# Design of Simple Modified Werner Array Electrodes for Soil Nutrient Sensor of Palm Oil Plantation

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**Abstract.** Plants need nutrients that can be derived from the soil and from outside in the form of fertilizer. The amount of fertilizer used on certain conditions varies depending on the type of soil, crops and plantations. The composition and quality of the soil varied and plays role in the fertility of crops and required the use of sensors that can measure soil nutrients to determine the specific value of the optimal fertilizer, especially for oil palm plantations to make efficiency of fertilizer and costs savings. In this research, a nutrient sensor works based on the measurement of impedance changes due to the ionic nature of the land affected by dissolved fertilizer in the soil has been designed. The sensor works at a given excitation frequency from 50 kHz up to 10 MHz of 10mV amplitude with three levels of concentration of urea fertilizer, KCL and TSP. The characterization results showed the phase shift and amplitude changes relevant to fertilizer concentration.

## Introduction

Indonesia is now one of the largest producer and exporter of palm oil. According of Ministry of Agriculture (Ministry of Agriculture), the palm oil plantations in Riau in the current year 2014 has around about 2.1 million hectares. However, this data is in stark contrasting to the way oil palm cultivation by the farmers self. of several factors that influence the success of an oil palm cultivation, knowledge of soil nutrients carried through fertilization is the lowest level of knowledge independent smallholders. Fertilization aims to maintain a balance of nutrients, if one needs nutrients in the soil under conditions of minimal or so plants will respond through the disruption of the growth of plant morphology.

In this research, a multi-sensor system that measures simultaneously simple some variation of soil parameters such as soil moisture, salinity, temperature and pH based on the change in the real value of the electrical conductivity factor (Electrical Conductivity, EC) is presented. The electrical conductivity is an indirect measurement that relates very closely with some soil physical and chemical properties in order to obtain information nutrient density of oil palm plantation land that allows farmers to manage the plantation to the efficiency of fertilization.

## Soil Physical Characteristics

Measurement of soil nutrients is a management tool that can accurately determine the availability status of soil macro nutrients. There are 17 essential nutrients that plants need and divided into macro and micro elements. The proportion of the extent of the nutrients absorbed by plants depends on the type of plant. Based on the level of need for oil palm plants, nutrients are classified as macro elements are N, P, K, Mg, while the micro elements are: B, Cu, Zn, Fe. Basically fertilizer application aims to replace the deficient element missing from the soil due to leached and transported plants. Therefore, the amount of fertilizer application on oil palm land should be based on soil conditions the plant needs and the required dose of fertilizer soil nutrient will be covered by the fertilizer.. The lower the quality of the soil (marginal soils), the dose of fertilizer tends to rise especially sloping region. The results of research conducted in the village of Giri Sako District of Logas Land Army is known that the slope of the land is closely connected with the efficiency of fertilization. the steep slope steepness (>20°) then decreased fertilization efficiency

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reached 78.4% where the fertilizer that will carry over (runoff) to a lower place like a river [1]. Generally, runoff and erosion processes remove topsoil from the top to the bottom of the summit that will change the spatial distribution of land and water that will change the nutrient content of the affected area [2]. Soil moisture is a key factor in agriculture, to measure soil moisture, there are three basic methods, namely gravimetric techniques, nuclear and electromagnetic. In the electromagnetic technique, method of time domain reflectometry (TDR) is the most common method used [3, 4]. The growing need for high-quality, low-cost oscillator has led to a tendency to use the technique to measure soil moisture capacitance [5]. The probe capacitance is relatively inexpensive and easy to operate. Some researchers have calibrate the capacitive sensor for certain soil types such as [6]. Lazuardi [7] have developed soil moisture sensor based on the principle of the complex impedance measurements with the instrument can be described in this component as below. Measurement of soil nutrients is influenced not only by moisture but also chemicals dissolved in the soil. For that we need a system of detection, low-cost soil nutrient that can provide information of nutrients in the soil that can be operated in a simple to oil palm farmers.

## Experiment

The sensor was designed based on modified Wenner-Array Structure 4 electrodes as shown in Fig. 1 below.

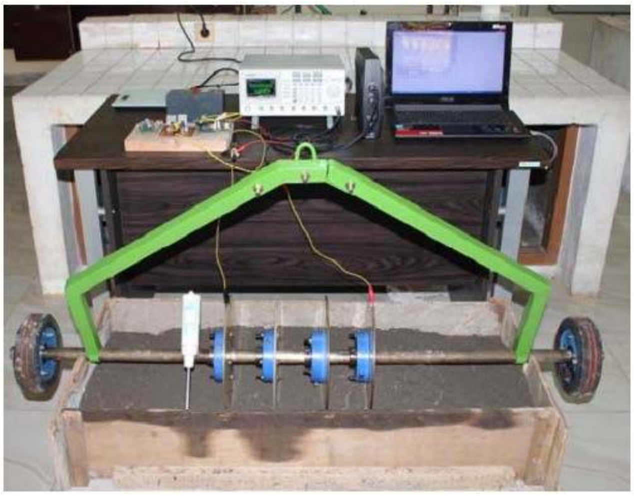

Fig. 1. Experimental set up for soil nutrition detection

The sensor is then formed as a disk to make easier penetrate into the ground, the electrode will be buried in soil samples of defined nutrient levels by giving a solution of fertilizer Urea, KCL and TSP. Due to changes in the bulk of dissolved salts in the soil, the permittivity of soil is changes which are an indicator of soil properties.

During the experiment, the sensor is excited using 10 mV AC current at various frequencies from 50 KHz up to 10 MHz to the electrodes outer electrodes of sensor while the voltage measured at inner electrodes and acquired using an oscilloscope. Current source frequency feed by the function generator unit and controlled by a PC which also simultaneously acquire the voltage data obtained from the oscilloscope. The data is then processed to determine the parameters of soil nutrients are extracted from the value of the electrical conductivity.

## Results and Discussion

Measurement and characterization of sensor respond to soil nutrition is done using fertilizer Urea, KCl, and TSP. Tests conducted with various concentrations of 5 grams of fertilizer, whereby the amplitude of AC signal is remain constant at 10 mV with a range from 1 MHz to 10 MHz on soil samples with defined fertilizer dose.

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Testing is done by varying Urea contained in the soil. Variations were made are 5, 10, 15, and 20 grams in 10 kg of soil, respectively. The measurement results are shown in the Fig. 2 below;

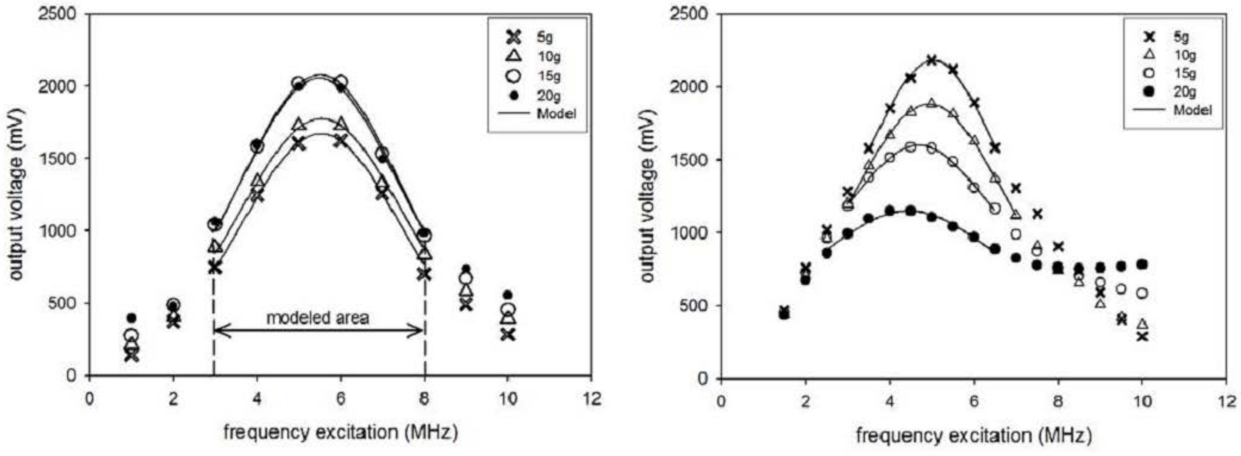


Fig. 2. Fertilizer urea (a) and (b) KCl responds at various frequencies

From the graphic above shows the output voltage peak occurs at a frequency of about 5MHz more. But if observed more closely and approximated by a quadratic equation would seem that there is a quite small shift of the peak. Experiment in the same way also performed on soil mixed KCl. The results of the output voltage in response to KCl are shown in the figure 2 above. In the same way to see the peak output voltage as the urea process is carried out. From the results obtained it turns peak shifted output voltage is greater than the urea.

Characterization of TSP fertilizer is the last test for nutrients tested. The process is done the same way as the previous two processes are performed on urea and KCl. The frequency variation for each mass of fertilizer gave the same response with urea and KCl. Measurement results shown in the following Fig. 3.

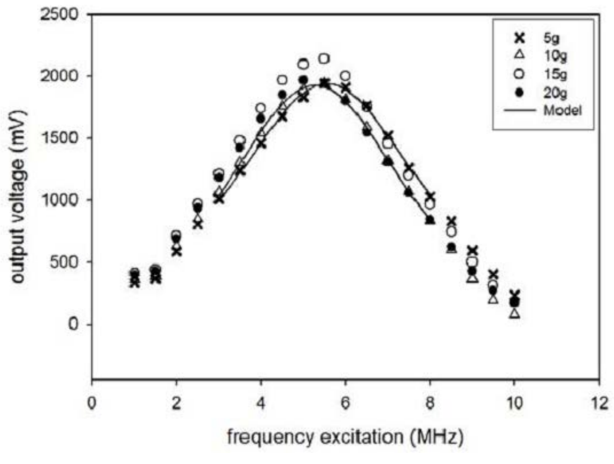


Fig. 3. Characterization of TSP at different frequencies

From the Fig. 3 is depicted that also the peak shift curves for different TSP mass. After the curves are approximated by a quadratic equation it can be seen breaking point. From the peak there is a tendency fourth peak frequency decreases with increasing mass of the curve given TSP. Shifting of excitation frequencies and the maximum amplitude can be determined by modeling the curve at the top row to the mass of Urea 5, 10, 15, and 20 grams is as follows:

$$U_0 = y_0 + a \cdot \exp\left[-0{,}5\left(\frac{x - x_0}{b}\right)^2\right] \quad (1)$$

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where $y_0$, $a$, $b$ and $x_0$ are the parameters of the models depend on the fertilizer concentration.

Using curve fitting, the maximum amplitude at resonance frequencies for certain concentration can be simultaneous determined. Fig. 4 shows three different fertilizers at various concentrations and show a linear relationship to the frequencies see Table 1.

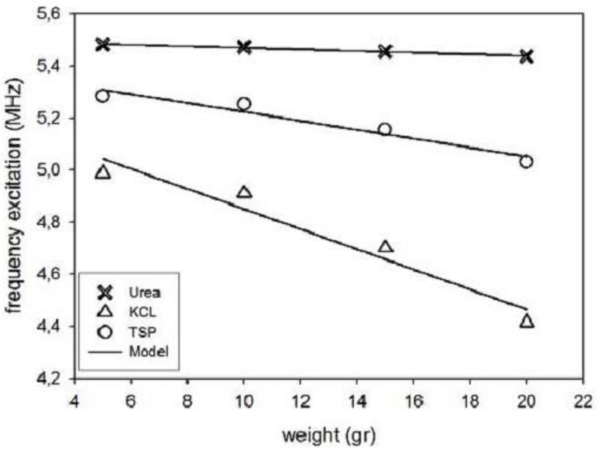


Fig. 4. Frequency shifting due to fertilizer concentration

$$f = y_0 + a \cdot m \qquad (2)$$

Table 1. Parameter curve fitting

| No | Fertilizer | Parameters | |
|---|---|---|---|
| | | $y_0$ | $a$ |
| 1 | Urea | 5.499 | $-3.06\times10^{-3}$ |
| 2 | KCl | 5.236 | - 0.0386 |
| 3 | TSP | 5.394 | -0.0171 |

From the Fig. 4 is shown that different fertilizer Urea, KCL and TSP response to the concentration and have the resonance frequency shifting 45.8 KHz, 578.8 KHz and 256.8 KHz respectively. Urea has the smallest frequency reduction, followed by the TSP, and then KCl. From these curves it appears that each fertilizer has its own characteristic curve. This characteristic curve can process by the method of Partial Least Square (PLS) in order to obtain a model for each nutrient.

## Summary


Sensor system for soil nutrients determination is presented and show results in line with expectations. After testing on samples defined, the results showed a response to changes in sample variation. The results of the measurement will be processed using specific algorithms to generate recommendations enable the measurement of the level of fertilization in the soil.


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## References


[1] G.M. Manurung, 2011. Budidaya Kelapa Sawit Di Lahan Marginal Dan Efisiensi Pemupukan (Marginal Gambut, Tanah Berlereng, Tanah yang dipengaruhi oleh Pasang Surutnya air), Pelatihan Teknik Pemupukan kelapa sawit. Kementerian Pertanian Republik, Bagansiapiapi.



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[2] S.K. Balasundram,, P.C. Robert, D.J. Mulla and D.L. Allan, 2006. Relationship between oil palm yield, and soil fertility as affected by topography in an Indonesian plantation. Commun. Soil Sci. Plant Anal., 37: 1321-1337. DOI: 10.1080/00103620600626817.
[3] C.M.K Gardner, D.A. Robinson, K. Blyth, and J.D. Cooper. 2000. Soil water content. p.1-64. In K.A. Smith, and C.E. Mutlins (ed.) Soil and environmental analysis: Physical methods. Marcel Dekker, New York.
[4] K. Noborio, 2001. Measurement of soil water content and electrical conductivity by time domain reflectometry: A review. Compute. Electron. Agric. 31:213-237.
[5] L.C. Paltineanu, and J.L. Starr. 1997. Real-time soil water dynamics using multisensor capacitance probes: Laboratory calibration. Soil Sc3. Soc. Am. J. 61:1576-1585.
[6] R.L Baumhardt, R.l. Lascano, and S.R. Evett. 2000. Soil material, temperature, and salinity effects on calibration of multisensory capacitance probes. Soil Sd. Soc. Am. J. 64:1940- 1446.
[7] Lazuardi and Rahmondia, 2012, Low Cost Soil Sensor Based on Impedance Spectroscopy for In-Situ Measurement, The 5th Asian Physics Symposium (APS 2012), 10-12 July, 2012, Bandung, Indonesia.

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