Journal of Image Processing and Intelligent Remote Sensing
ISSN 2815-0953
Vol: 03, No. 05, Aug-Sept 2023
http://journal.hmjournals.com/index.php/JIPIRS
DOI: https://doi.org/10.55529/jipirs.35.1.9

Design and Analysis of Proximal Soil Sensing System Based on Electrochemical ISE Sensor for Total Nitrogen and Potassium Fertility Assessment

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Received: 29 April 2023 **Accepted:** 18 July 2023 **Published:** 04 September 2023

Abstract:** Traditional agriculture is the most practiced form of agriculture around the world. Conventional agriculture depends on applying harmful chemicals to the soil and plants, which are mostly synthetically formulated in a laboratory. A modern approach is known as Precision Agriculture (PA) has been introduced in the last two decades produce healthier crops and higher yields compared to conventional agriculture. By using precision agriculture, the farmers can improve their farming techniques and solve decades-old problems. From the study, plants suffering from a lack of N and K show decreasing photosynthetic activity and plants' abilities to resist disease, leading to reduced crop yield quality and overall quantity. To solved this, the assessment and data analysis for N and K is required. This study aims to get the accurate value of N and K fertilizer used in the field to help restore the ecosystem and optimize yield while remaining environmentally sustainable. The fertilizer A and B will fill and mix into the aqueous solution, then proximal soil sensing ISE sensor will measure the concentration of Nitrate and Potassium ions in aqueous samples. The feedback signal from the ISE sensor will enter the Raspberry Pi controller and analysed through the Internet of Things (IOT) platform using the Node Red and Phyton simulation. Lastly, the data will be processed and monitored through the LCD. The evaluation performance and the result of the ISE Sensor will be validated using a correlation method. The correlation of the soil sensor and the lab analysis has shown that the right amount of NK fertilizer can help the farmer to manage the plant in the field.

***Keywords:** Precision Agriculture, Nitrogen, Potassium, Electrochemical ISE Sensor.*

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1. INTRODUCTION

Traditional agriculture is the most commonly practiced form of agriculture around the world. Traditional agriculture depends on the application of harmful chemicals to the soil and plants, which are mostly synthetically formulated in a laboratory. These products are used to protect the plant from having been exposed to disease or pests. The result is that these crops have been proven in causing fatty tissues, and chances in developing an illness and cancer growth. A modern approach known as Precision Agriculture (PA) has been introduced in the last two decades to increase the needs of humans and society from conventional agriculture. By using precision agriculture, the farmers can improve their farming techniques and solve decade old problems. Precision agriculture utilise the new technologies, integrates with data collecting, and effectively analyse it to improve the production efficiency while ensure the profitability, sustainability and protection of the environment [1]. Precision farming is one of the top ten new agricultural technologies [2]. Precision agriculture, in an era of rising food demand, produces higher yields at lower input costs while reducing emissions and labour [3]. Precision agriculture is one of the modern farming techniques that improve productivity. Farmers and soils perform better, not harder, with precision agriculture.

Objective

1. To design and analyse the Proximal Soil Sensing System Based on Electro-Chemical Ion Selective Electrode (ISE) Sensor for Nitrate and Potassium Fertility Assessment.
2. To develop an IoT monitoring system based on the smart farming concept using Raspberry Pi (Node Red) for the integrated data fusion of proximal soil sensing devices.
3. To evaluate the performance of the developed system and validation of the ISE sensor with IoT platform by using correlation analysis.

Problem Statement

The first problem statement of this study is the time taken to analyse the soil fertility using laboratory method. The standard way to analyse the composition of the Nitrate (N), and Potassium (K) in the soil takes a time of about 2 or 3 months to get the result.

The second problem statement is the farmer is using the manual way to monitor the plants growth, previously farmer do not know exactly the NPK composition for the plants. NPK stands for nitrogen, phosphorus, and potassium, three of the most vital nutrients that plants require. If the plants suffering from a lack of N and K fertilizer, it will show the decreasing photosynthetic activity and plants' abilities to resist disease, leading to a decrease in crops yield quality and overall quantity.

The third problem statement is the accuracy of single sensor is mostly low and limited compared to multi-sensor due to the fact that all proximal soil sensors react to less than one interesting soil property. It will also affect the capability and performance of the data collection. The data collected from different area's soil sample should be recorded and validate to help farmers to do the farm management.

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2. LITERATURE REVIEW

The study of literature covers a broad range of theories, working principle of system and sensor, the importance of Internet of Thing (Iot), evolution of Precision Agriculture and previous research done. In order to minimize the waste of fertilizer and to get the accurate value of N and P fertilizer used in the field to help restore the ecosystem, the application of Proximal Soil Sensing System Based on Electro-Chemical Ion Selective Electrode (ISE) Sensor for Nitrate and Potassium Soil Assessment will be introduced. The literature review will focus on soil fertility and nutrient conservation, soil and crop properties affecting the fertilization process, Nitrate and Potassium soil assessment and Electro-Chemical Ion Selective Electrode (ISE) sensors that affect plant growth in Smart Farming area.

2.1 Precision Agriculture

Precision agriculture (PA) is a method of farm management that uses information technology (IT) to provide high-quality products and ensure that crops and soil receive exactly what they need to grow and produce at their best. PA's mission is to maintain profitability, increased efficiency, as well as the preservation of the environment's long-term sustainability. As stated by the United Nations Food and Agricultural Organization (FAO), global population will reach 9.2 billion by 2050. There is no way to avoid a global food crisis by planting more crop fields or breeding more cattle. [4].

2.2 Soil Nutrient

Plant growth requires soil as a source of nutrients. Nitrogen (N), phosphorus (P), and potassium (K) are the three most essential nutrients. The trio known as NPK is made up of them. Compounds are found, for example boron, iron, copper, manganese, zinc, and molybdenum are also necessary by plants, but only in trace quantities.

2.3 Proximal Soil Sensing

Proximal soil detection is used to receive signals from the soil whenever the sensor's detection is in contact with it or near to it (within 2m). (Viscarra Rossel et al., 2011) [5]. Proximal soil sensing is used to collect data on physical measurements that are related to the soil and its properties.

2.4 Application of Iot in Agriculture

According to the United Nations Food and Agriculture Organization, the world would need to produce 70% more food in 2050 to feed the growing population. Forced migration, climate change, water scarcity, lack of arable land, labour demand, crop failures due to pest and disease outbreaks, and other factors will worsen the demand for global food output [6]. IoT solutions aim to help farmers bridging the gap between demand and supply by maximizing yields production, sustainability, and environmental preservation conservation.

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3. METHODOLOGY

In this part of the chapter, the researcher will thoroughly explain the methodology and procedures of the project.
In addition, it gives an idea of how the process worked through all experimental works.

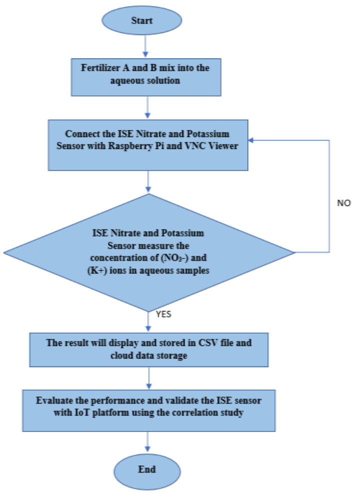

Figure 1: Flow Chart of the Project Hardware

Figure 1 shows the flow chart of the project hardware using the Nitrate and Potassium ISE sensor, and then it will measure the concentration of Nitrate and Potassium ions in fertility assessment. Furthermore, the evaluation performance of the developed proximal soil sensing system and validation of the ISE sensor with IoT platform by using correlation study will be studied in this research.

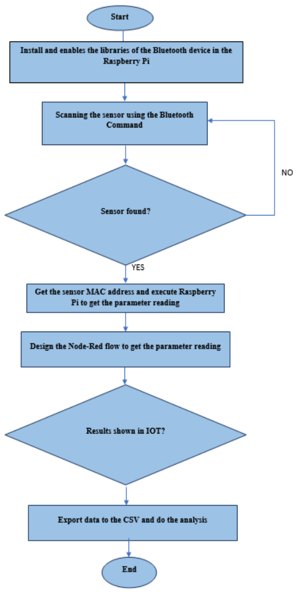

Figure 2: Flow Chart of the Project Software (Raspberry Pi)

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Figure 2 above shows the flow chart of the project software. The software using is Node-Red by Raspberry Pi, and user has to design the node-red flow to get the parameter and output reading. The data will be displayed on the mapping, gauge, and graph dashboard. Then the data will be export from a CSV file, and further analysis has to be done.

Develop an IoT monitoring system using Node Red (Raspberry pi) for the integrated data fusion of proximal soil sensing system based on smart farming concept.
The development of the proximal soil sensor system will be carried out once the suitable sensors are selected. The ISE sensor chosen for the purpose of this research is to measure the content of Nitrogen and Potassium. Figure 3 below shows the block diagram of the hardware connection between, MSES, ISE sensor, Raspberry pi and the user interface which is Virtual Network Computing (VNC) platform.

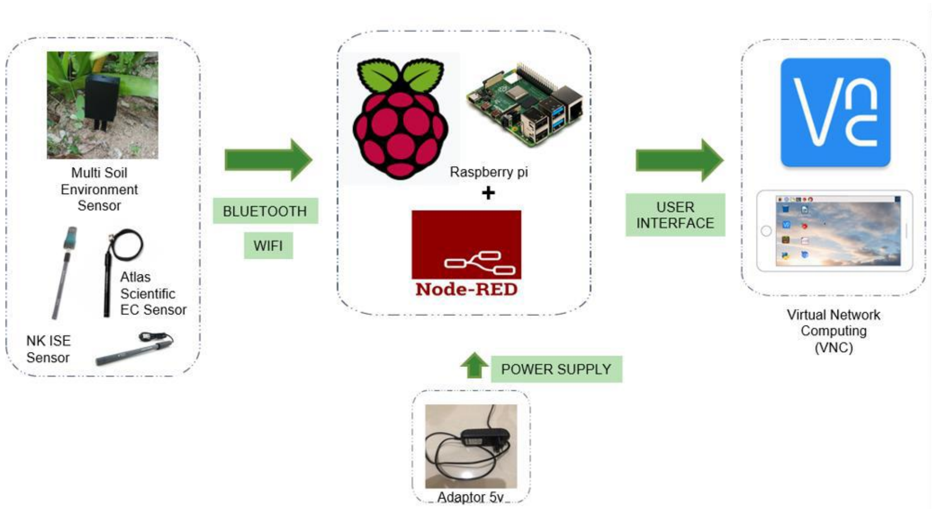

Figure 3: Block Diagram of the Hardware and Software Connection

The raspberry pi has been powered using 5 V adaptor. The internet connection must be ON all the time through the data process collection since this is an IoT (Internet of Things) configuration.

4. RESULT AND DISCUSSION

This chapter will discuss on the result and data analyses and evaluation done for this project. The evaluation of the performance and validation of the system developed will be done and the result obtained will be discussed in this chapter.

4.1 The Phyton Code and Node-Red Flow
The experiment has been done using Iot connection integrated with hardware and software devices. The output data will be displayed on the dashboard and VNC (Virtual Network Connecting) platform.

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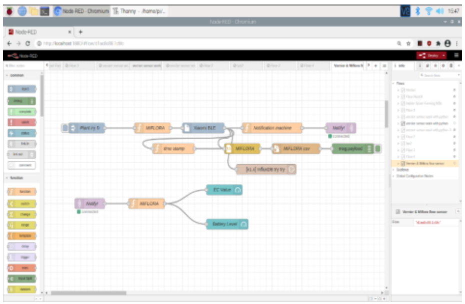

Figure 4: MSES Node-Red Flow

Figure 4 above show the node-red flow for MSES EC Sensor. This project has been done using the three sensors which are MSES, ISE Nitrate and Potassium Sensor and Atlas Scientific EC Sensor. The flow starts with the data received from each of the sensors. The web socket node was connected the local host address of the Raspberry pi controller will receive the data from the sensors. The connection will be created using the flow provided in the Raspberyy pi. The data was then exported as the csv file after the flow was completed. The user interface also formed by using the Node RED. The user interface real-time monitoring the concentration of nitrate and potassium ion measured, the battery percentage of the ISE sensors, and the value of the electrical conductivity.

4.2 Analysis 1 – Electrical Conductivity in Different Volume of Fertilizer

The aim for this study is to evaluate the performance of integrated data of fertility asessment through an electrical conductivity sensor with IoT-based platform to manage the fertility asessment.

1. FERTILIZER A

FERTILIZER A		
AMOUNT OF FERTILIZER A (ML)	MULTI SOIL ENVIRONMENT SENSOR (MSES), (µs/m)	ATLAS SCIENTIFIC EC SENSOR (µS/m)
1	609.5	664.48
2	953.3	945.8
3	1499	1172.8
4	2285.2	1737

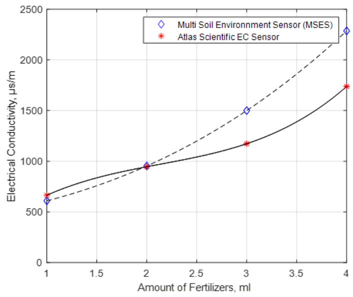

Figure 5: MSES vs Atlas Scientific EC Sensor in Fertilizer A

2. FERTILIZER B

FERTILIZER B		
AMOUNT OF FERTILIZER A (ML)	MULTI SOIL ENVIRONMENT SENSOR (MSES), (µs/m)	ATLAS SCIENTIFIC EC SENSOR (µS/m)
1	807.8	835.63
2	960.8	957.58
3	1267.1	1151.8
4	2294.2	1819.6

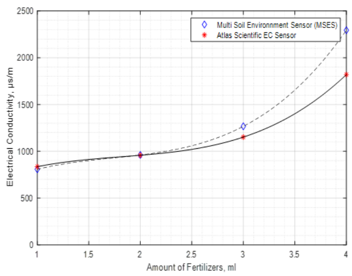

Figure 6: MSES vs Atlas Scientific EC Sensor in Fertilizer B

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3. FERTILIZER A + B

FERTILIZER A + B		
AMOUNT OF FERTILIZER A (ML)	MULTI SOIL ENVIRONMENT SENSOR (MSES), (µs/m)	ATLAS SCIENTIFIC EC SENSOR (µS/m)
1	711.4	751.28
2	943.1	955.5
3	1221.7	1134.3
4	2446.1	1829.1

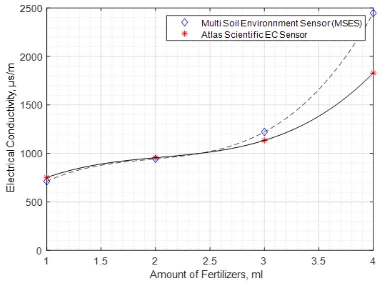

Figure 7: MSES vs Atlas Scientific EC Sensor in Fertilizer A+B

When the amount of fertilizer in a solution increase, the electrical conductivity of the solution also increases. Other than to examine the electrical conductivity of different amounts of fertilizer, the accuracy of these two sensors was also compared. Based on the result, there is only a slight difference in the value of electrical conductivity between these two sensors. Hence, in order to save their budget, farmers can use MSE sensor to observe their soil fertility. MSES using quick and simple installation. MSES is portable, easy to used, just stick it into the soil and pair it the users phone.

4.3 Analysis 2 – Relationship Between Electrical Conductivity (EC) Value With Plants Leaf Growth

The aim for this experiment is to study the relationship between Electrical Conductivity (EC) value with plants leaf growth in different volume of fertilizer.

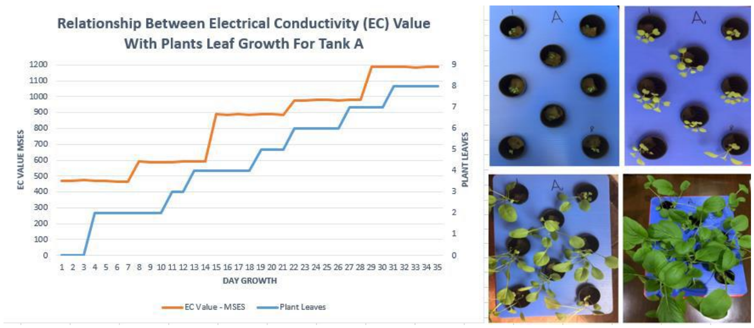

Figure 8: EC Value and Plant Leaves Relationship for Tank A

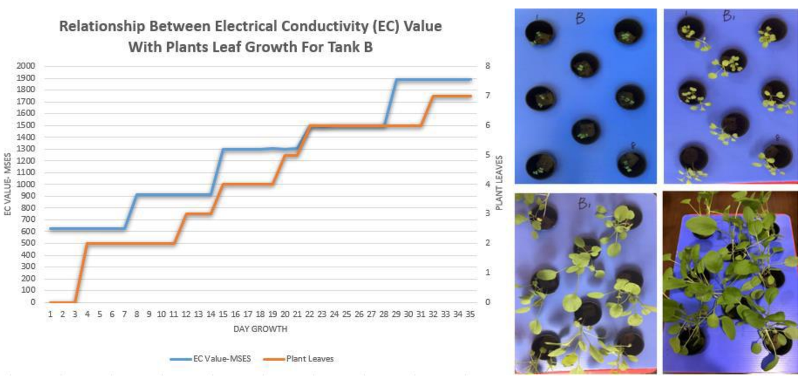

Figure 9: EC Value and Plant Leaves Relationship for Tank B

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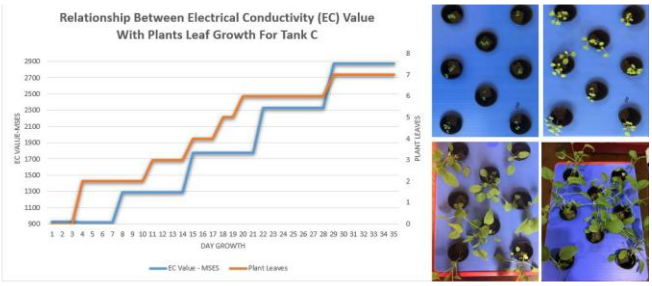

Figure 10: EC Value and Plant Leaves Relationship for Tank C

As we can obtained from the graph, as the EC value increased, the plants growth will increase. The plants leaf will grow accordingly to the volume of EC value. Excessively high EC levels lead to stunted growth, leaf damage, and eventually plant death. If farmers apply too much fertilizer, then it cannot be taken up by plants fast enough, or retained by the soil, so there is a danger that it will be washed through into the drainage water and get into the rivers. If this happens then algal growth (and the growth of other water plants) in rivers can be stimulated and the result is eutrophication. This is another reason for not applying too much nitrate.

5. CONCLUSIONS

As the conclusion, all of the objectives of this project were achieved. The overall of this thesis describe the overview of design and analyse the Proximal Soil Sensing System Based on Electro-Chemical Ion Selective Electrode (ISE) Sensor for Nitrate and Potassium Fertility Assessment. The ISE sensor used to identify the soil fertility by measure the macronutrient ion contain in fertilizer. By using the proximal soil sensing system based on electro-chemical ion selective electrode (ISE) sensor for nitrate and potassium soil assessment together with Internet of Things or known as IoT in smart farming, all the data can be access and analyse to ensure the plants will get the maximum advantages from this study. The system able to help the farmer to manage their farm and the use of fertilizer was controlled. the MSES measure is in acceptance range to be used in real time monitoring system since it has 97% accuracy, cheaper in price, portable, and easy to use. For the future improvements, an automatic mixer fertilizer can be developed to increase the productivity of the agricultural activities. Control function such as automatic watering system also can be added to help the farmers.

Acknowledgment
Many thanks to all who have contributed directly and indirectly to this project and make it successful research.

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