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Could Dielectric Devices Replace Laborious Methodologies in Determining Soil Salinity

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The rapid expansion of world population unavoidably demands for an equivalent or so food production increase. This might be achieved by various means and methodologies such as genetic engineering and others which invariably would lead in an intensification of irrigated agriculture. On the other hand natural resources and more specifically soil and water are no longer considered unlimited and therefore we could only use them rationally and orthologically with ultimate respect, since we are borrowing them from the generations to come. It is our duty, if not increasing them quantitatively or improving them qualitatively, at least keep them and use them sustainably.

Irrigation waters are not always suitable nor are in adequate quantities to cover crop water requirements in various places of the world. A major negative effect of irrigation is when using marginal quality waters, which gradually deteriorate the soils due to salt accumulation. Since there is not an easy solution to the problem, the agricultural lands which are negatively affected by this secondary salinization are increasing in extent day by day, we are left with the solution of enforcing various prevention measures [1]. Such a preventive measure is the soil-salt profile leaching. This again can be effective if a salt concentration profile monitoring is feasible. In the past various methodologies have been applied in order to have relevant information concerning soil salinity status.

During the first 50 years of previous century, soluble salt contents for soils were estimated from the electrical conductivity of saturated soil-pastes. A 50 cm^3 cylindrical conductivity cell was used to measure electrical conductivity and this cup became known as the "Bureau of soil cup" [2].

As the understanding of saline soils progressed, the electrical conductivity of saturated soil-paste extract (EC_e) was advocated as the preferred index of soil salinity [3]. This widespread methodology consisted of collecting soil samples from various soils and depths, using them in the Laboratory to producing saturated soil-pastes or other methods using various ratios of soil to water volumes i.e. 1:1, 1:5 and from their electrical conductivities inferring the salinity status of the soil under investigation. This procedure was certainly laborious and time consuming. Alternatively, salinity can be indirectly determined from measurement of the electrical conductivity of a saturated soil-paste (EC_p) or from the electrical conductivity of the bulk soil (EC_a). EC_p can be measured either in the laboratory or in the field using simple and inexpensive equipment. EC_a can be measured in the field either using electrical probes (electrodes) placed in contact with the soil or remotely using electromagnetic induction devices. The latter two sensors are more expensive than those used to measure the EC of water samples, of soil-extracts or soil-pastes [4,5].

It seems that in our days, osmosis of various, seemingly, different scientific branches made it feasible the production and gradual development of simple and not too expensive tools and devices which can contribute in the study and management of difficult problems encountered in the modern way of applying, in an intensified manner, irrigated agriculture. The introduction into agricultural sciences of Time Domain Reflectometry (TDR) technology [6] which measures soil water (θ) and EC_a simultaneously and in the same soil volume, revolutionized EC of pore water (EC_w) evaluation until it became the reference method in spite of its high cost [7]. In response to the success of TDR, several commercial soil water sensors have been developed that use soil dielectric properties but are less expensive than TDR for many applications and do not require waveform analysis.

Dielectric permittivity ε^* is generally a complex function

$$\varepsilon^* = \varepsilon' - j\varepsilon'' \tag{1}$$

where $j = \sqrt{-1}$

If we divide eq. (1) by ε_0 which is the dielectric permittivity of free space (ε_0=8.854×10^{-12} F m^{-1}) then eq. (1) becomes

$$\varepsilon_r^* = \varepsilon_r' - j\varepsilon_r'' \tag{2}$$

and it is called relative dielectric permittivity which as such, is dimensionless. The real component of eq. (2) is called relative dielectric constant of the medium and in this sense it dictates the change of a plane capacitor's capacitance according to the relationship

$$\varepsilon_r' = \frac{C}{C_0} \tag{3}$$

which shows how much the capacitance C is increased from its value, C_0, when between the plates of the capacitor is the vacuum. As is known water has (at 20°C) an exceptionally large relative dielectric constant 80 while all other soil constituents have ε_r' values less than ~5. Thus water presence in soil drastically affects soil's relative dielectric constant and therefore, an empirical expression between $\sqrt{\varepsilon_r'}$ or ε_r' and soil moisture θ may be found which could be used, after a proper calibration for each individual sensor, soil and some other factors, for a reliable θ-prediction or θ(z) profile establishment.

Dielectric sensors could also provide, through the imaginary component ε_r'' (eq. 2) related to energy losses due to a number of reasons, when an electromagnetic field is applied in a dielectric medium, the prediction of the medium's soil bulk electrical conductivity, EC_a. Moreover, from measurement of EC_a one could estimate the soil pore water electrical conductivity, EC_W, which is directly related to the soil water salinity regime and its detrimental effects on crop production. This has been attempted by various models [2,8-12].

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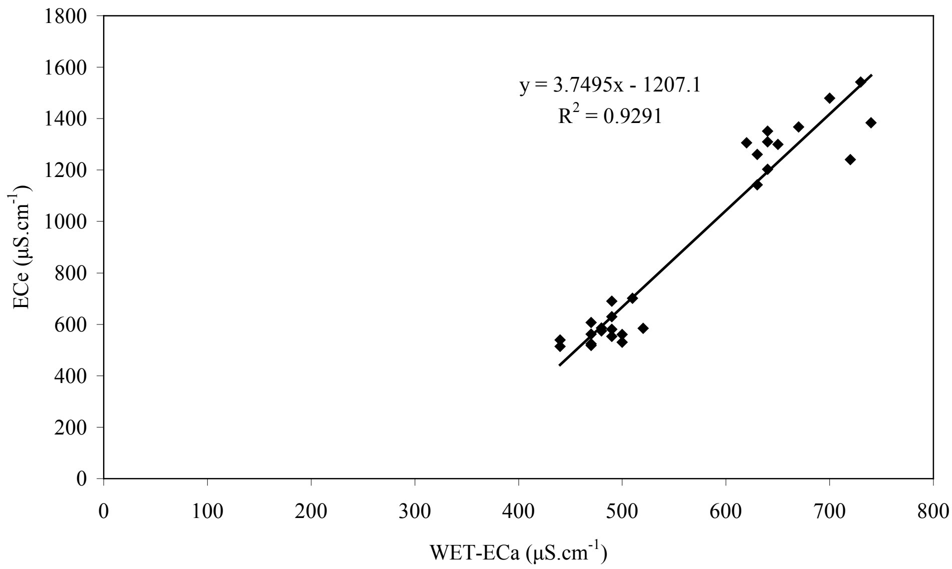

Figure 1: The relationship between EC_e-EC_a from bulk soil-paste electrical conductivity for clay-loam soil.

In a number of works determining soil salinity (EC_e) from soil-paste electrical conductivity or soil bulk electrical conductivity have been reported [13,2,4,5].

A useful application work is presently needed, which could relate previously used procedures and methodologies of providing EC_e with bulk electrical conductivity of saturated paste as this can be obtained by a dielectric sensor. One such method eliminates the need of aqueous extractions, though it still requires the collection of soil samples and the making of saturated soil pastes.

The WET is a relatively new capacitive dielectric sensor which estimates independently both the real and imaginary parts of the complex relative permittivity of a substance simultaneously at an operating electromagnetic signal frequency of 20 MHz. The sensor could be connected to an HH2 moisture meter which applies power to the sensor and measures the output signal voltage returned [14]. The sensor probe detects the changes to the 20 MHz electromagnetic signal and sends this information to the HH2, which measures the capacitance (C) and conductance (G) of the material between the rods (soil). Then, the dielectric properties of the medium are inferred from in-built calibration files [14].

In our preliminary investigation WET-EC_a values of saturated paste are compared with EC_e values obtained conventionally. This is attempted for various soils. Such a relationship is shown in Figure 1 below for a clay loam soil. As one can see linear relationship is established with quite a large number of R^2. $EC_e = 3.749 EC_a - 1207.1$ (EC_e and EC_a in µS cm^{-1}).

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