Sensor of electrical measurements and its correlation with soil texture

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Abstract. *This work aims to study precision agriculture, looking for low-cost alternatives. Due to the great environmental impacts that improper handling causes to the soil, the definition of areas of production using tools such as electrical conductivity sensors of the soilhelps to perform a faster soil type analysis and assist in the decision to be taken for soil correction. For the determination of strength and electrical soil capacitance,it was used the Octopus Soil Humidity sensor modified with digital and analog multimeters. From the readings, correlations were made with soil attributes (sand, silt, clay). The results were satisfactory mainly with the use of the analog multimeter, which showed a strong correlation of the electric resistance reading with soil attributes, as sand and clay.*

Keywords: *Soil Attributes, Electrical Conductivity, Soil Correction.*

1. INTRODUCTION

The spatial variability of the soil attributes, productivity, fertility, electrical conductivity and other factors can be measured and recorded and the knowledge of these data can be used to make decisions in the chemical applications at each point of the cultivated area, and not more by the simple average of the total area.

For Grego et al. [1], the investigation of possible causes of spatial variability found in crop productivity results has been attributed to soil factors such as physical and chemical properties. However, these are obtained by sampling that, in the majority, require high demands for labor, time and cost. The electrical conductivity of the soil has called attention, mainly, because is obtained through efficient and fast methods as by the sensors of direct contact with the soil. Also in the research of Barreto et al. [2], it was verified that the salts present in the soil solution can be evaluated by the electrical conductivity of the soil. However, these are obtained by laboratory-analyzed samplings which, for the most part, require a high demand for labor, time and cost.

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 electric charge. If the soil is used as such medium, its physical and chemical characteristics may affect the behavior of the circuit and, thus, the electrical parameters measured ADAMCHUKA et al. [3]. The measurement of apparent electrical conductivity of the soil has been widely used and has become an important tool for the previous evaluation of the area to be studied, facilitating the definitions of the management zones according to RABELLO et al. [4]. Salton et al. [5] verified that the uses of soil electrical conductivity measurements may help to identify and delimit homogeneous areas of the soil with previous knowledge of the area's management history.

Oliveira and Benites [6] conducted a research on soil variability as an opportunity of precision agriculture, aiming to characterize the spatial variability by quantitative techniques and with that to obtain information that help in the decisions to have a productive system. In the study, they further emphasize 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 optimized schemes of soil sampling.

For Cruz et al. [7], the knowledge of the levels of electrical conductivity of the soil, determined without limitation of sample density, allows correlating 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 the soil, organic matter, among others. Rocha et al. [8] showed in their research the potential of using a portable electric conductivity meter of the soil as an auxiliary tool in soil characterization.

As the soil electrical measurement performed with sensors of direct contact with soil has been used as variables that correlate with soil characteristics, the objectives of the research were to electrically modify the Octopus Soil Humidity sensor used commercially for soil moisture measurements, to adapt it, to evaluate its performance and to verify the correlation between the resistance readings and the electric capacitance of the soil using the modified sensor with some soil physical attributes (sand, silt and clay).

2. MATERIAL AND METHODS

The Octopus Soil Humidity sensor used commercially for soil moisture measurements was electrically modified to meet the methodology proposed for the development of the work according to Figure 1.

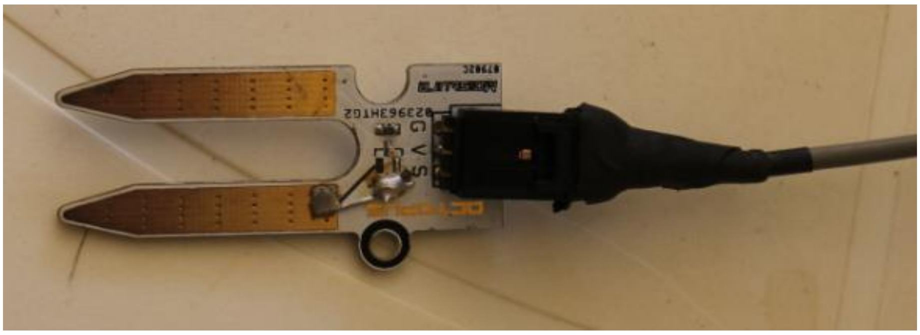

Figure 1- Octopus Humidity Sensor Modified. Source: The autors, 2015.

In its standard form, this sensor uses the two probes to pass electrical current through the soil and then read the soil voltage to obtain the humidity level. It is a simple, inexpensive and efficient sensor of the resistive type. In order for this sensor to be used to read the resistance and electric capacitance of the soil, an adaptation was necessary in the electric circuit of the same one. 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.

Soil samples were taken from a glebe of the Capão da Onça Farm, belonging to the State University of Ponta Grossa, in a no-tillage area with approximately 3 hectares, totalizing 30 samples. The distance between the samples was not exactly the same, but the relative position of each sample was georeferenced.

In order to analyze the correlation between the electrical resistance and capacitance readings obtained by the sensor with the physical attributes of the soil, the results of the soil samples analyzed in the laboratory were used. A part of the samples was used to perform the tests with the sensor in the Electronic Laboratory of the State University of Ponta Grossa, and in the other part of the soil samples were analyzed the levels of sand, silt and clay in the Laboratory of Soil Physics of FCA -UNESP.

The instruments of measurement to measure the resistance and electrical capacitance of the soil samples used were: an analog multimeter of Minipa brand, model ET-2022, selected to operate as ohmmeter, and to measure the electrical capacitance of the soil samples a digital multimeter was used, CIE brand, model 5175XL, selected to operate as a capacmeter, according to Figure 2.

Figure 2 - Resistance Measurement and Electrical Capacitance.

Source: The autors, 2015.

3. RESULTS AND DISCUSSION

The correlation coefficients between the data involved in the study are presented in the tables below. These tables refer to the correlation between electrical resistance and capacitance and the attributes of the soil: sand, silt and clay contents using the analog multimeter to measure electrical resistance and digital multimeter to measure electrical capacitance of the soil. Table 1 shows the correlations between electrical resistance and soil attributes: sand, silt and clay contents using an analog multimeter.

Table 1 - Correlation coefficients of the electrical resistance in relation to the soil attributes, using analog multimeter.

Soil attributes	**Sand**	**Silt**	**Clay**
Pearson's Correlation	0,25	0,10	0,27
Correlation - Polynomial Trend Line/3rd Order Regression	0,77	0,36	0,81
Correlation - Polynomial Trend Line/6th Order Regression	0,86	0,42	0,85

Table 2 shows the correlations between electrical capacitance and soil attributes: sand, silt and clay contents using the digital multimeter.

Table 2 - Correlation coefficients of the electric capacitance in relation to the soil attributes using digital multimeter.

Soil attributes	**Sand**	**Silt**	**Clay**
Pearson’s Correlation	0,10	0,22	0,06
Correlation - Polynomial Trend Line/3rd Order Regression	0,40	0,42	0,39
Correlation - Polynomial Trend Line/6th Order Regression	0,59	0,52	0,59

The analysis of the correlation of the data was calculated using the Microsoft Office Excel 2007 program. We can observe that the correlation results that demonstrated a strong correlation with sand and clay were obtained with the analog multimeter. In a study by Mccutcheon et al. [9], it was also noticed what was observed in this study in question. That is, the results showed that measured soil properties, such as sand and clay, had almost equal responses, strong correlations with soil electrical resistance. Celinski and Zimbach [10] also used an electric resistance sensor by contact with an analog multimeter to verify correlation values with sand, silt and clay, respectively, (0,63), (0,42) and (0,58), results close to the work in question.It can also be verified, in the literature, that the electrical conductivity measured by contact sensor adequately reflects the variation in claycontentes of the soil under no-tillage, for use in the definition of management zones according to MACHADO et al. [11]. Also Morari et al.

(2009) verified in their research that there is a spatial dependence between the electrical conductivity of the soil and its physical properties.Lezzi [13], in his work, tested the applicability of the soil electrical resistivity sensor in the field, and the results showed that the sensor can be applied to measure soil electrical resistivity, however its use should be limited to the evaluation of areas where the soil is more sandy and less compacted. Also in the research conducted by Rabello et al. [14] it was verified that the use of the soil electrical conductivity method through tools such as those used in this research, aiming at precision agriculture can provide a fast and efficient method for the collection of soil data.

4. CONCLUSIONS

The electrically modified Octopus Soil Humidity sensor demonstrated ability to measure the variation of electrical resistance and capacitance of the soil. The electrical resistance of the soil measured by the analog multimeter correlated strongly with the clay and sand contents and moderately with the silt content. Using the digital multimeter, the electrical capacitance of the soil correlated weakly with the levels of sand, silt and clay. Thus, it was verified the possibility of use of the sensor only using the analog multimeter correlating with the electrical resistance of the soil to verify the soil texture in non-homogeneous areas.

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