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Can we quantify local groundwater recharge using electrical resistivity tomography?

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Electrical resistivity tomography (ERT) has become a common tool to observe flow processes within the saturated/unsaturated zones. While it is still doubtful whether the method can reliably yield quantitative results the qualitative success has been shown in “numerous” examples. To quantify the rate of rainfall which reaches the groundwater table is still a problematic venture due to a sad combination of several physical and mathematical obstacles that may lead to huge errors.
In 2007 an infiltration experiment was performed and observed using 3D array ERT. The site is located close to Hannover, Germany, on a well studied sandy soil. The groundwater table at this site was at a depth of about 1.3 m. The inversion results of the ERT data yield reliably looking pictures of the infiltration process. Later experiments nearby using tracer fluid and combined TDR and resistivity measurements in the subsurface strongly supported the assumption that the resistivity pictures indeed depict the water distributions during infiltration reliably. The quantitative interpretation shows that two days after infiltration about 40% of the water has reached the groundwater. However, the question remains how reliable this quantitative interpretation actually is.

The first obstacle: The inversion of the ERT data gives one possible resistivity distribution within the subsurface that can explain the data. It is not necessarily the right one and the result depends on the error model and the inversion parameters and method. For these measurements we assume the same error for every single quadrupole (3%), applied the Gauss-Newton method and minimum length constraints in order to reduce the smoothing to a minimum (very small lambda). Numerical experiments showed little smoothing using this approach, and smoothing must be suppressed if preferential flow is to be seen. The inversion showed artefacts of minor amplitude compared with other inversion parameter settings.
The second obstacle: The petrophysical function that relates the resistivity changes to water content changes is doubtful. This relationship was constructed by two ways; firstly by comparing in situ measured water contents and the ERT inversion results, secondly by laboratory measurements of soil samples taken at different depth. The results of these both methods vary; moreover, heterogeneity in the subsurface may cause an even greater variability of this relationship. For the calculation an “average” function was applied.
The third obstacle: The pore water conductivity may change during the infiltration due to exchange of pore water. This effect is neglected for this experiment on account of the very similar resistivity of original pore water and infiltrated water. This effect, however, is of great importance if saline water is used for infiltration experiments. It will also hamper the quantitative interpretation if solution and precipitation processes within the soil during the infiltration are expected.
The fourth obstacle: The disadvantageous shape of the function relating resistivity and water content. Unfortunately at high water contents only very little change in resistivity is observed if the water content increases or decreases, the function is steep only at small and medium water contents but very flat at high water contents.
We conclude from the combination of these four obstacles that quantitative interpretation of recharge with ERT is possible only in fortunate cases. ERT can enable us to actually measure recharge processes. However, if the conditions are not fortunate, the interpretation of the ERT data will permit the conclusion whether there is recharge. The quantitative value will remain doubtful if no additional measurements are taken that narrow the uncertainties. Particularly TDR/resistivity measurements with the same probe are helpful to get the information about the mixing of the pore water.