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A NEW METHOD TO ESTIMATE TOTAL DISSOLVED SALTS IN SOIL SATURATUION EXTRACTS FROM ELECTERICAL CONDUCTIVITY UNDER EGYPTIAN CONDITIONS

El-Sayed, M. H. and M.M.I. El-Kholy
Soil, Water and Environment Res. Inst., Agric. Res. center, Giza, Egypt

ABSTRACT

Fifty two soil samples with different quantities and qualities of salt were taken from different places in Egypt to present the most soil types. A saturation extract from each sample was prepared and its electrical conductivity (EC) and total dissolved salts (S) were determined. Both EC and S values ranged from 0.74 to 185 dSm^{-1} and from 0.44 to 309 g dm^{-3}, respectively.

The relationship between S and EC was not linear. When the saturation extracts were diluted with progressively large quantities of distilled water [1(saturation extract):10, 25, 50, 100, 250, 500, 1000 (distilled water)] and their electrical conductivity were calculated (EC_e) with the equation: $EC_e = (EC_d - EC_w)F$, where EC_d and EC_w were the conductivity of the diluted extract and the distilled water, respectively, and F was the dilution factor, the relationship between S and EC_e tended to be linear.

The highest linear correlation coefficient relating S (mg dm^{-3}) and EC_e (dS m^{-1}) was reached when EC_e values were calculated for dilution with an electrical conductivity (EC_d) between 0.1 and 0.5 dSm^{-1} (EC_e^*). The regression equation was $S=425\ EC_e^*$ with $R^2=0.989$. This relationship can be used in all saturation extracts, regardless of the concentration and type of ions present.

Keywords: Soil saturation extract, total dissolved salts and electrical conductivity.

INTRODUCTION

The soil solution is a source of plant nutrients and medium for all reactions, nutrient cycling in ecosystems, and pollutant transformation and transport in soils. Chemically, it can be defined as the soil water and its dissolved electrolytes, gases and water soluble compounds (Agbenin, 2003). The composition of the soil solution is greatly affected by nutrient uptake, fertilization, leaching (Nemeth *et al*., 1970) and other soil properties, which vary in time and space. So, it is different to predict total dissolved salts from electrical conductivity measurements for soils with a high content of soluble salts.

If the temperature and geometry of a cell, through which an electric current is passed, are fixed, the electrical conductivity of a solution will be a function of the concentration, total charge and mobility of the ion species (Simon *et al*., 1994). This relationship between ion concentration and electrical conductivity means that the latter parameter is highly useful for calculating the total content of salts dissolved in soil extract (US Salinity Laboratory Staff, 1954 and McNeal *et al*., 1970). However, the relationship is not completely linear because electrical conductivity is directly related to total charge and ion mobility, and as the concentration increases there is a concomitant decrease in both these parameters due to relaxation and

electrophoretic phenomena and also to the formation of ion pairs (Tanji and Bigger, 1972; Marion and Babock, 1976). This last factor depends in turn upon the type of ions in solution. More ion pairs are formed with Ca^{2+}, Mg^{2+} and SO_4^{2-} than with Na^+ and HCO_3^-(Alzubaidi and Webster, 1983, and Simon *et al*., 1994)

For this reason the numerous attempts that have been made to establish a relationship between electrical conductivity (EC) and total quantity of dissolved salts (S) in saturation extracts of soil have yielded very different results, depending on the concentration and type of ions present. Therefore, results of those attempts have limited application. In Spain, Simon *et al*., 1994 investigated this above relationship using thirty-nine soil samples and reached a highest linear correlation coefficient between total dissolved salts (S); mg dm^{-3}, and EC_e, dSm^{-1}, when EC_e values were calculated for dilutions with a conductivity (E_d) ranged from 0.1 to 0.3 dSm^{-1}(E_{ce}^*); and they established this regression equation: $S= 490E_{ce}^*$, $R^2 =0.999$.

The aim of this study is to establish an equation relating electrical conductivity to total dissolved salts, which would be applicable to any kind of soil-saturation extract, whatever was the salt concentration or composition, under Egyptian conditions.

MATERIALS AND METHODS

Fifty two soil samples with different quantities and qualities of salt were taken from different places in Egypt to present the most soil types. A saturation extract from each sample was prepared and its electrical conductivity (EC) and total dissolved salts (S) were determined (US Salinity Laboratory Staff, 1954). Each saturation extract was then diluted to increasingly large distilled-water: soil-extract ratios (10, 25, 50, 100, 250, 500 and 1000) and the electrical conductivity of each dilution (EC_d) was determined. From electrical conductivity value of diluted sample and that of distilled water (EC_w), we calculated new electrical conductivity values (EC_e) for each of the soil extracts via the equation:

$$EC_e = (EC_d – EC_w) F \quad (1)$$

Where F is the dilution factor of the distilled water: soil-extract ratio in each dilution. The value of EC_w was 0.003 dSm^{-1}.

Electrical conductivity of the saturation extracts and their respective dilutions were measured with a conductivity meter with a standard conductivity cell. Calcium, magnesium, carbonates & bicarbonates, and chlorides were titrated by Na_2-EDTA, H_2SO_4 and $AgNO_3$, respectively. Potassium and sodium were determined by usinflame photometry, and sulphates were precipitated as $BaSO_4$ (Black *et al*., 1965). The values of total salts (S) were derived from these data by multiplication in equivalent weight and summation. Obtained data of chemical analysis of the saturation extracts were presented in Table (1).

Table (1) Electrical conductivity (EC), ionic composition and total dissolved salts (S) of soil saturation extracts.

Soil sample No.	EC (dSm^{-1})	Ionic composition ($mmol_c dm^{-3}$)								Total salts (gdm^{-3})
		Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	(S)
1	0.74	2.38	0.06	2.0	1.00	0.00	1.38	3.09	2.87	0.44
2	1.27	2.20	0.12	3.0	4.00	0.00	3.10	3.09	4.13	0.66
3	7.20	35.1	6.81	20.0	25.00	0.00	2.59	29.7	60.6	5.89
4	81.1	1980	17.10	290	30.00	0.00	1.11	1910	415.9	140.2
5	2.86	12.4	0.95	8.00	8.00	0.00	1.85	3.96	28.5	2.19
6	1.96	6.00	0.23	6.00	8.00	0.00	1.48	6.93	17.5	1.54
7	2.88	12.00	0.35	12.0	6.00	0.00	4.07	10.9	19.4	2.17
8	6.60	41.00	2.30	27.0	12.00	0.00	2.59	39.6	48.2	5.59
9	2.80	12.90	0.64	10.0	7.00	0.00	2.22	9.90	16.4	1.88
10	3.71	6.00	1.07	14.0	20.00	0.00	2.59	6.93	36.6	2.86
11	3.71	22.30	0.66	15.0	5.00	0.00	2.59	2.97	42.4	3.20
12	4.90	9.80	0.52	32.0	18.00	0.00	1.48	3.96	59.9	4.21
13	3.57	7.40	1.18	15.0	13.00	0.00	2.59	4.59	33.1	2.58
14	1.39	6.50	0.17	6.00	4.00	0.00	1.48	8.91	11.3	1.27
15	40.0	597.3	3.40	39.0	8.50	0.00	1.65	566.5	86.1	39.1
16	5.60	49.00	0.80	11.0	5.00	0.00	0.55	30.9	36.6	4.33
17	9.53	89.3	0.90	5.00	4.00	0.00	1.10	65.9	34.6	6.30
18	184.8	5000	18.30	30.0	90.00	0.00	0.55	4532	603.5	307.3
19	1.38	4.02	1.05	2.00	4.00	0.00	1.65	4.90	6.43	0.80
20	1.10	7.80	0.35	1.00	3.00	0.00	0.55	10.0	2.60	0.76
21	1.02	7.10	0.42	1.00	2.00	0.00	1.10	6.18	5.24	0.76
22	0.92	8.60	0.30	1.00	1.00	0.00	1.10	4.12	6.41	0.76
23	4.98	30.30	6.00	12.0	8.00	0.00	1.10	14.4	39.7	3.75
24	7.67	62.50	0.14	10.0	20.00	0.00	0.55	49.4	41.8	5.68
25	15.0	100	3.70	45.0	31.00	0.00	1.65	154.5	22.7	10.4
26	6.65	28.0	3.80	32.0	16.00	0.00	1.10	41.2	35.5	4.86

Table (1). Cont.

Soil sample No.	EC (dSm^{-1})	Ionic composition ($mmol_c dm^{-3}$)								Total salts (gdm^{-3})
		Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	(S)
27	32.0	260	4.60	107	56.6	0.00	1.10	379	48.9	24.8
28	4.98	34.5	1.24	9.00	5.00	0.00	0.55	28.8	24.8	3.33
29	25.4	266	4.60	40.9	.20.0	0.00	1.10	356	44.9	22.2
30	75.4	870	16.5	120	80.0	0.00	0.55	951	138	64.4
31	27.7	248	7.50	65.0	58.0	0.00	0.55	391	70.9	25.3
32	15.0	140	4.40	25.0	19.0	0.00	0.55	165	22.1	11.1
33	49.8	446	4.20	21.0	48.0	0.00	.55	412	110	31.4
34	15.2	130	5.00	40.0	16.0	0.00	0.55	146	46.2	11.6
35	6.43	36.0	4.20	21.0	19.0	0.00	0.55	45.3	35.1	4.97
36	12.3	118	3.10	35.0	12.0	0.00	0.55	128	38.7	10.1
37	5.04	26.8	1.39	16.0	14.0	0.00	1.10	40.5	41.5	4.66
38	1.98	15.1	0.70	2.12	3.18	0.00	4.50	13.4	4.80	1.44
39	4.70	38.4	1.50	5.26	4.24	0.00	9.00	26.9	14.0	3.27
40	9.71	78.9	1.84	11.7	26.6	2.00	10.0	64.7	40.3	7.40
41	6.35	43.9	1.10	9.54	14.9	2.00	10.0	37.7	20.8	4.49
42	20.0	180	1.20	42.0	32.8	0.00	5.00	124	125	16.1
43	4.80	34.0	0.50	11.0	4.00	0.00	6.00	26.2	16.1	3.14
44	9.43	59.8	0.90	28.5	14.8	4.00	8.00	48.5	39.5	6.50
45	5.90	46.2	4.52	4.22	9.56	0.00	5.00	37.0	25.2	4.27
46	8.66	47.2	2.20	31.8	31.8	0.00	5.00	32.3	72.7	7.13
47	30.6	190	3.20	84.8	94.0	0.00	5.00	256	114	22.2
48	10.7	57.0	2.00	38.2	31.8	0.00	5.00	57.0	70.0	8.22
49	9.01	39.6	1.30	31.1	35.0	0.00	5.00	51.6	52.4	6.66
50	4.13	28.3	0.84	6.36	12.7	0.00	6.00	19.8	24.0	3.18
51	13.0	52.9	3.20	33.9	44.0	3.00	6.00	64.0	63.0	8.39
52	2.64	15.0	0.52	7.38	4.20	0.00	10.0	12.3	6.00	1.90

RESULTS AND DISSCUSSION

The EC values obtained ranged from 0.74 to 185 dSm^{-1}, and total salts (S) from 0.44 to 307 gdm^{-3} (Table 1). The types of salts varied. In general, Na^+, Ca^{2+}, Mg^{2+}, Cl^- and SO_4^{2-} were the predominant ions in the extracts, accounting for more than 80% of S. In the extracts where EC<10 dSm^{-1}, Na^+, Ca^{2+} and SO_4^{2-} were the predominant ions and ranged from 40.2 to 88.9% of S; and Na^+: Ca^{2+}, Na^+ : Mg^{2+} and SO_4^{2-}: Cl^- ratios ranged from 0.32 to 20.5, 0.85 to 42.98 and 0.35 to 20.0, respectively. In the extracts where EC>10 dSm^{-1}, Na^+, Ca^{2+} and Cl^- were the predominant ions and ranged from 42.3 to 90.2% of S; Na^+: Ca^{2+}, Na^+: Mg^{2+} and Cl^- :SO_4^{2-} ratios were form 1.72 to 192, 2.31 to 135 and 0.6 to 5.87, respectively.

Relationship between EC and S:

When EC was regressed against S, the data corresponded reasonably well to a third order polynomial regression equation:

$$\mathbf{EC = -1.17 + 1.62\ S - 0.011\ S^2 + 2.36 \times 10^{-5}\ S^3\ (R^2 = 0.990)} \quad \mathbf{(2)}$$

Data presented in Fig (1) showed a non linear positive relationship between EC and S, and this could be attributed to ion pairing and decreased mobility of ions. A comparison of soil extracts either having EC less or greater than 10 dSm^{-1} showed that Na^+ and Cl^{-1} ions had more superior influence on EC values than the other ones, indicating that Mg^{2+}, Ca^{2+} and SO_4^{2-} have a greater tendency to form ions pairs than Na^+ and Cl^- (**Alzubairdi & Webster, 1983 and Simon *et al*., 1994**). This tendency was confirmed by a stepwise multiple regression between the EC values and the corresponding ion concentrations, in $mmol_c dm^{-3}$, of Na^+, Mg^{2+} and Ca^{2+} in equations (3, 4, and 5) and Cl^- and SO_4^{2-} in equations (6 and 7). The partial correlation coefficient square of Na^+, Mg^{2+} and Ca^{2+} ions with EC values as indicated in the equations was 0.9193, 0.0472 and 0.0037, respectively; and that of Cl^- and SO_4^{2-} ions was 0.9397 and 0.0019, respectively.

$$\mathbf{EC = 7.18 + 0.038\ Na^+} \quad \mathbf{(R^2 = 0.9193)} \quad \mathbf{(3)}$$

$$\mathbf{EC = 1.35 + 0.032Na^+ + 0.346\ Mg^{2+}} \quad \mathbf{(R^2 = 0.9665)} \quad \mathbf{(4)}$$

$$\mathbf{EC = 0.894 + 0.032Na^+ + 0.046\ Ca^{2+} + 0.309\ Mg^{2+}} \quad \mathbf{(R^2 = 0.9702)} \quad \mathbf{(5)}$$

$$\mathbf{EC = 6.51 + 0.042Cl^-} \quad \mathbf{(R^2 = 0.9397)} \quad \mathbf{(6)}$$

$$\mathbf{EC = 5.29 + 0.037Cl^- + 0.043\ SO_4^{2-}} \quad \mathbf{(R^2 = 0.9416)} \quad \mathbf{(7)}$$

Relationship between EC_e and S:

When the saturation extracts were diluted with increasing quantities of distilled water the EC_e values rose steeply at first (Fig.2), and reached higher values as the EC value increased.

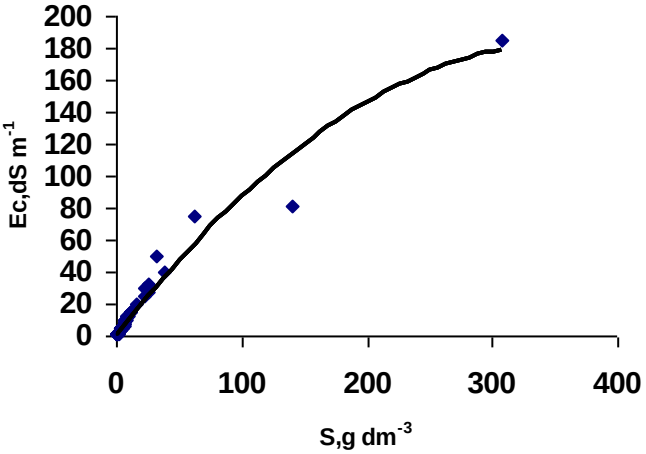

Fig (1). Relationship between the electrical conductivity (EC) and Total dissolved salts (S) in soil saturation extract.

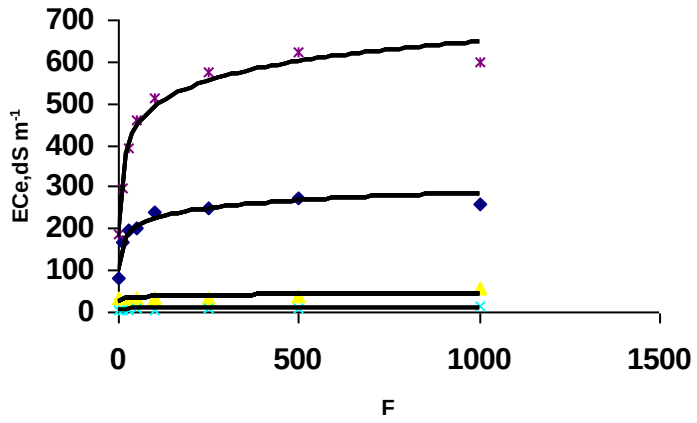

Fig (2) Evolution of the electrical conductivity calculated from diluted soil-saturation extracts (EC_e) with the dilution factor (F) for soil-saturation extracts with different electrical conductivities (EC_e).*, EC_e (soil 18)= 179 + 67.7 ln F, R^2=0.969; ♦, EC_e(soil4)=98.0+ 27.1 ln F, R^2=0.943; Δ, EC_e(soil 27)= 21.9 + 3.17 ln F, R^2=0.482; x, EC_e (soil12) = 3.77 + 1.12 ln F, R^2=0.604.

Furthermore, as the soil extracts were increasingly diluted, the slope of the curves relating EC_e values to S increased in slop and gradually straighten (Fig.3). This obvious tendency towards a linear relationship by increasing dilution indicated an advantage in diluting the saturation extracts.

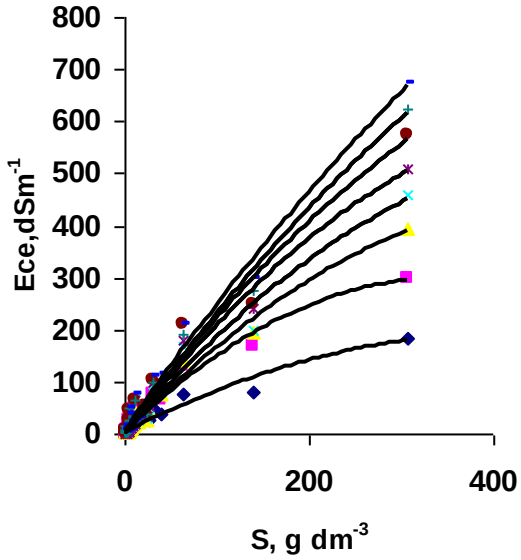

Fig. (3). Relationship between the electrical conductivity of the soil-saturation extracts (EC) or the electrical conductivity calculated from diluted soil-saturation extracts (EC_e) and concentration of the total dissolved salts (g dm^{-3})

- $EC_e(F=1000) = 6.79 + 2.54\ S - 1.2\ x10^{-3}\ S^2$ (R^2= 0.983)
+ , $EC_e(F=500) = 5.23 + 2.28\ S - 0.9\ x10^{-3}\ S^2$ (R^2= 0.983)
●, $EC_e(F=250) = 3.83 + 2.28\ S - 1.5\ x10^{-3}\ S^2$ (R^2= 0.971)
***,** $EC_e(F=100) = 2.33 + 2.22\ S - 1.9\ x10^{-3}\ S^2$ (R^2= 0.975)
X, $EC_e(F=50) = 3.70 + 1.92\ S - 1.5\ x10^{-3}\ S^2$ (R^2= 0.963)
Δ, $EC_e(F=25) = 1.92 + 1.83\ S - 1.8\ x10^{-3}\ S^2$ (R^2= 0.979)
■, $EC_e(F=10) = 2.41 + 1.72\ S - 2.5\ x10^{-3}\ S^2$ (R^2= 0.966)
♦, $EC = 2.95 + 0.906\ S - 1.1x10^{-3}\ S^2$ (R^2= 0.957)

Another advantage in using calculated conductivities (EC_e) was the reduction in the variation caused by the nature and behavior of the ions present in the solution. In fact, as noted above with respect to the relationship between EC and S (Fig.1), the scatter of the data point outside the curve seemed to be due to differences in the Na^+: Ca^{2+}, Na^+: Mg^{2+} and Cl^- : SO_4^{2-} ratios.

Data presented in Fig.(3) also showed that the correlation coefficient was, to a great extent, higher as the dilution increased. The multiple regression equations between EC_e values for each dilution and the ion concentration, in $mmol_c\ dm^{-3}$, of Na^+,Ca^{2+}: and Mg^{2+} (Equations 8-13), and Cl^- and SO_4^{2-} (Equations 14-19) clearly showed that the regression coefficients of both Na^+ and Cl^- tended to increase and to equalize with increased dilutions. Whereas that of Mg^{2+}, Ca^{2+} and SO_4^{2-} was not regular.

$EC_e(F=10) = 1.58 + 0.055Na^+ + 0.188Ca^{2+} + 0.302Mg^{2+}$ (R^2 =0.96) (8)
$EC_e(F=25) = 1.42 + 0.074Na^+ + 0.148Ca^{2+} + 0.296Mg^{2+}$ (R^2 =0.98) (9)
$EC_e(F=50) = 1.45 + 0.084Na^+ + 0.086Ca^{2+} + 0.476Mg^{2+}$ (R^2 =0.97) (10)
$EC_e(F=100) = 1.54 + 0.096Na^+ + 0.152Ca^{2+} + 0.382Mg^{2+}$ (R^2 =0.97) (11)
$EC_e(F=250) = 2.12 + 0.107Na^+ + 0.11Ca^{2+} + 0.468Mg^{2+}$ (R^2 =0.98) (12)
$EC_e(F=500) = 3.93 + 0.117Na^+ + 0.111Ca^{2+} + 0.394Mg^{2+}$ (R^2 =0.98) (13)
$EC_e(F=1000) = 4.12 + 0.126Na^+ + 0.12Ca^{2+} + 0.534Mg^{2+}$ (R^2 =0.981) (14)
$EC_e(F=10) = 5.58 + 0.049Cl^- + 0.157\ SO_4^{2-}$ (R^2 =0.94) (15)
$EC_e(F=25) = 5.04 + 0.073Cl^- + 0.125\ SO_4^{2-}$ (R^2 =0.97) (16)
$EC_e(F=50) = 8.62 + 0.096Cl^- + 0.047\ SO_4^{2-}$ (R^2 =0.96) (17)
$EC_e(F=100) = 7.18 + 0.103Cl^- + 0.093\ SO_4^{2-}$ (R^2 =0.97) (18)
$EC_e(F=250) = 9.02 + 0.120Cl^- + 0.059\ SO_4^{2-}$ (R^2 =0.97) (19)
$EC_e(F=500) = 8.78 + 0.126Cl^- + 0.084\ SO_4^{2-}$ (R^2 =0.98) (20)
$EC_e(F=1000) = 9.82 + 0.132Cl^- + 0.089\ SO_4^{2-}$ (R^2 =0.98) (21)

Nevertheless, even at very high dilutions (F=1000), the relationship between S and EC_e was not exactly linear (fig.3) and the data points consistently showed a curvature as ion-pair formation increased with salt concentration (Alzubaidi&Webster, 1988, and Simon *et al*., 1994).

A linear relationship between EC_e and S can be obtained if, instead of using fixed dilution ratios for all extracts, the dilution ratio was always selected in such a way that the final conductivity of the diluted extract (EC_d) fell within a moderately narrow range. Optimum results (EC^*_e) were obtained when the conductivity of the diluted extracts ranged from 0.1 to 0.5 dSm^{-1}. Under these conditions the relationship between EC_e^* and S (Fig.4) was, to a great extent, linear, the correlation coefficient was very high and errors did not increase with salt concentration (Equation 20):

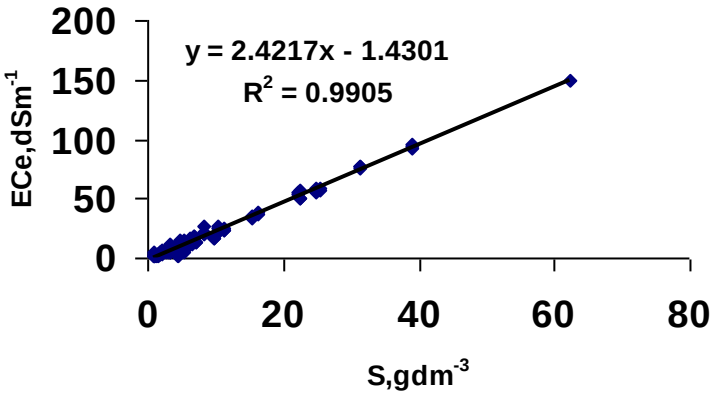

Fig.(4). The relationship between optimum EC_e results (EC_e^*) and total dissolved salts (S) when the conductivity of the diluted extracts (EC_d)ranged from 0.1 to 0.5 dSm^{-1}.

$EC_e^* = -1.43 + 2.422\ S$ (R^2=0.991) (20)

The optimum EC_d range (0.1 – 0.5 dSm^{-1}), though narrow, was nevertheless wide enough that the preparation of diluted extracts was quite simple. The values of EC could be used as a guide for selecting the dilution ratio (Table 2); however, if EC_e was higher than 40 dSm^{-1}, the relation between EC_e and S was so uncertain (Fig.1) that the final conductivity of the diluted extracts was the only reliable guide.

Table (2). Approximate dilution factors (distilled water: soil-extract ratios) necessary for reaching a conductivity of the diluted extract (EC_d)within the range of 0.1 – 0.5 dSm^{-1}.

EC(dSm^{-1})	Dilution factor
1-2	10
2-5	25
5-9	50
9-15	100
15-25	250
25-40	500
40-75	1000

These results provided a new equation for calculating the total salt content (S) of saturation extracts. Given that when EC_e^* was zero, S was also zero, the regression line should pass through the origin, and the regression equation would be:

$$S = 425EC_e^*$$

With R^2= 0.989, and S expressed in mg dm^3 and EC_e^* in dSm^{-1}. This equation can be used in all saturation extracts, regardless of the concentration and type of ions present.

Conclusions:

In this study a new method to calculate the total soluble salt content, S, of soil saturated extracts, under Egyptian conditions, has been proposed. This method resulted in the most accurate results for EC by diluting the saturation extract until its electrical conductivity (EC_d) has a value of between 0.1 and 0.5 dSm^{-1}, from which EC_e^* could be calculated as follows:

$$EC_e^* = (EC_d - EC_w)\ F.$$

Where EC_w was the electrical conductivity of the distilled water used for the dilutions, and F is the dilution factor.

For the saturation extract, S(mg dm^{-3}) was then calculated using the equation: $S = 425EC_e^*$

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طريقة جديدة لتقدير الاملاح الكلية الذائبة فى مستخلصات عجينة التربة المشبعة من التوصيل الكهربى تحت الظروف المصرية

مصطفى حلمى السيد و محمد محسن ابراهيم الخولى

معهد بحوث الاراضى والمياه والبيئة-مركز البحوث الزراعية-جيزة-مصر

اخذت ٥٢ عينة تربة مختلفة فى محتواها من الاملاح ونوعيتها من اماكن مختلفة فى مصر لتمثل معظم انواع الاراضى الموجودة. تم تحضير مستخلص عجينة التربة المشبعة لكل عينة وقياس التوصيل الكهربى فيها (EC) وكذلك تقدير الاملاح الكلية الذائبة(S). تراوحت قيم كل من الُ S، EC, من ٠,٧٤ الى ١٨٥ ديسيسيمنز/متر (dSm^{-1})و٠,٤٤ الى ٣٠٩ (جم/م^{٣}) على الترتيب.

لم تكن العلاقة بين الEC و S خطية وعندما أجرى تخفيف للمستخلصات المشبعة بكميات كبيرة متزايدة من الماء المقطر [١(مستخلص مشبع) : ١٠، ٢٥، ٥٠، ١٠٠، ٢٥٠، ٥٠٠، ١٠٠٠ (ماء مقطر)] وحسب لهم التوصيل الكهربى (EC_e) من المعادلة $EC_e = (EC_d - EC_w)$ حيث أن كل من EC_w , EC_d تعبر عن التوصيل الكهربى للمستخلص المخفف والماء المقطر على الترتيب، و F هو معامل التخفيف اتجهت العلاقة بين الEC_e و S لتكون خطية.

تم التوصل الى معامل ارتباط قوى بين الاملاح الكلية الذائبة (S) وقيم التوصيل الكهربى للتخفيفات (EC_e^*) والتى حسبت من التوصيل الكهربى للتخفيفات (EC_d) والتى تراوحت بين ٠,١ الى ٠,٥ ديسيسيمنز/متر (dSm^{-1}) وكانت معادلة الانحدار التى تربط بينهما كالاتى:

$$(S= 425\ ECe^*,\ R^2=0.989)$$

ويمكن استخدام هذه العلاقة لكل المحاليل المشبعة بغض النظر عن تركيز ونوع الملح الموجود