





4th Global Workshop on **Proximal Soil Sensing**

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Soil apparent electrical conductivity and soil profile characteristics: is there a reasonable relation among electrodes separation and depth of investigation?

Leandro Gimenez, José P. Molin*

Department of Biosystems Engineering, "Luiz de Queiroz" College of Agriculture, University of Sao Paulo, Brazil Corresponding Author's Email: ipmolin@usp.br

Abstract

Vertical electrical sounding (VES) is used to characterize earth profile variability. Near surface soundings on agricultural fields are rare given its operational burden. In this research four soil profiles were characterized through VES, undisturbed soil samples and by determining aparent electrical conductivity (ECa) along pit walls. Comparison among ECa obtained from VES and that of the walls showed lack of agreement. Soil structure related properties presented high importance for three soils. The relation among electrode separation and depth of investigation that allowed best agreement with ECa measured in the pit varied among soils.

Keywords: resistivity, layer, porosity, ferrasol, acrisol

1. Introduction

Physical and chemical properties of soils can be inferred through the measurement of electrical resistance and the calculation of apparent conductivity (ECa). In agriculture, ECa maps are used to characterize soil variability along fields in which soil properties as porosity, texture, salinity and compaction can be regionalized and management units established (Corwin et al, 2008). Galvanometric instruments, in which sets of electrodes induce currents and measure potentials are the more robust and widely employed. The depth of investigation for contact instruments depend on the arrangement of the electrodes being proportional to its separation. To characterize soil variability in the horizontal the method of constant separation traversing is employed, in which fixed arrays of electrodes are moved along transects in the field. The vertical electrical sounding method (VES), in which the midpoint of the array is kept stationary and the array length is lengthened, is suited to characterize vertical variability (Allred et al, 2008). Instruments for exploring both methods simultaneously are available (Dabas et al, 2000). Soil vertical variability influences the depth in which the electrical current crosses the layers. In a homogeneous medium the relation among depth of prospection and electrodes separation is known, but for heterogeneous medium it is not determined (Szalai et al, 2009). Near surface soil variability characterization for agriculture applications is carried using instruments with few sets of electrodes. Although in the last twenty years extensive research is available exploring the subject, a lack of information exists on soil profile variability effects on ECa measured at surface with few sets of electrodes. Soil ECa maps are used to define soil sampling schemes in which depth is kept constant following traditional agronomic recommendations. The lack of homogeneity on soil profile ECa is a potential source of error in defining the sampling strategies since horizontal variability perceived in the maps is also related to vertical variability. The objective in this research was to explore ECa variability along soil profiles and its relation to soil properties on tropical soils with varied properties and stratification.

2. Materials and methods

Soils of central Brazil, located in the savannas largely employed for the soybeans production where selected. Four soil units with texture ranging from sandy loam to clay where characterized according to EMBRAPA (1999), three Ferrasols (LATOSSOLO), and one Acrisol (ARGISSOLO). Ferrasols are used for grains production and Acrissol for pasture. Vertical electrical sounding of the soils were carried using arrangements of four equally separated electrodes positioned in the soil surface. A total of 27 separations ranging from 0.10 to 2.70 m were used. Pits were dug and undisturbed samples taken in the depths of 0.05, 0.25, 0.45, 0.65 and 0.85 m immediately after the measurement of soil electrical resistance. Soil grain size distribution, bulk density, porosity, penetration resistance and water content were determined. Electrical resistance was measured in nine depths along pit walls, five of them being the same of undisturbed samples. Soil resistivity was calculated according to the model proposed by Wenner (1915), and ECa obtained by inverting this values. ECa was correlated with soil properties determined in the samples. The relation among electrode spacing and depth of investigagion was considered as showed in the Equation 1. Assuming this, as exposed by Roy and Apparao (1971), the depth of maximum contribution to the signal (Z^*) i.e. the point that mainly influences the observed resistivity and ECa. The values of ECa obtained in the surface (ECaS) were compared with those obtained in the pit walls (ECaP) and soil properties. For the identification of soil properties influencing ECa, correlations were done using ECaP.

$$Z^*=3_x a_x k$$
 in which, $a=$ electrode spacing and $k=$ constant=0.105 (1)

Values of the constant k where simulated for each soil oscillating from 0.1 and 3. The root mean square error among ECaS and ECaP calculated.

3. Results

Water content was not controlled and oscilated among soils and along the profiles variyng from 0.07 to 0.34 m^3m^{-3} . Clay content varied from 88 to 802 g kg⁻¹, bulk density from 1.0 to 1.6 Mg m⁻³ and total porosity from 40 to 63%. The ECaS presented distinct behavior for the soils, as presented in Figure 1. The Ferrasols ECaS reduced with the increase of electrodes separation even with increasing content of clay.



Figure 1. Variation of ECa for the Ferrasols, LVd1, LVd2, LAd, and the Acrisol, PVe.

In the Acrisol a peak was observed for the electrodes separations close to 1.0 m, demonstrating the presence of a more conductive layer. During soil classification a Bt horizon with increased clay content was identified at 0.55 to 0.78 m. The values of ECa varied from 0.34 to 5.11 mS m^{-1} , demonstrating the low cation exchange capacity and pronounced weathering stage of such soils.

The comparison among normalised values of ECaS and ECaP (Figure 2) showed distinct behaviour for the soils with exception of LVd1 in which both were clearly related.

Correlations showed soil structure related properties influenced ECa more that clay or water content, for PVe no single parameter was consistent (Table 1).

Soil	*WC	Clay	Silt	Sand	Micropores	Macropores	*Bd	*PR
LVd1	0.67	-0.87	0.80	0.67	0.63	-0.62	0.61	0.75
LVd2	-0.47	-0.64	-0.37	0.70	0.75	-0.52	0.37	0.25
LAd	0.18	-0.79	0.46	0.74	0.45	-0.83	0.87	0.90
PVe	0.16	-0.02	0.32	-0.13	0.08	-0.05	0.05	-0.12

Table 1. Correlation of soil properties with ECaP.

*WC: water content; Bd: bulk density; PR: penetration resistance

Values for the constant k that minimized errors for predicting ECaP using ECaS were 0.117, 0.133, 0.183 and 0.233 for LVd1, LVd2, LAd and PVe respectively, Figure 3.

4. Discussion

Previous researches on soil spatial variability properties related with ECa demonstrated clay and water content as the main influencing factors but no detailed ECa and soil structure related parameters were available.

In spite of no control for water content, this research demonstrated negative correlations among clay content and ECa for three Ferrasols and positive correlation with microporosity, indicating that for such weathered, quartz rich soils, the electrolytic



path of current through soil solution water in the porous space has prevalent importance.

Figure 2. Profile variability for water content, clay content, microporosity, macroporosity and ECa obtained though measurements made at surface, ECaS, and along pit walls, ECaP.



Figure 3. Deviations of actual values for each soil when varying k constant in the calculation of investigation depth.

The relation among electrodes spacing and depth of investigation varies according to the stratification of the medium and this characteristic is used by geophysics in the identification of layers usually in depths of tens of meters. For near surface applications in fields affected by agricultural practices, devices became inoperable when the number of electrodes and their length increase. Users usually assume a constant relation among electrode separation and depth of investigation and employ two or three electrode arrays. This research demonstrated that the depth of investigation varies among soils. In the presence of this variation along a field, the correlation of ECa obtained through constant separation traverse method with soil properties can become ambiguous.

5. Conclusion

Vertical electrical sounding was capable of identifying soil profile variability; however, the use of a unique relation among electrode separation distance and depth of investigation can lead to incorrect assumptions on soil profile variability. Well-weathered soils ECa depends largely on electrolytic current flow, which maximizes in presence of microporosity.

Acknowledgements

This project was funded by FAPESP - (São Paulo State Research Foundation).

References

ALLRED, B.J., GROOM, D., EHSANI, R.M., DANIELS, J.J. 2008. Resistivity methods. In: BALLRED, B.; JEFFREY, D.; EHSANI, R.M. (Ed.). Handbook of agricultural geophysics. Boca Raton: Taylor & Francis Group, 4: 85-108.

CORWIN, D., LESCH, S.M., FARAHANI, H.J. 2008. Theoretical Insight on the measurement of soil electrical conductivity. In: BALLRED, B.; JEFFREY, D.; **EHSANI, R.M.** (Ed.). Handbook of agricultural geophysics. Boca Raton: Taylor & Francis Group, 3: 59-83.

EMBRAPA. 1999. Sistema brasileiro de classificação de solos. Brasília: Embrapa produção de informação; Rio de Janeiro: Embrapa Solos, 412.

ROY, A., APPARAO, A. 1971. Depth of investigation in direct current methods. Geophysics, London, 36:943-959.

SZALAI, S., NOVÁK, A., SZARKA, L. 2009. Depth of investigation and vertical resolution of surface geoelectric arrays. Journal of Environmental and Engineering Geophysics, Denver, 14:15-23.

TABBAGH, A., DABAS, M., HESSE, A., PANISSOD, C. 2000. Soil resistivity: a non-invasive tool to map soil structure horizonation. Geoderma, Amsterdam, 97:393-404.

WENNER, F. 1915. A method of measuring earth resistivity. Bulletin of the Bureau of Standards, Washington, 12: 469-478.