

**Measuring Soil Water Content and Electrical Conductivity
Under High Salinity Conditions Using a Novel TDR Method**

Problem and Research Objectives

Approximately one-third of the developed agricultural land in arid and semi-arid regions reflect some degree of salt accumulation, while more than 25% of the 47 million acres of irrigated agricultural land within the U.S. is affected by salinity (Allison 1964, Tanji 1990). Determining the accurate measurement of soil water content and electric conductivity (EC) in highly saline soils can improve the practical operation of irrigation systems, guide the installation of drainage systems, and provide fundamental information for establishing and validating the algorithm of microwave remote sensing of soil moisture. However, the widely used nondestructive in-situ method, time domain reflectometry (TDR), failed to work under high salinity condition.

Feng et al. (1999) proposed an alternative inverse analysis method to analyze the data from the TDR measurements in the frequency domain. They developed a model, the scatter function of a multi-section transmission line, which can theoretically be applied to any salinity condition. This theoretical model estimates the dielectric permittivity (DP), which is then converted to soil water content by calibration. However, there is no published material that specifically explores using the inverse analysis method under high salinity conditions.

The following are the objectives of this research study:

1. Apply the inverse analysis method proposed by Feng et al. (1999) to measure soil water content and EC under highly saline conditions.
2. Examine the accuracy and upper limit of measurability by the inverse analysis method using commercial probes.

Methodology

To achieve these objectives, the study:

1. Conducted laboratory experiments to determine the accuracy and upper limit of the measurability by the inverse analysis method. The NaCl solutions were made by mixing different amount of NaCl with deionized water. The Makiki soil (fine, mixed, active, isohyperthermic typic haplustepts) was taken from a depth of 0 to 5 cm at a site located on the bank of the Makiki Stream, Oahu, Hawaii. The soil water content varied from 0.15 to 0.47 $\text{m}^3 \text{m}^{-3}$, and the soil bulk EC varied from 0.09 to 0.28 Sm^{-1} . The commercial CS605 probe (Campbell Scientific, Inc.) with three rods of 30-cm length, and TDR100 device (Campbell Scientific, Inc.), were used to measure the waveforms of electromagnetic wave propagating along the probe inserted in the NaCl solution or soils. The estimates of DP and EC were obtained from the detailed algorithms for data analysis (Shuai et al. 2009). The upper limit of the measureability by the inverse analysis method was obtained by comparison of the estimates and the results from the materials under actual test conditions.
2. Analyzed the sensitivity of the mathematical models in the inverse analysis method. In high salinity conditions, the direct current conductivity was significant and the transmission line may be viewed as being connected to a resistor between the central rod and outside rods. Instead of using the measured scatter function (S_{11}), the variation of (1-

$S_{11_{1m}}/(1+S_{11_{1m}})$ was used to illustrate the sensitivity of the inverse analysis method to EC and DP of materials under test conditions.

Principal Findings and Significance

1. The measurement of EC in soils and sodium chloride solutions was inaccurate when EC was higher than 0.35 Sm^{-1} .
2. The measurement of dielectric permittivity of soils and sodium chloride solutions was inaccurate when EC was higher than 0.08 Sm^{-1} .
3. The findings supported the results from the simulation of the scatter function, which was sensitive to EC but not to DP.
4. More work is needed to improve the measurement accuracy of DP in high salinity conditions.

Publications Cited in Synopsis

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