Electrical measurements sensor and its correlation with soil properties

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Abstract. *This work aims to study the precision agriculture, seeking low-cost alternatives. Due to major environmental impacts that mismanagement cause to the soil, the definition of production areas using tools such as soil electrical conductivity sensors help perform faster analysis of some soil properties and assist in the decision to be taken to correct the ground. For the readings of the electrical resistance of the soil, the sensor used was a modified Octopus Soil Humidity, and the readings were obtained using a source of variable electric voltage and a digital multimeter. From the voltage and electric current readings of soil samples has been calculated the value of electrical resistance and correlations were also performed with the chemical properties of soil samples. The results showed that the highest linear correlation values with the electrical resistance of the soil were the soil properties calcium, magnesium and sum of bases.*

Keywords: *Precision Agriculture; Electrical Conductivity; Electrical Resistivity.*

1. INTRODUCTION

The spatial variability of soil attributes, productivity, fertility, electrical conductivity and other factors can be measured and recorded. The knowledge of these data can be used to make decisions in the chemical applications at each point of the cultivated area, and no longer by the simple average of the total area.

According to research by Grego et al. (2006), physical and chemical properties, soil factors, directly affect crop yields. Soil analysis is done by sampling, requiring high demand for labor, time and cost. Obtaining the electrical conductivity of the soil, through direct contact sensors, is an efficient and fast method. The mapping of soil electrical conductivity helps in the establishment of management areas (MOLIN et al., 2005). In the study by Barreto et al. (2012), it was verified that the salts present in the soil solution can be evaluated by the electrical conductivity of the soil.

The objective of this work was to obtain a low cost alternative for application in precision agriculture, studying the chemical properties of the soil with the use of a sensor in direct contact with the soil, which measures its electrical conductivity to correlate the results with the chemical properties of the soil analyzed in the laboratory.

2. THEORETICAL FRAMEWORK

The various systems for measuring soil characteristics are based on electrical circuits and used to determine the ability of certain means to conduct or accumulate the electric charge. If the soil is used as such medium, its physical and chemical characteristics can affect the behavior of the circuit and also the electrical parameters measured (ADAMCHUCK, 2004). The measurement of soil electrical conductivity has been widely used, making it an important tool for the preliminary evaluation of the area to be studied, which facilitates the definition of the management zones, according to Rabello et al. (2014).

Oliveira and Benites (2011) carried out a research on the soil variability directed to the precision agriculture, aiming to characterize the spatial variability by quantitative techniques and, with this, to obtain information that would help in the decisions to have a productive system. In the study, it was emphasized that the electrical conductivity of the soil is an important tool in the interpretation of the spatial variation of the terrain and in the support to the soil sampling.

For Cruz et al. (2014), the knowledge of the levels of electrical conductivity of the soil, determined without limitation of sample density, allows to correlate with other parameters of the soil, where its spatial and temporal variation can be attributed to the variations of moisture, clay content, dissolved salts in soil, organic matter, among others.

The work of Monteiro Junior et. al. (2012) evaluated the use of the Arduino microcontroller in the reading of soil electrical conductivity sensors for application in precision agriculture. Also in the research by Damiati et al. (2014) the same microcontroller was used with the Octopus Soil Humidity sensor, modified to obtain readings of electrical resistance of the soil. In the works of Damiati et. al. (2014) and Monteiro Junior et. al. (2012), the voltage of 5 volts was used on the sensor, because they used the working voltage of the Arduino, free electronic hardware prototyping platform. The present research work, using the same modified soil humidity sensor and a variable source of electrical voltage, tested the best reading response for different values of voltages applied to the soil electrical conductivity sensor.

3. MATERIAL AND METHODS

The Octopus Soil Humidity sensor used commercially for soil moisture measurements was modified electrically to meet the proposed methodology for the development of the work, in its standard form, this sensor uses the two probes to pass electrical current through the ground, and then , read the soil tension to obtain the moisture level. It is a simple, inexpensive and efficient sensor of the resistive type. In order for the sensor to be used to read the electrical resistance of the ground, an adaptation was necessary in the electric circuit of the same. The two rods have been connected directly to the sensor output, where each face of the sensor (front and back) represents a polarity (positive and negative) of the electrical circuit of the system.

The soil sample collection was carried out in a farm of Capão da Onça Farm, belonging to the State University of Ponta Grossa, in a no-tillage area with approximately three hectares, totaling 30 samples. In order to analyze the correlation between the electrical resistance readings obtained by the sensor and the chemical properties of the soil, the results of the soil samples analyzed in the FCA-UNESP soil physics laboratory were used. Another part of the samples was used to perform the tests with the sensor in the Electronic Laboratory of the State University of Ponta Grossa.

An electrical circuit was set up for the development of the experiment: a variable continuous voltage source to feed the modified sensor inserted in the soil samples and a digital ammeter to measure the electric current of the circuit. With the aid of the variable voltage source with built-in voltmeter, different voltage values were applied to this sensor, in order to obtain the readings of electric current according to Figure 01.

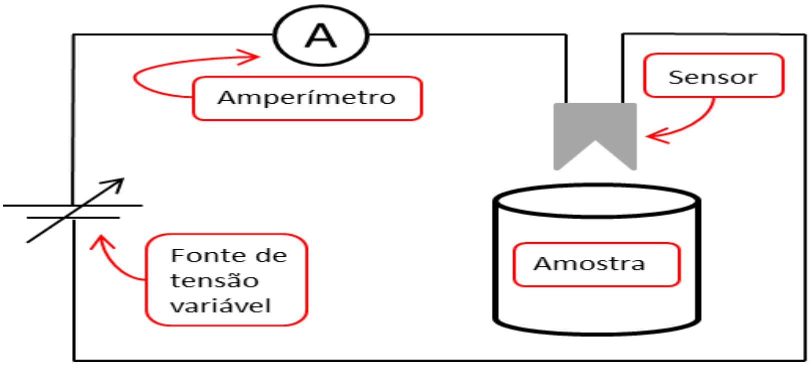

Figure 1. Electric circuit used in the experiment - Source: The authors, 2015.

Using the variable voltage source, voltages of 5, 10, 15, 20, 25 and 30 volts were applied to each of the 30 samples, varying the voltage applied to the sensor, to verify the behavior of the electric current. Previously, all samples were also humidified. After insertion of the sensor into the soil sample, the time of 2 minutes was standardized for the electrical circuit to be connected to each measurement of the electric current of the samples, at which time the readings became stable to be collected.

With the values of electric voltage applied and the electric current obtained by a digital multimeter in the ammeter function, Ohm's law was applied, dividing the voltage values by the current values to obtain the electrical resistance values of the soil samples. The chemical characteristics of the soil were: hydrogen (pH), organic matter (OM), phosphorus extracted from the resin (Presin), potential acidity (H + Al), potassium (K), calcium magnesium (Mg). And the parameters: base sum (SB), cation exchange capacity (CTC) and base saturation (V%). The pH and V% values are dimensionless numbers. The remaining of the units of measurement are density values, which measures the degree of mass concentration in a given volume.

4. RESULTSAND DISCUSSION

Given the values of soil properties and electrical resistance, a correlation can be drawn between the electric resistance variables with each soil property. The present study related some of the properties of the soil with the electrical resistance to obtain the degree of Pearson's linear correlation, according to Table 01.

Table 1. Pearson correlation index between electrical resistance and soil properties

	Soil Properties									
Applied voltage	**pH**	**MO**	**P_{resin}**	**H+Al**	**K**	**Ca**	**Mg**	**SB**	**CTC**	**V%**
5	-0,319	0,015	0,135	0,190	-0,297	-0,366	-0,393	-0,393	-0,097	-0,332
10	-0,378	-0,013	0,093	0,224	-0,351	-0,445	-0,470	-0,475	-0,125	-0,393
15	-0,420	0,008	0,109	0,275	-0,365	-0,493	-0,515	-0,521	-0,097	-0,442
20	-0,432	0,029	0,134	0,302	-0,353	-0,499	-0,520	-0,526	-0,064	-0,455
25	-0,453	0,041	0,149	0,326	-0,353	-0,520	-0,541	-0,545	-0,050	-0,478
30	-0,468	0,061	0,162	0,348	-0,357	-0,527	-0,548	-0,553	-0,026	-0,494

For a voltage of 5 volts applied in the sensor, Pearson's linear correlation coefficients between electrical resistance of the soil and the chemical properties and very low soil parameters, close to zero, are observed. This proximity of zero indicates a very weak linear dependence between the two analyzed variables.

The three highest correlation coefficients found were: calcium (Ca), magnesium (Mg) and sum of bases (SB). These were the parameters that obtained the best responses to the experiment: when the voltage increased in the sensor, the correlation coefficient increased proportionally. As observed in Table 01, all Pearson correlation coefficients are weak for a voltage equal to 5 volts, revealing little linear dependence. However, as the voltage applied to the electric conductivity sensor increases, the correlation coefficients also increased, increasing the sensitivity in the current reading and revealing greater dependence between electrical resistance and soil chemical parameters.

By applying 30 volts to the sensor, the maximum voltage used in the experiment, the correlation coefficients reached their highest values when the electrical resistance is compared with SB, Mg and Ca. There is a weak correlation between the electrical resistance and MO, Presin and CTC, even increasing the applied voltage. The task of reading the data can be automated, generating speed to the process of analysis and characterization. It should be considered that the results of the study are valid for the type of soil used, other types of soil may lead to different results.

5. CONCLUSION

According to the experiment, it was observed that the higher the voltage applied to the sensor, the more stable the current reading became, reducing the time to determine the current reading that the soil sample leads to and increasing the correlation coefficient between resistance and soil chemical properties. It is possible to obtain a higher correlation between the data obtained by increasing the voltage applied in the sensor to values greater than 30 volts. Another point to be considered was the use of Pearson's linear correlation coefficient. Different correlation values can be obtained if other regression methods are used. The present work opens doors for future experiments with different sensors and the improvement of the sensor used in this study.

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