENTS NAME      | QUANTITY | DESCRIPTION                                            | Price  |
|-------|----------------------|----------|--------------------------------------------------------|--------|
| 1     | Arduino Board        | 1        | Embedded system (Arduino Nano)                         | 1200   |
| 2     | ESP32 Board          | 1        | Development Board for the ESP32 ESP-32S (ESP-WROOM-32) | 2050   |
| 3     | NR24L01 Module       | 2        | 2.4 GHz Wireless Transceiver Module NRF24L01           | 900    |
| 4     | NPK Sensor           | 1        | Soil NPK Sensor by JXIOT                               | 14500  |
| 5     | Soil Moisture Sensor | 1        | v2.0 of the capacitive soil moisture sensor            | 450    |
| 6     | Temperature Sensor   | 1        | Waterproof Temperature Sensor DS18B20                  | 550    |
| 7     | Modbus Module        | 1        | MODBUS MAX485                                          | 2050   |
| 8     | Resistor             | 1        | 4.7K Resistor                                          | 20     |
| 9     | Power Supply         | 1        | 9V - 12V DC Power Supply                               | 300    |
| 10    | Connecting Wires     | 20       | Jumper Wires                                           | 100    |
| Total |                      |          |                                                        | 22,020 |

### **4.3 Summary**

The Result and Discussion chapter described the complete workflow of the work. It explained all phases sequentially. Smart IoT-Based Agriculture Soil Nutrient and Fertilizer Monitoring System the domain model and problem model using IoT based are explained with the implementation procedure. The Conclusion is presented in the next chapter with future work.

## **Chapter-5**

## **Conclusion**

---

## Conclusion

---

### 5.1 Conclusion

The main focus of this work is to assist growers in making an informed decision before planting by advising them to produce the best crop depending on various parameters. It is possible to grow more profitable crops if the correct information about the soil of the agricultural land is known for growing agricultural crops. Through this one can contribute to the development of the country by meeting the lack of global food demand. The proposal will play an important role in the development of agricultural infrastructure by providing various information related to agricultural production to the farmers. The work modules will act as an effective tool for farmers to quantify the different soil properties of their land for produce the most profitable crops suitable for that land. Farmers in rural areas in particular will be encouraged to use new technologies (IoT, Cloud Computing) to increase agricultural yield through which smart villages can be implemented. The proposed framework will help open up new horizons in making soil and agriculture researchers more efficient with effective solutions by using them to develop an IoT based soil nutrient and fertilizer monitoring system. The soil moisture, N, P, K, Humidity, and temperature values are continuously monitored and reported by this system.

### 5.2 Future Work

Basis on real-time dataset a predictive crop recommendation system would be proposed. Depending on the season, this system can be enhanced to include a surplus of features like weather forecasting, drought conditions, flood detection, and agricultural price forecasting. An Android app would be created and integrated with the suggested system to make it simpler for farmers to use.

## References

- [1] Arun Kumar, Abhishek Kumar, Akash De, S. Shekhar and R. K. Singh, "IoT Based Farming Recommendation System Using Soil Nutrient and Environmental Condition Detection," International Journal of Innovative Technology and Exploring Engineering (IJITEE), vol. 8, no. 11, pp. 3055-3060, 2019.
- [2] R. Madhumathi, T. Arumuganathan and R. Shruthi, "Soil NPK and Moisture analysis using Wireless Sensor Networks," in 2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT), Kharagpur, India, 2022.
- [3] I. A. Lakhari, G. Jianmin, T. N. Syed, F. A. Chandio, N. A. Buttar and W. A. Qureshi, "Monitoring and Control Systems in Agriculture Using Intelligent Sensor Techniques: A Review of the Aeroponic System," Hindawi Journal of Sensors, vol. 2018, no. 8672769, p. 18, 2018.
- [4] N. Ananthi, J. Divya, M. Divya and V. Janani, "IoT based smart soil monitoring system for agricultural production," in 2017 IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR), Chennai, India, 2017.
- [5] Salve Akshay, Sagar Sonali, Patne Mahesh and Jangam Omkar, "SOIL NUTRIENT IDENTIFICATION USING ARDUINO AND ELECTROCHEMICAL SENSOR," International Research Journal of Engineering and Technology (IRJET), vol. 05, no. 02, pp. 1327-1329, 2018.
- [6] Jash Doshi, T. Patel and S. k. Bharti, "Smart Farming using IoT, a solution for optimally monitoring farming conditions," in The 3rd International workshop on Recent advances on Internet of Things: Technology and Application Approaches(IoT-T&A 2019), Coimbra, Portugal, 2019.
- [7] Abdullah Na, W. Isaac, S. Varshney and E. Khan, "An IoT based system for remote monitoring of soil characteristics," in 2016 International Conference on Information Technology (InCITE) - The Next Generation IT Summit on the Theme - Internet of Things: Connect your Worlds, Noida, India, 2016.
- [8] S. N. Shylaja and M. B. Veena, "Real-time monitoring of soil nutrient analysis using WSN," in 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS), Chennai, India, 2018.

- [9] A. Chlingaryana, S. Sukkarieha and B. Whelan, "Machine learning approaches for crop yield prediction and nitrogen status estimation in precision agriculture: A review," *Computers and electronics in agriculture*, vol. 151, pp. 61-69, 2018.
- [10] N. Ahmed, D. De and I. Hussain, "Internet of Things (IoT) for Smart Precision Agriculture and Farming in Rural Areas," *IEEE INTERNET OF THINGS JOURNAL*, vol. 5, no. 6, pp. 4890 - 4899, 2018.
- [11] N. Ananthi, J. Divya, M. Divya and V. Janani, "IoT based smart soil monitoring system for agricultural production," in *2017 IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR)*, Chennai, India, 2017.
- [12] C. Bepery, S. S. Sozol, M. Rahman, M. Alam and N. Rahman, "Framework for Internet of Things in Remote Soil Monitoring," in *2020 23rd International Conference on Computer and Information Technology (ICCIT)*, Dhaka, Bangladesh, 2020.
- [13] R. Maheswari, . H. Azath, P. Sharmila and S. S. Rani Gnanamalar, "Smart Village: Solar Based Smart Agriculture with IoT Enabled for Climatic Change and Fertilization of Soil," in *2019 IEEE 5th International Conference on Mechatronics System and Robots (ICMSR)*, Singapore, 2019.
- [14] Ritesh Dasha, Dillip Ku Dash and G. C. Biswal, "Classification of crop based on macronutrients and weather data using machine learning techniques," *Results in Engineering*, vol. 9, no. 100203, 2021.
- [15] Z. Doshi, S. Nadkarni, R. Agrawal and . N. Shah, "AgroConsultant: Intelligent Crop Recommendation System Using Machine Learning Algorithms," in *2018 Fourth International Conference on Computing Communication Control and Automation (ICCUBEA)*, Pune, India, 2018.
- [16] A. Sharma, A. Jain and P. Gupta, "Machine Learning Applications for Precision Agriculture: A Comprehensive Review," *IEEE Access*, vol. 9, no. 20324010, pp. 4843 - 4873, 2020.
- [17] M. I. Jordan and T. M. Mitchell, "Machine learning: Trends, perspectives, and prospects," *SCIENCE*, vol. 349, no. 6245, pp. 255-260, 2015.
- [18] Dr. Bashar Rajoub, "Supervised and unsupervised learning," in *Biomedical Signal Processing and Artificial Intelligence in Healthcare*, Dubai, United Arab Emirates, ScienceDirect, 2022, pp. 51-89.

- [19] P. Chandra Sen, M. Hajra and M. Ghosh, "Supervised Classification Algorithms in Machine Learning: A Survey and Review," Springer Singapore, vol. 937, pp. 99-111, 2019.
- [20] Hooman H. Rashidi, N. Tran, S. Albahra and L. T. Dang, "Machine learning in health care and laboratory medicine: General overview of supervised learning and Auto-ML," *Int J Lab Hematol*, vol. 43, pp. 15-22, 2021.
- [21] A Suresh, P. Ganesh Kumar and M. Ramalatha, "Prediction of major crop yields of Tamilnadu using K-means and Modified KNN," in 2018 3rd International Conference on Communication and Electronics Systems (ICCES), Coimbatore, India, 2018.
- [22] P. S. Nishant, P. S. Venkat, B. L. Avinash and B. Jabber, "Crop Yield Prediction based on Indian Agriculture using Machine Learning," in 2020 International Conference for Emerging Technology (INCET), Belgaum, India, 2020.
- [23] Aruvansh Nigam, S. Garg, A. Agrawal and P. Agrawal, "Crop Yield Prediction Using Machine Learning Algorithms," in 2019 Fifth International Conference on Image Information Processing (ICIIP), Shimla, India, 2019.
- [24] Shreya V. Bhosale, R. A. Thombare, P. G. Dhemey and A. N. Chaudhari, "Crop Yield Prediction Using Data Analytics and Hybrid Approach," in 2018 Fourth International Conference on Computing Communication Control and Automation (ICCUBE), Pune, India, 2019.
- [25] A. Kumar, S. Sarkar and C. Pradhan, "Recommendation System for Crop Identification and Pest Control Technique in Agriculture," in 2019 International Conference on Communication and Signal Processing (ICCSP), Chennai, India, 2019.
- [26] Tanhim Islam, T. A. Chisty and A. Chakrabarty, "A Deep Neural Network Approach for Crop Selection and Yield Prediction in Bangladesh," in 2018 IEEE Region 10 Humanitarian Technology Conference (R10-HTC), Malambe, Sri Lanka, 2018.
- [27] M. Mamun Ali, B. Kumar Paul, K. Ahmed, F. M. Bui, J. M.W. Quinn and M. A. Moni, "Heart disease prediction using supervised machine learning algorithms: Performance analysis and comparison," *Computers in Biology and Medicine*, vol. 136, no. 104672, 2021.
- [28] J. Lacasta, F. J. Lopez-Pellicer, B. Espejo-García, J. Nogueras-Iso and F. J. Zarazaga-Soria, "Agricultural recommendation system for crop protection," *Computers and Electronics in Agriculture*, Elsevier, vol. 152, pp. 82-89, 2018.

[29] N. H Kulkarni, G N Srinivasan, B M Sagar and N K Cauvery, "Improving Crop Productivity Through A Crop Recommendation System Using Ensembling Technique," in 2018 3rd International Conference on Computational Systems and Information Technology for Sustainable Solutions (CSITSS), Bengaluru, India, 2018.

#### Annexure-01

##### **Cost Estimate:**

|     |                                        |              |
|-----|----------------------------------------|--------------|
| (a) | Cost of Material                       | Tk.22,020/-  |
| (b) | Field works                            | Tk.5000/-    |
| (c) | Conveyance/ Data Collection            | Tk.5000/-    |
| (d) | Typing, Drafting, Binding & Paper etc. | Tk.3500/-    |
|     | Total=                                 | Tk. 35,520/- |