Non-invasive Observation of the Shallow Soil Profile Stratification and Its Effect on Soil Water Regime

Jakub Jeřábek (jakub.jerabek@fsv.cvut.cz) and David Zumr
Department of Irrigation, Drainage and Landscape Engineering, Faculty of Civil Engineering, Czech Technical University in Prague, Czech Republic

Summary

Water regime of arable soils is influenced by a presence of the compacted layer below the topsoil. At this upper part of the soil profile can be some discontinuities modifying the impact of the compacted layer on the total runoff from the hillslope. The complementary measurements of

- electrical resistivity,
- penetration resistance and
- undisturbed soil samples characteristic

were used to detect existence of such discontinuities.

Objectives are

- to obtain continuous information about the compacted layer,
- to assess the possible effect of the compacted layer to the shallow runoff.

1 Introduction

State of art of the electrical resistivity tomography (ERT) measurement technique concerning the topsoil/subsoil discontinuity is introduced. We show detailed description of used method and the description of the study site.

1.1 Brief State of Art

The application of the ERT technique for the upper soil layers is questionable due to the principle of measurement. According to Besson et al. (2004), identification of the compacted layer position using 2D ERT were doubted after the visual inspection of the measured profile. The recognition was improved, when the top soil was more homogeneous. Séger et al. (2009) employed the 3D ERT measurement to improve the top soil features (clods, loose material, cracks or wheel tracks) identification. The expected sharp delineation of the compacted layer exhibited only by smooth changes of the electrical resistivity. The ERT can probably only assist to the compacted layer identification in the soil profile as mentioned Basso et al. (2010).

1.2 Methods

ERT

- 2D shallow multielectrode electrical resistivity tomography (ARES, GF Instruments)
- dipol-dipol array
  - 9.4 m, 48 electrodes, span 0.2 m
  - 4.7 m, 48 electrodes, span 0.1 m
- calculation of the resistivity field by the inverse 2D finite element modelling (Res2DInv, GEOTOMO) (Loke, 2002)

Penetration resistance

- penetrologger (06.15.SC Eijkelkamp), 60° steel cone
  - 5 tests within each penetration plot
  - 3 to 5 plots per each ERT profile

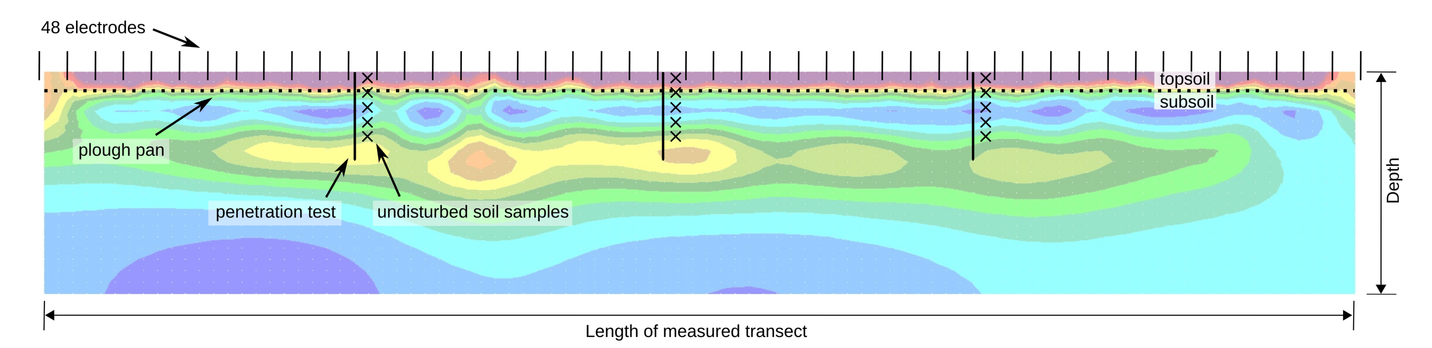
Soil samples

- gravimetry
  - bulk density, total porosity, volumetric water content
  - particle size analysis

1.3 Study site

- The Nucice experimental catchment, central part of the Czech Republic
- Humid continental climate
- Average annual precipitation of 630 mm, evapotranspiration of 500-550 mm
- Mean annual air temperature is 6°
- The average elevation is 401 m with the mean slope 3.9%
- 95.3% of the total area (0.5 km^2) is exposed to the active cultivation
- Soil classified as Cambisols and Luvisols
  - loamy with clay content around 8%
  - loamy Ap horizon (0.1 - 0.2 m)
  - silty and silty-clay B horizon
  - low inner aggregate (soil matrix) hydr. conductivity (0.1 - 2 $\frac{cm}{d}$)
  - topsoil saturated hydraulic conductivity is significantly higher and varies depending on the season

1.4 Typical measurement set up



2 Measured time series and other measurements

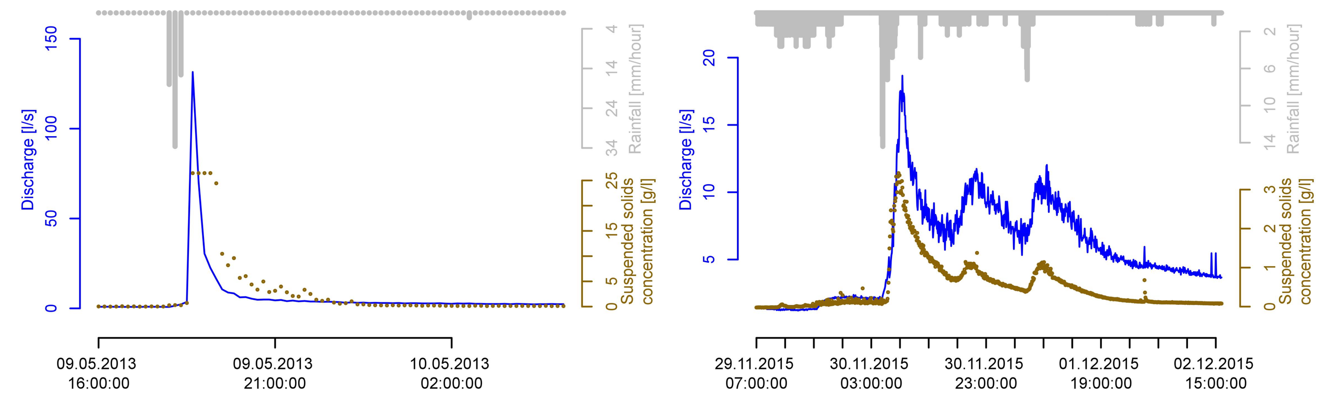
Recorded rainfall-runoff events show a rapid response of the catchment. The overland flow (indicated by high turbidity at the catchment outlet) is however rare. This fact can lead to a conclusion that the compacted layer, which is ofter formed at the agricultural catchments is the factor causing the rapid runoff response. Following results show the macroscopic structure and spatial heterogeneity along the measured transects.

2.1 The water regime

The water regime at the catchment scale is influenced by the compacted layer.

left: overland flow causes rapid response and large sediment concentrations at the catchment outlet

right: sub-surface runoff is also rapid, but the sediment concentrations is low and mostly caused by displacement of sediment from the watercourse bed



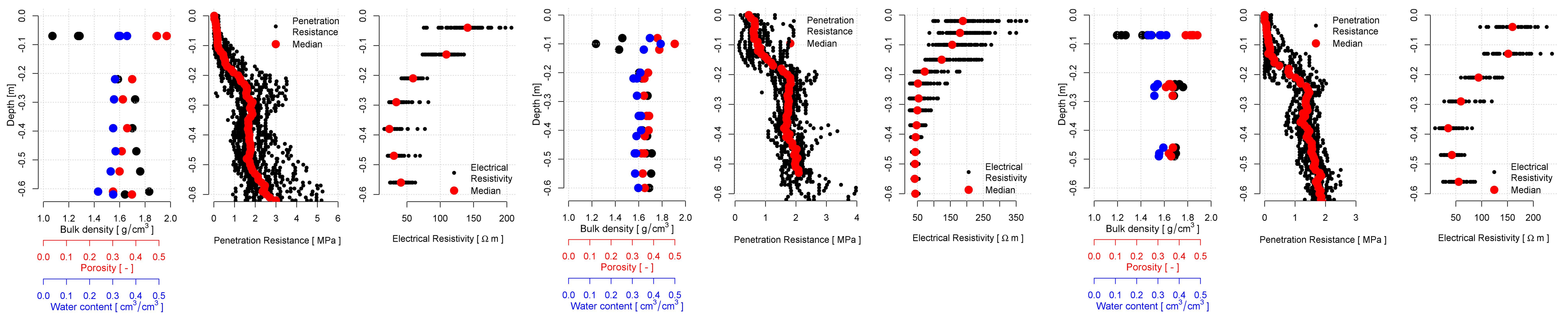
2.2 Comparative measurements

Undisturbed soil samples physical properties, penetration resistance and electrical resistivity of measured transects along soil depth.

A) Measurements at field where deep ploughing disrupts the compacted layer (R at Fig.1)

B) Measurements at field where conventional tillage takes place (T at Fig.1), after seedbed preparation

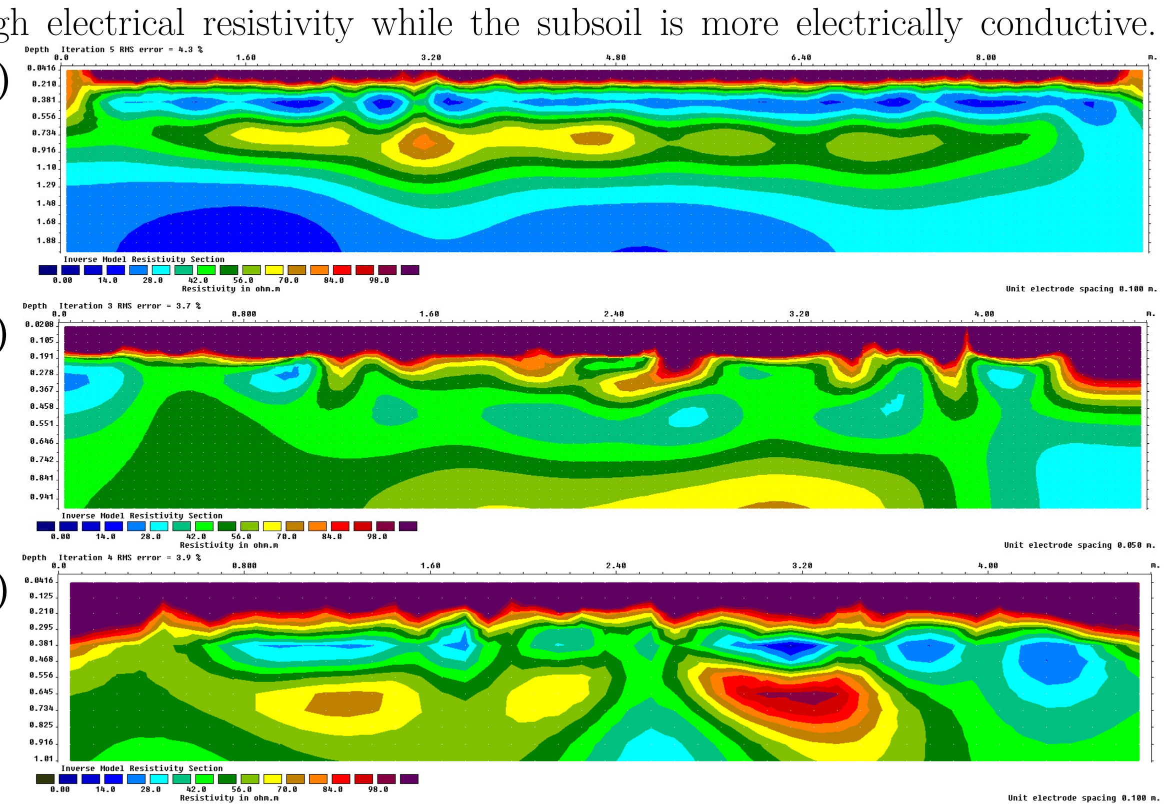
C) Measurements at field where conventional tillage takes place (T at Fig.1), after winter with no cultivation activity



2.3 ERT results

ERT profiles indicate the changes in soil structure. Topsoil exhibits high electrical resistivity while the subsoil is more electrically conductive.

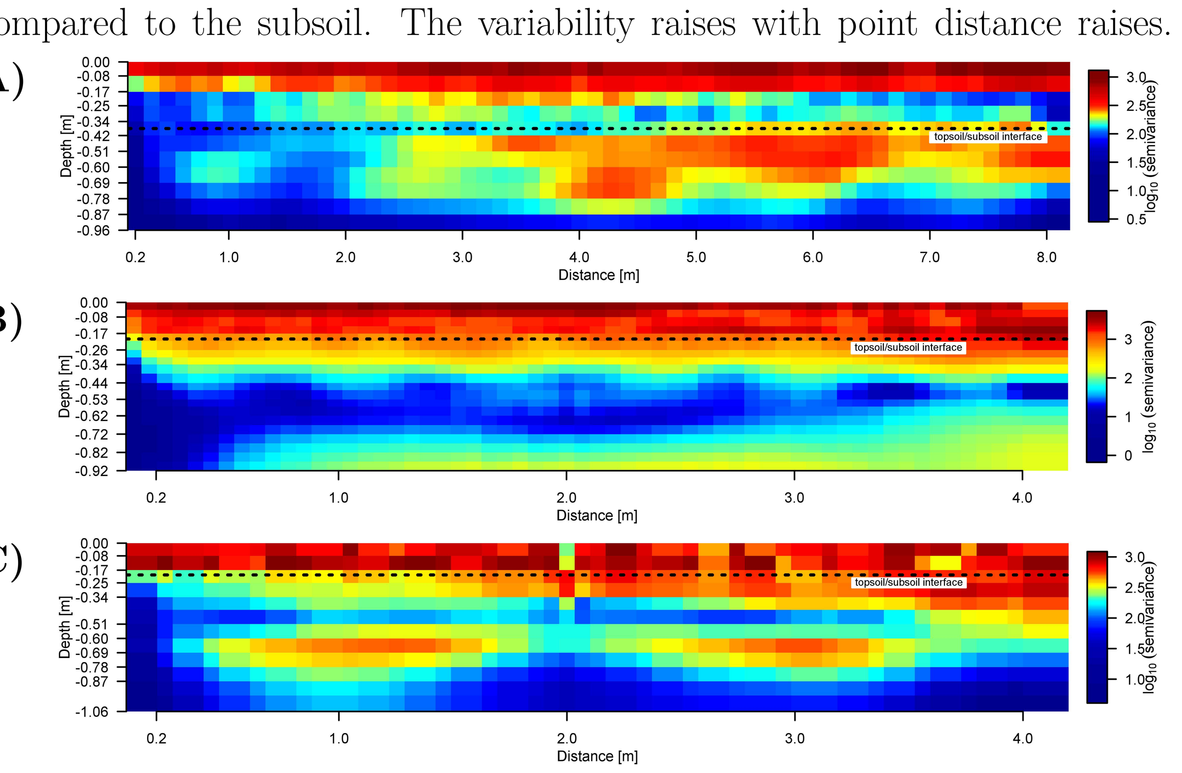
A)
B)
C)



2.4 Semivariance of el. resistivities

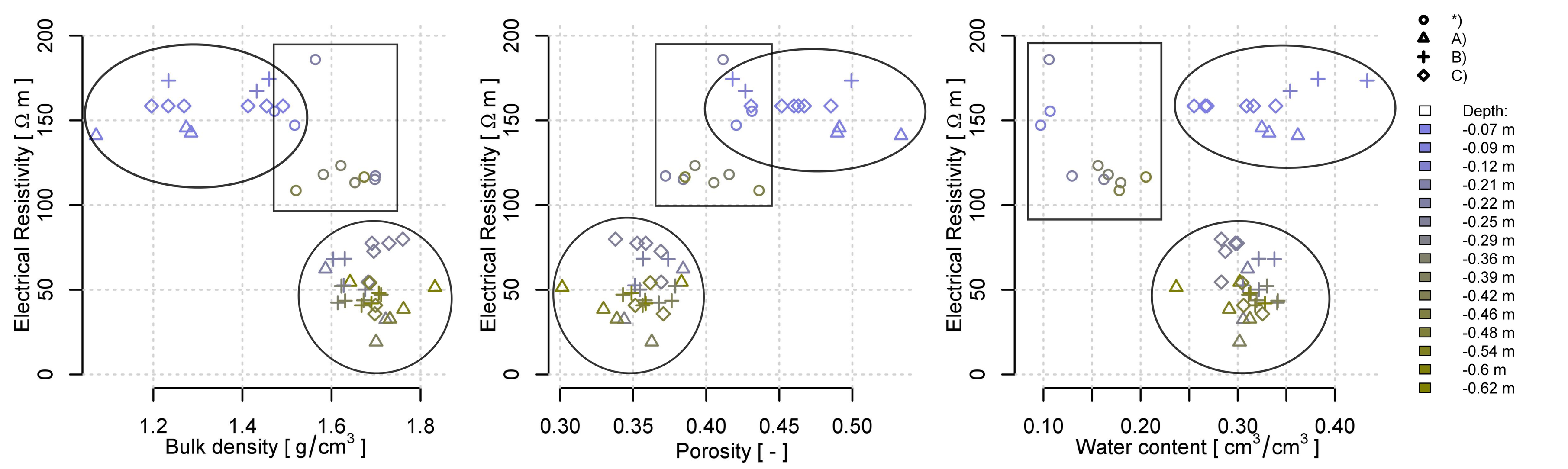
Topsoil with high electrical resistance also exhibits larger spatial variance compared to the subsoil. The variability raises with point distance raises.

A)
B)
C)



2.5 el. resistivity vs. soil properties

Scatter-plot of electrical resistivity and soil physical properties. Under moderate to high water content conditions the data points exhibit two clusters (data points in circles). Upper cluster contains measurements from topsoil, lower cluster from subsoil. Data points circumscribed by rectangle were collected under very dry conditions and exhibit no clustering.



*) data not shown at previous figures

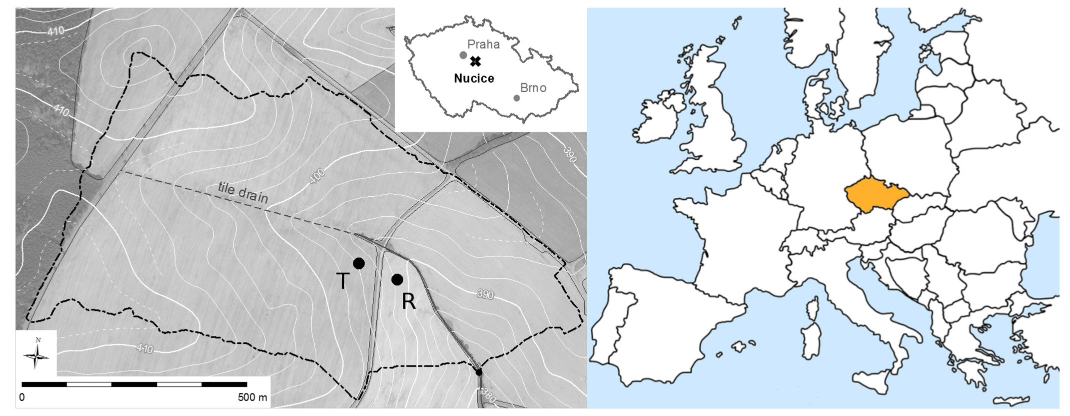


Fig. 1: The study site location

The topsoil/subsoil divide and studied field

3 Results and Conclusions

3.1 Results

- Penetration resistance measurement and ERT were strongly influenced by the water content
- A threshold moisture content has to be reached to obtain reliable data
- Soil bulk density, el. resistivity and resistance to mechanical penetration are correlated
- El. resistivity semivariance decreased rapidly with depth for all distances

3.2 Conclusions

- The obtained ERT profiles are influenced by the actual soil conditions. Measuring under relatively wet conditions resulted in well stratified layers. The method is not suitable for very dry soil conditions
- Compacted layer position, as measured by different techniques, is in an agreement. There are no major disturbances. Minor discontinuities, such as macropores, are below the ERT resolution
- Predominant shallow runoff is possible, since the saturated region emerged at the soil layer transition

3.3 Acknowledgement

The research has been supported by CTU internal project SGS16/143/OHK1/2T/11 and by project granted by Czech Science Foundation No. 13-20388P

3.4 References

Basso, B., Amato, M., Bitella, G., Rossi, R., Kravchenko, A., M., L. S. L., Carvahlo, and Gomes, J. (2010). Two-dimensional spatial and temporal variation of soil physical properties in tillage systems using electrical resistivity tomography. *Agronomy Journal*, 102(2):440–449.

Besson, A., Cousin, I., Samouëlian, A., Boizard, H., and Richard, G. (2004). Structural heterogeneity of the soil tilled layer as characterized by 2d electrical resistivity surveying. *Soil and Tillage Research*, 79(2):239–249.

Loke, M. H. (2002). Res2dinv ver. 3.54. rapid 2-d resistivity and ip inversion using the least square method. *Geotomo Software*.

Séger, M., Cousin, I., Frison, A., Boizard, H., and Richard, G. (2009). Characterisation of the structural heterogeneity of the soil tilled layer by using in situ 2d and 3d electrical resistivity measurements. *Soil and Tillage Research*, 103(2):387–398.

The latex template used to create this poster was made by Computational Physics and Biophysics Group, Jacobs University under the licence: CC BY-NC-SA 3.0 (http://creativecommons.org/licenses/by-nc-sa/3.0/)