CHAPTER 1

INTRODUCTION

1.1 Background

Soil plays an important role in all plant growth processes. Soil can provide water and various macro and micronutrients important for plants. Soil can perform its metabolism with the availability of nutrients. Three macronutrients play a role in plant development and are required in large quantities [1][2]. Nitrogen is one of the important nutrients contained in the soil. The availability of nitrogen can boost the growth and development of leaves, branches, and fruit production [2].

Properly managing nitrogen fertilizer is important to optimize crop yields and achieve the desired quality. Farmers generally apply fertilizer doses based on soil testing before the planting process is carried out [3]. Three factors can cause the loss of nitrogen elements from the soil, such as evaporation, drainage water leaching, and plant absorption [4]. Nitrogen testing in soil is usually obtained from laboratory tests. When the nitrogen element of the soil is not sufficient to carry out the planting process, nitrogen fertilizer will be given according to the amount needed. Fertilization is applied to refill the nitrogen in the soil.

The nitrogen content of soil can be determined using two methods, which are the conventional and non-conventional methods. Conventional methods are obtained by taking soil samples and directly brought to the laboratory to be tested for content. This method will use a large cost and a long time to get the results [5]. Non-conventional methods are divided into two, which are using contact sensors and non-contact sensors. In the contact sensor, many use NPK sensors to measure the NPK content of the soil which will be connected to the IoT platform so it can be monitored remotely [6]. NPK sensors can determine the nutrients present in the soil instantly. However, NPK sensors have a weakness in sensor effectiveness that can be affected by moisture content and other soil conditions, potentially affecting the reliability of nutrient measurements. Contact non-conventional measurement methods will need a lot of time because it must be plugged in directly into the soil [6] [7]. Nutrient measurement in soil using non-contact sensors can be implemented using remote sensing techniques. In a wide area, soil nutrient detection using remote sensing techniques is fast and efficient. These remote sensing methods include hyperspectral cameras [8] [9] [10], fiber optic sensors [11] [12], and Ground Penetrating Radar (GPR) [13].

In previous research [8][9][10], using non-contact sensors using hyperspectral cameras can take pictures with a more flexible viewing angle and be capable of reaching areas that are difficult to access manually. The use of expensive hyperspectral cameras will generate high costs. Based on research [8], the method used in data processing is to use feature selection methods such as Competitive Adaptive Reweighted Sampling algorithm (CARS) and Successive Projections Algorithm (SPA). These methods require proper parameter selection to avoid overfitting. When the parameter selection is not correct, the decision-making from hyperspectral camera results will result in inaccurate data. Research [9] used the Genetic Algorithm Back Propagation Neural Network (GA-BPNN) method in predicting soil nutrient content using hyperspectral data. This research can map soil nutrient content widely. However, this method also requires accurate and relevant spectral data to predict soil nutrient content. In research [11] [12] have in similarity that is using fiber optic in detecting nutrient content. The difference between these two research is that [11] detects NPK content in soil solution using fiber optic sensors. This sensor uses optical fiber as a light transmitter and receiver and measures changes in light intensity that occur after passing through the soil solution. Research [12] uses an optical transducer that can be used to detect and measure the content of NPK elements in soil. This optical transducer uses a light transmission system and a light detection system consisting of an LED with a wavelength that matches the absorbing wavelength by NPK nutrients in the soil. Research [11] [12] has been dependent on a stable and regular light source to provide consistent measurement results.

The measurement of nutrient content using a radar system is one of the best methods to use. If the distance can be adjusted, then this system has a wide area. The radar system that is widely used to measure the content of soil is Ground Penetrating Radar (GPR). In previous research [13] used GPR to see the correlation between GPR response and agrotechnical properties of several soil types. This research has not tried to detect nutrients in the soil. Therefore, this can be a reference for the proposed thesis research. This research shows that the response of GPR can capture changes in soil properties. Ground penetrating radar (GPR) is mostly developed because it is a measurement technique that is not damaging to the soil structure because it uses electromagnetic waves to find targets buried in the ground, so it does not require excavation of the soil [14].

Research [15] using SFCW radar in detecting soil water content has been successfully carried out. The theoretical approach to estimating soil water content has the Topp Model [16] which proves the relationship between soil permittivity and soil moisture values in the formula. SFCW radar works by transmitting electromagnetic signals in the form of pulses that are transmitted continuously in stages with a specified frequency range. SFCW radar can determine the distance of a target from the phase shift of the signal reflected by the target. SFCW radars are capable of producing a wide bandwidth [17]. On a wide plantation area, the use of SFCW radar can be an efficient method because it has a wide area, and only needs a few human resources in detecting nitrogen elements.

The proposed research focuses on detecting soil nutrient content using SFCW radar by analyzing the response of electromagnetic waves. In this research, a laboratory experiment was conducted to see the reflection coefficient produced by the radar. The reflection coefficient generated from the radar is the response of all elements contained in the soil. Every element contained in the soil has a different electromagnetic response. The response of electromagnetic waves depends on the electrical properties of each element. To identify the nitrogen element from other elements, the addition of urea fertilizer is required. The SFCW radar will obtain a peak-to-peak value that is used as a reference to determine the trend curve of nitrogen content. Based on the trend curve, the inference method of the nitrogen element contained in the soil will be found. The inference method in this research can use an interpolated lookup table. Based on the literature study that has been conducted, nitrogen detection using SFCW radar has the potential to be carried out using the method proposed in this research.

1.2 Problem Formulation

Soil is composed of many nutrients and water contents. Nutrient manage the soil is important in the process of plant growth. Nitrogen elements in the soil function to boost the growth and development of leaves and increase the production of plants. In general, plantation and agricultural areas have a wide area of soil. Knowing the level of nitrogen in the soil can help farmers manage and improve crop yields. Radar systems that have a wide area can help farmers find out the availability of nitrogen elements in the soil. Therefore, the problem formulation in this study is as follows:

1. More detailed knowledge is needed about the effect of the reflection coefficient on soil nitrogen using the SFCW radar system.
2. More detailed knowledge is needed about the inference method for the correlation between nitrogen elements to the reflection coefficient of the SFCW radar system.

1.3 Objective

The purpose of this research is to detect soil nitrogen content based on electromagnetic wave response using SFCW radar. This detection is used to estimate the availability of nitrogen elements in the soil to facilitate the fertilization process. The detailed research objectives are as follows

1. Determine the effect of the reflection coefficient on soil nitrogen content using the SFCW radar system.
2. Obtain an inference method for the correlation between nitrogen elements and the reflection coefficient of the SFCW radar system.

1.4 Scope of Work

The limitation of the problem discussed in this research is focused on the reflection coefficient obtained from the soil using SFCW radar. The reflection coefficient obtained can be used to see the relationship between the electromagnetic wave response and the soil nitrogen content. The electromagnetic wave response obtained from the radar is the peak-to-peak value. The SFCW radar used works in the frequency range of 50Khz - 6Ghz. The case study was conducted within the scope of a laboratory experiment. Data collection was carried out at the same place with different nitrogen values. The difference in nitrogen value was obtained by adding urea fertilizer to the soil.

The radar distance to the soil box is 40cm with soil box dimensions of 50cm x 38cm x 15cm.

1.5 Hypothesis

Based on literature studies, electromagnetic waves make it possible to reduce costs and speed up the collection of nitrogen content data. The elements contained in the soil have different electromagnetic responses. The response of electromagnetic waves depends on the electrical properties of each element. Knowing the effect of the reflection coefficient on soil nitrogen elements using the SFCW radar system and obtaining an inference method that connects the correlation between nitrogen elements and the reflection coefficient of the SFCW radar system can help in detecting the availability of nitrogen elements in the soil. To identify the nitrogen element from other elements, the addition of urea fertilizer is required. The SFCW radar will obtain a peak-to-peak value which is used as a reference to determine the trend curve of nitrogen content. The peak-to-peak value can also be used to see the relationship between the electromagnetic wave response and the nitrogen element in the soil. Therefore, the hypothesis in this research is that the detection of nitrogen elements using electromagnetic waves can be a non-contact sensor method that is more efficient than contact methods or conventional methods such as laboratory soil tests.

1.6 Research Methodology

To complete this research, steps are required to be carried out. Overall, the steps that will be taken during the research can be seen in **Figure 1.1.**

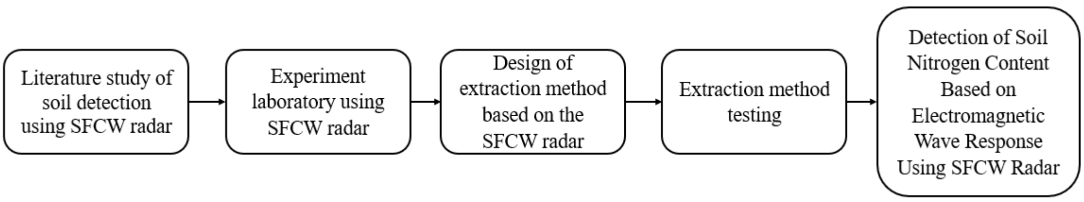

Figure 1.1 Research Steps

1. The first stage is a literature study to formulate the basic concept of soil nutrient detection using SFCW radar. This activity aims to understand the working principle of the SFCW radar that will be used.

2. The second stage is an experiment using SFCW radar. This activity includes conducting experiments in the laboratory under controlled conditions. This stage also includes adding fertilizer to obtain different nutrient values.
3. The third stage is the design of the inference method using SFCW radar. The activities carried out are the design of inference methods such as determining the curve fitting and seeing the relationship between the response of electromagnetic waves and nitrogen elements in the soil.
4. The fourth stage is testing the inference method. This stage includes collecting data directly from the soil using SFCW radar, which will then be processed to produce graphs using MATLAB software. The results of this experiment will produce an equation to estimate the soil nitrogen content.

1.7 Research Method

The research method used in making this thesis is as follows:

1. Literature study

   The purpose of this step is to know the basic concept of the inference method to determine the relationship between the level of soil nitrogen content and the response electromagnetic waves as well as the SFCW radar system that can detect soil nitrogen content.
2. System design

   The purpose of this step is to design the SFCW radar system to detect soil nitrogen content and achieve the expected results. The design of this system will start by collecting data directly from the invasive sensors and radar SFCW.
3. Experiment Laboratory

   The experiment process is conducted in a laboratory setup. The soil to be detected will be conditioned to have different nitrogen element values. The soil to be detected was taken from one place and will be conditioned to have different nitrogen element values. Conditioning is obtained by randomly adding urea fertilizer.

4. Analysis

   The data obtained will be processed and analyzed based on literature studies. The results of the experiments that have been carried out can be analyzed based on the peak-to-peak values obtained. This value is also compared with the invasive sensor so that conclusions can be drawn from all experiments.

5. Preparation of report

   Preparing the report is the final stage. The entire process will be analyzed and concluded in the form of a report. The report will be prepared in thesis report format.