

1976

Soil Salinity Measurement by the Four-Electrode Probe Technique

K. Sriotai

University of Arkansas, Fayetteville

John T. Gilmour

University of Arkansas, Fayetteville

Follow this and additional works at: <https://scholarworks.uark.edu/jaas>



Part of the [Agronomy and Crop Sciences Commons](#)

Recommended Citation

Sriotai, K. and Gilmour, John T. (1976) "Soil Salinity Measurement by the Four-Electrode Probe Technique," *Journal of the Arkansas Academy of Science*: Vol. 30 , Article 33.

Available at: <https://scholarworks.uark.edu/jaas/vol30/iss1/33>

This article is available for use under the Creative Commons license: Attribution-NoDerivatives 4.0 International (CC BY-ND 4.0). Users are able to read, download, copy, print, distribute, search, link to the full texts of these articles, or use them for any other lawful purpose, without asking prior permission from the publisher or the author.

This Article is brought to you for free and open access by ScholarWorks@UARK. It has been accepted for inclusion in *Journal of the Arkansas Academy of Science* by an authorized editor of ScholarWorks@UARK. For more information, please contact scholar@uark.edu.

Soil Salinity Measurement by the Four-Electrode Probe Technique*

K. SRIYOTAI and J. T. GILMOUR
Department of Agronomy, University of Arkansas,
Fayetteville, Arkansas 72701

ABSTRACT

The four-electrode probe method was tested on a Crowley silt loam soil in which salt type, salt content, and water content were varied. Theory associated with this technique of assessing soil salinity was verified. Equations were developed which quantified the relationships between soil electrical conductivity obtained by the four-electrode probe technique (EC_e), saturation extract (EC_e), and 1:2 soil to water extract ($EC_{1:2}$).

INTRODUCTION

Historically, the presence of salt in soil has been detected by laboratory analysis of soil samples obtained from the field. A saturation (U.S. Salinity Laboratory Staff 1954) or 1:2 (w/v) (Jackson 1958) soil to water extract has been made and tested for electrical conductivity (EC). Though such procedures have provided much useful information, they require a large time investment if extensive and/or intensive evaluations of soil salinity are desired. A portable *in situ* method for measuring soil salinity, the four-electrode probe method, has been developed which overcomes these problems (Shea and Luthin 1961, Rhoades and Ingvalson 1971, Gupta and Hanks 1972, Rhoades 1975).

The objectives of this study were (1) to verify the usefulness of the four-electrode probe method, (2) to evaluate mathematical relationships associated with four-electrode probe method, and (3) to provide calibration data which will allow use of the four-electrode probe method on Crowley silt loam soil.

METHODS AND MATERIALS

Crowley silt loam soil was obtained from the Rice Branch Experiment Station, Arkansas County, Arkansas. The soil was air-dried and ground to pass through a 20 mesh sieve. Reagent grade $NaCl$, Na_2SO_4 , or $CaCl_2$ salts were mixed thoroughly with 5000 g of soil to give estimated EC_e (EC of the saturation extract) of 4, 8, 12, and 16 mmhos/cm for $NaCl$ and 4 and 12 mmhos/cm for Na_2SO_4 and $CaCl_2$. Known solution EC relationships (U.S. Salinity Laboratory Staff 1954) were used in association with a calculated soil porosity (50%) to make these computations.

The soil was placed in a plastic box which could be sealed. The soil depth was about 9 cm. Distilled water was added to give a desired gravimetric soil water content (θ), the lid was placed on the container, and the soil-water mixture was allowed to equilibrate. The EC of the soil was measured by the four-electrode probe technique and the sequence was repeated at a higher water content. Water contents considered were 15, 20, 25, 30, 35, and 45 (flooded soil) percent by weight. The EC_e (U.S. Salinity Laboratory Staff 1954) and $EC_{1:2}$ (Jackson 1958) were measured over the entire soil depth after the EC by the four-electrode probe method had been determined at 45% water content and the soil had been allowed to dry to 38% water content (saturation).

The four-electrode probe instrument which includes a current source and resistance meter has been described by Rhoades and Ingvalson (1971). Four stainless steel electrodes were mounted in a linear array in Plexiglas to create a probe with an electrode spacing of 7.50 cm and electrode depth of 1.56 cm. The depth to which the electrode measures salinity is equal to the electrode spacing (Rhoades 1975). The electrode probe was calibrated by placing it in a series of solutions of known salinity and measuring resistance. Equation 1 describes the relationship between the measured

resistance, R (ohms), the apparent electrical conductivity (mmhos/cm), EC_e , and the cell constant, k (mmhos \cdot ohm/cm).

$$(1) \quad EC_e = k \cdot f / R$$

where:

f is the temperature correction factor from Rhoades (1975) which is used to convert all EC_e to standard temperature (25C).

The value of k for the 7.50-cm probe was 74 mmhos \cdot ohms/cm. The value of f was unity as these experiments were conducted at 25C. A more thorough description of the factors influencing k and additional probe calibration techniques are given by Shea and Luthin (1961) and Rhoades (1975).

RESULTS AND DISCUSSION

To verify the usefulness of the four-electrode probe technique, EC_e data were compared with EC_e values at different water contents by linear correlation analysis. This relationship was evaluated for the probe with a 7.5-cm spacing which detected salinity to a depth comparable to the soil depth sampled for EC_e . Table I shows the relationships obtained for the various gravimetric water contents. Correlation coefficients were highly significant at each of the water contents, and slope and intercept values increased as water content increased. The standard error of the estimate for EC_e ranged from 0.08 to 0.26 mmhos/cm. Intercept values ($EC_e = 0$) approximate the electrical conductivity due to ions associated with colloidal surfaces in soil. Van Olphen (1963) has stated that for most soil colloids, this surface conductance should increase as bulk soil solution salt concentration decreases. Because salt concentration decreased with increases in water content, the intercept data agreed well with theory. The increases in slope as water content increased were largely a result of the effect of the pore size and tortuosity of this soil upon the bulk soil solution assuming that the EC of colloid surfaces was much smaller than the EC of the bulk soil solution. At small water contents the bulk soil solution resides in small, tortuous pores, whereas at large water contents the bulk soil solution occupies larger, less tortuous pores. Larger, less tortuous pores are less restrictive to the mobility of ions (Van Olphen 1963) and so slope values would be expected to increase as water content increases, even though actual bulk soil solution concentration decreases.

Rhoades (1975) proposed the equation shown below which quantifies the interrelationship between EC_e , EC_e (EC of the bulk soil solution), EC_c (EC of colloidal surfaces), and θ (gravimetric water content).

$$(2) \quad EC_e = EC_c \cdot \theta \cdot T + EC_e$$

where:

T is a transmission coefficient which varies with pore size and tortuosity and is linearly related to θ by $A \cdot \theta + B$.

Substituting $A \cdot \theta + B$ for T in equation 2 and using data from all treatments over all θ allowed determination of the constants A and B by statistical methods where:

*Published with the approval of the Director of the Arkansas Agricultural Experiment Station.

K. Sriyotai and J.T. Gilmour

$$(3) \quad EC_e = EC_c \cdot \Theta^2 \cdot A + EC_c \cdot \Theta \cdot B + EC_s$$

The multiple correlation coefficient (0.977, d.f. = 214) for equation 3 was highly significant and values of the constants A and B were 2.58 and -0.16, respectively. The value found for EC_c over all treatments was 0.13 mmhos/cm, whereas the standard error of the estimate for EC_c calculated from equation 3 ranged from 0.17 to 0.26 mmhos/cm. These results compare well with those reported by Rhoades (1975). And, the influence of T and Θ on the part of equation 2 ($EC_c \cdot \Theta \cdot T$) associated with EC of the bulk soil solution supports the contention that the EC_c as reflected by EC_e increases as water content (Θ) increases. Similarly, the supposition that EC_c is much smaller than EC_e as EC_e increases was verified. Thus, the four-electrode probe method appears to describe adequately soil salinity over a range of salt and water contents for the Crowley silt loam soil.

To compare EC_e, EC_{1,2}, and EC_{1,3}, the linear correlation between EC_{1,2} and EC_e was evaluated and yielded the following relationship.

$$(4) \quad EC_{1,2} = \text{slope} \cdot EC_e + \text{intercept}$$

The correlation coefficient was highly significant (0.945, d.f. = 34) with slope and intercept values equal to 0.24 and 0.04, respectively. The use of equation 4 and data from Table I provides calibration data for the Crowley silt loam soil which allow computation of EC_e or EC_{1,2} from EC_c data. Such data are necessary in comparing EC data obtained by the four-electrode probe technique with data obtained by more traditional methods. It should be noted that the EC_{1,2} by the method of Jackson (1958) differs from the EC_{1,2} currently used in routine soil testing procedures in Arkansas.

LITERATURE CITED

- GUPTA, S. C. and R.J. HANKS. 1972. Influence of water content on electrical conductivity of soil. *Soil Sci. Soc. Amer. Proc.* 36(6):855-857.
- JACKSON, M.L. 1958. *Soil chemical analysis*. Prentice-Hall, Inc., Englewood Cliffs, N.J. Pp. 87-110.
- RHOADES, J.D. 1975. Measuring, mapping and monitoring field salinity and water table depth with soil resistance measurements. *In* Expert consultation on prognosis of salinity and alkalinity. Food and Agriculture Organization of the United Nations, Rome, Italy.
- RHOADES, J.D. and R.D. INGVALSON. 1971. Determining salinity in field soils with soil resistance measurements. *Soil Sci. Soc. Amer. Proc.* 35(1):54-60.
- SHEA, P.F. and J.N. LUTHIN. 1961. An investigation of the use of the four electrode probe for measuring soil salinity in situ. *Soil Sci.* 92:331-339.
- U.S. SALINITY LABORATORY STAFF. 1954. Diagnosis and improvement of saline and alkaline soils. USDA Handbook 60. 160 pp.
- VAN OLPHEN, H. 1963. *An introduction to clay colloid chemistry*. Interscience Publishers, New York. 301 pp.

Table I: Relationship Between EC_c and EC_e (EC_e = Slope•EC_c + Intercept) for Amended and Control Crowley Silt Loam Soils at Various Water Contents

Water Content (%)	Slope	Intercept	r (34 d.f.)
15	0.056	0.048	0.918**
20	0.141	0.051	0.954**
25	0.183	0.144	0.956**
30	0.238	0.143	0.970**
35	0.278	0.228	0.979**
45	0.329	0.407	0.981**

**Significant at the 99% level of confidence.