# DESIGN AND DEVELOPMENT OF ON-THE GO SOIL FERTILITY MEASUREMENT BY USING ATV

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**DESIGN AND DEVELOPMENT OF ON-THE GO SOIL FERTILITY MEASUREMENT BY USING ATV**

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## DECLARATION

I declare that this thesis entitled "DESIGN AND DEVELOPMENT OF ON-THE GO SOIL FERTILITY MEASUREMENT BY USING ATV " is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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## APPROVAL

I hereby declare that I have checked this report entitled "DESIGN AND DEVELOPMENT OF ON-THE GO SOIL FERTILITY MEASUREMENT BY USING ATV" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

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# DEDICATIONS

To my beloved mother and father

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# ABSTRACT

The agriculture is the main source of foods and it plays an important role on economic growth. The chemical fertilizer that does not absorbed by the plant become the chemical waste in the soil and flow to the underground water and cause water pollution, soil pollution and acidic rain. The waste of fertilizer in agriculture activities should be minimize to prevent the degradation of the environment. Hence, this project describes the design and development of on-the go and real time measurement for soil fertility by using All Terrain Vehicle (ATV). Conventionally, the soil sample need to be sent to laboratory for lab analysis and take about 2-3 months. Therefore, the device that can measure and analyses the soil fertility on-the go to determine the fertilizer recommendation. The Ion selective electrode (ISE) for Nitrate (NO3-) and Potassium (K) micronutrient with the GPS device will be installed on the ATV mobile platform and can be easily changeable. The main objective of this paper is to design and develop a soil proximal sensory based soil collecting system with GPS that able to analyses the concentration of the micronutrient contain in the soil and form a fertility mapping. The percentage of error for the sensor will be evaluated before the starting the soil sampling. The soil sample will be done in palm oil field, the depth of the soil collected in 20 cm and 42 samples collected in distance of 10 m between each sample in area of 4 acres. The correlation of the proximal soil sensor and the lab analysis will be done. In the end, the soil mapping and the recommendation map to the farmer based on the result will be developed.

# *ABSTRAK*

Aktiviti pertanian memainkan peranan yang penting dalam pembekalan sumber makan dan pembanguan ekonomi negara. Dalam aktiviti pertanian, baja kimia yang tidak diserap oleh tumbuh-tumbuhan akan menyebabkan pencemaran terhadap alam sekitar. Oleh itu, pembaziran baja kimia haruslah dielakkan dalam aktiviti pertanian. Projek ini berobjektif untuk mereka dan membina sebuah sistem yang dapat mengukur and menganalisis kepekatan nutrien yang terkandung dalam tanah dari masa ke semasa menggunakan ATV. Biasanya, sampel tanah akan dihantar ke makmal kajian untuk membuat analisis nutrien. Tetapi proses in memakan masa sepanjang 2 hingga 3 bulan. Oleh itu, projek ini bertujuan untuk membina sistem yang dapat menganalisiskan nutrien tanah tanpa menggunakan masa yang panjang. Sensor yang dipakai adalah ISE nitrate dan ISE potassium, GPS teknologi juga digunakan untuk mencatat lokasi persampelan and mengeluarkan peta nutrien untuk membantu pertani untuk meningkatkan produktiviti pertanian. Sebelum memulakan persampelan tanah, kesalahan peratusan sensor yang dipakai akan diuji. Persampelan tanah akan dijalankan di ladang kelapa sawit yang sebesar 4 ekar. Sampel tanah akan dikorek dengan kedalaman 20 cm dan jarak antara sampel adalah sepanjang 10m, selepas itu, 42 sampel akan dikumpulkan. Sampel tanah akan dihanter ke makmal kajian untuk membuat penbandingan dengan dapatan kajian sensor. Akhirnya, peta pembajaran akan diwujudkan berdasarkan dapatan kajian.

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| | | |
|---|---|---|
| ATV | - | All Terrain Vehicle |
| ISE | - | Ion-Selective Electrode |
| GPS | - | Global Positioning System |
| IoT | - | Internet of Things |
| NPK | - | Nitrogen, Phosphorus, Potassium |
| VRF | - | Variable Rate Fertilizer |
| EC | - | Electrical Conductivity |

## LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Agriculture is the key that rise human civilization. The agriculture had begun since thousands year ago. The farmer plants the wild grains and domesticate the animal as the food resources. The survey of Food and Agriculture Organization mention that, agriculture is the main source of food and it affect the economy of a country [1]. The productivity of the agriculture should be increase for the evolving population [1]. The crop yield of the food can be improved by the help of the automatic system compare to the traditional method. The implement science and technology are required to increase the yield.

Nowadays, the world focus on the green revolution and sustainable agriculture. The word sustainability refers to the agricultural and industrial technologies that reduced and prevent the degradation of environment due to the economic activity. An idea of sustainability of soil (Hopkin 1996) was promoted by United State to stabilize the economic and environment [2]. The concentration of metal and pH in the soil was analysed to identifies the sustainability of the soil. The Asian Institute of Technology stated that the not replacing resources should be use in more productive way and prevent the degradation of environment bring the better future [4]. The use of fertilizer in agriculture also affect the ecosystem and environment of the Earth. The waste of fertilizer that does not absorbed by the plant will cause the soil pollution, water pollution and acidic rain.

Therefore, the precision farming was required in the sustainable agriculture. Smart farming also known as precision farming is a smart management to the farm. The precision farming focuses on the controllable factor and variability of the farming environment helped by the modern technology [3]. Precision agriculture was defined as the art and science of utilizing advanced technology for the efficiency of economic and minimize the environment pollution. The idea of the smart management is recognized the variability of the farm, recorded it, and managed the specific location by applying the specific amount of inputs. The GPS (Global Positioning System) and Geographic Information System (GIS) always take part in smart farming [3]. The device plays an important role on data record and collection.

## 1.2 Motivation

In 2020, the precision farming was mainly focus on the technological invention to allow for the site-specific farming. In Industry Revolution 3.0, the automated system had replaced the human energy in many industries. The traditional method agriculture had replaced by the automated machine. This help to increase the productivity and save the human energy. In Industry Revolution 4.0, the collection of the industry data was required to improve the system. The Internet of Things and Big-Data analysis are recent technologies from the last few years and being developed widely as the key of technologies [6]. The sensors are widely used as the input signal of the data such as, the environmental sensor, gas sensor, temperature sensor, humidity sensor and other. The Cloud Computing and Mobile Computing are mature technologies and applications exists in almost every field of smart agriculture [5].

The Internet of Things is a technology that collect the information to the Internet. The application is developed based on the IoT to enable the device monitoring and control [5]. The IoT is widely used in the smart agriculture. The sensor and monitoring system are used to identify the variability of the soil properties. The mobile computing plays an important role in the agriculture. The farmer able to refer to their product information and weather information though the mobile computer. The big data is a massive data collector, the data collected from sensor data, social networking data and business data. Big data used to supply chain management of agro-products, to minimize the production cost.



With the combination of GPS with the IoT system, the map that able to help the agriculture management can be created. The map such as fertilization mapping can be created by combining the data collected from the soil sensor and the GPS technology [9]. The fertilization mapping able to monitoring the nutrient required by different area of soil and minimize the waste of fertilizer. This can prevent the degradation of the environment because the chemical fertilizer that does no absorbed by the plant will become the chemical waste in the soil. The chemical waste will flow to the underground water with the rain. In 2011, the marine pollution occurred at the Gulf of Gabes at Tunisia and effect the marine productivity and ecosystem [8]. The result of water quality analyses shown there are high concentration of phosphoric acid in the water sample. The main cause of the pollution is the chemical flow from underground water to the ocean and pollute the ocean.

### 1.3 Problem Statement

The first problem statement of the study is the of soil fertility analyses. Normally, the way to analyses the soil samples' fertility take time about 2 to 3 months. The soil sample was collected manually and sent to the laboratory for the nutrient analyses. The time required for the analyses is too long since the soil variability will cause the result of the analyses become not accurate. To overcome this, the real time soil nutrient analyses is required. The real time soil nutrient analyses using soil sensor able to save the time and help the farmer to identify the amount of fertilizer required by the soil. The automated soil sample collector also important to save the time and energy during soil sample collection.

The second problem statement is the capability of the data collection. Farm management required big amount of data. Large amount of soil samples is needed to be collected from different area of the field to help the farmer in farm management. To overcome this, the combination of IoT and GPS technologies are required. The data collected by the soil sensor combine with the GPS to form a fertilization mapping to help the farmer control the use of fertilizer during agricultural activities.

## 1.4 Objective

1. Design an automated soil sampler collecting system that can be install on All Terrain Vehicle (ATV) with Ion-Selective Electrode Sensor (ISE) and GPS.
2. Develop a real time and on the go soil nutrient, Nitrate and Potassium analyses system with ISE sensor that able to analyses the nutrient contain in the soil.
3. Evaluate the performance of the developed system and validation of the ISE sensor with the GPS fertilization mapping by using linear regression method.

## 1.5 Scope

- Raspberry Pi used as the main controller and data logging system to setup the configuration of hardware and IoT platform.
- Nitrate and Potassium ISE sensors used to identify the soil nutrient concentration.
- Arduino UNO and Neo 6M GPS device used to collect the locational data.
- A monitoring system with user interface that real time monitoring the soil nutrient concentration, GPS data dan battery percentage of the sensor.
- The QGIS software used to develop the fertilization mapping.
- ATV will be used as the mobile platform for on the go and real time measurement.
- Automated hardware system with actuator used as the soil sample collector.
- The soil sampling will be done at the palm oil field.
- The proposed system is plug and play and easy to change.
- The soil sampling will be done at palm oil field UiTM, Jasin with area 4 acres.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

In order to minimize the waste of fertilizer, a proximal soil sensing device with GPS mapping function will be install to the mobile platform All-Terrain Vehicle (ATV) to analyses the real-time soil nutrient contain in the soil and form the soil nutrient mapping. The literature review covers a wide variety of theories, working principle of system and sensor, and previous research done. The themes included are precision agriculture, on-the-go sensing, soil nutrient, soil sampling and testing, proximal soil sensor, Internet of Things (IoT), controller and data analysis.

## 2.2 Precision Agriculture

The world population increasing day by day and predicted to reach 9 billion people at 2050. In order to feed this large population, the world food production should be increased by 70% to full fill the daily needs of the society [13]. Agriculture sector faced the challenge in increase the yield crop, because the productivity of the yield crop was depending on many variabilities, such as, climate, soil's condition, irrigation water quality and application rate. The precision farming able to solve the problem faced by the farmer. With the help of technology, farmers able to analyses the variabilities of the field and allow they to do some manual vary treatment to improve the yield crop.

The precision agriculture is focus on the environment friendly agriculture. The concept of the precision agriculture organizes the agriculture system that toward low input, high efficiency and sustainable agriculture. The use of technology device such as Global Positioning System (GPS), geographic information system (GIS), miniaturized computer components, automatic control, in-field and remote sensing, mobile computer, advanced information processing, mobile platform and telecommunication system bring a lot of benefit in the process to identify the variabilities of the field [10].

The variabilities of agriculture production can be categorized into six group which are, yield variability, field variability, soil variability, crop variability, variability in anomalous factors and management variability. The soil variability and management variability play important roles in order to control the use of fertilizer during agriculture activities. Soil variability related to soil fertility such as Nitrate (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Carbon (C), Iron (Fe), Manganese (Mn), Zinc (Zn), and Copper (Cu). Soil fertility provide nutrient that help the plants grown. Soil physical properties-texture such as density, mechanical strength, moisture content and electric conductivity. Soil chemical properties such as pH, organic matter, salinity and CEC. Soil plant available water holding capacity and hydraulic conductivity and soil depth. Most of the variability are treated as independent variables. The most extensively studied independent variable is soil fertility level. In fact, the variable-rate technology (VRT) for chemical applications have been developed on fertilizer application [15].

The managing of the soil variability can be achieved by two approaches, which are map and sensory based. The information of soil variabilities can be analyses from soil samples by using the proximal soil sensor and the map used to control the variable -rate applicator. Since the nutrient required by the plants are different and the soil variabilities change from time to time, the farmer will usually do the grid sampling every 2 to 3 months [21]. In previous research, there are many mobile platforms used in agriculture activities to saves the man power. The traditional mobile platform that commonly used in the agriculture activities is tractor. Tractor is suitable in agricultural sector; tractor performs a wide range of operation such as farming jobs and gardening tasks. Tractor also able to handle a heavy load. However, the tractor is unable to operate in small area due to it large operating surface area [13]. In 2019, the drone or Unmanned Aerial Vehicle (UAV) was applied in the agricultural sector [14]. The UAV with autopilot and GPS coordinate's function bring a lot of benefit to the agriculture activities. UAV offer less stressful environment, safer environment and able to operate in long period. AUV system is a cheap and effective crop monitoring system. The infrared sensor of the drone used to detect the crop health. The AUV system also able to do the fertilization and insecticides tasks [18]. However, the AUV system having the difficulty on soil sample collecting, the soil sample collection needs to be done with depth 20 cm and larger drone are required to install the soil sample collector. In this case, the All-Terrain Vehicle (ATV) was selected as the mobile platform for this research. The ATV is stable, having small operation surface area compare to tractor and it able to travel in many environments such as muddy and sandy field. The changeable soil sample collector developed will be install at the back of the ATV.

## 2.3 On-the-go Sensing

The specifications of the proximal soil sensing system are analysis time, measurement precision and the cost effectiveness. For the on-the-go sensing, the measuring process undergoes during travelling process. For the on-the-go sensing in the agricultural sector, the sample collecting and measurement needs to satisfy the variability of the field and provide a fine management solution to improve the yield crop [20].

## 2.4 Soil Nutrient

### 2.4.1 Micronutrient NPK

Soil is the foundation of life in ecosystem, soil is the source of nutrient that help the growth of the plant. There are three main nutrient which are nitrogen, N, Phosphorus, P and Potassium, K that play important role for the growth of the plant [11]. Nitrogen is the main nutrient required by the plant, it can be found in all plant cells, plant proteins and hormones and in chlorophyll. Nitrogen able to help the growth of leaf of the plant. Potassium able to increases the vigor and disease resistance of the plant. It also helps to form and move the starches, sugars and oils in the plants to improve the quality of the flower and fruits. Phosphorus helps to transfer the energy from the sunlight to all part of the plant and stimulates the growth of root [9]. The content of the soil nutrient can be increased by adding the fertilizer. However, plant will only absorb the amount of fertilizer that required for the growth the extra fertilizer will become a chemical waste in the soil. Figure 2-1 shown the plant and the main nutrient required for the growth.

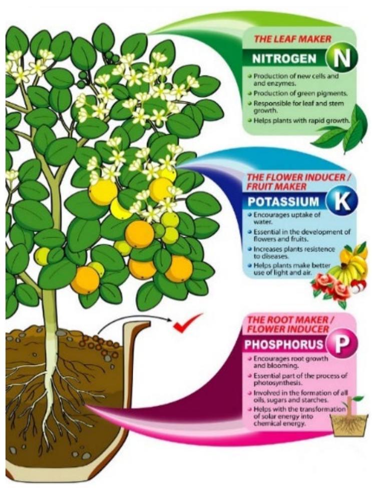


Figure 2-1: The main soil nutrient required by the plant.

In soil study, the researcher will analyze the amount of fertilizer required to meet the crop's demand depending on the concentration level of the micronutrient ion contain in the soil. Concentration of nitrate ion contain in the soil is the way to measure the nitrogen in the soil that can be absorbed by the plants. It is measured in unit of nitrogen per kilogram (mg/kg) or nitrogen per liter (mg/L), which similar to parts per million (ppm). [30] The concentration level of nitrate contain in the soil should not lower than 10 mg/L and should not exceed 50 to 60 mg/L to keep the crop's health. Figure 2-2 shown the guide to interpretation of nitrate-nitrogen values for soils. [30]

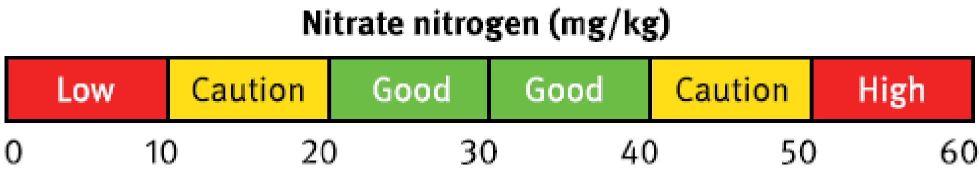


Figure 2-2: Guide to interpretation of nitrate-nitrogen values for soils.

Plant required higher concentration level of potassium nutrient compare to the nitrate to help the growth of the fruit and flower. [34] The amount of concentration contain in the soil can be measure by using ion specific electrode method to analyses the concentration of the potassium ion in unit of mg/L or ppm. [35]

### 2.4.2 Soil pH

The soil's pH also plays an important role on the plant growth. The soil pH may affect the bacteria in the soil, the most suitable pH for the bacteria to releases the nitrogen nutrient is between 5.5. to 7.0. When the soil pH is lower than 5.0, the aluminum ion will be released and cause the aluminum toxicity. This may harm the growth of the plant. In previous research, the measurement of level of the soil pH is important for the soil science, including the availability of the plant nutrients and efficacy of the herbicides. The pH level of the soil can be measure by using the electrochemical sensors such as pH sensor or ISE sensor. The inferred analyses method also can be used to analyses the pH level of the soil and it is more accurate compare to electrochemical sensor [21].

## 2.5 Soil Sampling and Soil Testing

Soil sampling and soil testing play important role in agricultural sector. This is because the soil properties vary in space and time. The proximal soil sensing is an easy and cost-effective method to do the soil properties survey. By combining the result from the proximal soil sensing and GPS technology, the digital soil mapping can be created. The soil mapping able to help the farmer to manage the variabilities of the field. A previous research that related to the soil testing has been done at the southern slopes of Mt Kenya in Embu Country in Eastern Kenya. The research's objective is to identify the relationship between the soil properties and the yield crop. The soil properties analyse method is portable X-ray fluorescence (PXRF) sensor, a handheld optical sensor based on two specific wavelengths, a mobile phone application to determine the soil color by photography and an electromagnetic induction (EMI) sensor [19].

The EMI sensor used to measure the electrical conductivity (EC) of the soil, the EMI sensor was held 0.15 meter above the ground and it able to measure the depth of 0.5 to 1.0 meter. The infrared sensor as the predictor variables in the predictive modeling of different soil properties by measuring the electromagnetic spectrum of the soil samples. The PXRF sensor is a capable of detecting abundancies of a range of elements, from magnesium and heavier [19]. Figure 2-3 shown the proximal sensors tested.


Figure 2-3: The proximal sensor tested: (a) electromagnetic induction sensor, (b) optical sensor, (c) portable X-ray fluorescence (PXRF), (d) soil color application

The soil sample has been collected from 4 different location which are Irangi, Kathande, Embu University College (EUC), and Rwika and the coordinate of the sampling location was recorded by using GPS. To ensure the accuracy of the measurement, the plant litter layer (10-20 mm) was cleaned and the soil was slightly