COMPARISON OF THE RESPONSES OF LOW COST ELETRICAL SOIL SENSORS, AND A ARDUINO MICROCONTROLLER PLATFORM

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Abstract: *This work aims to study the precision agriculture, and from previous studies compare the results of collected data by electrical conductivity sensors using measurement instruments dedicated as ohmmeters, with data from the same electrical conductivity sensors collected through a microcontroller using the Arduino platform. With a simple circuit and the use of analog inputs of the microcontroller, seek to automate some processes of soil analysis. Arduino platform was chosen because it uses the concept of open hardware, have libraries and an open source development platform (free). With the choice of sensors, this work was carried out at the "Fazenda Capão da Onça", belonging to the State University of Ponta Grossa, in an area of approximately 13 hectares, 60 measurements were recorded at different points. The data collected by Arduino were compared with data obtained using an analog multimeter. The developed system stores the data into a memory card. As a comparator, we used the electrical resistance of the soil. After comparison and correlation of data obtained, it was verified the possibility of making use of the microcontroller to obtain measures from soil electrical conductivity sensor.*

Keywords*: Precision Agriculture; Electrical conductivity; Arduino Microcontroller*

1. INTRODUCTION

Precision agriculture is directly linked to high technology. One of the major goals of this type of agriculture, according to Coelho and Silva (2004): "the increase of farmers' income, achieved in two different ways, but complementary: the reduction of production costs, and increase of productivity (and sometimes also the quality) of cultures. "Applying of a model of precision agriculture involves several factors, such as regional climate, solar incidence, crop diseases and other ones. However, in most cases

the application of a model is linked to the type of soil, ability to retain humidity, nutrients, pH and organic matter.

Soil testing has been used for years by farmers seeking balance between nutrients and soil acidity. A precise analysis often means a good productivity with less cost and less environmental impact, since the soil remediation will use a more precise amount of fertilizer and / or products to correct ph. Therefore, to avoid waste and greater environmental damage.

According Pincelli (2004), developed countries use techniques such as precision agriculture, the correlations found between the concepts of electrical conductivity and soil attributes (texture, moisture, salinity, acidity).

Moreover, the same reports that the electrical conductivity systems are directly connected to qualitative indicators of physical and chemical attributes of the soil. Since the early twentieth century, some researchers were looking for a development of a methodology that producers could sampling, testing and mapping the soils, a simple and practical and that resulted in a savings of applied inputs (WAR, 2006).

For Greek et. al. (2006), to investigate possible causes of spatial variability found in the results of crop productivity, has been attributed to soil factors, such as physical and chemical properties. However, these samples are obtained by requiring in most cases, high demand of skilled manpower, time and cost. The electrical measurements from the ground have drawn attention, primarily because they are obtained by means of fast and efficient methods, for example, using sensors in direct contact with the ground.

In searching of lowering the cost of tools of precision agriculture, among other relevant factors, Celinski (2008) proposed the development of a sensor for electrical measurements. This sensor allows the verification of the correlation between the readings of electrical resistance and capacitance and physical and chemical attributes of the soil, these are directly linked to the quality of soils.

The use of sensors for soil analysis also aims to reduce the time for analyzing samples. Some sensors, working as measurement instruments: analog ohmmeter and / or digital, and digital capacimeter to obtain the potential difference, electrical resistivity and capacitance soil. The data and geographical position obtained by GPS precision, are stored in a spreadsheet, and then through a geostatistical software obtains the maps: conductivity, resistivity, electrical resistance and capacitance of the soil, which correlated analyzes soil performed in the laboratory, will generate maps of estimated soil properties pertaining to such analyzes.

The use of microcontrollers allows automatization and addition of the tasks together in one unit, making the process more dynamic, providing immediate answers to the farmer about the nutrients. To run the automation, it is necessary previously to evaluate the response of sensors already tested against the response of the new embedded system.

This study aims to compare and correlate the results of sensor readings of soil electrical conductivity. Used to do this, an analog ohmmeter, their notes of electrical conductivity in spreadsheets, using the Arduino microcontrolled platform, which automatically stores the data obtained during the readings on a SD memory card

(secured digital content), where these data may be transferred later to software for specific applications.

2. BIBLIOGRAPHICAL REVIEW

Aiming to optimize resources, sustainability and environmental protection, precision agriculture (PA) is a control system which is based on agricultural spatial variation of soil properties in different cultures existing crops.

Despite reports that the PA has emerged since the early of twentieth century, however, occurred in Europe in the 1980s the generation of the first map of productivity and in U.S. was made the first fertilization with varying doses. But it was with the advent of GPS around 1990, which then could determine more precisely and efficiently implementing the PA. Since 1995, the PA began to getting stroger in Brazil. Even still few and privileged farmers, there were imports of harvesters yield with productivity monitors.

Although it has numerous application forms, PA seeks always use means of dissolving problems of non-uniformity of crops, and even take advantage of these problems, identifying regions of great potential fertile for example.

The PA is also a management system of agriculture that takes into account the spatial variability of crops in all its aspects: productivity, soil (physical, chemical, compression and other characteristics), Infestation of weeds, diseases and pests. But today, especially in Brazil, the solutions of PA have been focused only on the application of fertilizers and in a variable way.

Inside the PA, considering only the use of fertilizers, there are two strategies to be adopted. The simplest and most used in Brazil, mainly in grain crops and sugar cane, is subject to management of soil fertility through the management of its correction and fertilization (fertilizer, lime and gypsum) crops based sampling georeferenced soil.

This choice is used to be a quick and simple approach - since the withdrawal of a sample until the final process of data processing and generation of application maps, do not spend more than 15 days (Brazil's Ministry of Agriculture, Livestock and Supply , 2011).

The other strategy by taking into account also the plants and not only just soil, it becomes a more extensive and elaborate. This considers the yield of the prior crop to carry replacement of nutrients. It required the generation of productivity maps, which considers production historical soil-plant.

Despite being more expensive and complex, due to the need for more sophisticated equipment and more improved technical knowledge, this technique can be seen as more accurate and efficient since not only study the changes in the soil.

Given the scientific knowledge, it is necessary to identify the causes that may be causing low productivity and where it is manifested. This interpretation and explanation of the facts becomes the most complex part of this method, due to the distinct characteristics of each crop.

A negative view of this second method is through the consume of inputs and also equipment spending. Besides the first and most widely used approach, has as positive a reduction in spending of inputs and also lower investment in equipment.

However, it cannot be said that a strategy is more advantageous over the other, considering the growing crops as a whole. It is necessary, above all, individual analysis of each type of crop and also the capacity of the investment of the involved former.

Currently, there are specialists and companies that perform services on sampling and generation of application and productivity maps. The values of these services depend on some variables, including the sampling density that is directly linked with the quality / reliability of the study to be practiced.

In the market, we found electronic monitors that perform the application of the products. This is basically an electronic component that governs a hydraulic motor that drives the feeder. It required their installation on machines fertilization and dispersion of additives.

Sensors

Sensors are devices related to the environment, both physical and chemical, and usually provide an electrical answer. This type of sensor can be analog, digital, serial, among others.

Multimeters

Multimeters are used in the field of eletronics for measurements of different types of units such as electrical current, voltage, resistance and capacitance. Some also provide temperature reading test, transistor, diode test and other tests of components.

Microcontrollers (MC)

"Microcontroller is an electronic element, designed to perform specific tasks with specific command language." (NICOLOSI, 2005, p. 60).

Also according to Nicolosi (2005, p 60). "Its purpose is to perform specific task engraved in his memory code, the ROM". Microprocessors use its input ports and output to communicate through bus with its peripherals such as RAM, ROM, keyboards, displays and more. They are found in notebook, PC (personal computer), video games.

Although it contains many common features to known microprocessor, the MC has different internal architecture, and also has more functions than a microprocessor. The difference between microprocessor and microcontroller is: "The microcontroller corresponds to a typical microprocessor and its peripherals, all together in one chip" (NICOLOSI, 2005, p. 69).

An MC has the advantage of being smaller, because its structure is an unified hardware, be cheaper than having a microprocessor and a low consumption of current. Its use is common in embedded platforms, phones, cars. Today there are MCs with higher performance and internal memory, making it a great alternative to developing new products.

RTC (Real Time Clock)

An RTC works as a clock that communicates with the MC via the I2C protocol. Every MC has an internal clock, however, its parameters are reseted whenever the microcontroller is reseted. The use of separate RTC holding times and dates even with MC off, thanks to a 3V battery.

The DS1307 RTC was chosen because it has a low current consumption and can last for years without losing its data.

SD Memory Card (Secured Digital Content)

A memory card has the primary purpose of a quickly and easily data storing and, since a small device compared to other media storage such as hard disk, and also has the plug-and-play (PnP) technology (HowStuff Works, 2012), where the user does not need to install it, just connect the SD to the device he wants.

Due to its simplicity of operation and convenience, also the affordable price, Monteiro Junior, Nunes and Foltran et.al. (2011) chose this technology for partial data storing, so that they were subsequently analyzed and / or stored on a computer or any other tool defined by the user.

Global Positioning System - GPS

The global positioning system is a technology that allows to determine the position anywhere on the globe (COELHO, 2005). Developed by the Department of Defense of the United States of America, and available for many civilian uses, from fishing to navigation, the GPS also turned the precision agriculture into reality. It can be compared to a single AM or FM radio that receives signals from a constellation of 24 satellites revolving around the earth at an altitude of approximately 20,000 killometers. The GPS uses the NMEA 0183 protocol communication. The NMEA uses ASCII based character and is open to users. Among the data provided, was used the GPGGA code.

Open Hardware

According to the Open Hardware Organization (2011), this means sharing the design of physical or electronic objects with the public, in a similar way of Open Source Software.

The use right, modify, redistribute, and manufacturing, commercially or as a nonprofit organization, is granted to all without any financial commitment or fee. Thus, the Open Hardware designers expect enrich the society through the development of a library project of useful objects that everyone can make, use and improve.

One example of a possible solution to the Open Hardware developers is the Arduino platform.

Arduino

The Arduino is an open platform for developing of hardware devices based on a family of Atmel microcontrollers company. This board was developed and improved by a community, which promotes their boards and their codes, and uses the Open Hardware design.

Shields

Shields are boards that can be connected to the Arduino board to expand the capacity of its operation. They are widely used for communication with extra peripheral such as displays, Ethernet communication, USB. All without changing the main hardware, the use of Shields makes easier exchanging and update of peripherals.

Pearson's Correlation

The Pearson's Correlation coefficient measures the degree of correlation between two metric scale variables, the results of which can be interpreted as follows:

• 0.70 plus or minus indicates a strong correlation.

• 0.30 to 0.7 indicates positive or negative moderate correlation.

• 0 to 0.30 is a weak correlation.

Pearson Equation

$$\rho = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2} \cdot \sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} = \frac{\operatorname{cov}(X, Y)}{\sqrt{\operatorname{var}(X) \cdot \operatorname{var}(Y)}}$$

3. METHODOLOGY

In his stage design, the data collection and initial execution of this study was conducted at Capão da Onça Farm, owned by Universidade Estadual de Ponta Grossa - Ponta Grossa's State University, in Portuguese -, in an area of approximately 13 hectares (Figure 1).

Figure 1. Capão da Onça's plot

Source: the authors

It was used two sensors, one consisting of a rod of PVC with copper terminals (Figure 2), Celinski (2008), and the other comprises a phenolite plate with a double sided copper, with one track without copper (Figure 3), making both sides isolates Celinski (2011). The sensors are introduced into the soil for each sample point, then the resistance was measured with an analog multimeter and with the CDATA Monteiro Junior, Nunes e Foltran et.al. (2011). A process was repeated replacing the measure of capacitance by the resistance by using the digital multimeter, excluding the analog meter because it does not provide for this parameter (Figure 4).

Figure 2. Copper rod sensor

Source: the authors

Figure 3. Phenolite sensor.

Source: the authors

Figure 4. Soil analysis

Source: the authors

The final reading is displayed on CDATA (Figure 5). After the conference, it is automatically saved in the card along with the location, date and time. It was also collected at some points measurements of temperature and humidity, because future studies to verify their influence on the readings of data.

Figure 5. CDATA's reading

Source: the authors

In the next step the geographical position is checked using both the CDATA as the commercial GPS. Those readings are compared. With the data obtained, it was performed the calibration of CDATA.

The data generated by CDATA are saved in CSV format, this can be "read" by programs like Microsoft Excel, CALC, among others. The format of data presentation is shown in Figure 6.

A2 712966.18

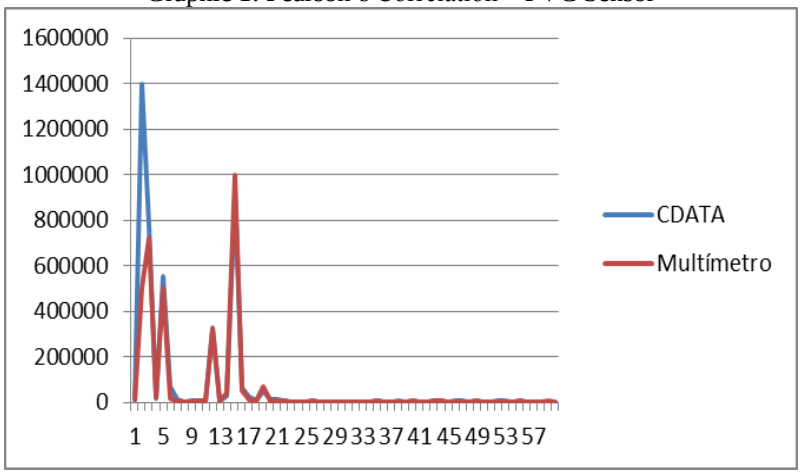
	A	B	C	D	E	F	G	H
1	Resistencia	Latitude	Orientacao	Longitude	Orientaca	Altitude	Data	Hora
2	712966.18	25.057.244	S	50.030.609	W	1021.6	14/06/2012	15:20:19
3	3519.39	25.057.413	S	50.030.313	W	1035.4	14/06/2012	15:44:00
4	9755.70	25.057.428	S	50.030.231	W	1035.1	14/06/2012	15:48:13
5	3523.23	25.057.449	S	50.030.144	W	1030.3	14/06/2012	15:55:36

Figure 6. Data presentation.

Source: the authors

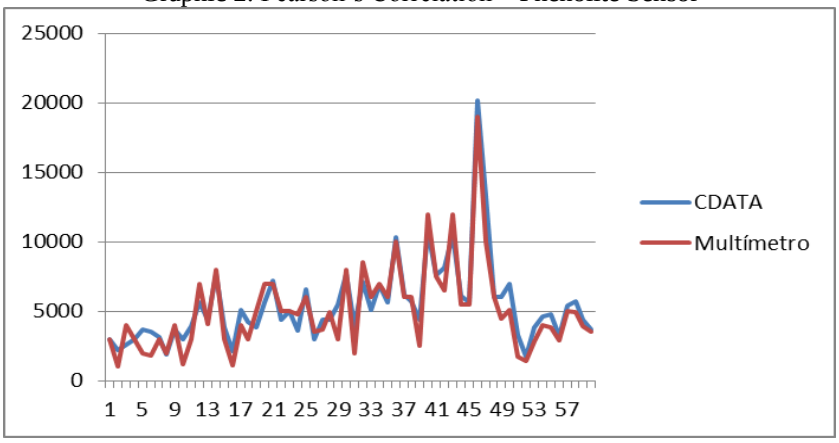
For statistical analysis was used the statistical program Microsoft ® Excel 2007, and worked with the index of Pearson linear correlation which is one of the most used indicators in the area of agronomics.

Graphic 1: Pearson's Correlation – PVC Sensor



Source: the authors

Graphic 2: Pearson's Correlation – Phenolite Sensor



Source: the authors

The results obtained for the PVC sensor and for the phenolite sensor in Pearson correlation was respectively 0.89 and 0.94. Both considered strongly related.

The Graphic 1 represents the PVC sensor, the electrical resistance in each sample and the correlation between the multimeter and CDATA. In Graphic 2 is shown the same samples with the phenolite sensor.

5. CONCLUSIONS

For the conditions in which this research was performed, the microcontroller displayed ability to measure changes in the electrical resistance of the soil, correlating strongly with measurements obtained by analog ohmmeter. This demonstrated the possibility of CDATA to be used to check soil fertility, thus enabling further research work, performing mathematical expressions that represent the correlation between the electrical properties of the soil and laboratory analysis of physical and chemical properties of the soil, providing for future research, generation of maps of soil attributes aiming applications on precision agriculture.

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