GEOPHYSICAL CHARACTERIZATION OF GOLF COURSE GREENS IRRIGATED WITH RECLAIMED WASTEWATER

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Abstract

The main objective of this study is to demonstrate that near-surface geophysical methods can provide useful information for improving the maintenance labours of golf courses irrigated with reclaimed wastewater. Typically, for determining the geometry, textural properties and salinity of soils and substrates, samples should be removed from the different zones of the golf course and submitted to an accredited physical soil testing laboratory, which is expensive and time-consuming. Electrical resistivity tomography method is an efficient tool that can be used by golf course greenkeepers to assess lateral and vertical variability of soils and substrates and prevent salinity hazard from irrigation with reclaimed wastewater. The study has shown that, although soil electrical resistivity depends simultaneously on many soil properties like moisture and salinity, can be easily correlated with the textural composition of sandy soils used for building green areas of golf courses.

Introduction

Actually, there are over 300 golf courses and more than three thousand licensed players in Spain and golf cannot be considered simply as one sport activity, because very significant economic interests are involved in it. In Catalonia, golf produces an economic impact of almost 20 million euro per year and the Tourism Authority of Catalonia proposed some time ago golf as a policy to promote special-interest tourism. Considered as one of the most rapidly expanding types of extensive land-use and water requirements, golf course development generates controversy. For this reason, in the recent years there has been a considerable demand for golf courses to adopt environmentally sustainable strategies and particularly water authorities are forcing by law golf managers to irrigate with alternative water resources, mainly reclaimed wastewater (Mujeriego and Sala, 1991). Water requirements for irrigating a golf course depend on climatic variables and also to a great extent on the characteristics of the soil that serves as substrate. Sandy soils do not retain water in the same way as muddy or clayey soils. Infiltration is generally faster as soil grains are coarser; therefore, water must be applied more frequently. Therefore, non-destructive tools are needed for obtaining information on shallow subsurface features of the golf course, particularly tees and greens (Tapias and Salgot, 2006).

To date, few researches have reported about the utility of geophysical methods for a fast, accurate and cost-effective inspection of soils and substrates of golf courses. Boniak et al. (2002) tested ground penetrating radar at two golf course greens of Illinois and were successful in mapping subsurface features (soil layers and drainage pipes). Allred et al (2005) focused on the use of electromagnetic induction and ground penetrating radar at three different golf courses of Ohio and Ontario. Xia and Miller (2007) used integrated geophysical survey in defining subsidence features on a golf course constructed over a landfill in Kansas. In this study a detailed geophysical survey using electrical resistivity tomography profiles have been recorded with the objective to assess the usefulness of this technique to characterize the thickness and textural properties of the materials used to build the different greens of a golf course.

Methods

The geophysical survey was conducted over the greens of the Girona Golf Club. Eighteen electrical resistivity tomographies were acquired using a mixed Wenner-Schlumberger configuration with electrodes placed 0.5 meter apart. Small stainless-steel nails were used as electrodes to avoid any damage in the fine turfgrass of greens The resistivity meter was set for systematically and automatically selects current electrodes and measurement electrodes to sample apparent resistivity values. An inversion technique was employed to process the data using RES2DINV software based on the smoothness-constrained least-squares inversion of pseudo-section data (Loke and Barker 1996) where the resistivity of each block is evaluated by minimizing the difference between observed and calculated pseudo-sections using an iterative scheme.

Particle size analysis (PSA) has been performed on soil materials of any putting green. The PSA analysis has been composed of two distinct phases. The first has been the textural analysis of the soils for determining the content of sand, silt, and clay fraction via the use of a stack of sieves with decreasing sized openings from the top sieve to the bottom. Subsequently, the hydraulic conductivity of the substrates has been evaluated by means of Bredding and Hazen empirical relationships.

Results and discussion

In figure 1 the inverted resistivity models of two profiles recorded along the most contrasting green models of the Girona Golf Club are shown. The same resistivity scale has been chosen for make simpler the visual assessment and interpretation of the profiles. Each model has the same two layers structure with a high resistivity layer at top followed by a lower resistivity layer (Figure 2). Nevertheless, the differences in thickness and resistivity values of the sandy top layer are quite evident and correlate with the texture derived from the particle size analysis. Also is shown that the resistivity of the underlaying layer changes considerably giving information about the lithology of the natural geological formation lying under the substrate of sand added for building the putting green.

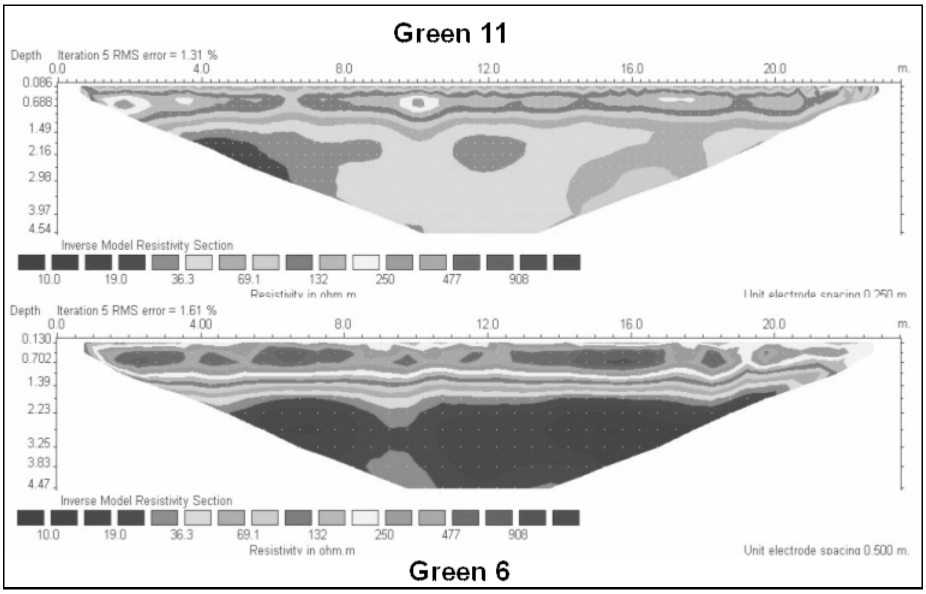

Figure 1. Inverted resistivity models of the profiles recorded along the greens of the holes 11 and 6, showing the same two layers structure with a high resistivity layer at top followed by a low resistivity layer with differences in thickness and resistivity values.

Conclusions

This study has demonstrated that electrical resistivity tomography method can be very useful for the non-destructive precise characterisation of soils and substrates of golf courses. Many golf courses use diagnostic core testing when making decisions concerning maintenance and renovation, nevertheless this procedure gives only poin- valuable insight about the subsurface characteristics. In opposition, electrical resistivity tomography method provides information on spatial changes of electrical resistivity properties that can be correlated with changes in texture, wetness and salinity of the subsoil within different areas of a golf course irrigated with reclaimed wastewater.

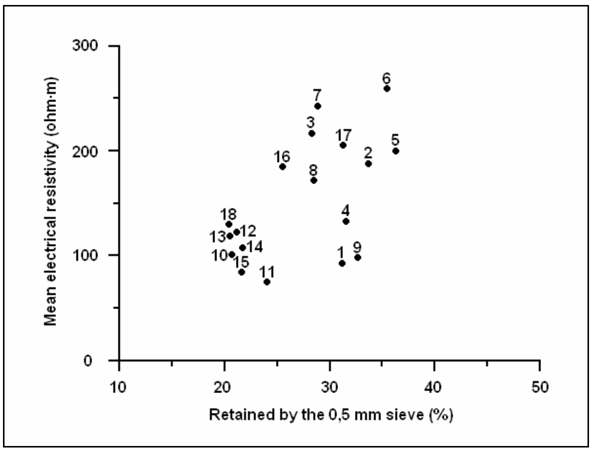

Figure 2. Relationship between mean electrical resistivity and texture of the upper sandy layer used to build each green at the Girona Golf Course.

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