

**Soil Electrical Conductivity: An Educational Resource in Experimental Agricultural Research****Condutividade Elétrica do Solo: Um Recurso Educacional em pesquisas Agrárias Experimentais**

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**ABSTRACT**

This article presents a didactic material designed for the teaching of electrical conductivity of a soil sample. This proposal aims to develop targeted content to experiments done in a physics laboratory, produced in form to contemplate the context of students for undergraduate research in the agricultural sciences. This type of initiative is towards the interests of these students to reinforce their learning in areas of professional bond. The results indicated that the experiment has shown fairly consistent in the electrical characterization of the soil, and provide to students a broader view of possibilities of these studies in practical activities.

**Key words:** agricultural sciences, conductivity, soil.

**RESUMO**

Este artigo apresenta um material didático visando o ensino, na determinação da condutividade elétrica de uma amostra de solo. Essa proposta tenta desenvolver conteúdos voltados para

experimentos feitos em laboratórios de física, objetivando-se a realização de projetos de pesquisa voltados para alunos de iniciação científica, na área de ciências agrárias. Este tipo de iniciativa vem em direção aos interesses desses alunos por trabalhos que reforcem seu aprendizado em suas áreas de vínculo profissional ligados ao seu curso. Os resultados obtidos indicaram que este tipo de experimento mostra-se bastante coerente na caracterização elétrica do solo, além de proporcionar ao aluno uma visão mais ampla das possibilidades destes estudos em atividades práticas.

**Palavras-chave:** ciências agrárias, condutividade, solo.

## 1 INTRODUCTION

The electrical conductivity is a parameter that can be measured experimentally. It is a useful parameter for professionals and postgraduate students, with specialization in physical, electrical or physicochemical engineering, who intend to study the characteristics of a certain system when subjected to an electric current.

A measurement technique consists of determining the admittance of a sample of the material under investigation between two electrodes, apply an electrical stimulus and measure its response. Various types of stimulus can be considered, nevertheless, the most common procedure or standard procedure is to alternating voltage of the sinusoidal type, and measure the complex admittance. The measurements of the real part and the imaginary part of admittance, as a function of frequency, determine the values of conductivity and permittiveness, respectively, of the analyzed system. These values make up the sample spectrum or a map of an area to be characterized, electrically.

Among current propagation studies and analysis of the response of its effects and behavior, it is the soil. Independent of its constitution, the soil is an environment that can be measured by electrical current stimuli. Depending on the area of interest, this allows electrically characterize a particular environment. Among these characteristics is the soil electric conductivity. These studies range from the characterization of the soil for projects of interest protection systems atmospheric (ROCHA,2007), to projects linked to the agriculture (VALENTE,2012;CORWIN,2003), in appropriate management, in application of a certain quantity of nutrients (RABELLO,2014), which is compatible with the environmental example.

This text describes a content proposal for activities with students from the agrarian sciences who chose to develop work in our physics laboratory, in scientific initiation. In this way, it aims to awaken the interest of these students in soil physics, from an introduction to physical-chemical characterization using electric current to determine their conductivity. For this, the sequence of the work presents the equipment used, experimental procedures and some considerations about the results obtained.

**2 EXPERIMENTAL PROCEDURE**

The experiment described was developed in the Cyber-Physical Systems Laboratory of the Federal Rural University of the Amazon. Students of scientific initiation of the Forest Engineering course attended each stage. Likewise, all measurement and equipment handling procedures were performed by them, based on a script that follows the same description of this methodology. For this, the following materials were used: wooden box; Soil sample; Aluminum foil; AC voltage source; oscilloscope; multi-test; connectors and two screwdrivers, which serve as a connection point inside the box to measure the ddp.

The box is made of wood and easy to acquire, since it was obtained from discarded materials. The soil sample, in a single block, was collected from the vicinity of a deforested area near a football field. Belonging to the dependencies of the University and deposited inside the box.

It is worth mentioning that the original soil structure was preserved, maintaining the same characteristics in terms of density and humidity. Two flat aluminum blades (0.50 x 0.40 m) were fixed inside the box and kept on the two inner faces of the smaller area, considering the largest distance between them.

As shown in Figure 1, the electrodes were placed on the blades or plates. The box has dimensions of 0.70 m in length, 0.50 m in width and 0,40 m in height. The voltage source used was a 60 Hz alternating voltage source, as well as multi-testers and oscilloscopes, for the measurement of current, frequency and resistance values.



Figure 1. Box containing soil samples and connectors.  
Source: Authors (2017).

Figure 2 shows the image of an alternating voltage source, often at 60 Hz, used in this experiment.



Figure 2. Image of the experiment using an AC source.  
Source: Authors (2017).

Therewith, the soil sample was brought to the lab preserving its characteristics, in other words, with the same physical properties of the area that was removed. Thus, it is possible to measure values such as the admittance of this soil and, therefore, to measure its conductivity (MOLIN;LADISLAU,2011). This parameter has a value of importance for the evaluation of the concentration of chemical elements in the earth (NETO,2014;SANTANA,2007). Figure 3 illustrates the model used in the lab.

### 3 THE MODEL AND RESULT

The equations that describe the mathematical formalism of the physics of this experiment, shown in Figure 3, are shown below:

$$I_{\text{circuito}} = \frac{V_s}{R_s} \quad (1)$$

$$|Y_{\text{solo}}| = \frac{I_{\text{circuito}}}{V_e} \quad (2)$$

$$G = \text{Real}\{Y_{\text{solo}}\} = \frac{\sigma A}{d} \rightarrow \sigma = G \frac{d}{A} \quad (3)$$

$$B = \text{Imag}\{Y_{\text{solo}}\} = \frac{\omega \epsilon}{d} \rightarrow \omega \epsilon = B \frac{d}{A} \quad (4)$$

Where Y is the admittance measured at 60 Hz, d is the distance between the electrodes, and A is the cross-sectional area of the soil sample. Where  $G = \text{Re}(Y)$  is called conductance and  $B = \text{Im}$

(Y) is called susceptance. Also, being  $V_e$  measured with the multimeter and  $V_s / R_s$  (electric current injected into the electrodes of the box -  $I_{\text{circuit}}$ ) measured with the Oscilloscope.

The conductivity value was measured and the voltage of 80 V was selected at the frequency of 60 Hz. At this voltage, the circuit current ( $I_{\text{circuit}}$ ) measured 50 mA. To obtain the  $V_e$  value, the electrodes inside the box (Figure 2) were spaced at  $d = 0.25$  m, with cross sectional area  $A = 0.2$  m<sup>2</sup>. The value obtained was  $V_e = 32$  V. Thus, using equation (3), the measured value of the conductivity is  $\sigma = 1.95$  mS / m.

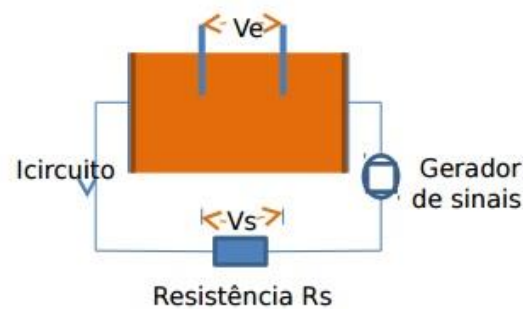


Figure 3. Model for the determination of conductivity and permittiveness of the soil.

Source: Authors (2017).

## I - GENERAL ASPECTS

The technique described in this experiment for the determination of conductivity is a very fast, simple and inexpensive method for agriculture, especially with regard to the verification of soil health.

In the same way, it opens space for a range of academic discussions on subjects related to their electrical properties. As a starting point, it should be clearly shown that, in the soil, water is the primordial element for the propagation of the electric current to happen and, therefore, conductivity (SANTANA,2006). In this respect, in the same proportion, as pH is a good indicator of the balance of available nutrients, the conductivity can almost be seen as the available quantity of these nutrients (BRANDÃO;LIMA,2002). Thus, for agriculture, the determination of the value of soil conductivity, allows to take more suitable cultivation decisions (VALENTE,2012) and in this lays the importance of this theme.

Other factors that also contribute to soil conductivity variation include the relationship of water present with soil density, its structure, and aggregation (BRADY;WEIL,2013). In addition to these are electrolytes, that is, salinity, exchangeable ions, the amount of water in the soil and its temperature. On the other hand, the conductivity of the mineral phase (FIGUEIREDO,2008) can affect the conductivity reading, for example, types and quantities of minerals, the degree of isomorphic substitution and exchangeable ions.

In general, what contributes most to soil health is predicted by its conductivity value, as it is consistently correlated with its properties and is what will determine what will grow there. In this aspect, one can list soil texture, cation exchange capacity, drainage conditions, salinity, organic matter level, and its fauna present. Therefore, this means that the conductivity of a particular type of soil is a great indicator of the health of the plants that will grow there.

Because it is a measure of reliability, electrical conductivity is a measure that is among the most frequent tools used in the determination of organic matter, moisture, and anthropogenic activities (leaching, irrigation, drainage and compaction due to machinery) that influence agricultural productivity (RABELLO,2014).

Since the current flowing through the water is proportional to the concentration of dissolved ions, the higher the dissolved salt/ion concentration, the more conductive the sample is and therefore the higher its conductivity reading. However, considering the pros and cons, it is difficult to establish an adequate level of conductivity, of a particular type of soil, because there are so many variables involved that the better way is to analyze the problem over time. This observation will generate a significant set of data based on the performance of the crops and their inputs used there.

As a general guideline, a good level of soil conductivity should remain between 20 mS / m and 120 mS / m. Any soil below 20 mS / m means no nutrients are available. This may indicate sterile soil with little microbial activity. This matches perfectly the type of soil used in this experiment ( $\sigma = 1.95$  mS / m), mainly due to the location of its origin - as mentioned at the beginning of this work. Otherwise, a conductivity reading above 120 mS / m may indicate excess salinity or lack of drainage.

In the case of water, distilled water is a good indicator of conductivity. Its conductivity values should be below 2 mS / m, as it indicates no polluting substances or contamination. For drinking water, with a conductivity reading above 20 mS / m, its origin is not from a reliable source.

Finally, it is always worth remembering the importance of reading the conductivity (PATEL; LAKDAWALA,2014), in several situations of its relation with the agrarian sciences. Here are some ranges of values that characterize certain types of materials, agricultural inputs (ANLON,2012):

1. **Fertilizer:** approximated between 150-200 mS/m. In the initial stage of fermentation, it can have a reading of 1000 mS / m and in the course of the process can even reach values greater than 10,000 mS / m.
2. **Foliar fertilizers:** approximated between 1500 - 3500 mS / m.
3. **Leaf sap tests:** approximated between 200 - 1200 mS / m.

In this case, the conductivity is a factor of measurement of the vegetable sap to evaluate the transformation of ions into sugars. It is worth mentioning the Brix level; this index is used in food industry to measure the approximate amount of sugars in fruits, vegetables, juices, wine and non-

alcoholic beverages. As the conductivity reading decreases, one can expect Brix levels, that is, sugars being produced by photosynthesis.

## **II - PARTICULAR ASPECTS**

Another case to be taken into account is the equation (4). From this equation, the determination of the electrical permittivity of the soil in the direction of propagation of the alternating current is made. However, this value has no purpose for the intended results described in this text. Even though in the whole experiment, only one frequency (60 Hz) for a voltage value at 80 V was maintained and to validate an expressive electrical permittiveness result, a range of variation should be observed. This is due to the fact that the value depends on the frequency, since it is an anisotropic medium. However, there is no reason why this type of experiment cannot be developed as a content that focuses on engineering, in studies related to energy quality, for example (ROCHA,2007), simply add a signal generator to the equipment list required in the lab.

## **4 CONCLUSIONS**

This proposal is directed mainly to courses of agrarian sciences, in which the first contact of students with the basic physical discipline is not satisfactory. In a way, a large portion of students has difficulty in basic concepts of physics, which is also a consensus among mathematics professors. The evaluation of these activities, particularly in a physics laboratory, has several positive aspects and among them is the opportunity to offer, in a concrete way, the chance to show to an undergraduate student the usefulness and importance of the mathematical formalism of applied physical concepts. Another aim is the preliminary preparation for the students of scientific initiation, who needs this technique in their studies or professional performance, regarding the physical-chemical analysis of the soil. Therefore, the methodological description that was presented is perfectly adequate and feasible for an undergraduate laboratory, since it requires equipment, usually available in most basic physics laboratories. Finally, it can be concluded that the experimental practice is an essential object in the construction of didactic contents and in the instrumentation directed to the teaching of physics, within a certain area of study.

## **REFERENCES**

ANLON, E.A. **Soil pH and Electrical Conductivity: Soil Laboratory Manual**. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, (2012).

BRADY, N.C.;WEIL,R.R..**Elementos da Natureza e Propriedades dos Solos**. Porto Alegre/RS, Bookman Editora Ltda, (2013).

BRANDÃO, S.L; LIMA, S.C. **pH e Condutividade Elétrica em Solução do Solo, em Áreas de Pinus em Cerrado na Chapada, em Uberlândia (MG)**, Revista Caminhos de Geografia 3, 6, (2002).

CORWIN, D. L.; LESCH, S. M.**Application of Soil Electrical Conductivity to Precision Agriculture: theory, principles, and guidelines**. Agronomy Journal, 95, 3 (2003).

FIGUEIREDO, E.R.H.; GALIDO,A.C;MOREIRA, J.A.M; LINS,. , F.A.P.L.**Condutividade Térmica em Rochas Silicáticas Cristalinas, com Ênfase a Rochas Graníticas da Província Borborema, NE do Brasil, e sua Correlação com Parâmetros Petrográficos e Texturais**. Revista Brasileira de Geofísica, 26, 3 (2008).

MOLIN, José P.; RABELLO, Ladislau M. **Estudos sobre a Mensuração da Condutividade Elétrica do Solo**. Agricultural Engineering Journal, 31, 90 (2011).

NETO, T.M.A; COELHO, E.F.**Concentração de Potássio em Função da Condutividade Elétrica da Solução do solo**. Water Resources and Irrigation Management, 3, 13 (2014).

PATEL, D.H.; LAKDAWALA,M.M.**Study of Soil's Nature by pH and Soluble Salts Through EC of Kalol-Godhra Taluka Territory**. Pelagia Research Library, 5, 2 (2014). [13]E.A. Anlon, Soil pH and Electrical Conductivity: Soil Laboratory Manual. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, (2012).

RABELLO, Ladislau Marcelino; BERNARDI, AC de C.; INAMASU, Ricardo Yassushi. **Condutividade elétrica aparente do solo**. Agricultura de precisão: resultados de um novo olhar. Brasília/DF, Embrapa, (2014).

ROCHA, Pedro Loques.**Introdução à Modelagem de Sistemas de Aterramento**. 2007. 89 f. Trabalho de Conclusão de Curso – Departamento de Engenharia Elétrica, Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2007.



SANTANA, G.S.;COELHO, E.F; SILVA, T.M.;RAMOS, M.M. **Estimativa da Condutividade Elétrica da Solução do Solo a Partir do Teor de Água e da Condutividade Elétrica aparente do Solo**. Revista de Engenharia Agrícola, 26, 3 (2006).

SANTANA, G.S.;COELHO, E.F; SILVA, T.M.;RAMOS, M.M.**Relação entre Potássio na Solução do Solo, Umidade e Condutividade Elétrica Aparente do Solo**. Revista Brasileira de Engenharia Agrícola e Ambiental. 11, 2 (2007).

VALENTE, Domingos Sárvio Magalhães et al.**The Relationship Between Apparent Soil Electrical Conductivity and Soil Properties**. Revista Ciência Agronômica, 43, 4 (2012).