

# Equivalent electrical circuit model for system containing quartz sand and purified water

Mika Lampela<sup>1</sup>, Tapani Repo<sup>1</sup>, Raimo Silvennoinen<sup>2</sup>, Leena Finér<sup>1</sup>



## Introduction

Detailed knowledge is needed of the effects of the growth substrate in order to measure root growth by electrical impedance spectroscopy. The aim was to study electrical impedance of quartz sand as a function of soil moisture content.

## Material and Methods

The impedance spectra (IS) of quartz sand were measured using the setup in Fig. 1. Fine-textured silica sand (grain size 0.063 – 0.2 mm 0.9%, 0.2 – 0.63 mm 28.5%, 0.63 – 2 mm 70.6%) was dried and then moistened by fixed amounts of distilled water. The IS measurements (201 frequencies between 60 Hz and 1MHz) were repeated twice at each moisture content with the probe set perpendicularly. Complex Nonlinear Least Squares (CNLS) fitting program (LEVW ver.8.0) was used to estimate the parameters of the proposed equivalent electrical circuit (Fig. 2).

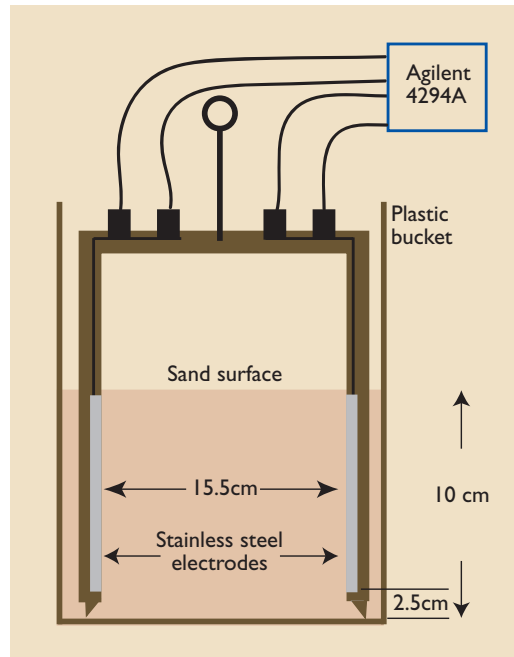


Fig. 1. The electrode probe for measuring impedance spectra of soil. Electrode surface area was 20 mm x 60 mm.

## Results

The IS of silica sand changed with increasing volumetric soil moisture content (MC) (Fig. 3). The proposed model fit well into the IS data. Resistance  $R_2$  was most strongly dependent on soil MC, especially at the low MC levels (Fig. 4B). The relative errors of parameters by CNLS fit were typically between 1 and 2% and even less for resistance  $R_1$  (Fig. 5).

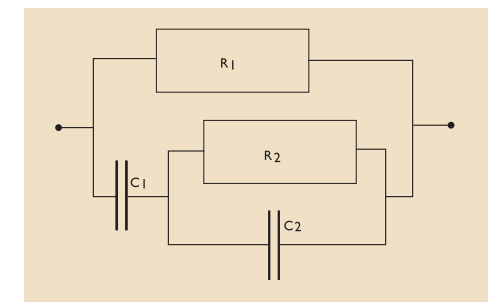


Fig. 2. The equivalent electrical circuit for silica sand.

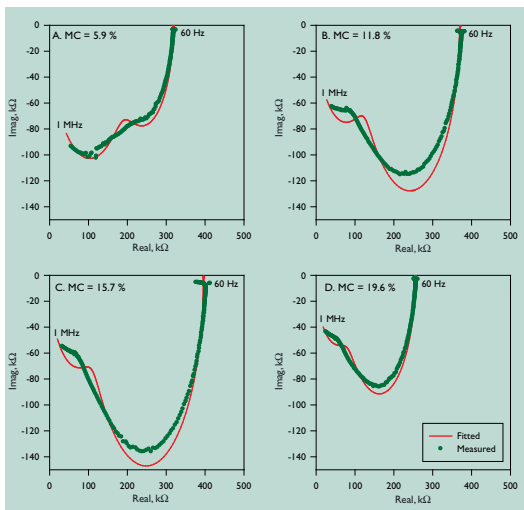


Fig. 3A-D. Examples of the measured impedance spectra for silica sand at different volumetric moisture contents (MC), and the best fit of the equivalent circuit in Fig. 2.

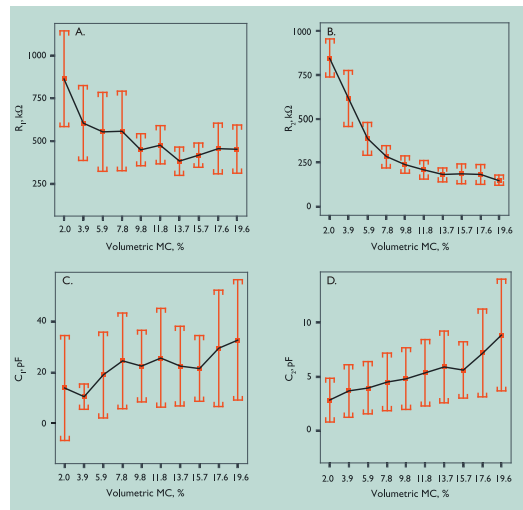


Fig. 4A-D. The parameters of the RC-circuit in Fig. 2 (mean and 95% CI) with volumetric moisture content (MC) (n=10).

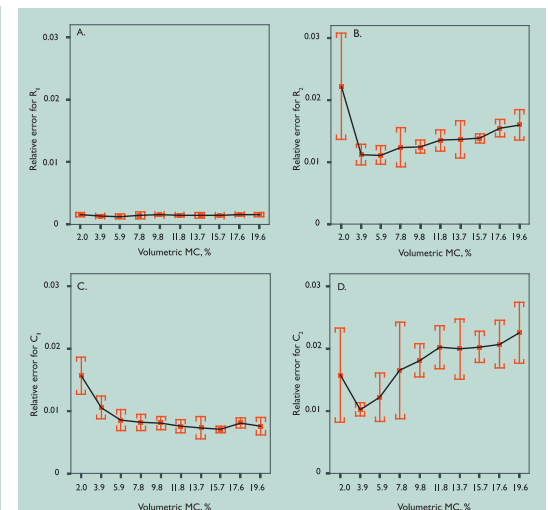


Fig. 5A-D. Relative errors (standard deviation/parameter estimate) for the fitted circuit parameters (mean and 95% CI) with volumetric moisture content (MC) (n=10).

## Conclusions

The impedance characteristics of soil, especially soil moisture content, should be considered in further development of the method for monitoring root growth.

<sup>1</sup> Finnish Forest Research Institute, Joensuu Research Unit, P.O. Box 68, FI-80101, Joensuu, Finland. e-mail: mika.lampela@metla.fi

<sup>2</sup> University of Joensuu, Department of Physics and Mathematics, P.O. Box 111, FI-80101, Joensuu, Finland