

Acquisition and reliability of geophysical data in soil science

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Abstract

We present results of the EU- funded project iSOIL (Interactions between soil related sciences- Linking geophysics, soil science and digital soil mapping). One focus of iSOIL is the acquisition and combination of different geophysical data for proximal soil sensing and the evaluation of single geophysical methods according to their reliability. The data acquisition follows a concept, which combines different scales from plot scale to point sampling. This strategy is enabled by the application of mobile geophysical platforms, which allow fast and flexible measurements. Furthermore it is possible to mount different instruments on platforms and combine them.

A prerequisite for the common interpretation of different methods is the reproducibility of data of a single method. We present results concerning reproducibility of Electromagnetic induction (EMI) – data. EMI data depend on many factors which are also caused by the instrument itself. We investigated following aspects:

- 1) Comparison of two identical EM38DD-instruments
- 2) Comparison of the calibration of different persons
- 3) Variation of calibration height

In our presentation we show which facts have to be regarded during calibration procedure.

Key words

Measuring design, hierarchical approach, combination of methods, electromagnetic induction, reliability of data.

Introduction

The focus of the project iSOIL “Interactions between soil related sciences – Linking geophysics, soil science and digital soil mapping” is to develop new and to improve existing strategies and innovative methods for generating accurate, high-resolution soil property maps. At the same time the developments will reduce costs compared to traditional soil mapping. The project tackles this challenge by integrating the following three major components:

- high resolution, non-destructive geophysical (e.g. electromagnetic induction - EMI; ground penetrating radar, magnetics, seismics) and spectroscopic methods,
- spatial inter- and extrapolations (e.g. geostatistics, machine learning) concepts (McBratney *et al.* 2003), and
- soil sampling and validation schemes to provide representative and transferable results (Brus, *et al.* 2006; de Gruiter, *et al.* 2009; Behrens *et al.* 2006).

Thus, within iSOIL we will develop, validate, and evaluate concepts and strategies for transferring measured physical parameter distributions into soil property, soil function and soil threat maps of different scales, which are relevant to and demanded by the “Thematic Strategy for Soil Protection” (European Commission 2006). The final aim of the iSOIL project is to provide techniques and recommendations for high resolution, economically feasible, and target- oriented soil mapping under conditions which are realistic for end-user. The resulting soil property maps can be used for precision agriculture applications and soil degradation threats studies, e.g. erosion, compaction and soil organic matter decline.

Acquisition of data

The application of mobile geophysical platforms is a fast and cost efficient way to detect physical parameters of soils at large areas (Figure 1). Another advantage is the flexibility of these platforms since different kind of instruments can be mounted and combined. Hitherto following commercially available instruments are used on platforms within iSOIL project: EMI, GPR, γ -spectrometry and magnetics.



Figure 1. Mobile geophysical platform: EM31 (1st sledge) and EM38DD (2nd sledge) are towed by a tractor.

Since geophysical methods provide only physical parameters it is essential to combine them with conventional soil sampling methods for ground truthing. Via transfer functions physical parameters have to be converted into soil parameters. We need to develop measuring designs for the evaluation and combination of different geophysical methods. The application of a hierarchical approach is one way to combine different scales and parameters. The implementation of this approach works in iSOIL in the following way (Figure. 2): the first step is a survey of the total area with EMI and γ -spectrometry. The distance between two lines is 10 – 20 meters. By means of the geophysical data and a digital elevation model, 25 representative soil sampling points are chosen, via a weighted conditioned latin hypercube sampling scheme (wLHS) based on conditioned latin hypercube sampling (cLHS; Minasny and McBratney 2006).

cLHS is based on a simulated annealing scheme where samples are partly replaced randomly and based on the analysis of the cumulative frequency distribution (cdf) until the cdf of all sensors in the sample set is representative for the original cdf based on the interpolated sensor maps. In the same manner the correlation between the different sensors is preserved in the sample set. Thus, the sample set is fully representative for the original sensor data. In addition wLHS allows to integrate the state space of different sensor data separately according to a given weight.

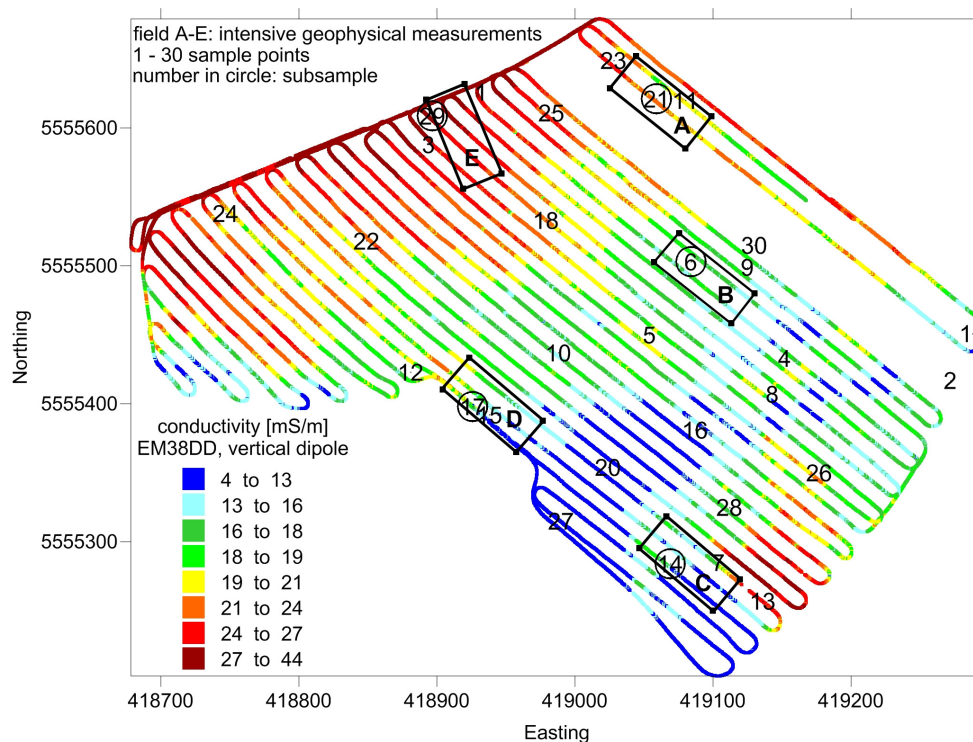


Figure 2. Implementation of a hierarchical approach: 1. survey with EM38DD (coloured lines), 2. sampling points for soil parameters calculated by cLHS (numbers), 3. fields of intensive geophysical measurements (rectangles)

All 25 soil sampling points are probed consistently by a – in iSOIL developed – sampling protocol with

conventional soil sampling methods with regard to texture, organic matter content, etc. Out of these sampling points five points are chosen for further detailed measurements. Around a single point a small area of 30 x 70 meters is placed to accomplish geophysical high resolution measurements. Besides EMI and γ -spectrometry also magnetics, seismics and GPR are applied. The line distance is only one meter and also the towing-velocity is slow.

The combination and common interpretation of different methods require several prerequisites to a single method. The measurements need to be comparable within several fields and over time. As a representative we show in the following results of a comparability study with the EMI instrument EM38DD.

Reproducibility of electromagnetic induction measurements in the near surface area

EM38DD is a widely-spread instrument for near surface applications to detect electrical conductivity of the subsurface. Among others it is used in the field of precision agriculture. The measured signal depends on many internal (caused by the instrument) and external criteria, hence measured data can be used only for qualitative interpretation.

In particular for monitoring aspects the data need to be reproducible in a quantitative manner additionally. External criteria are weather conditions as well as water content of soils and cannot be influenced. The second group of criteria implies calibration of the instrument and changes in electronics of the instrument over time.

A field campaign focused on internal factors and the results show serious differences in single measurements. At all we measured 30 test series on two lines regarding following factors:

- 1) Comparison of two identical EM38DD-instruments
- 2) Comparison of the calibration of different persons
- 3) Variation of calibration height

The influence of the factors needs to be regarded for horizontal and vertical dipole separately.

1) The comparison of both instruments shows a good reproducibility of absolute values of instrument A. The vertical dipole measures in nearly all cases the same conductivity. On the contrary vertical dipole of instrument B shows significant higher variances and a deviance in absolute values related to instrument A. This is caused by the last absolute calibration, which is longer ago for instrument B than for instrument A. The absolute calibration can be done only by the producer, but a periodic recalibration is not suggested (Figure 3a)).

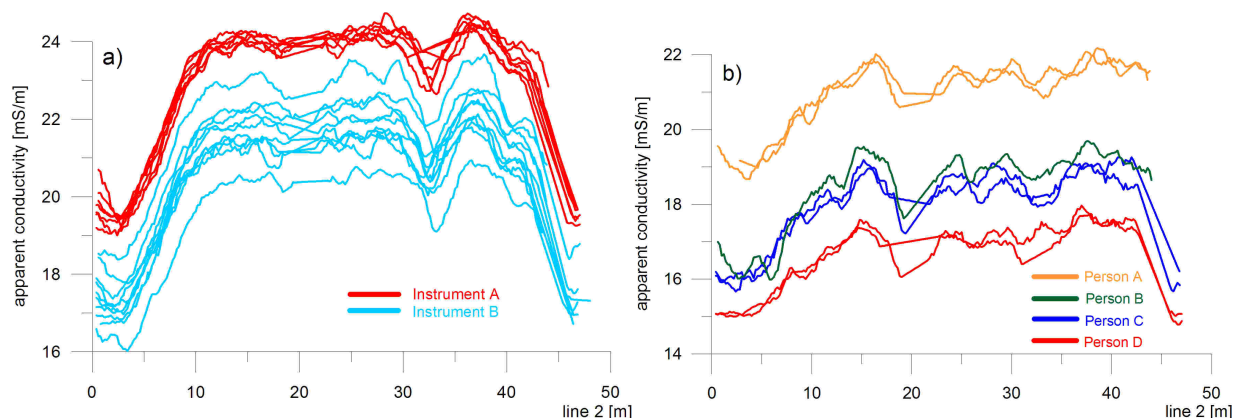


Figure 3. a) comparison of two instruments: Measurements with instrument A are reproducible, absolute values of Instrument B are lower and disperse more than Instrument A (vertical dipole). 3 b) comparison of different person: a single person calibrates the instrument in the same way, but there are differences between the persons (horizontal dipole).

2) At instrument A occur at the horizontal dipole strong dependencies, which originate by the calibration of different persons. A single person calibrates repeatable, but there deviances in different persons. The horizontal dipole of instrument B could not reproduce any data even within a single person (Figure 3 b)).

3) According to producer information the instrument should be calibrated in a height of 1.5 meters. Instead many users calibrate the instrument in shoulder height, which is seldom measured. Hence the stated height is not held. These measurements show that the vertical dipole is very stable against variations of height. Even at measurements below 1.5m the vertical dipole measures comparable data in comparison to the right height. In contrast the horizontal dipole is very sensitive to any changes in calibration height. Even small under-usage led to deviances, which are not classifiable.

If these factors accumulate, it is nearly impossible to measure reproducible data. For that reason we need to develop methods, how to evaluate the single factors and how to unify the calibration procedure.

Conclusion

Within EU-funded project iSOIL we combine different mobile geophysical method for fast and efficient soil mapping. The major prerequisite for combining is the reliability and reproducibility of data of each single method. As an example we show results of electromagnetic induction measurements. The focus of this poster is to compare three different man made factors that influence electromagnetic induction measurements: the instruments itself, the influence of the person who calibrates and the calibration height. The results show strong deviances between different instruments of the same type (EM38DD). Furthermore the measured values depend on the person who is calibrating the instrument. And at least the variation of height of calibration leads to non-classifiable variations in measured values.

Due to these factors it is necessary difficult to measure quantitative values for monitoring aspects, but errors can be minimized by reducing changes in calibration height, using always the same instrument and only one person should calibrate within one field campaign.

In addition to this contribution please see the poster presentation „iSOIL and Standardization“ for details on one activity of the iSOIL project: the CEN Workshop to establish a widely accepted voluntary standard for a best practice of EMI- measurements.

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