DESIGN AND PERFORMANCE ANALYSIS OF INDUSTRIAL SOIL SENSOR FOR NUTRIENTS MONITORING

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Computer Engineering with Honours

Faculty of Electronics and Computer Technology and Engineering
Universiti Teknikal Malaysia Melaka

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

DECLARATION

I declare that this report entitled "Design and Performance Analysis of Industrial Soil Sensor for Nutrients Monitoring" is the result of my own work except for quotes as cited in the references.

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Signature : ……………………………………

Author : NUR ALIYA NAZIRA BINTI MOHD NAZRI

Date : 19/6/2024

APPROVAL

I hereby declare that I have read this thesis, and, in my opinion, this thesis is sufficient in terms of scope and quality for the award of Bachelor of Computer Engineering with Honours

Signature : fakrulradzi ....

Supervisor Name : DR. FAKRULRADZI BIN IDRIS

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Date : 19/6/2024

DEDICATION

I dedicate this thesis to my dear parents who have always supported and encouraged me throughout my academic journey. Both of you have been my constant source of inspiration and encouragement, always supporting me. To my mentors and who guided and inspired me with their knowledge and wisdom, which was invaluable in shaping my understanding and approach to this project. To my friends and colleagues who have supported me through challenges and milestones. You all made this trip more enjoyable and meaningful. Finally, I dedicate this work to my own commitment to striving for excellence and innovation in my field.

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ABSTRACT

It has become evident that precision farming is vital as the methods of the contemporary agriculture change to maximize results. This paper, therefore, describes the design of a wireless soil nutrient sensing system comprising of a Soil Sensor, Temperature and Humidity Sensor (DHT11) and NodeMCU ESP32 microcontroller. Real time monitoring and data transfer to the cloud is done with the help of Blynk IoT platform. The soil sensor quantifies the nitrogen (N), phosphorus (P), and potassium (K) that is needed in an appropriate ratio to grow plants besides humidity, temperature and conductivity. The designed system uses the Blynk IoT platform allowing for real-time monitoring and sending data to the cloud improving control and decision-making for farmers and agronomists. Comparative tests conducted on a cornfield at UTeM showed that system's yield at six sites with different soil nutrient contents demonstrated systemic differences. Investigations in the future will be directed toward the refinement of the relevant sensors as well as the farther application of smart sensors in various agricultural areas with an emphasis on proper utilization of the fertilizers and farming technologies that would increase yields while reducing negative effects on the environment.

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ABSTRAK

Apabila pertanian moden berkembang, ketepatan untuk teknik pertanian menjadi semakin penting dalam mengoptimumkan hasil dan penggunaan sumber. Kajian ini memperkenalkan pembangunan sistem sensor tanah tanpa wayar untuk pemantauan nutrien masa nyata, menggunakan Sensor Tanah, Sensor Suhu dan Kelembapan (DHT11), dan mikrokontroler NodeMCU ESP32. Platform Blynk IoT digunakan untuk pemantauan masa nyata dan penghantaran data ke awan. Sensor tanah mengukur nutrien penting seperti nitrogen (N), fosforus (P), dan kalium (K), bersama-sama dengan kelembapan, suhu, dan konduktiviti. Menggunakan platform Blynk IoT, sistem ini membolehkan pemantauan masa nyata dan penghantaran data ke awan, meningkatkan aksesibiliti dan kesenangan untuk petani dan ahli agronomi dalam membuat keputusan. Hasil ujian perbandingan di ladang jagung di UTeM mendedahkan prestasi sistem di enam lokasi, menunjukkan perubahan tahap nutrien dalam tanah. Penyelidikan masa depan akan memberi tumpuan kepada peningkatan sensor dan penyebaran jangka panjang di pelbagai tapak pertanian, bertujuan untuk mengoptimumkan penggunaan pupuk, meningkatkan hasil panen, dan meminimalkan kesan alam sekitar melalui teknik pertanian presisi.

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LIST OF SYMBOLS AND ABBREVIATIONS

UN	:	United Nation
N	:	Nitrogen
P	:	Phosphorus
K	:	Potassium
NPK	:	Nitrogen, Phosphorus, and Potassium
DHT11	:	Humidity and Temperature Sensor
IoT	:	Internet of Things
IDE	:	Integrated Development Environment
Blynk	:	Blynk IoT Platform
SSID	:	Service Set Identifier (Wi-Fi Network Name)
IP	:	Internet Protocol
Wi-Fi	:	Wireless Fidelity
PERG	:	Photonics Engineering Research Group
%	:	Percent
°C	:	Degrees Celsius
mg/kg	:	Milligrams per Kilogram
V	:	Voltage
mV	:	Millivolt

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µS/cm : Micro siemens per Centimeter (unit of EC)

pH : Potential of Hydrogen (measure of acidity/alkalinity)

USB : Universal Serial Bus

RAM : Random Access Memory

SRAM : Static Random Access Memory

GPIO : General Purpose Input/Output

ADC : Analog-to-Digital Converter

DAC : Digital-to-Analog Converter

I2C : Inter-Integrated Circuit

SPI : Serial Peripheral Interface

PWM : Pulse Width Modulation

ISE : Ion-Selective Electrode

ISFET : Ion-Sensitive Field-Effect Transistor

TTL : Transistor-Transistor Logic

UART : Universal Asynchronous Receiver-Transmitter

LoRa : Long Range

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CHAPTER 1

INTRODUCTION

The chapter presents a brief introduction about the project. Basic introduction of Industrial Soil Sensor is sensor that is used to measure soil nutrients like Nitrogen (N), Phosphorus (P), Potassium (K), Soil Temperature, Soil Humidity and Soil Conductivity. This chapter also provided background studies which was followed by a problem statement and the projects' goals. The scope of the project can be determined based on the problem statement and project objectives. Finally, the organization of the report is clarified.

1.1 Introduction

Agriculture may therefore be defined as the business and science of cultivating plants and animals and other related crops. Thus, only through knowledge of various processes, one can fully utilize the productive power of nature. There is a need for field preparation or tilling or plowing, application of manure and water. It should therefore mean that soil properties should harmonize well with the right crops[1]. It is necessary to plant the seeds at the appropriate time. Plants must be protected from pests and weeds, and these are just some of the concerns that farmers face every year.

Since agriculture is the main source of food and other raw materials, it is considered the basis of life for the human species. This is necessary for the growth of the national economy[2]. The growth and development of the country's economics is hinged on the development of the agriculture industry. The UN social report brands the global population to increase to 9. 7 billion roughly tomorrow in 2050 and ten in the future at 2100. 4 billion by 2100. This population growth puts much pressure on sourcing for more means that must be produced through the increase in agricultural yields to cater for the increased population needs. Still there is usually a need to convey accuracy in a precise fashion because innovative changes in the contemporary form of farming often rely on precision farming practices. The specific approach used in this precision farming is the constant analysis of the nutrient status present in the soil to avail the right nutrients to these crops for development.[3].

The objectives of this research paper shall include the design of an industrial soil sensor system and the subsequent evaluation of the system's performance as regards the measurement of nitrogen, phosphorus, and potassium contents in the soil. Contemporary farming requires the use of the industrial soil sensor that can determine and assessing the distribution of nutrients in the soil. Since the determination of nitrogen, phosphorus and potassium content of the soil allows farmers and agronomists to properly select the corresponding fertilizers. It does not only improve yields and enhance crops, but also decreases the proliferation of fertilizer, decreases the effects on the environment, and enhances the implementation of harmonious farming. Data generated by the industrial soi sensor therefore permits the formulation of sound decisions that enhance the utilization of resources and enhance the status of soil. This tool makes nutrient monitoring in the soil easier with the development of other advanced sensors and is an effective proactive solution to agriculture.

1.2 Objectives Of Project

i. To design a wireless industrial soil sensor for soil nutrients monitoring.
ii. To analyze the collected data from industrial soil sensor to derive insights on nutrient levels and variations in different agricultural contexts.

1.3 Problem Statement

For instance, in the contemporary world of farming, the various quantities of soil nutrients particularly Nitrogen (N), Phosphorus (P) and Potassium (K) are very vital in determining yield potential and crop quality. However, the reliability of the currently available soil sensors used in precision agriculture is still an issue. Errors have the effect of putting into the soil inadequate quantities of fertilizer while at the same time increasing production costs, diminishing yields and polluting the environment after producing excessive nutrient runoff. Hence, the real-world application of the current sensors may be somehow restricted by their ability to produce data under different forms of soil types and environmental conditions. This ideation imperfect translates in the following research question: This project seeks to undertake to fill this research gap by establishing, testing and coming up with an industrial soil sensor that can measure the nutrient content of soil by adapting to different forms of agriculture.

1.4 Scope Of Project

For the hardware, this project will incorporate a Soil Sensor, Temperature & Humidity Sensor (DHT 11), and NodeMCU ESP32 microcontroller. On the software level, for writing the codes for the sensor to perform its tasks and for data acquisition; the Arduino Integrated Development Environment (IDE) will be used. For the development of sensors and continuous data transfer, the Internet-of-Things (IoT) such as Blynk framework will enable wireless communication of the soil sensor in the cloud for processing. The Wi-Fi capacities connected to the NodeMCU ESP32 contribute to the stable and effective sending of the data to the cloud The main objective of this experimental work is to assess the analytical capability and dependability of the Soil Sensor in the field of precision agriculture focusing on nutrient monitoring.

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By equipping the sensor node and the display interface, it is planned to recreate real usage conditions of the nutrient management for growers. The outcomes will now illustrate the potential and accuracy of the soil sensor network application in altering the producer’s fertilization practices and improving nutrient utilization efficiency.

1.5 Project Limitation

In assessing the performance of the system capabilities of soil nutrient monitoring, one needs to consider of certain restrictions that may arise in the performance analysis of soil sensors.

Because the amounts of the discrete elements may vary widely in different locations, one of the main drawbacks of the method is the variability of soil composition. Sensors tend to be influenced by the type and properties of the soil in which they are intended to work. The issue is that some airplanes require an adjustment based on the soil condition, and thus, creating an adjustment model that can fit any condition of the soil may be difficult. Interference by one or the other of environmental factors like changes in weather patterns such as drought or rainfall also affects the measurements made by the soil sensor. Nothing is perfect in this world, and that goes for the weather as well, which means that fluctuations in temperature, humidity, pressure or other such factors can introduce a certain level of uncertainty that can only be addressed through improved algorithms or more sensors.

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Another limitation is in the context of the power demands that the sensor system can carry out. Another issue that arises when supplying power to sensors located in areas of agriculture without a constant power source is the practicality of the supply. These are some of the issues to tackle to avoid this limitation; hence, battery life, power consumption and energy-efficient design.

Furthermore, when it comes to soil sensor measurement, they embrace a popular simple detection method if rapidity is of essence, thus, there might be certain inconsistencies. Currently, the means of electronic measurement is ineffective for NPK measurement because the sensor displays trends rather than numerical data.

Also, the sensor was installed to collect written NPK data; however, the function of utilizing written NPK data was not considered in this project because of the absence of a standard measuring device. These limitations show that the sensor technology should be advanced, and support checked for practical usage to enhance particularity and conclusiveness in cultivating aviation.

1.6 Report Structure

This thesis is a combination of five chapters that contain introduction, background study, methodology, result and discussion and the last chapter is the conclusion and recommendation of the project.

Chapter 1 is an introduction to the project. In this chapter, we will explain the background and objectives of the project. An explanation of how the project will work will be explained and an overview of the project will be discussed in this chapter.

For chapter 2, the literature review will cover soil nutrients monitoring which includes soil health agriculture and limitations of traditional methods. The advances in soil sensing technology are covering about types and principles of soil sensors. The review of previous works determines gaps and establishes the groundwork for the study's contribution by critically examining previous research and technologies in this field.

Then, chapter 3 will explain about the methodology of this project. It will show the steps and flow for problem solving in such a specific method used to use soil sensor for soil nutrients monitoring to do some analysis on the result while for chapter 4, the expected results will be explained from this project and justify its performance to achieve the objectives of the research.

Finally, chapter 5 summarizes the entire research process. It underscores the research findings and implications on knowledge, presents the key findings and general conclusions. As the result of the study, this chapter includes a set of strategic recommendations that may be useful in future research or real-life implementation. So, it makes for a proper finality to the examination of the ability of the soil sensor in monitoring the nutrients in the soil explaining the significance of the study and demonstrating how it opens the door to other forms of scholarly work.

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CHAPTER 2

BACKGROUND STUDY

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Soil nutrient monitoring is critical to maintaining soil health and optimizing agricultural productivity. Traditional soil testing methods are effective, but often time-consuming, expensive and require specialized laboratories. Recent advances in soil measurement technology provide real-time monitoring capabilities, allowing these limitations to be addressed. This research investigates the design and performance analysis of industrial soil sensors with a focus on their integration into precision agriculture systems to improve crop and resource management. Reviewing the previous work that related to this project can contribute to the development of effective and reliable soil nutrient monitoring solutions.

2.1 Introduction to Soil Nutrients Monitoring

Soil nutrient evaluation entails the assessment of various nutrients in the agricultural soils, especially the NPK. It may be noted that most of these methods are carried out in laboratories and do not involve manual sampling and wet chemical testing for the determination of nutrient content in the soil.[4]. Nonetheless, with new technologies of sensors, and digital agriculture the evaluation of the key macronutrients in the field is fast especially using surfaces such as ion selective membranes, fluorescence optics, and electrochemistry potentialities. Since the level of NPK determines the functionality and the yields of crops grown, real-time Nutrient data empowers the application of the right measures of the fertilizer, that enhances productivity and curtail potential wastage through environmental leakage [5].

The advantages of modern ground sensors are, they are continuously monitoring, there is less human operator's involvement to be paid, and you obtain real-time information. These can be connected to a holding's Internet of Things (IoT) for instant data sharing and processing so that farmers can make decisions [6]. The use of IoT technology also allows the monitoring and controlling of the state of the soil from a distance, which is highly beneficial for large scale precision agriculture.

Nevertheless, there are still several factors that create a challenge in the process. Specifically, the researchers have discovered that the majority of the commercial electronic soil sensors produce accuracies that change with the type of soil, fertility gradients as well as moisture conditions[7]. The nature of the chemical properties and compounds of the soil in different geographical locations brings about divergent degrees of variation to the sensors hence the need to carry out the calibration and the calibration models which might not be easy to develop.

Furthermore, one can also name unpredictable phenomena, for instance, long periods of the absence of precipitation or, on the contrary, its excess may negatively influence the setting of ground sensors. Sudden changes in the temperature, humidity, and other factors could raise the variability and lead to the fact that the real behavior of the algorithm could be significantly different from what was expected during the calibration. Others are power requirements, which may become an issue to sensors planted in power-less farms in the Third World countries. To supply power and energy that is steady and constant means having to tackle issues such as battery lifetime, energy consumption and optimal power delivery.[8].

There is also the aspect of data security and privacy. Due to the flow of sensitive data to other servers or cloud-based platforms, appropriate encryption measures should be utilized, as well as data safety laws should be obeyed to preserve farmers' data and the effectiveness of the system.

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Besides, the measurement of NPK by other conventional rapid detection methods is liable to some degree of errors. Most of the current electronic measuring methods do not necessarily provide actual values, instead, they provide only trends and while most of the introduced sensors do support written NPK data this feature often is left unused due to the lack of a standardized measuring device[4]. These limitations suggest that the field of sensor technology still must be advanced and refined in order to achieve substantially more accuracy and credibility for viable application in precision agriculture.

The net effect of these advances is to supply farmers ambient data, free from 'noise,' which could be used directly to manage nutrients and to optimize application of fertilizers to meet yield targets while avoiding having a negative impact on the physical environment. As of the current restrictions and with constant enhancements being made to the sensors, soil nutrient screening can be formulated as the key principle of sustainable farming.

2.1.1 Soil Health and Agriculture

Hence, there is a strong relationship between soil health and sustainable agriculture productivity as well as the environment and ecosystem. Soil is alive and serves to feed plants, animals and mankind through such properties as physical, chemical and biological [1]. There are the major nutrients, Nitrogen (N), Phosphorus (P) and Potassium (K) which are vital for the plants. Nitrogen influences the synthesis of proteins and chlorophyll; hence, it influences the rate of growth and biomass yield, while phosphorus impacts energy transfer and the genetic makeup responsible for growth and seed yield. Potassium enhances enzyme activity, water relations and photophosphorylation that leads to high plant growth and vigorous disease-free plants. These nutrients must be present in the right proportions since their ratios the affect the availability of the nutrients and overall health of the plant and its produce[7].

Matters including crop rotation, use of cover crops, conservation tillage and incorporation of organic matter help to balance the nutrient status of the soil and consequently fertility status. Sulphate containing cover crops can both fix atmospheric nitrogen and add to the reserves of soil organic matter whereas reduced tillage helps maintain structures of the soil and habitats of the microorganisms [9]. As for the structure, it is pointed out that compost and similar organic amendments make up a

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source of slow-release nutrients. They help to build up physical characteristics of the soil as well as promote the activity of the microorganisms, making nutrients more available for the plants to support sustainable agronomic systems. Management of soil health can be examined as an important strategy of meeting escalating food requirements with no detriment to the environment.

2.1.2 Limitations of Traditional Methods

Although for many years wet chemical techniques that are carried out in laboratories have formed the basis of soil nutrient testing, there is always a major problem of in ability to undertake nutrient management on real time. These methods involve time consuming sample preparation, usage of hazardous reagents that must be handled carefully, exclusive apparatus and skilled labor which takes several days[4]. Such limitations limit traditional testing methods to simple snapshots and cannot capture dynamic field conditions.

On the other hand, electronic NPK sensors reduce several of these limitations due to fast and inexpensive measurements without sample preparation. That is why instead of transporting them, automation of field measurements allows visualizing the regional differences of nutrients in real time. Moreover, modern electronic sensors work with micro-volumes of reagents with the help of small-sized structures because of which the waste footprint is minimized.

However, there are still challenges such as the complexity of calibration continues, and severe accuracy limitations under varying humidity, salt, and soil conditions threaten the reliability required for field use. In addition, measurement of NPK using conventional rapid detection methods can introduce certain errors, since existing

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electronic methods often show trends rather than exact values[10]. Robust algorithms and additional sensors must be developed to account for these variations.

To increase the reliability of electronic ground sensors, more accurate validation of their operating range and greater transparency of their limitations are crucial. Addressing these issues will improve the practicality and reliability of precision agriculture nutrient detection techniques[11].

2.2 Advances in Soil Sensing Technology

Recently, new soil nutrient sensor technologies have become available that can be more efficient and environmentally friendly than traditional laboratory tests[1]. These include NPK sensors that measure important nutrients such as nitrogen, phosphorus and potassium directly from the soil. There are also sensors that monitor the properties of light and use tiny chips to mix soil samples with special chemicals[12]. These tools can be used to measure important nutrients as well as soil pH and electrical conductivity.

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NPK sensors detect ion levels in the soil with special electrodes or analyze the soil with optical sensors. They can provide immediate information on soil nutrient levels, helping farmers apply the right amount of fertilizer, improving yields and reducing environmental impact[13]. Despite their potential, high costs, the need for frequent calibration, and concerns about their durability in the field have limited their use. Tests have shown that these sensors can only be accurate 50-90% of the time in different ground conditions. Their accuracy can be affected by humidity, salinity and soil types[8].

To make soil sensors more reliable, it is important to clearly understand their strengths and weaknesses, improve their accuracy and ensure their longer service life in real conditions[3]. Addressing these issues will help these advanced sensors become a regular part of agricultural practices.

2.2.1 Types and Principles of Soil Sensors

The purpose of soil sensors is to quickly determine plant-available concentrations of nitrogen, phosphorus and potassium in agricultural soils for precise delivery of nutrients[14]. These tools enable real-time field quantification of inorganic ionic compounds, including nitrate, ammonium and potassium, facilitating the application of variable fertilizers according to local crops. Such site-specific nutrient information makes it possible to increase yields in deficient areas and minimize them in saturated areas, thus balancing productivity growth and environmental security[15]. However, for widespread adoption, NPK sensors must demonstrate consistent accuracy in a variety of environments at an affordable cost.

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Various electronic sensor principles are used to quantify soil nutrients. Potentiometric devices insert ion-selective membranes into electrode structures to generate voltage signals proportional to the activity of nitrate, phosphate or potassium ions. Optical sensors use spectroscopic techniques, including fluorescence and infrared analysis, to non-destructively assess total or labile nutrient concentration levels that correlate with crop response[4]. Microfluidic biosensors trigger nutrient-specific colorimetric chemical reactions in embedded paper microzones, enabling visual quantification. Each of these methods offers unique strengths and limitations[4].

Full validation of different soil types, weather conditions and farming systems is essential to identify optimal applications for each sensor type. This comprehensive approach helps determine the best places for these technologies and increases their reliability and effectiveness in precision agriculture.

2.3 Literature Review

The research paper addresses a study concerning the application of Internet of Things technology and sensors in the analysis and evaluation of the basic parameters of soil fertility, containing Nitrogen, Phosphorus, and Potassium (NPK) in relation to the nutritional requirements of crops. The proposed project mainly entails the identification of Sensoil Device which is a portable system that is fitted with some sensors that allows the project to substantiate real time data on the soils. Having organized the collected information, the system can come up with solutions that point at the fertility level of the soil, moisture level and need for more water. Accordingly, the study will help farmers and home gardeners to make better decisions regarding nutrients and crops management, and fertility of the soil in order to increase productivity in agriculture. Further, the paper is marked with the role of soil health in the agricultural practices and the significance of the essential nutrients and their incorporation into the plants and crops[7].

Regarding the authors' conclusions on the importance of adopting the discussed IoT technologies to support sustainable farming, the paper dwells upon the necessity of implementing IoT in agriculture to improve the lifestyle of people, raise yields, protect the environment, and optimize the usage of resources. The study also brings into focus about the nutrition need for plant growth which consists of Nitrogen, Phosphorus and Potassium and how the soil sensors not only can monitor the moisture

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content or soil temperature or change of pH level of the soil but play a chief role in helping the farmer to make the right decisions as to when to plant or bail or or add fertilizers in the soil. This work carries out literature review to examine works done earlier on data mining, machine learning, and the methodologies used in crop yield prediction. It can be seen from the data collection approach of the authors that they gather data sets over the years that correspond to crop yield prediction and other related soil heath parameters. They use different algorithms belonging to data mining and machine learning classification to analyze the data and perform crops yields based on characterize of soil and nutrient. The study highlights how the soil sensors are useful in measuring the moisture content, pH, temperature and nutrient levels of the soil. The authors have reviewed their own as well as other's research for comparing the performances of various classification models for yield estimation. This means that based on the performance of different algorithms for machine learning the general study has the objective of selecting the best one that should give good results in the matter of crop yield prediction. In using IoT systems that combine with soil sensors, farmers can improve the efficiency of crop yields, decrease on wastage of resources and improve on environmentally friendly auctions on farming. Thus, the paper highlights how soil status, nutrients, and farming efficiency are intertwined, stressing how technology plays a role in present-day farming methods.[3].

The paper contains a detailed literature review, analysis and discussion on the proposed construction of soil nutrient measuring device targeted at citrus plants. From the electrical circuit diagram, inputs, control and output part is shown which combines NPK sensors, NodeMCU and Thingspeak for representing graph. In the tool system circuit diagram, respectively, the structural design and the block diagram are used. A diagram illustrating the tool design came out with the help of the Fritzing schematic circuit software shows the sensor connection to the NodeMCU and data flow. The operation of interconnecting the tool is explained based on the ability of the sensor to sense the nutrients of the soil, convincing NodeMCU, and showing on Thingspeak for monitoring. Therefore, it can be concluded that the application of the tool under consideration makes it possible to monitor the content of nutrients in the soil for citrus plants efficiently. In summary, the paper aims at shedding light on the innovation of NPK soil sensors and IoT to boost plant growth management and nutrient supplement in agricultural practice. [16].

The specificity of NPK sensors is presented in the article as they play an essential role in plants' growth in contemporary agriculture. The goal of the research is to ascertain how well the sensors can capture one nutrient such as nitrogen (N), phosphorus (P) and potassium (K) when the tests are conducted using chemicals containing a single nutrient. Furthermore, the study assesses the efficiency of the sensors with NPK compound fertilizers and recognizes that the sensors affirmed NPK solutions proficiently without having any interaction with the actual NPK ratio of the examined solution. This steadiness points towards non selectiveness of sensors, or in other words the sensors are incapable of determining concentration of individual nutrients in the compound fertilizer. The non-specificity of the test solutions is only further highlighted when comparing their concentration ratios to the sensor readings. The results have emphasized the necessity of substrate specificity explaining concentration of nutrients in the soil that plays a crucial role in right application of fertilizers. The idea behind accurate and precise sensor data is that they will help farmers ascertain the right quantities of fertilizer required at the right time, and therefore improve crop productivity and optimal methods of farming without polluting the environment[17].

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The paper discusses the urgent need for proper water utilization in agriculture due to decreasing water tables and unpredictable environments. It proposes the use of temperature and moisture sensors at strategic locations to monitor crops, with an algorithm set to control water quantity based on threshold values. The system, powered by photovoltaic panels, features a duplex communication link for data inspection and irrigation scheduling through a web page. Additionally, advancements in Wireless Sensor Networks have enabled monitoring and control of greenhouse parameters in precision agriculture. The implementation of such technology in the agricultural sector aims to improve crop yield and overall production by addressing irrigation challenges and storage issues through remote-controlled robots, smart irrigation systems, and smart warehouse management [18].

The research paper focuses on implementing an IoT-enabled smart farm to assist farmers in monitoring plant and soil conditions in real-time. The system utilizes components such as the NPK sensor, DHT22 sensor, soil moisture sensor, NodeMCU Wi-Fi module, and MAX485 TTL to RS485 Module for data collection and analysis. By continuously monitoring soil nutrients, temperature, humidity, and moisture, the system provides farmers with valuable insights to make informed decisions for crop selection. The integration of a recommendation system based on a trained model from a dataset allows for personalized crop suggestions, leading to enhanced productivity and resource efficiency in agriculture. Additionally, advancements in sensor technology and connectivity options like GSM modules can further improve the system's accuracy and versatility for sustainable farming practices[6].

This paper aims at giving insight as to how soil fertility assists in plant growth in agriculture and how soil sensors combined with Arduino can enable fast determination of nutrient density of the soil. Soil NPK sensor enables one to observe and measure nutrient data, that is, nitrogen, phosphorous, and potassium to address fertility appropriately. So, the findings and analysis highlighted in the context of the study are able to assertively establish the effectiveness of this newly proposed system of recognizing the quality of the soil and the information regarding the amount and kind of fertilizers that will help grow crops efficiently. This system can be used as a cheap tool to check the status of soil of growers and hence, make the right decisions on the number of fertilizers to use to boost crop production. Furthermore, gathered information can be stored in the cloud and accessed at any convenient time to control the soil nutrients. There could be additional developments in the future that would include recommendations of appropriate crops according to the nutrient content of the soil and distinguishing nutrient-poor sites[14].

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CHAPTER 3

METHODOLOGY

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This chapter provides detailed instructions on research methodology for both hardware and software components used in the design and operation of industrial soil sensors which are includes the design and selection of the sensor, its integration with a USB converter, and the assembly and testing of the sensor system. On the software side, the programming and configuration of the data acquisition system was discussed, development of data processing algorithms, and creation of a user interface for real-time monitoring and visualization. We also outline procedures for collecting and analyzing soil samples and comparing sensor performance between two sensors. Finally, we detail the experimental setup, including the environment, controlled variables, testing phases, and timeline, ensuring the reliability and validity of our findings to facilitate further research in precision agriculture and soil nutrient monitoring.

3.1 Project Planning

This project was planned before it got started to obtain the expected result. The project planning is represented in figure 3.1 which outlines the timeline, milestones, and key deliverables. Each phase of the project is carefully detailed, allowing for clear tracking of progress and timely adjustments if necessary and the project planning for the first and second semesters of 2023–2024 is displayed in the Gantt chart below.

G. PERANCANGAN PROJEK
PROJECT PLANNING (GANTT CHART)

Senaraikan aktiviti-aktiviti yang berkaitan bagi projek yang dicadangkan dan nyatakan jangka masa yang diperlukan bagi setiap aktiviti.
List all the relevant activities of the proposed project and mark the period of time that is needed for each of the activities.

	SEM I																			SEM BREAK					SEM II															
Aktiviti Projek *Project Activities*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Background research on Performance Analysis of NPK sensor for soil nutrients monitoring.	X	X	X	X							SEMINAR PSM I																											SEMINAR PSM II		
Design the NPK Sensor architecture					X	X	X																																	
Develop the NPK Sensor						X	X	X	X	X		X	X	X	X																									
Testing the sensor development															X	X	X																							
Deploy the NPK sensor in agricultural sites																	X	X	X	X																				
Collect soil nutrient data																				X	X	X	X	X																
Analyze data for accuracy & consistency																							X	X	X	X	X	X												
Assess sensor performance under various performance & condition																												X	X	X	X	X								
Gather feedback from farmers & agricultural professional from the project.																														X	X	X	X	X	X	X				
Finalization for this project																																					X		X	X

Figure 3.1: Gantt chart for project planning.

3.2 Project Flowchart

The steps presented in figure 3.2: which is project flowchart below have been followed in an organized way to complete this project.

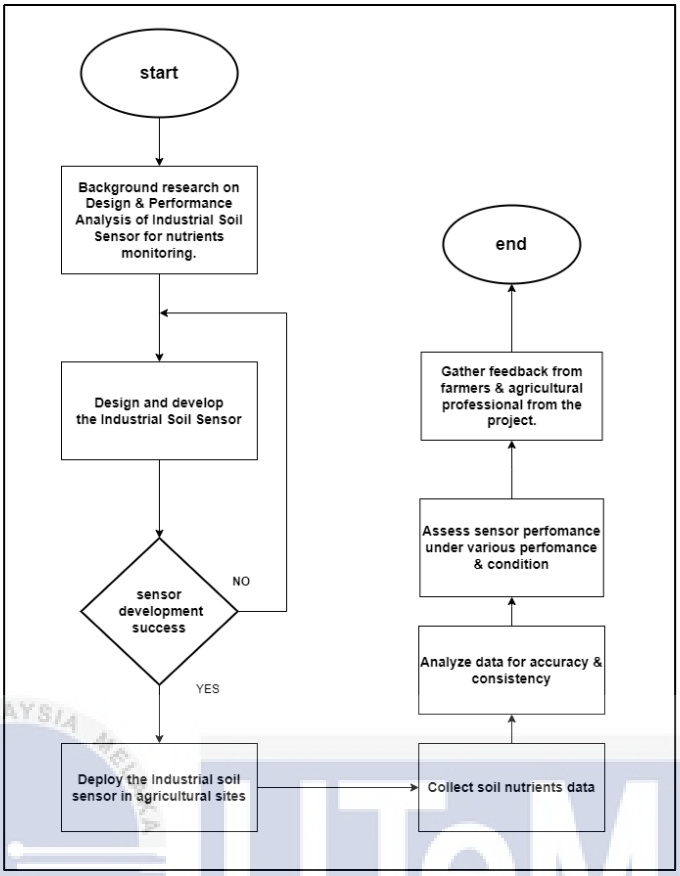

Figure 3.2 : Flowchart for this project

This project flowchart outlines a systematic process for developing, deploying, and assessing an industrial soil sensor for soil nutrients monitoring. It starts with background research that conducts thorough research on the performance of existing an industrial soil sensor which are NPK sensors, and the information was gathered on the requirements for soil nutrient monitoring and the existing challenges. Then, it followed by design and development that includes selecting the appropriate materials, technologies, and creating prototypes. If the sensor development becomes successful, it will proceed to the next step which is deployment sensor in sites. If not, it will go back to the design and development phase to make corrections.

Next, the deployment phase that developed sensor was deployed in real agricultural sites for practical use and then, the data was collected and will be analyzed. Lastly, the performance of the sensor will be assessed and gathering user feedback.

3.3 Schematic Diagram

A schematic diagram visually represents the electronic circuit configuration and components in a system, along with all the electrical connections and flows between them. For this project, figure 3.3, schematic diagram of the system will show the key components involved such as:

- Sensor: The soil sensor itself to measure nutrient levels
- Microcontroller: The processor such as ESP32 to control the sensor
- Power supply: Battery or other sources to power the system.
- Output device: Wi-Fi modules for wireless data transfer.
- Other inputs: DHT11 sensor for environment conditions

The schematic will have symbols to represent each component and lines to map the wiring connections between them. It acts as a blueprint of how every electronic element in the soil sensor system links together to enable the functionality of soil nutrient measurement, processing, display and transmission that allows visualization of components needing power versus output devices, interfaces different modules communication and electrical flows to achieve functioning.

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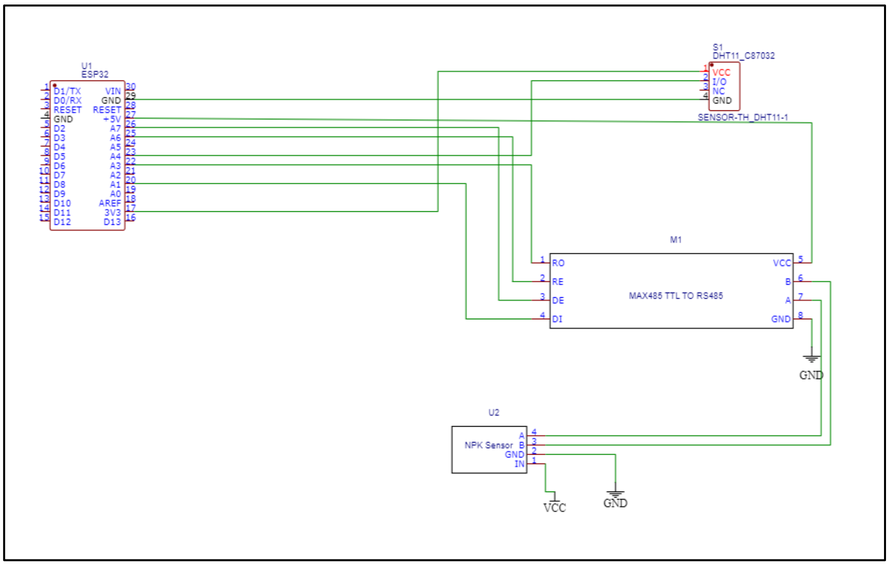

Figure 3.3 : Schematic diagram of the system

3.4 Technical Design

The main purpose of Design and Performance Analysis of Industrial Soil Sensor for Nutrients Monitoring project is to design, develop, and validate a customized industrial soil sensor that can measure soil nutrient levels such ad Nitrogen (N), Phosphorus (P), Potassium (K), temperature, humidity, and conductivity which is real-time data and under varying agricultural conditions that can support precision agriculture practices.

3.4.1 Block Diagram of System

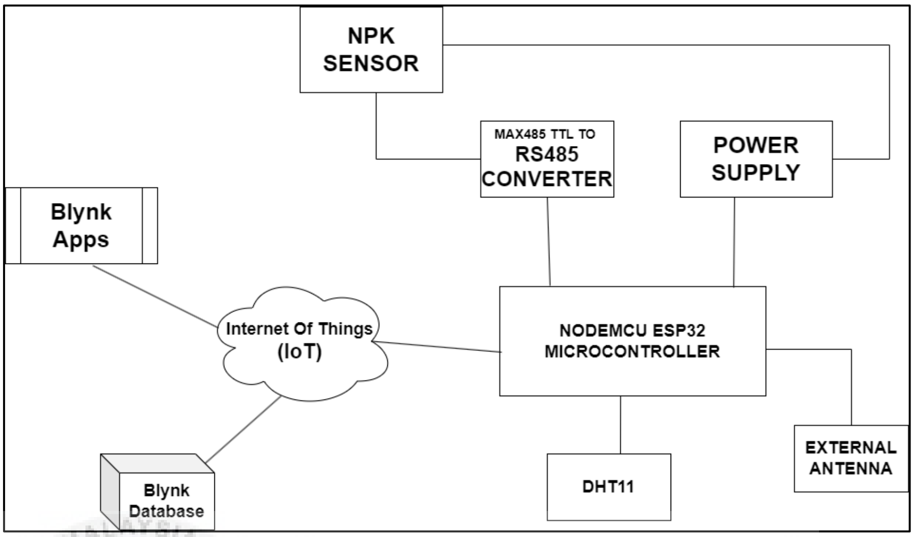

Figure 3.4 : Block diagram of system

Figure 3.4 shows a block diagram of system representing an Internet of Things (IoT) which is based on a soil nutrient monitoring system. The NPK sensor acts as an Industrial Soil Sensor that measures soil nutrient levels, which are then transmitted to the NodeMCU ESP32 microcontroller via a MAX485 TTL to RS485 converter. The microcontroller also collects environmental data from a DHT11 sensor. All data is sent to the cloud, enabling remote monitoring and control through Blynk apps. An external antenna ensures robust wireless communication, and the power supply ensures all components are powered and the data collected is stored in the Blynk database for analysis and visualization.

3.4.2 Components of Hardware

A complete set of hardware and software tools is required for the system to function properly. These tools include several components, from hardware infrastructure such as servers, network devices and sensors to software like operating systems, databases and algorithms. The harmonious integration of these tools is crucial for the smooth functionality and efficient operation of the system, ensuring its ability to effectively achieve the objectives.

3.4.2.1 ESP32 NodeMCU Microcontroller

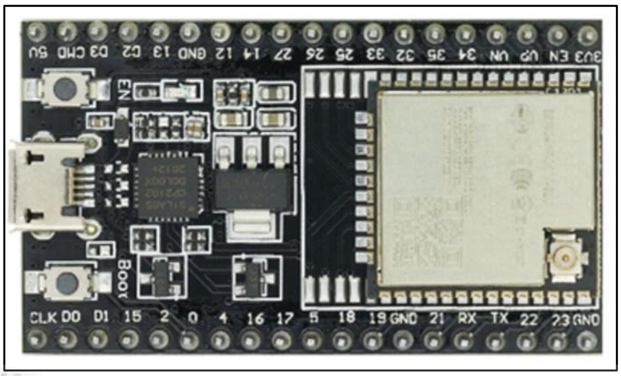

Figure 3.5 : ESP32 NodeMCU Microcontroller

Figure 3.5 is an ESP32 NodeMCU which is a robust microcontroller widely used in IoT applications due to its powerful features and flexibility. It comes equipped with 520KB of SRAM and typically 4MB of flash memory, providing ample space for running complex programs and storing data. It offers multiple GPIO pins for digital and analog interfacing, featuring several ADC channels with 12-bit resolution and DAC outputs with 8-bit resolution, making it highly versatile for connecting a wide range of sensors and actuators. This microcontroller is a popular choice for developers looking to build advanced, connected devices with ease.

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The chip developed by Espressif Systems is known as the ESP32. This gives embedded devices Wi-Fi (and, in some models, dual-mode Bluetooth) connectivity. While ESP32 is technically just a chip, the manufacturer frequently refers to modules and development boards that contain this chip as "ESP32". Its development ecosystem is comprehensive, supporting programming through the user-friendly Arduino IDE and the advanced Espressif IoT Development Framework (ESP-IDF), supplemented by extensive community resources and documentation. The ESP32 is also cost-effective, providing high functionality at a low price point. Additionally, it includes multiple built-in peripherals and interfaces such as SPI, I2C, UART, and PWM, further simplifying device connections. These advantages make the ESP32 a powerful and flexible solution for projects ranging from simple sensor nodes to complex connected devices in home automation, wearable technology, and industrial automation.

3.4.2.2 Industrial Soil Sensor

Figure 3.6 is a soil sensor that can detect the concentration of nitrogen, phosphorus and potassium in the soil. According to [8], most of the electrochemical methods used to determine soil nutrient levels are based on the use of an ion-selective electrode (ISE) equipped with a glass or polymer membrane or ion-selective field-effect transistor (ISFET). The sensor can be buried in soil for long periods and does not require chemical reagents. It has high measurement accuracy, fast response and interchangeability, and can be used with any microcontroller.

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Any Modbus module like RS485 or MAX485 is required to read NPK data. The Modbus module is connected to both the microcontroller and the sensor. The sensor works with a 5 V until 24 V battery. The resolution of measuring nitrogen, phosphorus and potassium is up to 1 mg/kg (mg/l). Many N, P, and K determination methods that were previously only available in laboratories have been adapted for portable sensor applications and can now be used in agricultural field measurements. [12].

Figure 3.6: Soil Sensor

3.4.2.3 MAX485 TTL to RS485 Converter

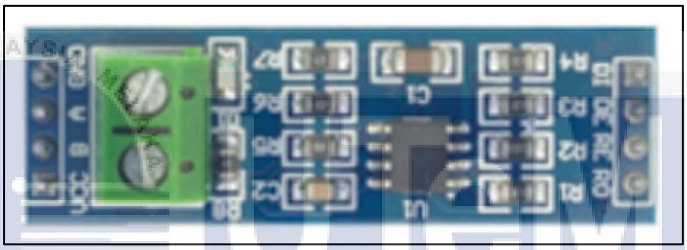

Figure 3.7 : MAX485 TTL to RS485 Converter

Figure 3.8 is a transceiver module that facilitates communication between devices using RS485 protocol, which is widely used in industrial automation and control systems. This converter allows microcontrollers and other TTL logic devices to communicate over long distances with minimal signal degradation. Using the MAX485 TTL to RS485 Converter involves connecting the converter to the microcontroller and the RS485 network, controlling the direction of data flow via DE/RE pins, and programming the microcontroller to handle serial communication. This setup enables reliable long-distance communication in industrial and automation applications

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3.4.2.4 Temperature & Humidity Sensor (DHT11)

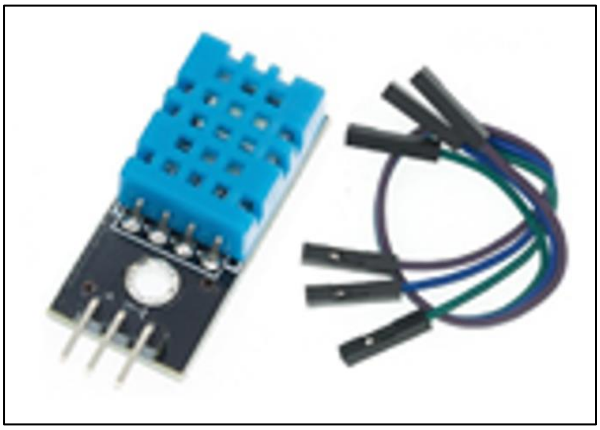

Figure 3.8 : DHT11 Sensor

Figure 3.9 depicts a low-cost, dependable digital sensor used to measure temperature and humidity. Its ease of use and integration with microcontrollers makes it popular in many environmental monitoring projects.

3.4.2.5 Compatible Dual Band Antenna

Figure 3.9 : dual -band Antenna

Figure 3.10 is intended to operate on two distinct frequency bands, usually within the radio frequency spectrum. This capability is critical for devices that require connectivity across multiple frequency bands, such as Wi-Fi routers, cellular devices, and some IoT (Internet of Things) applications.

- **Dual Band Antenna**: The main component that can operate on two distinct frequency bands, such as 2.4 GHz and 5 GHz for Wi-Fi.
- **Radio Frequency (RF) Transceiver**: Device or module that sends and receives RF signals includes Wi-Fi modules, cellular modems, or IoT devices.
- **Antenna Connector**: A connector (such as SMA, RP-SMA, or U. FL) that interfaces the antenna with the transceiver.
- **Microcontroller or Processor**: Manages the RF transceiver and processes the data sent and received.

3.4.3 Software Development

Figure 3.11 Arduino IDE Software provides an easy-to-use way to program microcontrollers such as the ESP8266 NodeMCU that act as an embedded processor that controls the NPK sensor. The Arduino IDE uses a C/C++-based language that enables coding functions that communicate with the sensor hardware using GPIO pins and analog-to-digital conversion modules. It allows writing calibration algorithms, controlling measurement frequencies, wirelessly transmitting sensor data and activating external devices. The simple IDE user interface allows the drag-and-drop installation of custom add-on libraries and Wi-Fi or Bluetooth modules for IoT connections to various sensors. Using a serial monitor, real-time testing allows parameter adjustments for soil nutrient quantification routines and wireless communication functions programmed into the NodeMCU. Once the application code is successfully coded and compiled, it can be wirelessly downloaded directly to the microcontroller via the soil sensor. The flexibility of the Arduino IDE enables rapid prototyping and minimal electronic knowledge to program the soil sensor and auxiliary devices such as DHT11 Sensor or communication modules.

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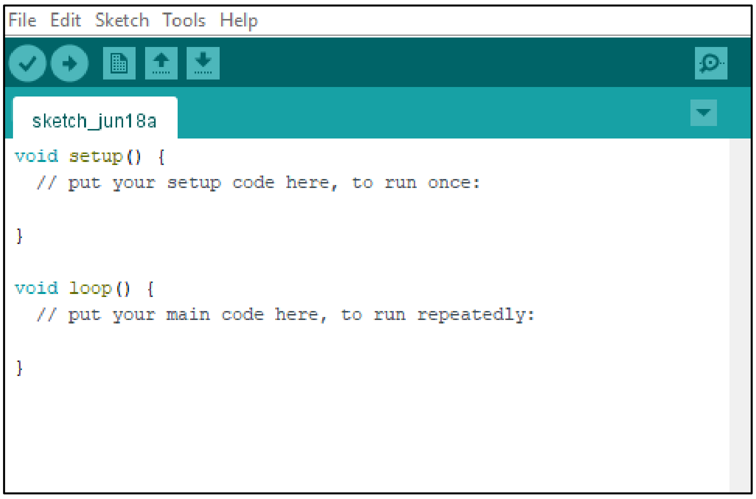

Figure 3.10 Arduino IDE Software

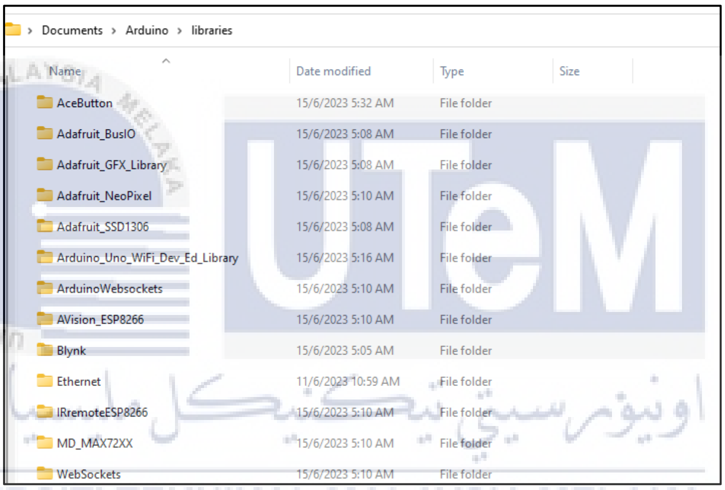

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Figure 3.11 Libraries in the software

3.5 Procedure

3.5.1 Configuration of Connection

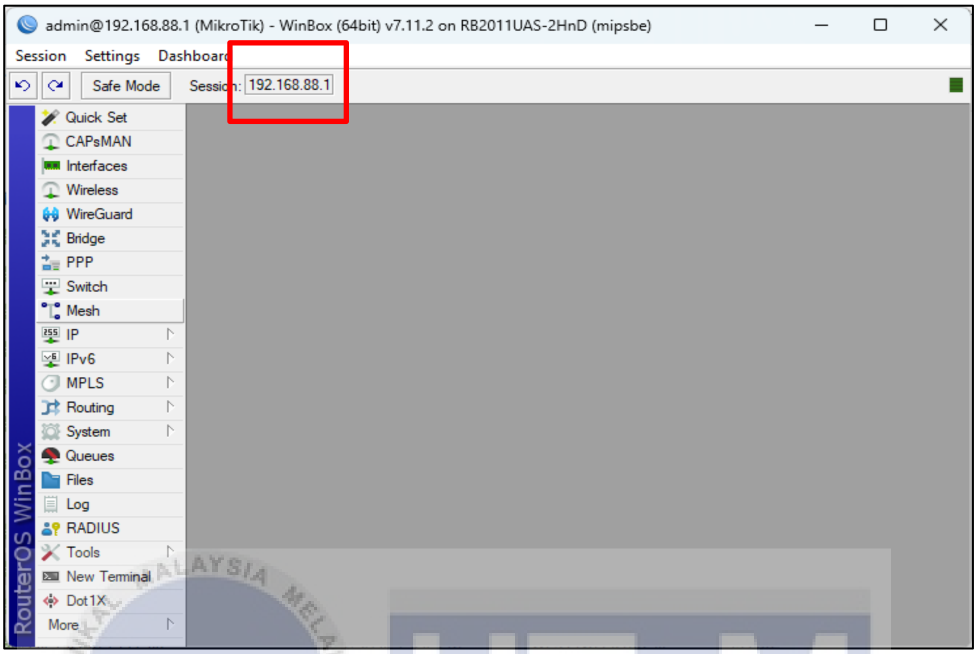

Figure 3.12 : IP address shown

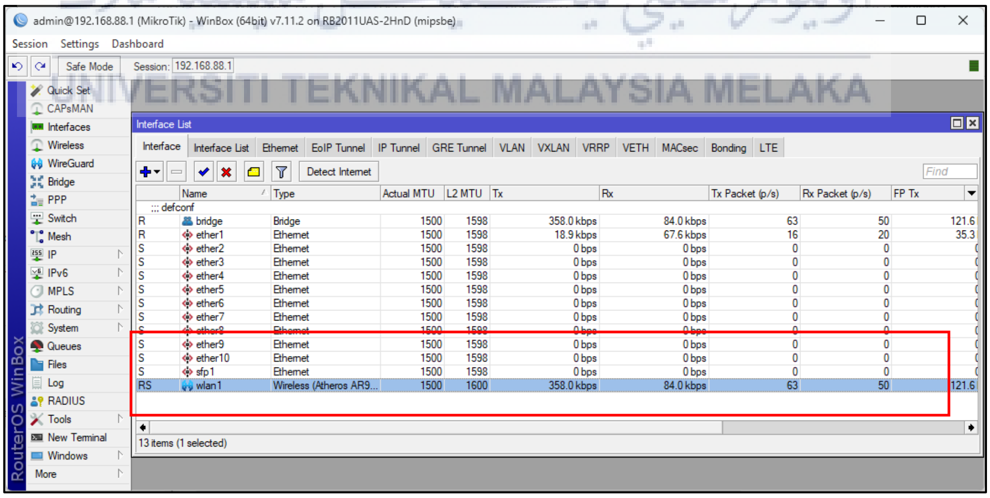

Figure 3.13 : Name of the Wi-Fi devices

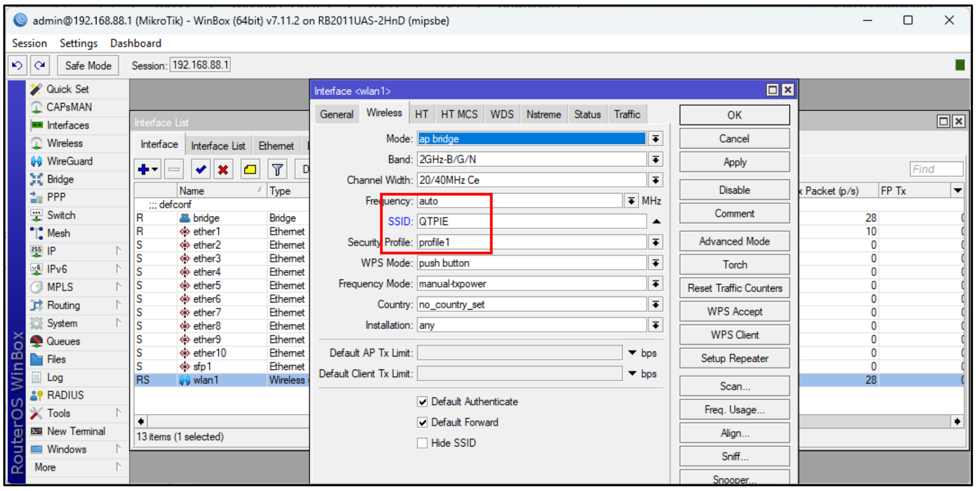

Figure 3.14 : SSID username changed

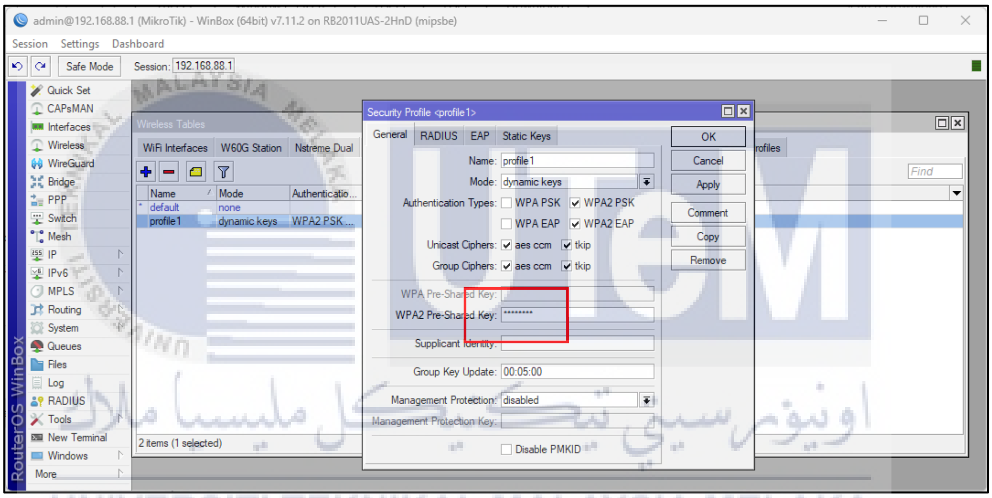

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Figure 3.15 : SSID password changed

The Wi-Fi credentials for my router need to be changed to the same username and password in the code. Firstly, start by connecting my computer to the modem's network. Open a web browser and enter the modem's IP address, usually found on the modem itself like in figure 3.13. Log in using the admin username and password provided by ISP and the name of Wi-Fi devices will be shown like in figure 3.14. Once logged in, navigate to the wireless settings section and we can change the SSID (Wi-

Fi network name) in figure 3.15 and the Wi-Fi password to my desired credentials like in figure 3.16. Save the changes, and my router will restart to apply the new settings.

3.5.2 Configuration of Blynk IoT

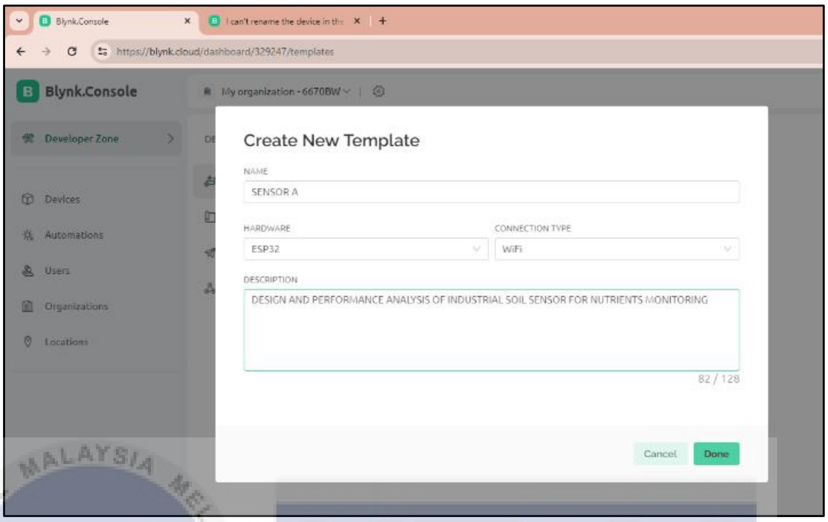

Figure 3.16 : Create new template

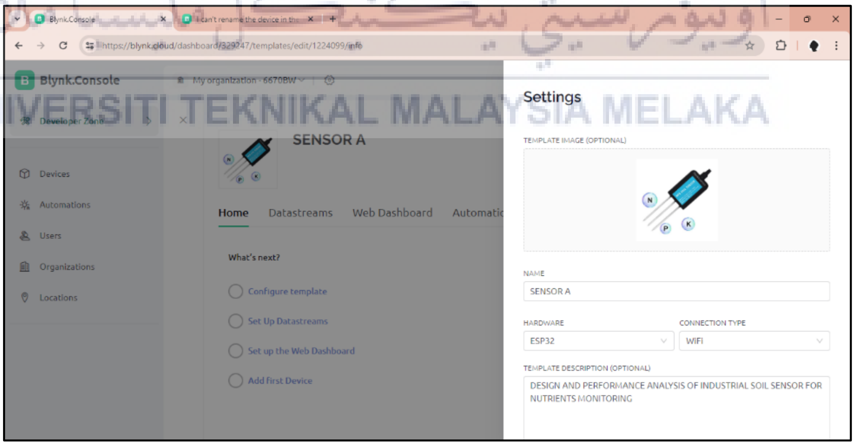

Figure 3.17 : Setting up template

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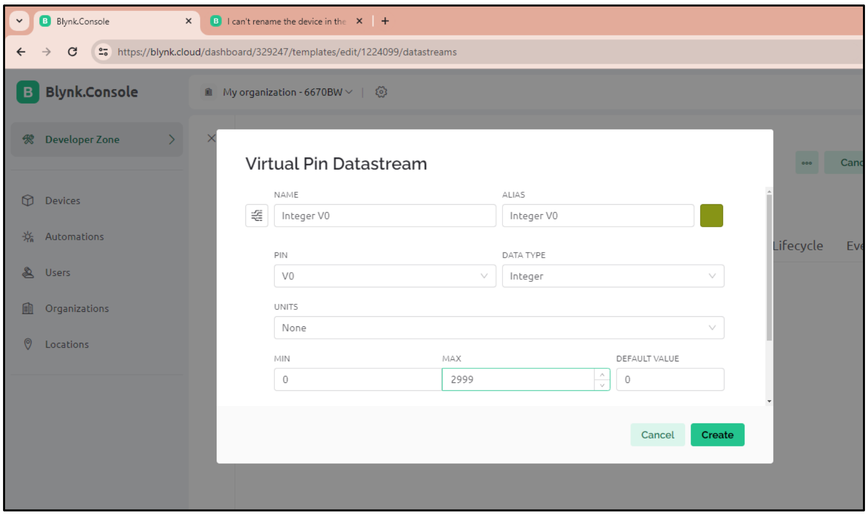

Figure 3.18 : Listing the Virtual Pin Datastream

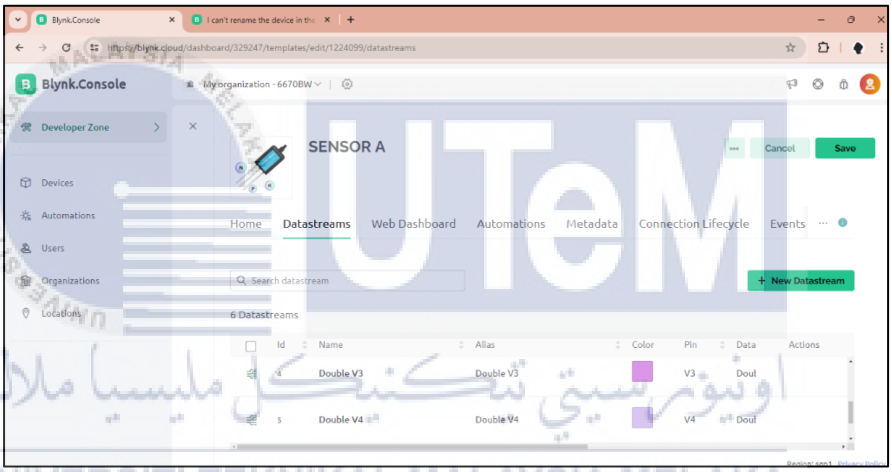

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Figure 3.19 : Virtual Pin Datastream listed

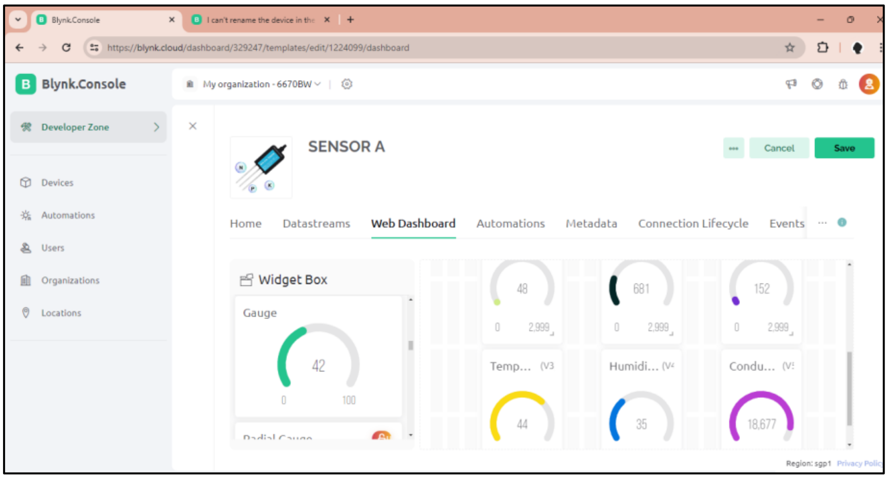

Figure 3.20: Designing the Web Dashboard

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Figure 3.21 : Firmware configuration shown

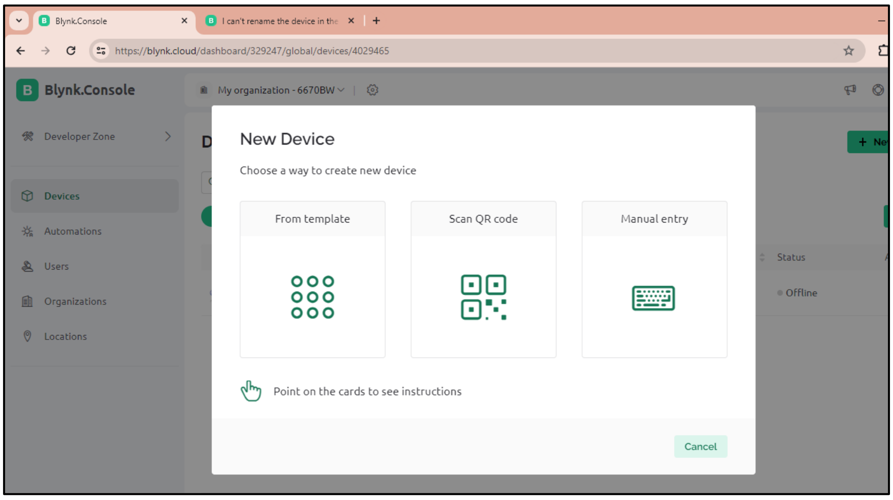

Figure 3.22 : Creating new device

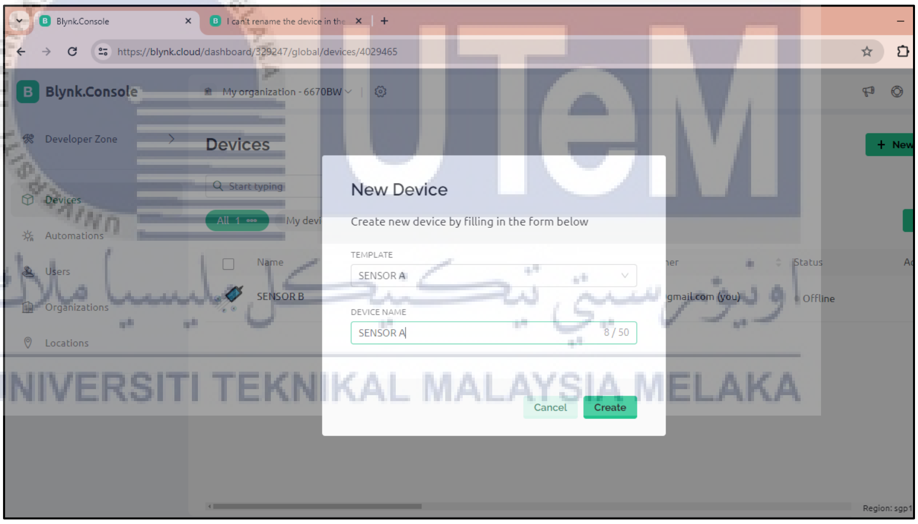

Figure 3.23 : Naming the new device

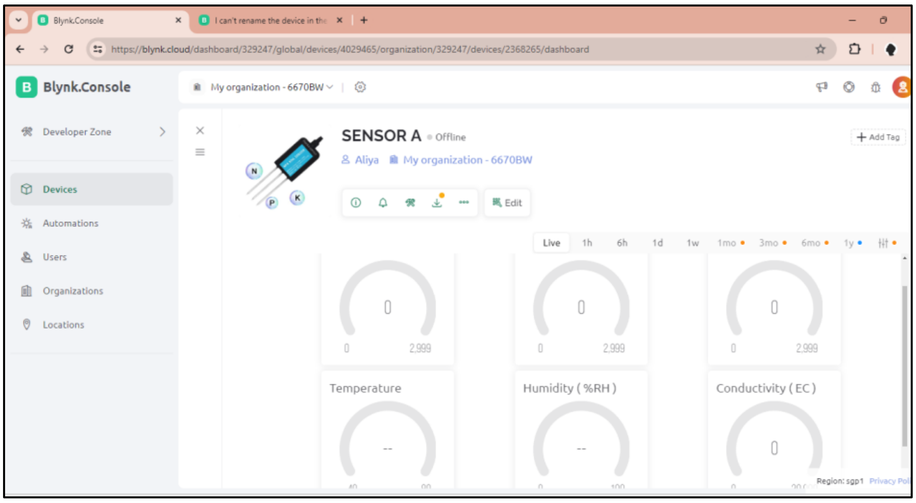

Figure 3.24 : Device Sensor A created

Figure 3.25 : Repeat the same step for Device Sensor B

Figures 3.17, 3.18, 3.19 and 3.20 are the first step to create Blynk template for web dashboard. For figures 3.21, 3.22, 3.23, 3.24 and 3.25 are steps used to create device after template created. Figure 3.25 shows device sensor A created and figure 3.26 shows the Device A and Device B.

3.5.3 Assembling Hardware Prototype

Assembling the hardware prototype includes choosing the router device like in figure 3.27. After the circuit connected, like in figure 3.28, the circuit was put in the container. Figures 3.29 and 3.30 show the two prototypes that are assembled in container.

Figure 3.26: Router device for Wi-Fi transmission

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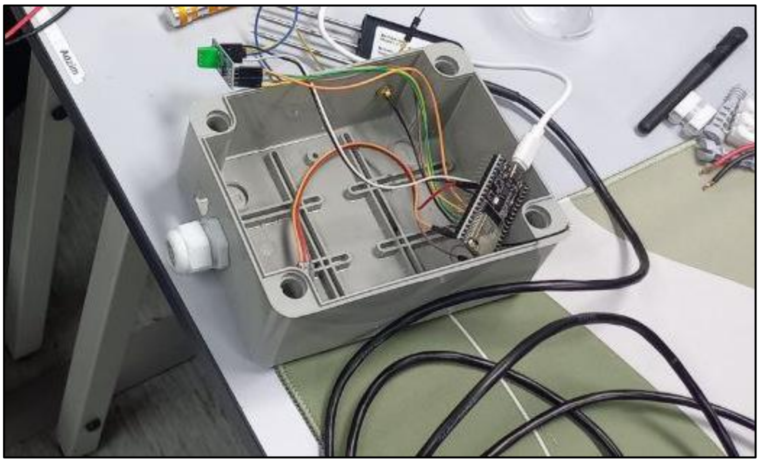

Figure 3.27: Putting the circuit into the container prototype

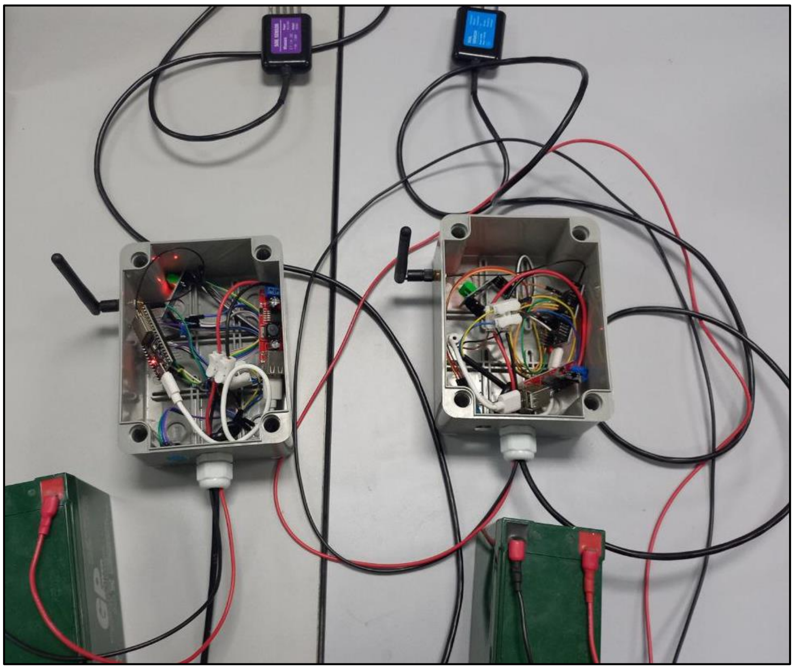

Figure 3.28 : Two circuit connected with the sensor and power supply

Figure 3.29 : Two prototype for Sensor A & Sensor B

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3.5.4 Collecting Soil Samples

The soil samples were collected at the cornfield before the deployment was conducted like figure 3.31. Some of corns' soils was collected like in figure 3.32.

Figure 3.30: Corn's soil

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Figure 3.31 : Soil Samples collected by me

3.5.5 Reading the data of samples using USB Converter

After the samples were collected, the reading of the nutrients level will be analyzed by the USB Converter before the real system used like in figures 3.35 and 3.36. The soil samples will be placed in the beaker like in figures in 3.33 and 3.34. Figures 3.37, 3.38, 3.39 and 3.40 show the reading of the nutrients values by the software used.

Figure 3.32 : Sensor A read the soil sample

Figure 3.33 : Sensor B read the soil sample

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Figure 3.34 : USB- Converter of Sensor A and Sensor B connected directly to the laptop

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Figure 3.35 : Sensor A and Sensor B

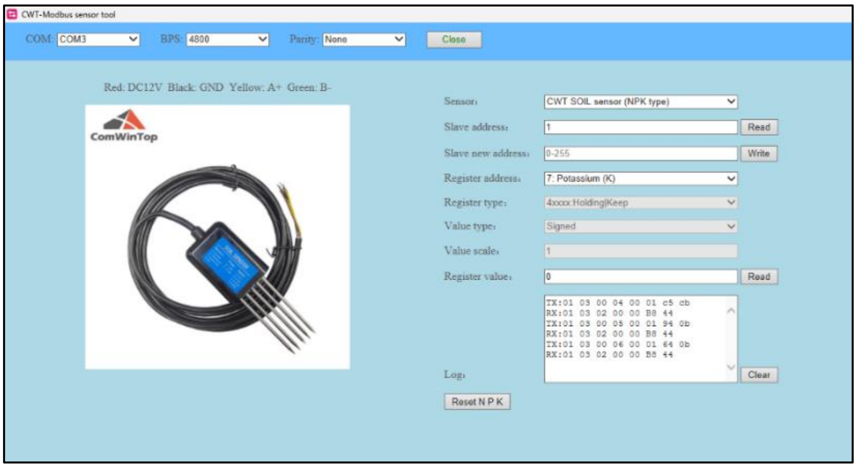

Figure 3.36 : Reading of Sensor A for Nitrogen, Phosphorus and Potassium (NPK)

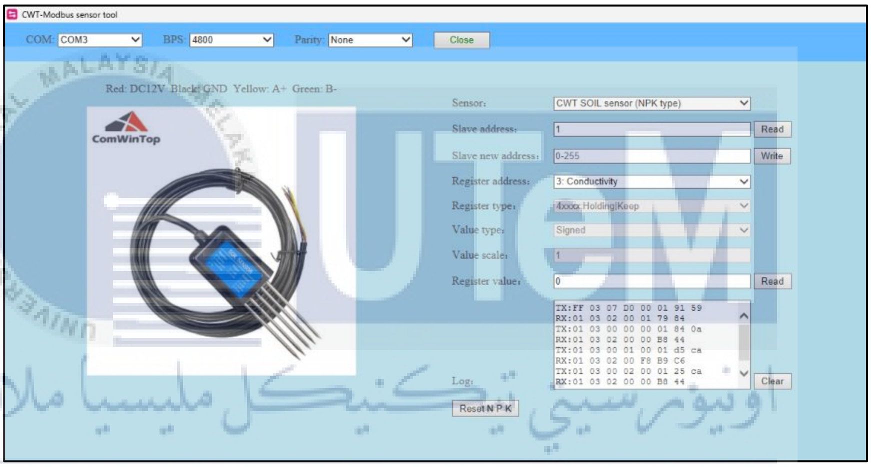

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Figure 3.37 : Reading of Sensor A for Temperature, Humidity and Conductivity.

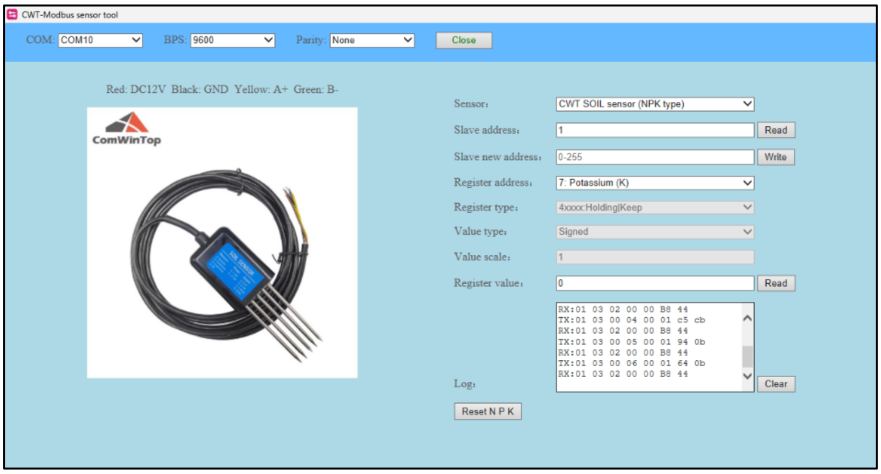

Figure 3.38 : Reading of Sensor B for Nitrogen, Phosphorus and Potassium (NPK)

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Figure 3.39 : Reading of Sensor B for Temperature, Humidity and Conductivity.

3.5.6 Deployment of the project in the actual sites

Figure 3.40 : Cornfield in UTeM

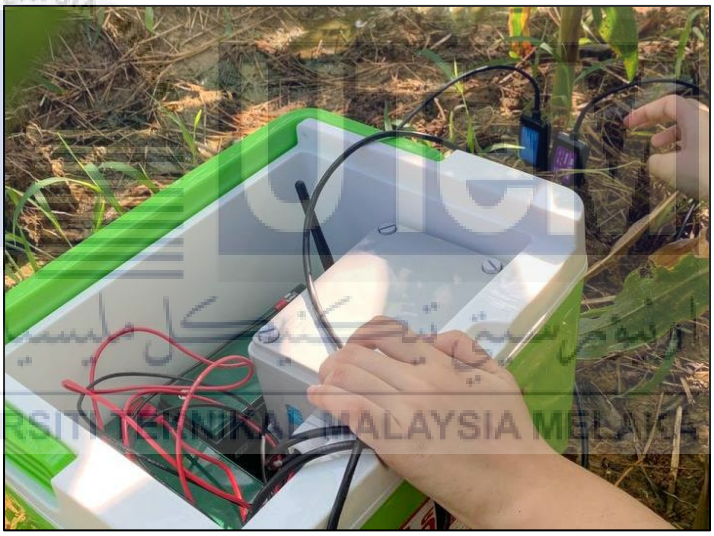

Figure 3.41 : Prototype in the container with soil sensor

Figure 3.42 : Sensor A and Sensor B deployed

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Figure 3.43 : The data collected using Blynk IoT

To deploy the soil sensor system at actual agricultural sites, first ensure all components, including the Soil Sensor, Temperature and Humidity Sensor (DHT11), and NodeMCU ESP32 microcontroller, are securely assembled and tested in a controlled environment like in figure 3.42. Next, choose representative locations within the field for sensor placement in figure 3.41, ensuring they cover areas with varying soil types and conditions. Install the sensors by embedding them at appropriate soil depths and securing the NodeMCU in a weatherproof enclosure in figure 3.43. Then, the data for the system was collected like in figure 3.44.

CHAPTER 4

RESULTS AND DISCUSSION

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In this chapter, the results are shown, and some analyses are discussed in the table and graph. For result of environment and sustainability also well explained in the Sustainable Development Goals (SDGs).

4.1 Analysis of the Readings from an Industrial Soil Sensor Using a USB Converter

Table 1 : Air condition

Parameters	Sensor A	Sensor B
Nitrogen (mg/kg)	0	0
Phosphorus(mg/kg)	0	0
Potassium(mg/kg)	0	0
Humidity(%RH)	0	2.7
Temperature (℃)	25.0	24.3
Conductivity(us/cm)	250	244

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Observations made on the data collected above using Sensor A and Sensor B under air conditions are; Both the Sensor A and Sensor B indicated that they could not detect any nitrogen, phosphorus and potassium, this infers that there are no soil nutrients in the air. The values of humidity are dissimilar, sensor A measures 0% and sensor B measures 2%. 7% while sensor A did In other words, the low humidity is identified by sensor B but not by sensor A. The temperatures are fine, A is 25. Sensor A is - 0°C and the sensor B is 24. Three degrees Celsius as a result of the ambient environment. The conductivity for sensor A is 250 µS/cm, and for the sensor B is 244 µS/cm prove some kind of electric conductivity in air, might be because of some slight environmental effects. These results enable the setting of reference values for the operations of the sensors in conditions not on the ground and moreover exhibit the high sensitivity and accuracy with which the sensors' parameters of the environment can quantify.

Table 2 : Soil Condition (Corn)

Parameters	Sensor A	Sensor B
Nitrogen (mg/kg)	24	53
Phosphorus(mg/kg)	102	45
Potassium(mg/kg)	95	110
Humidity(%RH)	20.10	25.40
Temperature (℃)	24.70	23.80
Conductivity(us/cm)	301	200

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From the given soil condition data of corn, the readings obtained by Sensor A and Sensor B differ greatly from each other. It is detected that the concentration of nitrogen in the soil is 24mg/kg from Sensor A, while that of Sensor B is 53mg/kg. For the phosphorous concentration, Sensor A records a value of 102 mg/kg while Sensor B records 45 mg/kg. For potassium, Sensor B records the concentration to be higher and is at 110 mg/kg as opposed to 95 mg/kg as recorded by Sensor A. Also, the values of humidity are different: Sensor A recorded 20. 10% relative humidity and Sensor B has a higher value with 25. 40%. Temperature readings are somewhat different with sensor

A reading a slightly higher value of 24. Sensor A was 70℃ and Sensor B being 23. 80 ℃. Conductivity is slightly higher in Sensor A with a value of 301 µS/cm than Sensor B with a value of at 200 µS/cm.

In total, these variations indicate the necessity of choosing the right sensor depending on the parameters of the soil that is necessary for the proper corn growing. Hence, Sensor A will be more appropriate when phosphorus and conductivity of the soil as compared to nitrogen, potassium, and humidity as cited by Sensor B.

Table 3 : Soil condition (Durian)

Parameters	Sensor A	Sensor B
Nitrogen (mg/kg)	11	40
Phosphorus(mg/kg)	73	32
Potassium(mg/kg)	65	95
Humidity(%RH)	18.50	25.0
Temperature (℃)	37.90	37.50
Conductivity(us/cm)	241	172

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. Comparing the collected data concerning the soil condition for durian, one can identify significant disparities between Sensor A and Sensor B in terms of parameters. Nitrogen detected by Sensor A is 11 mg/kg while Sensor B detects 40 mg/kg of nitrogen; phosphorus is equally detected higher by Sensor A at 73 mg/kg than what Sensor B detected at 32 mg/kg The potassium content is detected higher in Sensor B with the detection of 95 mg/ kg and, Sensor A detected potassium content at 65 mg/ kg only. Relative humidity reveals a significant variation; Sensor A logged 18 percent only. Relative humidity at 50% and Sensor B is measuring it at 25%. 0%. Values of the temperature are reasonably similar, and the starting point was 37° C for Sensor A. 90℃ and Sensor B at 37. 50℃. Conductivity is higher in Sensor A, with conductivity of 241 µS/cm, while in Sensor B the conductivity stands at 172 µS/cm.

From this analysis, were it not for identifying the right sensor according to the specific soil characteristics that are desirable to produce durian fruits, then this exercise would be meaningless. If levels of phosphorus and conductivity of soil are important factors, then sensor A is more appropriate to use. On the other hand, Sensor B is preferred when the levels of nitrogen and potassium in the soil has to be measured along with higher humidity.

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4.2 Analysis of the Reading Techniques Used by the Industrial Soil Sensor

Table 4 : Values Parameters for Corn 1

Location	Sensor A					
	Humid	Temp	EC	N	P	K
1	95	29.23	0.22	6.67	61.67	54
2	95	28.67	0.23	8	65	57.67
3	95	29.03	0.21	4	57	49

4	95	28.6	0.22	7	64	56
5	95	28.5	0.22	6	61	54
6	95	28.83	0.25	13	77.67	69.67

The collected data of the soil condition for different places using Sensor A shows that the measurements are accurate and precise for six different points. The moisture content is 95% for all the stations and thus depicts high moisture content in the ground. Opposing the temperature readings that are ranging from 28. 5℃ to 29. 23℃ with little departure from this mean across the selected sites. This stability in temperature is good for plants' growth conditions. For the conductivity (EC), it varies between 0. 21 µS/cm and 0. 25 µS/cm are which reciprocate the capability of the soil to transfer electrical current, which is a factor of soluble salts present within the soil. The lowest and highest EC are respectively seen at Location 1 and the sixth one, with an elevated EC of 0. 25 µS/cm than that of the control, which might mean that their nutrient available is higher.

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In Nitrogen, Phosphorus and Potassium, the Nitrogen levels are as follows 4 mg/kg in Location 3 to 13 mg/kg in Location 6. As for Phosphorus, it is essential in plant growth since it ranged from 57 mg/kg at location 3 to 77. 67 mg/kg at location 6. Some of the functions of phosphorus include energy transfer, root formation among plants and location 6 had the highest phosphorus content. Then, Potassium levels range as is evident by the following, 49 mg/kg location 3, 69. The highest magnitude of KNO3; intake was reported to be 67 mg/kg at location 6. Potassium is needed for the activation of enzymes, for photosynthesis; the highest amount is at location 6.

Looking at the reading from Sensor A and the concentration of nutrients; nitrogen, phosphorus, and potassium as well as the electrical conductivity, then it can be concluded that location 6 is the most effective place among the other five places. All the locations also have high humidity which is suitable for crops that need moisture all the time. These fluctuations are minor and thus cannot be considered as a threat to the growth of the plants. The effectiveness of the nutrient analysis of the soil enables the determination of the areas with the most suitable conditions for the planting of crops to improve the production of crops and their general wellbeing.

Table 5 : Values Parameters for Corn 1

Location	Sensor B					
	Humid	Temp	EC	N	P	K
1	95	29.13	0.15	30	22	83
2	85.67	27.9	0.16	33.33	26	87.33
3	80	28.23	0.16	32	24.33	85.33
4	83	28.6	0.15	30	22	83
5	73.33	27.9	0.15	29	21	81
6	59	29.2	0.15	31	23	84

From the data of soil condition obtained from Sensor B, one is able to consider several parameters at half a dozen different sites. Temperature is fairly stable; however, the amount of humidity differs greatly depending on the location: location 1 has 95% humidity, and location 6 only 59%. This variation may affect the availability of soil moisture to crops hence might affect production. Measures of temperature vary from 27. 9℃ to 29. reaching 2℃, though they fluctuate from one region to another. This deviation is normally speaking slight to a level that is bearable for most crops. The ratios of EC values are fairly stable from 0. 15 µS/cm to 0. 16 µS/cm. This has suggested a fairly good distribution of soluble salts in the soils.

Therefore, Nitrogen levels range from 29 mg/kg at location 5 to 33. 33 mg/kg at location 2. The reason for choosing the two different dosage values is due to the difference in the number of patients that are taken through the two different locations. More amounts of nitrogen like in location 2 are suitable for the growth and development of the plants. Phosphorus content varies from low of 21 mg/kg at site 5 to high of 26 mg/kg at site 2. Phosphorus is essential to plant roots specifically in development and also plays the role of transferring energy. Clearly, location 2 has the highest potassium with 87. The highest who's inhalation exposure was recorded was from location number 3 with 33mg/kg and the lowest from location number 5 with 81 mg/kg. The latter is used for enzyme activation and photosynthesis.

These are the following points that can be identified from the data of Sensor B and is related to the condition of the soil concerning the agricultural productivity: Here, it is possible to observe that location 1 and 2 are characterized by the highest level of humidity that might be useful for plants that need constant moisture. Location 2 is the only sample with relatively high concentration of nitrogen, phosphorus, potassium thus can be considered the most fertile out of the six locations. On the other hand, location 6 recorded the lowest avarage humidity which might not be too suitable for crops that do not grow well in dry environments. Knowledge of such differences

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could assist in adjusting the strategies of soil management according to the region, thereby, increasing crops' health and productivity.

Table 6 : Values Parameters for Corn 2

Location	Sensor A					
	Humid	Temp	EC	N	P	K
1	95	28.2	0.25	13	77	69.67
2	95	28.4	0.22	7	62	55
3	95	28.3	0.27	17	86	78
4	95	28.6	0.24	12	73	66
5	95	28.8	0.23	9	67	60
6	95	29	0.27	18	89	82

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The collected data of soil condition through Sensor A from several locations sheds light on the soil quality, which is crucial for the enhancement of agricultural yield. The percentage relative humidity does not vary with the location and records an average of 95%, which is discrete moisture ideal for most crop. The temperatures are quite reasonable and might fluctuate slighting within the range of 28. 2℃ to 29℃. This is slight variation within manageable range that enhance production of the plants among the species. Thus, EC values vary within the range of 0. 22 µS/cm to 0. 27 µS/cm that identified the highest value at location 3 and 6. The higher EC values indicate the greater solubility of the salts that can be proved beneficial for the nutrient absorption by the plants.

For, Nitrogen content which is essential nutrient ranges from 7 mg/kg at location 2 to 18 mg/kg at location 6. Nitrogen is essential for the growth of vegetative tissue; the highest nitrogen concentration is recorded in locations 6 and crops that require a higher nitrogen level may possibly be more fertile in this region. Averagely the content of phosphorus is between 62mg/kg at location 2 and 89 mg/kg at location 6. H3 : The phosphorus is important in root development and energy transfer; therefore, higher concentration in location 6 means better conditions for crop types that require more phosphorus. Potassium levels range with 55 mg/kg at the second location to 82 mg/kg at the sixth location. Potassium is important in enzymatic activities and photosynthesis; location 6 has the highest amount which is suitable for crops that require higher potassium.

According to values obtained in Sensor A, location 6 has the highest nitrogen, phosphorus, and potassium accumulation as well as the highest EC meaninging that location 6 is the most suitable for the growth of crops among all the six growing locations. It can also be noted that nutrient levels and EC values are comparatively high with the values observed for location 3 and 1 which depict good fertility status of the soil. Hence, all the nutrient level results signify that Location 2 has the lowest nutrient levels but still has high humidity and acceptable EC levels to support plant growth though nutrients should be added. High humidity in all the sites provides enough moisture in the soils and the slightly different temperatures are apposite for most crop growing.

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Table 7 : Values Parameters for Corn 2

Location	Sensor B					
	Humid	Temp	EC	N	P	K

1	95	27.6	0.18	42.67	34.67	97.67
2	82.33	27.8	0.17	36.67	29	90.67
3	78.67	27.8	0.18	41.67	33.67	96
4	78.67	28	0.18	44	36	99
5	73	28.2	0.16	34	27	88
6	56.33	28.7	0.18	45	37	100

The mode and analysis of the reading of soil condition at different locations using Sensor B provides such fundamental details about the quality and fertility of the soil. Humidity levels are 56% and 60%. The water usage varied with the location ranging from 33 % at location 6 to 95 % at location 1. This variation shows that the level of moisture varies in different areas, and this has a great affect on the growth of plants. Since Location 1 has the highest humidity, this sector affords right moisture conditions for many crops to be grown. Temperature readings vary to a lesser extent and fluctuating between the 27-th and the 30-th degree Fahrenheit. 6℃ to 28. 7℃. This is probably good for most crops because the range is quite narrow and prevents severe fluctuations that could affect growth in a negative way. Thumb positions and EC values are equal to zero, 0. Most of the sites have a TDS of 18 µS/cm, though there is a slight decrease to 0. 16 µS/cm in location 5 and 0. 17 µS/cm at location 2. Such values pre-suppose even dispersal of soluble salts which are important for nutrient intake.

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As for Nitrogen, its values ranges from 34 mg/kg at location 5 to 45 mg/kg at location 6. Nitrogen is useful for vegetative growth, and location 6 is the location with high N content meaning that crops that require higher N level will grow in that area.

Phosphorus content varies from 27 mg/kg in the location 5th to 37 mg/kg of the location 6th. Phosphorus is involved in the formation of roots and energy conduction, while location 6 contained the most of it. The potassium content rises, or is higher at, location 5 at 88 mg/kg and peaks at location 6 at 100 mg/kg. It is important in enzymatic activities and photosynthesis; thus, it will reveal areas ideal for crops that need high K content; location 6 received high K scores.

This is manifested in the fact that location 6 received the highest nutrient concentration of nitrogen, phosphorus, potassium, and a considerable amount of EC and temperature which are vital for crop farming. Thus, the conditions in Location 1 are the most favorable for agriculture due to the high humidity and a significant amount of nutrients in the soil. As for the locations 3 and 4, it is seen that their nutrient and EC contents are stable, which shows sufficient soil fertility. Thus, while Location 5 has the lowest nutrient levels, it is just above the acceptable range and may need boosters for extra plant development. The variation of these factors is beneficial when determining the right manner of handling the soil as a means of promoting the well-being of the crops and the yields that the intended planting will produce.

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4.3 Analysis of EC Reading for 2 Sensor in Six Location

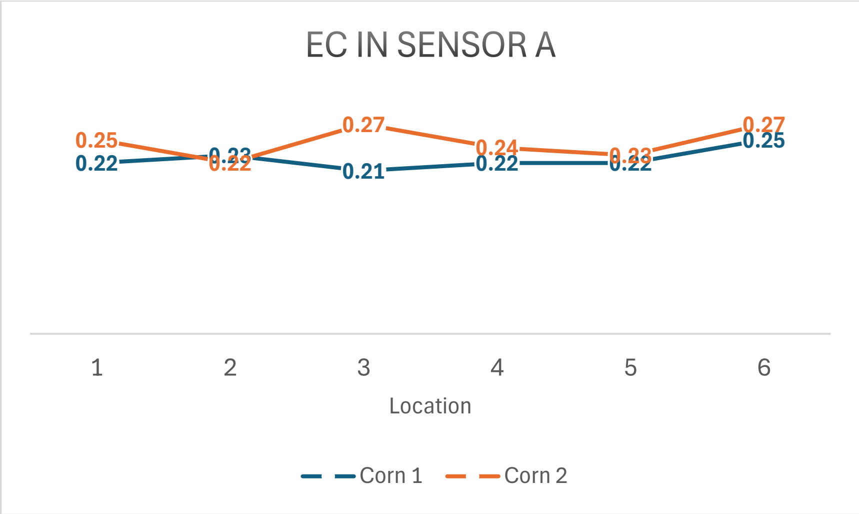

Figure 4.1 : Values EC in Sensor A in Six Locations

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The two graphs presented here show the EC values of Corn 1 and Corn 2 for six samples taken from the two positions with two different sensors: Sensor A and Sensor B.

Indeed, in the case of Sensor A, we observe from the graph that on corn 1 the EC varies between 0. 21 and 0. 27 µS/cm. The EC value present is the lowest one and it has been evaluated to be 0. 21 µS/cm at location 3 for the lowest EC while the highest is 0. The electrical conductivity at the three and six refer to point is 27µS/cm. As for corn 2, the values of the EC changed more smoothly, and they fluctuated in the range of 0. 22 to 0. 27 µS/cm. Here the possibility of transmission of CVD is highest while the lowest EC value is 0. 22 µS/cm at multiple locations which are location 2, location 4, and location 5. The highest EC value is 0. W1 20 µS/cm of resistivity of water at location 3.

Analyzing the results for Sensor A, both crops Corn 1 and Corn 2 have characteristics of similar nature for the EC fluctuations although Corn 1 presents more fluctuations. From figure 4, Corn 1 and Corn 2 have the maximum EC value at location 3, suggesting that nutrient is more available at this place.

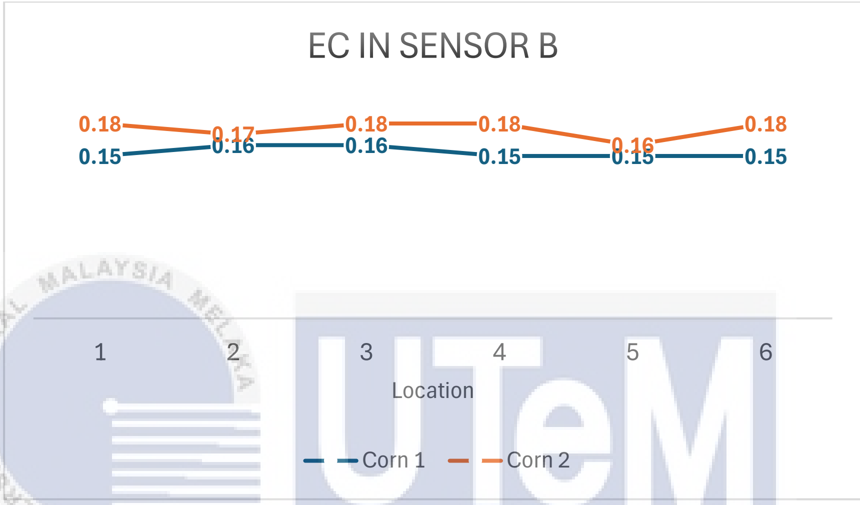

Figure 4.2 : Values EC in Sensor B in Six Locations

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Analyzing the data presented in the form of the graphs, it can be concluded that based on Sensor B, the EC values for Corn 1 are significantly low, fluctuating between 0. 15 to 0. 16 µS/cm. The minimum EC value found is 0. Below 15 µS/cm in four different locations, namely, location 1, location 4, location 5, and location 6. The maximum EC value is 0. Of these, the following values have been set; 8 µS/cm for location 1, 16 µS/cm for location 2 and 16 µS/cm for location 3. For Corn 2 the EC values also remain constant and they range between 0. 17 and 0. 18 µS/cm. The minimum possible EC value is equated to zero. Location 2 has the lowest EC of 17 µS/cm and the highest of all is 0. value of 18 µS/cm at these multiple locations namely location 1, location 3, location 4 and location 6.

As for Sensor B comparing Corn 1 and Corn 2, the EC values of Corn 2 are relatively higher than Corn 1 throughout the trials. The variation of both crops is a little bit low which implies that there is little changes in the soil conditions for all specified locations.

From the two graphs, Generator A has a wider range of EC values and thus it points out the variability of the state of the soils present in different locations. Similarly, as in the case of heat flux, both Corn 1 and Corn 2 achieve the maximum EC values at location 3. Ideal EC range is lower and is more constant for Sensor B; meanwhile, Corn 2 has a higher overall EC than Corn 1. These differences between the two sensors could be attributed to, for instance, the difference in sensitivity of the sensors or probably there is variation of soil characteristics and moisture content at the two sites. The differences in the EC in different layers point to these locations as having higher soluble salts that affect the nutrient status of the soil.

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4.4 Environment and Sustainability

The project "Design and Performance Analysis of an Industrial Soil Sensor for Nutrition Monitoring" is responsive to several of the United Nations' sustainable development goals most notably which are zero hunger, prosperity, and consuming and producing responsibly. By developing an advanced ground sensor system capable of real-time nutrient monitoring, the project directly supports SDG 2: SDG2 – Zero Hunger which focuses on the elimination of hunger, achieving food security and improved production of nutritious products and sustainable agriculture. This knowledge enables the farmers to have correct and efficient assessment of nutrients in the soil and properly apply fertilizers, thus enhancing food production, and thus food security, a fundamental element of human existence.

In addition, this project contributes to SDG 12: Sustainable management of resources including agricultural ones through the process of responsible consumption and production. Past methods of determining the type of soil mainly needed a lot of input and a lot of time and in the process a lot of fertilizers and other inputs were wasted. The soil nutrient management system developed enables farmers to utilize fertilizers efficiently by applying the right amount at the right time thus reducing wastage on unfertilized areas, hence reducing environmental impacts. The indicated accuracy of resources utilization bears with it the overall notion of sustainable management of resources as well as the efficient utilization of natural resources.

Then, the project contributes to SDG 13: Climate Action by making the performance of agriculture more climate friendly through intervention measures. The optimization of the nutrient limit also minimizes the likelihood of excessive fertilization as a cause of greenhouse gases, the most famous being nitrous oxide. Since the application of fertilizers is an efficient means of cutting energy use in agricultural practices, the project becomes instrumental in the following reduction of carbon footprint levels among farmers. Also, the improvement of the health of soil will enable it to hold more carbon hence enhancing the fight against climate change. The ideas of innovation and sustainability being used in the project also show that the goal of the project is to bring into light technologies that are necessary for the sustenance of the environment as well as for the economic benefit of farmers in the future sustainable agricultural system.

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CHAPTER 5

CONCLUSION AND FUTURE WORKS

This chapter summarizes the project and provides an overall conclusion. It will also recommend future works.

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5.1 Conclusion

The project has developed a wireless industrial soil sensor system, an indirect determination of the limitations solved in traditional methods for monitoring your land. The system achieved its project goal of designing a wireless industrial soil sensor for monitoring the amount of nutrients in soils by incorporating 2 different kinds of sensors which are Sensor A with probes having 5 pins and the other one is Sensor B has 3 pins. It bypasses existing soil sensor limitations, typically focusing on only parameters such as soil moisture and temperature by incorporating sensors that also record for other factors like conductibility of the soil, nitrate level (NPK) ingested via a straw or hole. This development enables a more complete understanding of soil without traditional manual, time-consuming laboratory tests, providing real-time information about nutrients.

In addition, the project conducted testing and performance measurements to prove that data on soil quality through anywhere where it has internet connectivity. These studies of this data revealed significant differences between the nutrient levels and contents in different agricultural environments which demonstrated that useful insights can be drawn from this network to enhance land use practices, so as maximize crop yield using very little input illumination.

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Providing a real-time comparison such as humidity, temperature and conductivity of multi-parameters soil analysis that is performed through reliable data sources has achieved the expected outcome for this project as well as nitrogen, phosphorus and potassium. The new product is a significant evolution in precision agriculture, giving farmers and agronomists the capability to make data-driven decisions that lead to more efficient soil management practices.

5.2 Future Work Recommendations

Based on the achievements of this project, several recommendations for future work can be made to improve the design and performance of an industrial soil sensor system for nutrient monitoring. One critical area for the future is the long-term use of the sensor system in various agricultural areas to enable continuous monitoring of soil nutrients. We will gather more and extensive data through using these sensors in different stages of crop growth such as the early development stage, post-fertilization period or taking seasonal variations like warm season, rainy season and others by monitoring over a long timeline This constant data collection offers useful information on the evolution of soil nutrient content under different agricultural practices and a long time. Creating awareness of nutrient dynamics through time helps to design soil management interventions to maximize output and sustainably build the health status of our soils.

Large margins of improvement also are available in the basic sensor system, such as in power and communication subsystems. So, incorporating solar energy systems into sensors minimizes the probable use of rechargeable batteries and also enhances the systems reliability and self-sufficiency. Self-charging capability of the sensors can be provided by the solar panels which will keep the sensors charged all the time unlike in these agricultural lands where frequent charging is difficult.

It is for longer distance communication where Long Range or abbreviation LoRa is recommended. LoRa has an extended range low power wireless data communication capability which is best suited in large expanse of agricultural land when normal wireless networks can prove ineffective. With LoRa transactions initiated by the sensor units, it becomes possible for sensor units to transmit data for several kilometers, thus making it easier even for the most remote sensors to be able to relay information back to the main control room. On the same note, the integration of a mesh system in which every single sensor can send information to the adjacent sensors makes it a stable and expandable setup. As such, this approach guarantees efficiency in data transfer, especially in problematic terrains, and does not require extensive investment at a large scale of agriculture domain.

Thus, the reliability of such a system requires a fine-tuning of the sensors' accuracy. Clearing up existing processes related to the calibration of the sensors, especially the ones used to evaluate conductivity and concentrations of nutrients NPK will enhance the reliability of the measurements. This can be achieved by looking for even more enhanced calibration procedures and putting into use machine learning algorithms to make the sensor data adaptive to the various environmental conditions.

Thus, the future work can extend these directions to enhance the performance of an industrial soil sensing system, contributing to rational, environmentally friendly, and evidence-based farming. Apart from augmenting the existing method of monitoring the nutrients present in the soil, it also relays relevant information to farmers in real-time thus enabling the farmer to make appropriate decisions to enhance the management of the crops, which consequently raises the productivity of agriculture.

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