Resistivity monitoring of an irrigation experiment at Högbytorp, Sweden

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Resistivity Monitoring of an Irrigation Experiment at Högbytorp, Sweden

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SUMMARY

An irrigation experiment was carried out close to the Högbytorp waste site outside Stockholm, Sweden, in which leachate water from the waste site was used for irrigation of a Salix plantation. Three different irrigation levels were used, plus no irrigation as control. Resistivity imaging was used at a number of time steps with the objective to try to monitor changes in water saturation and salinity in the ground. The monitoring results show strong potential for the method. Variation in soils properties are indicated by the variation in resistivity. Changes in resistivity that correlate well with differences in irrigation quantities and plant growth are evident. The experiment is planned to continue, and more in-depth analysis of all available data will be carried out. It is beyond doubt, however, that a lot of information related to variation in water quantity and quality is contained in the resistivity imaging results.

Introduction

An irrigation experiment was carried out close to the Högbytorp waste site outside Stockholm, Sweden, in which leachate water from the waste site was used for irrigation of a *Salix* plantation. Two different varieties of *Salix*, called Tora and Gudrun, were planted, according to the sketch map show in Figure 1. Three different irrigation levels were used corresponding to 0.47, 0.9 and 1.4 mm/day (referred to as treatment 1, 2 and 3) distributed as shown in Figure 1, plus no irrigation (treatment 0). The total amount of irrigation in mm for the different treatments is shown in Figure 2. Resistivity imaging was, among other methods, used at a number of time steps with the objective to try to monitor changes in water saturation and salinity in the ground. This paper presents preliminary results of the experiment that continues this year, where the evaluation has not yet taken into account all data available.

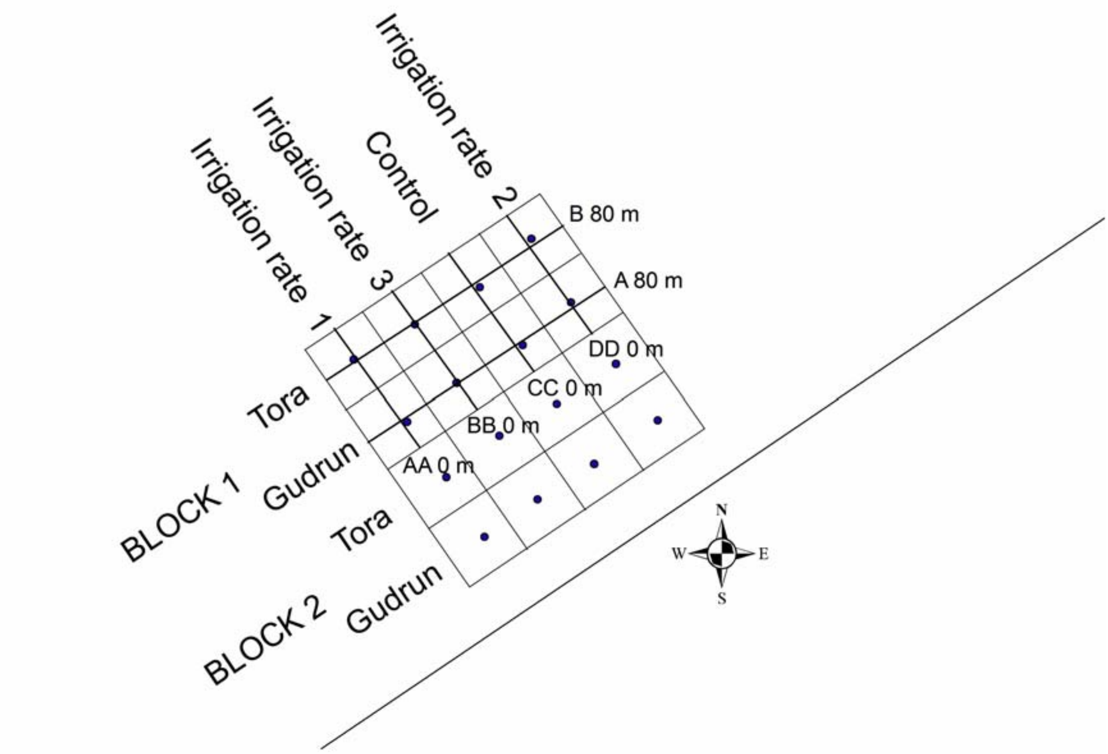

Figure 1. Sketch map of field experiment design including resistivity imaging lines (A, B, AA, BB, CC and DD) and positions of groundwater standpipes (marked by dots). The test square is 80 m x 80 m in size.

Method

Resistivity imaging was carried out along 6 lines. Two parallel (SW-NE direction) 80 metres long lines, Line A and Line B, were measured with 1 m electrode separation (see Figure 1). Four perpendicular (SE-NW direction) 40 metres long lines, Line AA, Line BB, Line CC and Line DD, were measured with 0.5 metres electrode separation in the. Measurements were carried out at 6 different occasions during July to September 2005. The shorter lines were measured each time, whereas the complete set including the longer lines were only measured at three occasions in order to save time in the field. The ABEM Lund Imaging System was used for multi-channel measuring using multiple gradient array (Dahlin and Zhou 2006), which gave a time efficient field procedure and stable results.

Data was inverted using Res2dinv to create model cross sections of the distribution of resistivity in the ground. Time-lapse inversion was used in order to analyse the change in resistivity with time (Loke 2001), where the first measured data was used as reference data set, and the results plotted as relative change in resistivity.

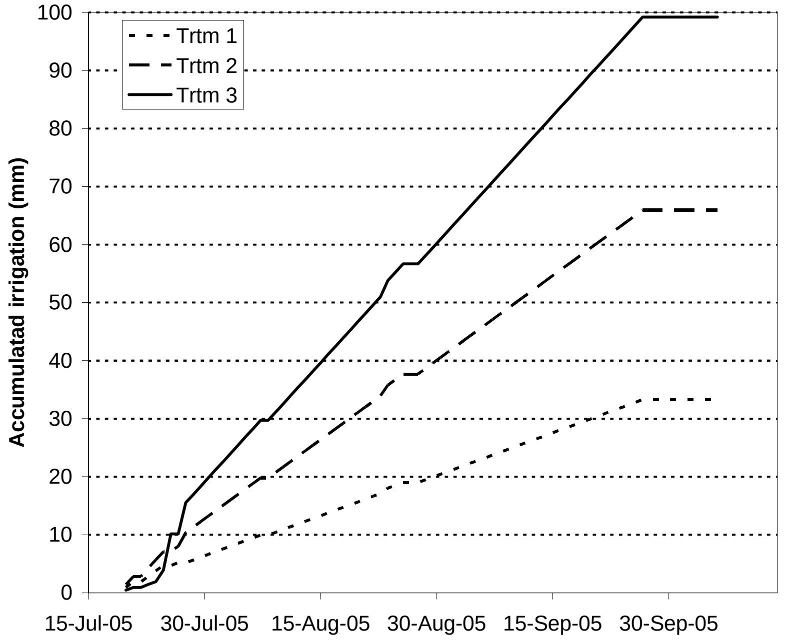

Figure 2. Accumulated irrigation for each treatment.

Results

The inverted resistivity sections (Figure 3a and Figure 4a) show that relatively low resistivities (10-25 Ωm) dominate the experiment site, corresponding to fine grained soils. The resistivities are slightly higher (up to around 40 Ωm) near the surface in the south-eastern part of the area, reflecting less fines. Higher resistivities (> 100 Ωm) are evident at a few metres depth, coming closer to the surface in the north-western corner, caused by coarse grained soils and/or bedrock. An anomalous zone is evident at 10 meters in Line BB (Figure 3), which coincides with the position of a metal pipe.

In the difference sections, the lines measured through irrigated squares show distinct zones of decrease in resistivity (>25% decrease) that match up well with the positions of the drop irrigation lines, as shown by the example in Figure 3b. The size of the resistivity decrease zones increase with increased accumulated irrigation (Figure 3b-f), and these zones can be interpreted as being caused by increased water content. Such zones are also evident for the lines that run across squares with smaller amounts of irrigation, but they are smaller in extent.

Less distinct zones of resistivity decrease (10-15%) are visible at around 1-2 metres depth, at line coordinates above 28 meters in Figure 3b, that seems to spread laterally with increasing time. This can be interpreted as increased ion content in the water of the shallow saturated zone, which accumulates and spreads in a more permeable zone. The groundwater level lies at 0.8 meters below surface on average. It may also to some extent be a result of higher water content in the unsaturated zone.

In between the irrigation lines there are zones of increased resistivity at the surface, which can be interpreted as being caused by a decrease in soil moisture as a result of water consumption by the plants via the roots. These zones of increased resistivity grow as the plants grow.

The low resistive feature associated with a metal pipe at 10 metes on Line BB displays decrease in resistivity in the first time steps (Figure 3b and 3C), which may be caused by water infiltrating along the pipe giving good coupling. Before the last survey the pipe had been removed, causing an increase in resistivity (Figure 3f).

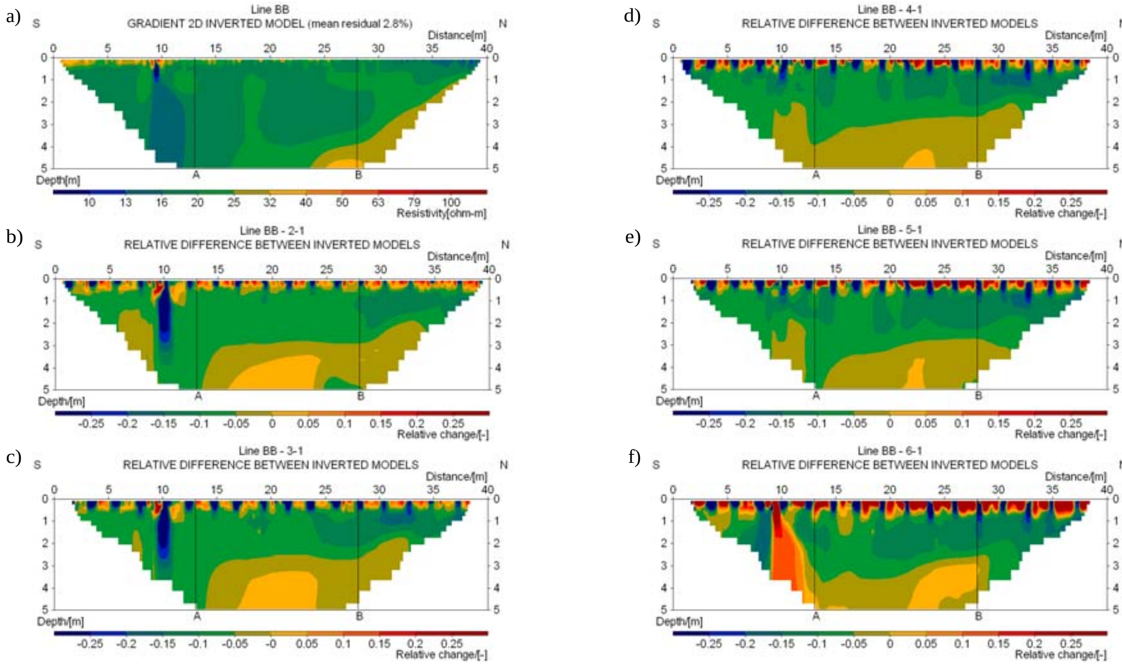

Figure 3. Results from Line BB, maximum irrigation treatment. a) resistivity model (before irrigation started), b) to f) change in resistivity relative to start of experiment during the period July to September 2005.

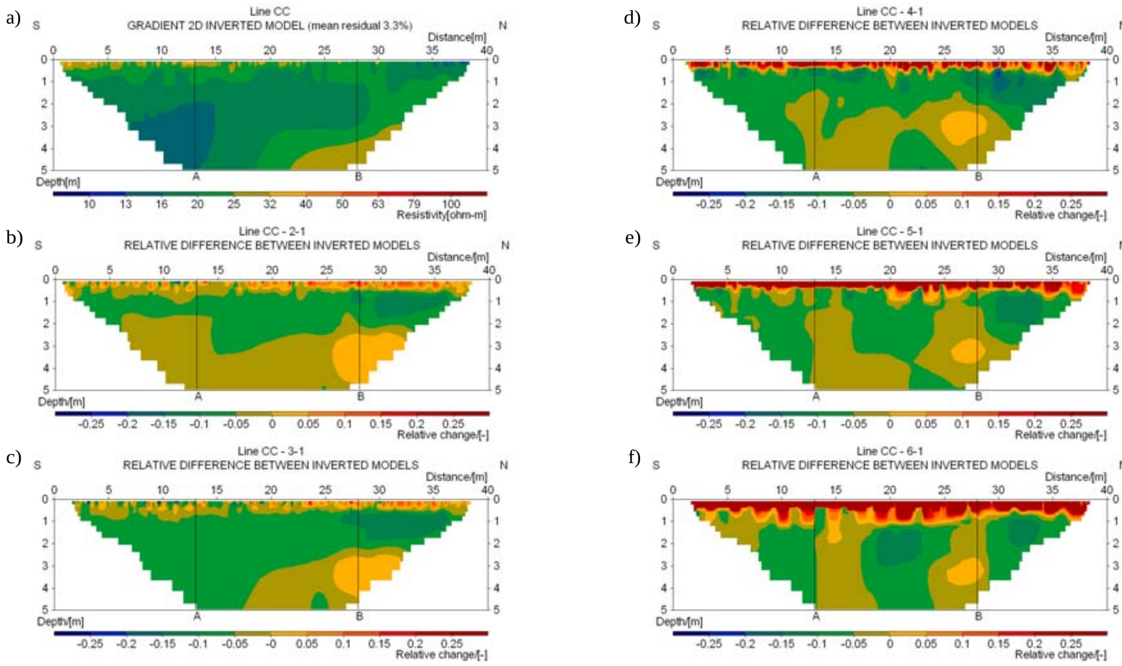

Figure 4. Results from Line CC, no irrigation treatment. a) resistivity model (before irrigation started), b) to f) change in resistivity relative to start of experiment during the period July to September 2005.

The line measured across the squares that are not irrigated (Line CC) does not have the near surface spots of decrease in resistivity, as expected. The zones of resistivity increase that are interpreted to be caused by plant water consumption are more prominent for this line, as would also be expected given that the extra water from the irrigation is absent. The zone of decrease in resistivity at 1-2 meters depth appears on this lines as well, although less prominent, and it may be interpreted as being caused by lateral movement of water from the irrigated lines.

Conclusions

Monitoring of the irrigation experiment with resistivity imaging shows a strong potential for the method. Variation in soils properties are indicated by the variation in resistivity. Changes in resistivity that correlate well with differences in irrigation quantities and plant growth are evident. The experiment is planned to continue, and more in-depth analysis of all available data will be carried out. It is beyond doubt, however, that a lot of information related to variation in water quantity and quality is contained in the resistivity imaging results.

References

Dahlin, T. and Zhou, B. (2006) Gradient array measurements for multi-channel 2D resistivity imaging, *Near Surface Geophysics*, 4, 113-123.

Loke, M.H. (2001) Constrained time-lapse resistivity imaging inversion, *Procs. SAGEEP 2001 (Symposium on the Application of Geophysics to Engineering and Environmental Problems)*, Denver, Colorado, March 4-7 2001.