SENSOR OF ELECTRICAL MEASUREMENTS AND ITS CORRELATION WITH THE SOIL CHEMICAL PROPERTIES

Victor George Celinski, Guilherme M. Biscaia, Tatiana Montes Celinski
State University of Ponta Grossa (UEPG) - Ponta Grossa, PR, Brasil.
E-mails: vgcelinski@uepg.br, gmbiscaia@hotmail.com, tmontesc@uepg.br

Abstract. *This paper focuses on the search of low cost alternatives with precision agriculture application. Incorrect soil management causes expenses and damages to production. Thus, a more accurate soil analysis arises in order to study its features, such as soil salinity. The analysis was made by electrical conductivity sensors, in order to provide the correction to be applied. Soil electrical resistance measurements were given by a sensor consisting of copper plates and an insulating material, along with an adjustable power supply, a digital multimeter and an analog multimeter. Based on the measurements, correlations with soil chemical properties were performed.*

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 on chemical applications at each point of the cultivated area, and not by the simple average of the total area.

The need to characterize soil factors drives the emergence of proposals and sensing and monitoring systems. Of the various systems, the study of soil electrical conductivity has excelled, working as salinity indicator and soil texture, for example CORWIN & LESCH [1].

In obtaining soil electrical conductivity measurements, conductivity meters are generally used NETTO et al. [2]. The electrical conductivity is able to report the concentration of soluble salts in the soil. Cultures respond differently to salt concentrations and can be quantified according to the electrical conductivity of the soil KLAR [3]. In search of Barreto et al. [4], it was found that the salts present in the soil solution can be evaluated by the electrical conductivity of the soil.

According to research of Grego et al. [5], the physical and chemical properties, soil factors, directly affect the crop yield results. Soil analysis is performed on samples requiring high demand of manpower, time and cost. The obtaining electric conductivity of the soil, through direct contact sensors, there is shown a fast and efficient method. The mapping of soil electrical conductivity helps in establishing management areas MOLIN et al. [6].

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

2. LITERATURE REVISION

The various systems for measuring soil characteristics are based on electrical circuits and used to determine the ability of certain means to drive or accumulate electric charge. If the soil is used as such a medium, its physical and chemical characteristics may affect the circuit behavior, and also the measured electrical parameters ADAMCHUK et al. [7]. The measurement of electrical conductivity of the soil has been widely used, making it an important tool for the prior assessment of the area to be studied, which facilitates the definitions of management zones, as RABELLO et al. [8]. Salton et al. [9] found that the use of soil electrical conductivity measurements can assist in the identification and delineation of homogeneous areas of soil with prior knowledge of the management history of the area.

Oliveira and Benites [10] conducted a survey on soil variability directed to precision agriculture, aiming to characterize the spatial variability from the use of quantitative techniques and, therefore, obtain information that would help in the decision to have a productive system. In the study, it was pointed out that the electrical conductivity of the soil is an important tool in the interpretation of the spatial variation of terrain and in the support to soil sampling.

In Cruz et al. [11], knowledge of the levels of electrical conductivity of the soil allows to correlate with other soil parameters, where spatial and temporal variation can be attributed to moisture changes, clay content, concentration of dissolved salts in the soil, organic matter, between others. Rocha et al. [12] showed in their study the potential of using a portable meter of soil electrical conductivity as an auxiliary tool in the characterization of soils. The development of new means of obtaining soil data for characterization and soil correction results in reduced environmental and financial losses. The correct handling of the cultivation areas, combined with precision farming, also results in greater productivity of the soil.

The work of Monteiro Junior et al. [13] evaluated the use of Arduino microcontroller in electrical conductivity sensors reading of soil for application in precision agriculture. Also in the search of Damiati et al. [14] was used the same microcontroller with Octopus Soil Humidity sensor (Figure 1), modified to obtain electrical resistance readings of soil. In the works of Damiati et al. [14] and Monteiro Junior et al. [13], the 5-volt voltage on the sensor was used because they used the Arduino working voltage, electronic prototyping plataform of free hardware. This research work, using the same soil humidity sensor modified and a supply with variable voltage, tested the best reading response for different values of voltages applied to the soil electrical conductivity sensor.

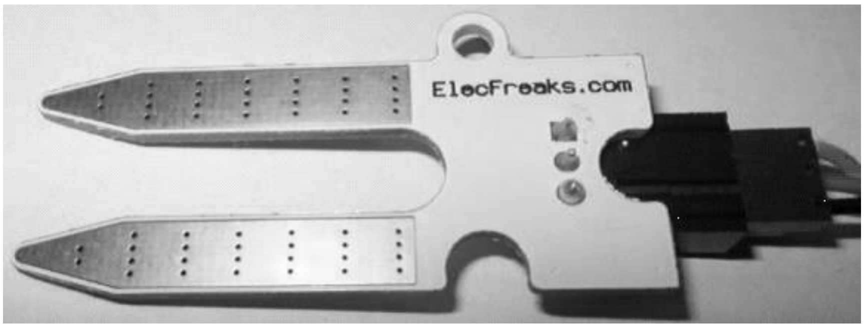

Figure 1 - Octopus Soil Humidity Sensor. Source: The authors

3. METHODOLOGY AND PRELIMINARY ANALYSIS

In the experiment were used 30 soil samples collected at Fazenda Capão da Onça, belonging to the State University of Ponta Grossa (UEPG), a commercial area of tillage with about four hectares. The experiment was conducted at the Electronics Laboratory of the Department of

Computer Science of UEPG.

It was mounted on an electric circuit for the development of the experiment: a source of continuously variable voltage to power the humidity sensor modified inserted in the soil samples and a digital ammeter for measuring the electric current circuit. The used sensor consists of two copper sheets separated by insulating material. With the aid of the variable voltage source with built-in voltmeter, were applied different voltage values to this sensor to obtain readings of electric current as shown in Figure 2.

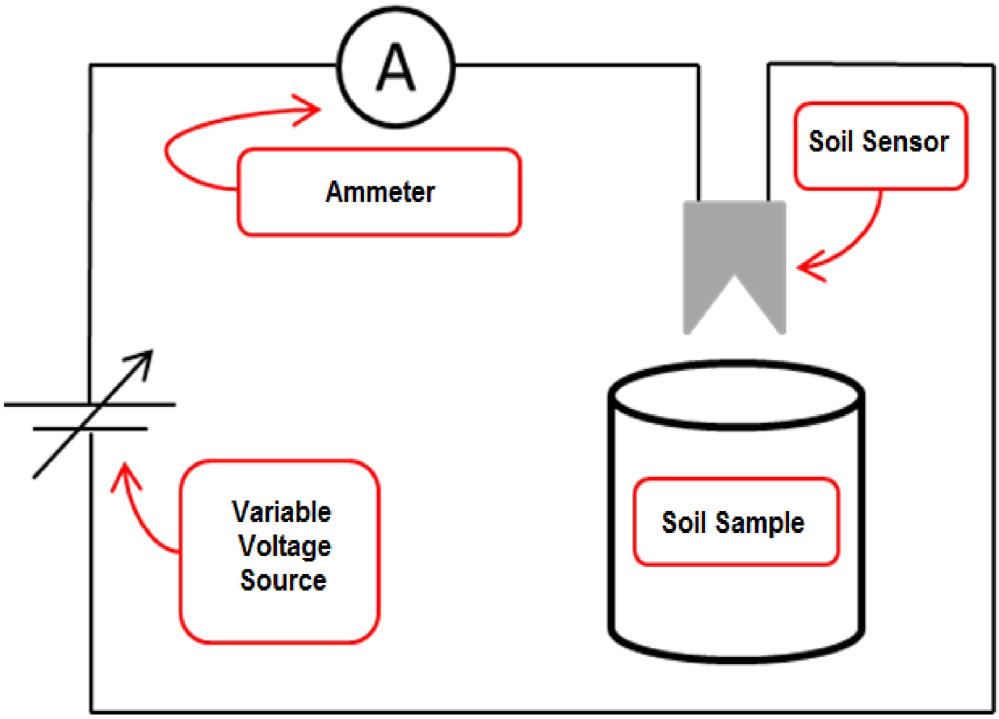

Figure 2 - Electrical circuit used in the experiment. Source: The authors

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

With the voltage values applied and the electric current obtained by a digital multimeter in ammeter function, it was applied the Ohm's law by dividing the voltage values by the current values to obtain the electrical resistance values of the soil samples as Table 1.

Table 1 - Voltage values applied, obtained electric current obtained and electrical resistance calculated by Ohm's law.

	5V		**10V**		**15V**		**20V**		**25V**		**30V**	
Sample	**I**	**R**	**I**	**R**	**I**	**R**	**I**	**R**	**I**	**R**	**I**	**R**

11	48	1042	73	1370	93	1613	116	1724	137	1825	151	1987
16	17	2941	27	3704	40	3750	52	3846	64	3906	79	3797
18	24	2083	47	2128	65	2308	80	2500	95	2632	109	2752
19	56	892,9	90	1111	100	1500	125	1600	151	1656	180	1667
20	25	2000	40	2500	55	2727	69	2899	85	2941	101	2970
22	55	909,1	105	952	141	1064	165	1212	191	1309	220	1364
23	60	833,3	90	1111	125	1200	152	1316	173	1445	190	1579
24	31	1613	55	1818	73	2055	86	2326	103	2427	119	2521
27	17	2941	30	3333	39	3846	45	4444	53	4717	61	4918
28	21	2381	31	3226	39	3846	48	4167	59	4237	68	4412
30	31	1613	51	1961	68	2206	83	2410	96	2604	106	2830
31	7,9	6329	16	6250	23	6522	29	6897	36	6944	42	7143
33	41	1220	60	1667	80	1875	99	2020	118	2119	140	2143
34	19	2632	35	2857	51	2941	66	3030	82	3049	99	3030
35	34	1471	54	1852	68	2206	83	2410	95	2632	110	2727
36	25	2000	41	2439	55	2727	68	2941	82	3049	98	3061
37	15	3333	25	4000	28	5357	30	6667	36	6944	42	7143
38	22	2273	34	2941	47	3191	60	3333	73	3425	87	3448
39	37	1351	59	1695	74	2027	92	2174	109	2294	126	2381
40	24	2083	36	2778	47	3191	58	3448	71	3521	84	3571
41	31	1613	46	2174	57	2632	67	2985	78	3205	86	3488
42	17	2941	27	3704	34	4412	41	4878	46	5435	55	5455
43	15	3333	26	3846	34	4412	41	4878	49	5102	57	5263
44	20	2500	31	3226	42	3571	53	3774	66	3788	80	3750
45	25	2000	39	2564	51	2941	62	3226	77	3247	91	3297
46	33	1515	56	1786	76	1974	90	2222	104	2404	121	2479

47	14	3571	20	5000	26	5769	33	6061	39	6410	46	6522
48	11	4545	18	5556	24	6250	28	7143	36	6944	43	6977
49	11	4545	19	5263	26	5769	33	6061	40	6250	48	6250
50	30	1667	50	2000	68	2206	85	2353	102	2451	121	2479

Electric current values (I) multiplied by 10^{-4}, reading in Amperes.

Electrical resistance values (R), reading in Ohms.

The laboratory analysis data of soil properties for the 30 samples analyzed in this experiment are shown in Table 2.

The chemical characteristics of the soil analyzed were: the hydrogenic potential (pH), the content of organic matter (MO), phosphorus resin (P_{resin}), potential acidity (H + Al), potassium (K), calcium (Ca) and magnesium (Mg). And the parameters: sum of bases (SB), capacity of cation exchange (CTC) and base saturation (V%). The pH and V% values are dimensionless numbers. The rest of the measurement units are density values, which measures the concentration of mass in a given volume.

The unit of measurement for P_{resin} is $mg.dm^{-3}$ or mg/dm^3 (milligram per cubic decimeter). The unit of measurement for MO is $g.dm^{-3}$ or g/dm^3 (gram per cubic decimeter) and the unit of measurement for H + Al, K, Ca, Mg, SB and CTC is $mmol_c.dm^{-3}$ or $mmol_c/dm^3$ (millimoles per cubic decimeter).

Table 2 - Laboratory analysis data of samples used in the experiment.

Sample	**pH**	**MO**	**P_{resin}**	**H+Al**	**K**	**Ca**	**Mg**	**SB**	**CTC**	**V%**
11	4,5	29	43	60	2,7	21	8	31	91	34
16	4,6	24	32	52	2,9	21	7	31	83	37
18	4,9	24	14	43	1,9	31	10	43	86	50
19	4,5	24	19	54	3,9	16	6	26	80	33
20	4,7	28	7	52	3,2	26	8	37	89	42
22	5,3	28	34	35	8,0	36	13	57	92	62
23	4,3	29	40	73	2,3	17	5	24	98	25
24	4,9	29	29	46	4,9	31	10	45	91	50
27	4,7	32	9	54	3,8	26	10	39	93	42

28	4,5	32	13	62	2,0	19	7	28	90	31
30	4,5	33	23	72	2,5	19	7	28	101	28
31	4,5	35	45	70	2,3	20	7	29	99	29
33	4,9	23	12	37	1,8	29	9	39	77	51
34	4,7	37	17	64	3,1	25	10	38	102	37
35	4,4	35	15	72	1,4	19	7	27	99	27
36	4,4	34	11	71	3,4	19	7	29	100	29
37	4,2	33	47	87	2,0	10	4	16	102	15
38	4,4	25	46	58	3,1	14	5	22	80	27
39	5,2	26	15	35	3,1	35	11	49	84	59
40	4,6	30	20	59	2,9	23	9	34	93	37
41	4,3	30	33	72	2,3	16	6	24	96	25
42	4,5	29	42	63	3,0	18	6	27	90	30
43	4,4	19	29	51	2,5	15	4	21	73	30
44	5,1	20	15	31	2,1	30	10	41	73	57
45	4,9	23	17	44	1,5	28	11	40	85	48
46	4,5	21	15	53	3,2	16	7	26	80	33
47	4,1	30	14	82	2,2	8	4	14	96	14
48	4,5	24	18	54	2,4	18	6	26	81	33
49	4,5	15	14	37	1,5	13	5	19	56	34
50	4,9	17	13	33	2,2	25	11	38	71	54

Given the values of the attributes of the soil and the electrical resistances, we can draw a correlation between the electrical resistance variables with each attribute of the soil. The Pearson's correlation discusses the linear dependence between two variables. In this case, the electrical resistance and the various attributes of the ground. For Doria Filho [15], the correlation coefficient is considered perfect, if equal to 1; strong, if greater than 0,75; average, if greater than 0,5; weak, if less than 0,5 and nonexistent if equal to 0. This study listed some of the soil properties with electrical resistance for obtain the degree of linear correlation of Pearson, as shown in Table 3.

Table 3 - Pearson's correlation coefficient between electrical resistance and soil properties

Voltage applied	Soil properties									
	pH	MO	P_{resin}	H+Al	K	Ca	Mg	SB	CTC	V%
5V	-0,32	0,02	0,14	0,19	-0,30	-0,37	-0,40	-0,39	-0,10	-0,33
10V	-0,38	-0,01	0,09	0,22	-0,35	-0,45	-0,47	-0,48	-0,13	-0,39
15V	-0,42	0,01	0,11	0,28	-0,37	-0,49	-0,52	-0,52	-0,10	-0,44
20v	-0,43	0,03	0,13	0,30	-0,35	-0,50	-0,52	-0,53	-0,06	-0,46
25v	-0,45	0,04	0,15	0,33	-0,35	-0,52	-0,54	-0,55	-0,05	-0,48
30v	-0,47	0,06	0,16	0,35	-0,36	-0,53	-0,55	-0,55	-0,03	-0,49

Analyzing Table 3, for a 5V voltage applied to the sensor, there is the Pearson's linear correlation coefficients between electrical resistance of the soil and chemical attributes and parameters of the soil too low, approaching zero. This zero proximity indicates a very weak linear dependence between the two variables analyzed.

It also was noted that all Pearson's correlation coefficients are weak for a voltage equal to 10V, revealing little linear dependence. However, as it increases the voltage applied to the electric conductivity sensor, correlation coefficients also increase, increasing the sensitivity of current reading and revealing greater dependence between electrical resistance and chemical parameters of the soil. When applying 30V voltage to the sensor, maximum voltage used in the experiment, the correlation coefficient has reached its greatest value when the electrical resistance is compared with SB, Mg and Ca, resulting in an average linear correlation with the electrical resistance of the soil. There is poor correlation between the electrical resistance and MO, P_{resin} and CTC, even increasing the applied voltage.

4. FINAL CONSIDERATIONS

The study demonstrated the value of the most appropriate voltage to be applied to the electric conductivity sensor in soil samples, when it is desired to correlate the sensor reading data with attributes and chemical parameters of the soil. According to the experiment, it was observed that the higher the voltage applied to the sensor, the more stable has become the current reading, reducing the time for determining the current reading wich the soil sample leads and increasing the correlation coefficient between electrical resistance and soil chemical properties.

It is possible to obtain a greater correlation between the data obtained by increasing the voltage applied to the sensor for values greater than 30V. Another possibility would be to improve the sensor, increasing the contact area with the ground. However, as it increases the contact area of the sensor, makes it difficult to insert the sensor in the ground. Another point to be considered was the use of linear correlation coefficient of Pearson. Different correlation values can be obtained if other regression methods are used.

This work opens doors for future experiments with different sensors and sensor improvements as used in this study. The task of collecting and reading can be automated, generating speed to the process of analysis and characterization. The automation of the collection and analysis process can also assist the producer in making decisions, providing data to enable the soil correction process for the cultivation area, allowing the producer to apply the correct amount of inputs in the soil. It must be considered that the study results are valid for the type of soil used, different types of soil may lead to different results.

REFERENCES

[1] CORWIN, D.L., LESCH, S.M. (2005). Apparent soil electrical conductivity measurements in agriculture. **Computers and Electronics in Agriculture**, Amsterdam, v.46, p.11-43.

[2] NETTO, A. O. A., GOMES, C. C. S., LINS, C. C. V., BARROS, A. C., CAMPECHE, L. F. S. M. e BLANCO, F. F. (2007). Características químicas e salino-sodicidade dos solos do Perímetro Irrigado Califórnia, SE, Brasil. **Ciência Rural**, Santa Maria, v. 37, n. 6, p. 1640-1645.

[3] KLAR, A. E. (1988). **A água no sistema solo–planta–atmosfera**. 2. ed. São Paulo: Nobel.

[4] BARRETO, H. B. F., AMARAL JUNIOR, V. P., LIRA, J. F. B., MAIA, F. E. N. e MIRANDA, N. O. (2012). Distribuição espacial do pH e condutividade elétrica em um solo aluvial no Rio Grande do Norte. **Revista Agropecuária Científica no Semiárido**, v. 8, n. 1, p. 28-33.

[5] GREGO, C. R., VIEIRA, S. R., MOLIN, J. P., MIGUEL, F. R. M. e PAVLU, F. A. (2006). Variabilidade espacial da condutividade elétrica do solo e da produtividade da mamona (Ricinus communis L.) no sistema de plantio direto. In: CONGRESSO BRASILEIRO DE AGRICULTURA DE PRECISÃO, 2., 2006, São Pedro. **Anais…** São Pedro.

[6] MOLIN, J. P., GIMENEZ, L. M., PAULETTI, V., SCHMIDHALTER, U., HAMMER, J. (2005). Mensuração da condutividade elétrica do solo por indução e sua correlação com os fatores de produção. **Engenharia Agrícola. Jaboticabal**, v. 25, n. 2, p. 420-426.

[7] ADAMCHUK, V. I., HUMMEL, J. W., MORGAN, M. T. e UPADHYAYA, S. K. (2004). On-the-go soil sensors for precision agriculture. **Computers and Electronics in Agriculture**, v. 44, p. 71-91.

[8] RABELLO, L. M.; INAMASU, R. Y.; BERNARDI, A. C. (2014). Equipamento de medida de condutividade elétrica aparente do solo. In: SIMPÓSIO NACIONAL DE INSTRUMENTAÇÃO AGROPECUÁRIA, 2014, São Carlos, SP. **Anais..**. São Carlos: Embrapa Instrumentação, p. 41- 44.

[9] SALTON, J. C., TOMAZI, M., COMUNELLO, E., ZANATTA, J. A. e RABELLO, L. (2011). Condutividade elétrica e atributos físicos e químicos de um Latossolo após 15 anos sob sistemas de manejo em Mato Grosso do Sul. **Agricultura de Precisão: um**

novo olhar, São Carlos, p. 254-260.

[10] OLIVEIRA, R. P. e BENITES, V. M. (2011). Variabilidade do solo como indicador da oportunidade da agricultura de precisão em sistema de plantio direto”. In: Inamasu, R. Y., Naime, J. M., Resende, A. V., Bassoi, L. H. e Bernardi, A. C. C. In: (Ed.). **Agricultura de precisão: um novo olhar**. São Carlos: Embrapa Instrumentação, 2011. p. 194-200.

[11] CRUZ, L. E. C., FILIPPINI, J. M. e PILLON, C. N. (2014). Condutividade elétrica aparente e sua correlação com o conteúdo de carbono orgânico total do solo em um agrossistema de arroz irrigado. In: SIMPÓSIO NACIONAL DE INSTRUMENTAÇÃO AGROPECUÁRIA, 2014, São Carlos. **Anais...** São Carlos: Embrapa Instrumentação, 2014. p. 97- 100.

[12] ROCHA, M. G.; NASCIMENTO, P. S.; COSTA, B. R. S.; SILVA, J. A.; BASSOI, L. H.; RABELLO, L. M. (2011). Mapeamento da condutividade elétrica aparente do solo com sensor portátil em um argissolo no semiárido. In: XXXIII CONGRESSO BRASILEIRO DE CIÊNCIA DO SOLO. **Anais**... Center Convention, Uberlândia, MG.

[13] MONTEIRO JUNIOR, M., NUNES, R. O, CELINSKI, V. G. (2012). Avaliação da utilização de um microcontrolador na plataforma Arduino na leitura de sensores condutividade eletrolítica do solo de baixo custo. **Revista de Engenharia e Tecnologia**, v. 4, p. 52.

[14] DAMIATI, F. V. F., CAMARGO, L. F. e CELINSKI, V. G. (2014). Avaliação da utilização de um microcontrolador na plataforma Arduino na leitura de sensores elétricos para correlação com atributos do solo. In: CONAITEC - CONGRESSO AGROPECUÁRIO, INDUSTRIAL E TECNOLÓGICO DO PARANÁ, 2014, Ponta Grossa. **Anais...**

[15] DORIA FILHO, U. (1999). **Introdução a bioestatística: para simples mortais.** São Paulo: Negócio.