

# Estimating Salinity of Soils from Northwest of Egypt using Different Soil-to-Water Ratio Extracts

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## ABSTRACT

Saturated soil paste extracts and different soil to water ratios are commonly used in soil salinity studies and field remediation of salt-affected soils. This experimental study was carried out to assess the possibility of estimating electrical conductivity and soluble ions concentrations of saturated soil paste extracts from 1:1, 1:2.5 and 1:5 soil to water ratios. Twenty-five undisturbed surface soil samples were collected to represent sandy, calcareous and clay soils commonly occur in the Northwest of Egypt. Electrical conductivity (EC) and major soluble ions concentrations were measured. Soil specific and combined regression equations and coefficients of determination of saturated soil paste EC and analytes versus 1:1, 1:2.5 and 1:5 soil to water ratios were evaluated. Estimation of saturated soil paste EC and other analytes from these soil to water ratios was successful with high correlation except for K and Ca ions in sandy and calcareous soil, respectively. Slopes of regression lines in proximity of 2, 4 and 7.5 for the 1:1, 1:2.5 and 1:5 soil to water ratios, respectively reflect the dilution effect of readily soluble salts. The use of these regression equations to estimate the saturated soil paste EC and other analytes has potential benefits of minimizing labor, time and costs required for saturated soil paste extract preparation. Soil specific regression equations are recommended for more precise estimation of saturated soil paste attributes.

**Keywords:** Salinity, Soil to water ratios, Extracts, Electrical conductivity, soluble ions concentrations.

## INTRODUCTION

Soil salinity represents the concentration of dissolved mineral salts in soil and it is considered one of the most important environmental factor that limits the yield of agricultural crops. Cultivated crops respond tremendously different to increasing soil salinity level where their production is adversely affected (Nassem et al., 2008; Sonmez *et al.*, 2008). Salinization of soils is commonly related to either intrinsic soil properties or environmental conditions. In addition, some agricultural practices such as irrigation water quality, fertilization, lack of or inefficient drainage, seepage..., etc. contribute significantly in soil salinity build up (Pitman and Lauchli, 2002; Shama et al., 2016). Arid and semi-arid regions are known to have extended areas of salt affected soils. Data on the extent and severity of salt affected soils are observational. Though, estimates showed that about 955 million ha of the world are under

different categories of salt affected soils (Qadir *et al.*, 2000).

Determination of soil salinity can be conducted by various methods depending on different situations. Measurements can be made on extracts from saturated soil paste, soil to water suspensions of different ratios or *in situ* soil water samples collected with vacuum extractors, or in soil, using buried porous salinity sensors or using four-electrode probes or remotely by electromagnetic induction techniques (Rhoades and Loveday, 1990).

The EC of the saturated paste extract,  $EC_{SP}$ , is a more meaningful measurement being closer to field water content and can be related to the large amount of published data on plant salt tolerance (Ayers and Westcot, 1989; Shaw, 1994). However, obtaining this saturated past extract encounters difficulties related to sample preparation, time consumption and reproducibility (USDA, 1954). The extraction methods of different soil to water ratios can overcome these difficulties due to the consistency of the amount of water and the objective nature of the method. Despite the differences between the results obtained from soil to water extraction methods, many laboratories started to use it due to its simplicity, reduced monetary and time investment (Franzen, 2003; Zhang *et al.*, 2005). Ion concentrations and electrical conductivities of the extracts of different soil to water ratios are typically lower than those of saturated paste extracts as a result of the increased dilution effect.

According to the USDA (1954), the EC and major ion concentrations obtained from the 1:1 extraction method can be adjusted with conversion factors. These conversion factors were based on soil moisture holding capacities and the theoretical and actual chemical solubility of ions in aqueous systems (USDA, 1954). However, the impacts of other soil properties such as texture, salt concentrations, organic matter content, cation exchange capacity on ion concentrations and EC were not considered. The exclusion of these soil properties in the conversion factors, coupled with the lack of extensive examination of relationships between the two methods and minimal experimental verification, could contribute to imprecise adjustment of 1:1 analyses when applied to a variety of soils (Franzen, 2003;

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Received July 17, 2016, Accepted August 15, 2016

Zhang *et al.*, 2005). To improve on the original factors, researchers have developed new conversion techniques using experimental data to generate empirical relationships.

EC conversion factors for 1:1 soil extracts were divided into three textural divisions for coarse, medium, and fine (Franzen, 2003). Hogg and Henry (1984) derived conversion factors for EC and individual ionic species. Soil to water extracts of 1:1, 1:2.5 and 1:5 were also used to obtain regression relationships with soil paste extracts of soil samples having different textures (Ozcan *et al.*, 2006; Sonmez *et al.*, 2008). Even with the reports of highly correlated relationships between these two methods, the observed variations in the values of conversion factors generated by these studies for various soils restricted its generalization (Sonmez *et al.*, 2008). This necessitates further examination and comparison of these extraction methods to generate a more refined adjustment of different soil to water extracts over a wide range of soil conditions. In addition, in soil laboratories, pH is measured in 1:2.5 soil water suspensions (Jackson, 1967). If suitable conversion coefficients were determined, EC and pH can both be measured in the same extract allowing to make the two measurements at once.

Therefore, the objective of this study was to assess the regression correlations between the EC and the major cations and anions concentrations in the saturated soil paste extracts versus different soil to water ratios (SW1:1, SW1:2.5 and SW1:5) for three different soil types commonly occur in the Northwest of Egypt.

## MATERIALS AND METHODS

### 1. Soil Sampling and Preparation:

Three different Egyptian soil types that are prevailing in the Northwestern area of Egypt, sandy textured soils (typic xeropsaments, denoted as SANWD), calcareous soils (typic calciorthids or typic gypsiorthids, denoted as CALMD) and lacustrine and alluvial clay soils (typic terrfluvents, denoted as CLYLA) were used in this study. Twenty five surface soil samples (0-20 cm) were collected for each soil type from different locations to represent various textural classes, soil salinity levels, and cultivated crops existing in the sampled areas. SANWD soil samples were collected from West Nubaria (30° 30' 34" N, 30° 09' 18" E), South El-Tahrir (30° 15' 58" N, 30° 36' 20" E) and Wadi El-Natron (30° 25' 04" N, 30° 19' 40" E) areas. CALMD soil samples were collected from Nubaria (30° 47' 08" N, 29° 46' 38" E), El-Hamam (30° 52' 35" N, 29° 43' 18" E), and Borg El-Arab (30° 53' 48" N, 29° 33' 07" E) areas. CLYLA soil samples were collected from Abis (31° 12' 43" N, 29° 58' 56" E), Kafr El-Dawar (31°

09' 09" N, 30° 08' 59" E) and Damanhour (31° 03' 29" N, 30° 26' 49" E) areas.

Collected soil samples were brought to the laboratory, air dried, sieved (< 2 mm sieve) and stored for subsequent analysis. Electrical conductivity (EC), pH and concentrations of major cations and anions in the saturated soil paste extracts of the collected soil samples were determined according to Jackson (1967). Soil texture was determined by the hydrometer method (Day, 1982). Summary statistics of the analysis results are given in Table (1).

### 2. Preparation and Analysis of Extracts:

Preparation of saturated paste extracts (SP) were carried out by adding distilled water to approximately 400 g soil sample with stirring until it reached saturation and left to equilibrate for 18 h (Rhoades, 1982). The soil extracts were obtained by vacuum, filtered using Whatman #42 filter papers and analyzed for major cations ( $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ ) and major anions ( $\text{Cl}^-$ ,  $\text{CO}_3^{2-}$ , and  $\text{HCO}_3^-$ ) according to Page *et al.* (1982). Concentration of  $\text{SO}_4^{2-}$  was calculated by subtracting the total amounts of anions and cations.

Suspensions of three different soil to water ratios (SW1:1, SW1:2.5 and SW1:5) were prepared. The (SW1:1) soil to water suspension was prepared by adding 100 ml of distilled water to 100 g of oven-dried soil sample while the (SW1:2.5) and (SW1:5) suspensions were prepared by adding 75 and 150 ml of distilled water to 30 g of oven-dried soil sample. Soil suspensions were shaken for 1 min by hand 4 times at 30-minute intervals (Rhoades, 1982). Extracts were obtained from the suspensions by filtration using Whatman #42 filter paper and analyzed using the same methods as with the saturated soil paste extracts. Triplicates of each soil sample were used in this study for the calculation of mean values.

### 3. Statistical Analyses:

Descriptive statistical analysis of the obtained data was carried out using the Costat software (Costat, 2004) to calculate mean, standard deviation, median, standard error, sample variance kurtosis, skewness, range, minimum, maximum and 95% confidence level. Regression analysis was also conducted for measured  $\text{EC}_{\text{sp}}$  and major cations and anions concentrations in saturated soil paste extracts versus those measured in SW1:1, SW1:2.5 and SW1:5 extracts. Regression equations were derived with and without intercepts. Regression slopes and coefficients of determination ( $r^2$ ) were used to evaluate the generated regression relationships in this study.

## RESULTS AND DISCUSSIONS

The main characteristics of the soils studied revealed that the highest ion concentrations measured in soil paste extracts were Cl and Na ions (Table 1). The descriptive statistics for EC of soil samples are given in Table (2). EC values of the soil samples studied range from 0.578 to 24.026 dS m<sup>-1</sup> for the saturated soil paste extracts, from 0.257 to 10.775 dS m<sup>-1</sup> for SW1:1 extracts, from 0.028 to 6.983 dS m<sup>-1</sup> for SW1:2.5 extracts, and from 0.039 to 3.349 dS m<sup>-1</sup> for SW1:5 extracts. As suggested by USDA (1954), Rhoades (1982) and Sonmez *et al.* (2008), the EC of soil extracts is decreased by increasing the soil to water ratios due to dilution effects.

Mean ion concentrations and electrical conductivities for saturated paste extracts were almost two fold greater than that of the SW1:1 extracts, about four fold greater than that of the SW1:2.5 extracts, and approximately eight fold greater than that of the SW1:5 extracts (Table 2). In other words, when soil to water ratios are increased about two fold, approximately two fold diluted values are measured. These results were also reported by Zhang *et al.* (2005) and Sonmez *et al.* (2008) who obtained two fold dilution when comparing the saturated paste result with (1:1) soil to water ratio.

The measured EC values of the saturated paste extracts (EC<sub>sp</sub>) versus those of different soil to water ratios (SW1:1, SW1:2.5 and SW1:5) for SANWD, CALMD and CLYLA soils are presented in Fig. 1, 2 and 3, respectively. Regression relationships revealed that the slopes of the regression lines increase with increasing the soil to water ratios reflecting the dilution effects. The linear regression relationships were found to be the best fit model to the obtained data for all soil to water ratios and soil types. The dashed lines in these figures represent the 95% confidence level intervals for the regression lines. The resulted regression equations with and without intercept are given in Table (3). High coefficients of determination of the regression equations range from 0.934 to 0.995. There are no drastic changes in either the slopes or the coefficients of determination of the regression equations when the intercept is excluded (Table 3). The high coefficients of determination obtained indicate highly significant relationships between saturated paste extracts and different soil to water ratios. These results are close to those reported by Shirokova *et al.* (2000), Zhang *et al.* (2005), Ozcan *et al.* (2006) and Sonmez *et al.* (2008).

The slopes of the regression equations of SANWD, CALMD and CLYLA soils are 2.424, 1.968 and 2.028, respectively, for SW1:1 extracts. These values are very close to those reported by Sonmez *et al.* (2008) who

obtained slopes 2.72, 2.15, and 2.03 for sandy, loamy, and clay textured soils, respectively, for (1:1) soil to water ratios. While The slopes of the regression equations of coarse, medium and fine soils given by Franzen (2003) were 3.01, 3.01, and 2.96, respectively, for the same soil to water ratios. These differences in results can be attributed to several soil characteristics such as texture, type and content of clay minerals, organic matter and calcium carbonate contents. An explanation to the high slope values for SANWD soils is that in the coarse textured soils soluble salts are easily washed to the solution due to the low surface area of soil particles, absence of layered-negatively charged clay minerals and hence low adsorption capacity of ions. The opposite behavior can be expected from the soils with high clay and organic matter contents (Franzen, 2003; Sonmez *et al.*; 2008). This can justify higher values of slopes of regression equations for the SANWD soils compared to the CLYLA soils (Table 3).

For SW1:2.5, regression slopes with intercept are 4.172, 2.948 and 3.701 for SANWD, CALMD and CLYLA soils, respectively (Table 3). These slopes are slightly increased to 4.394, 3.164 and 3.861, respectively when intercepts are omitted. SW1:5 extracts show the same trend but with almost doubled values due to the dilution effect. Regression lines with intercepts have slopes 7.412, 7.767 and 7.118 for SANWD, CALMD and CLYLA soils, respectively. These slopes are increased to 7.522, 7.762 and 7.412 for SANWD, CALMD and CLYLA soils, respectively when intercepts are included. Slightly higher slopes were reported by Sonmez *et al.* (2008) who obtained slopes of (1:2.5) soil to water ratio regression lines 4.34, 3.84 and 3.68 without intercepts and 4.41, 3.96 and 3.75 with intercepts for sandy, loamy and clay soils, respectively. They also obtained slopes of (1:5) soil to water ratio regression lines 8.22, 7.58 and 7.63 without intercepts and 7.98, 7.62 and 7.19 with intercepts for sandy, loamy and clay soils, respectively. On the other hand, Ozcan *et al.* (2006) reported a lower regression slope of 5.97 with intercept for the (1:5) soil to water ratio of sandy soils but they did not take soil textural classes into consideration.

Regression equations with coefficients of determination of soluble ions concentrations with and without intercept along with the EC equations are presented in Tables 4, 5 and 6 for SANWD, CALMD and CLYLA soils, respectively. Generally, slopes of the regression lines increase with increasing soil to water ratios for all ions but with different magnitudes among ions.

**Table 1. Summary statistics for soil texture and main chemical properties of the collected soil samples used to establish the regression relationships**

Statistics	Soil texture		pH	EC ds m <sup>-1</sup>	Concentration, me l <sup>-1</sup>									
	Sand ----- %	Silt ----- %			Clay ----- %	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Cl <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	CO <sub>3</sub> <sup>2-</sup>	SO <sub>4</sub> <sup>2-(b)</sup>	
<b>SANWD Soils</b>														
Mean	82.10	13.85	4.15	7.95	7.04	52.10	2.82	9.15	6.34	55.62	8.45	0.19	5.63	
Median	82.00	14.25	3.75	7.81	5.63	41.44	2.24	7.28	5.04	44.24	6.72	0.12	4.48	
Minimum	68.20	4.10	0.50	7.52	0.71	5.25	0.28	0.92	0.64	5.60	0.85	0.00	0.57	
Maximum	96.00	21.25	10.75	8.13	24.03	177.82	9.61	31.24	21.63	189.84	28.84	0.40	19.22	
SE	1.10	0.63	0.48	0.01	0.75	5.58	0.30	0.98	0.68	5.96	0.90	0.08	0.60	
<b>CALMD Soils</b>														
Mean	53.01	28.75	18.25	8.39	7.42	54.91	2.97	9.65	6.68	58.62	8.90	0.74	5.94	
Median	52.30	28.61	18.12	8.33	5.32	39.37	2.13	6.92	4.79	42.03	6.38	0.53	4.26	
Minimum	38.50	21.50	11.10	8.31	0.63	4.63	0.25	0.81	0.56	4.94	0.75	0.00	0.50	
Maximum	67.50	36.10	25.51	8.49	21.32	157.62	8.52	27.69	19.17	168.27	25.56	1.13	17.04	
SE	1.82	2.56	1.99	0.02	0.72	5.34	0.29	0.94	0.65	5.70	0.87	0.07	0.58	
<b>CLYIA Soils</b>														
Mean	23.75	43.38	32.88	7.79	6.28	46.47	2.51	8.16	5.65	49.61	7.54	0.63	5.02	
Median	23.75	43.35	32.71	7.72	4.86	35.96	1.94	6.32	4.37	38.39	5.83	0.49	3.89	
Minimum	9.51	36.25	25.75	7.41	0.58	4.28	0.23	0.75	0.52	4.57	0.69	0.00	0.46	
Maximum	38.33	50.51	40.10	8.61	17.98	133.05	7.19	23.37	16.18	142.04	21.58	1.08	14.38	
SE <sup>(a)</sup>	2.11	1.55	2.54	0.02	0.56	4.17	0.23	0.73	0.51	4.46	0.68	0.06	0.45	

<sup>a</sup> SE: Standard Error. <sup>b</sup> Calculated by subtraction of total anions from total cations.

**Table 2. Descriptive statistics for EC (dS m<sup>-1</sup>) of saturated soil paste extracts and different soil to water ratios**

Parameter	Extracts			
	Soil paste	SW1:1	SW1:2.5	SW1:5
Mean	7.01	3.27	1.82	0.91
Standard Error	0.68	0.32	0.20	0.09
Median	4.87	2.69	1.21	0.69
Standard Deviation	5.91	2.75	1.73	0.79
Sample Variance	34.97	7.57	3.01	0.62
Kurtosis	0.28	0.48	1.27	0.52
Skewness	1.07	1.11	1.39	1.13
Range	23.45	10.52	6.96	3.31
Minimum	0.58	0.26	0.03	0.04
Maximum	24.03	10.78	6.98	3.35
Count	75	75	75	75
Confidence Level (95.0%)	1.36	0.63	0.39	0.18

**Table 3. Regression equations and coefficients of determination (r<sup>2</sup>) for EC (dS m<sup>-1</sup>) in saturated soil paste extracts (EC<sub>sp</sub>) versus different soil to water ratios**

Extract	Without intercept		With intercept	
	Equation	r <sup>2</sup>	Equation	r <sup>2</sup>
SANWD soils				
SW1:1	EC <sub>sp</sub> = 2.424x	0.95 <sup>***</sup>	EC <sub>sp</sub> = 2.346x+ 0.424	0.96 <sup>***</sup>
SW1:2.5	EC <sub>sp</sub> = 4.394y	0.97 <sup>***</sup>	EC <sub>sp</sub> = 4.172x+ 0.685	0.98 <sup>***</sup>
SW1:5	EC <sub>sp</sub> = 7.522z	0.99 <sup>***</sup>	EC <sub>sp</sub> = 7.412x+ 0.192	0.98 <sup>***</sup>
CALMD soils				
SW1:1	EC <sub>sp</sub> = 1.968x	0.98 <sup>***</sup>	EC <sub>sp</sub> = 1.933x+ 0.222	0.97 <sup>***</sup>
SW1:2.5	EC <sub>sp</sub> = 3.164y	0.98 <sup>***</sup>	EC <sub>sp</sub> = 2.948y+ 0.927	0.96 <sup>***</sup>
SW1:5	EC <sub>sp</sub> = 7.762z	0.98 <sup>***</sup>	EC <sub>sp</sub> = 7.676z+ 0.138	0.98 <sup>***</sup>
CLYLA soils				
SW1:1	EC <sub>sp</sub> = 2.028x	0.98 <sup>***</sup>	EC <sub>sp</sub> = 2.102x+ 0.354	0.96 <sup>***</sup>
SW1:2.5	EC <sub>sp</sub> = 3.861y	0.97 <sup>***</sup>	EC <sub>sp</sub> = 3.701y+ 0.420	0.93 <sup>***</sup>
SW1:5	EC <sub>sp</sub> = 7.412z	0.98 <sup>***</sup>	EC <sub>sp</sub> = 7.118z+ 0.402	0.96 <sup>***</sup>

x, y and z are the values measured in SW1:1, SW1:2.5 and SW1:5 extracts, respectively.

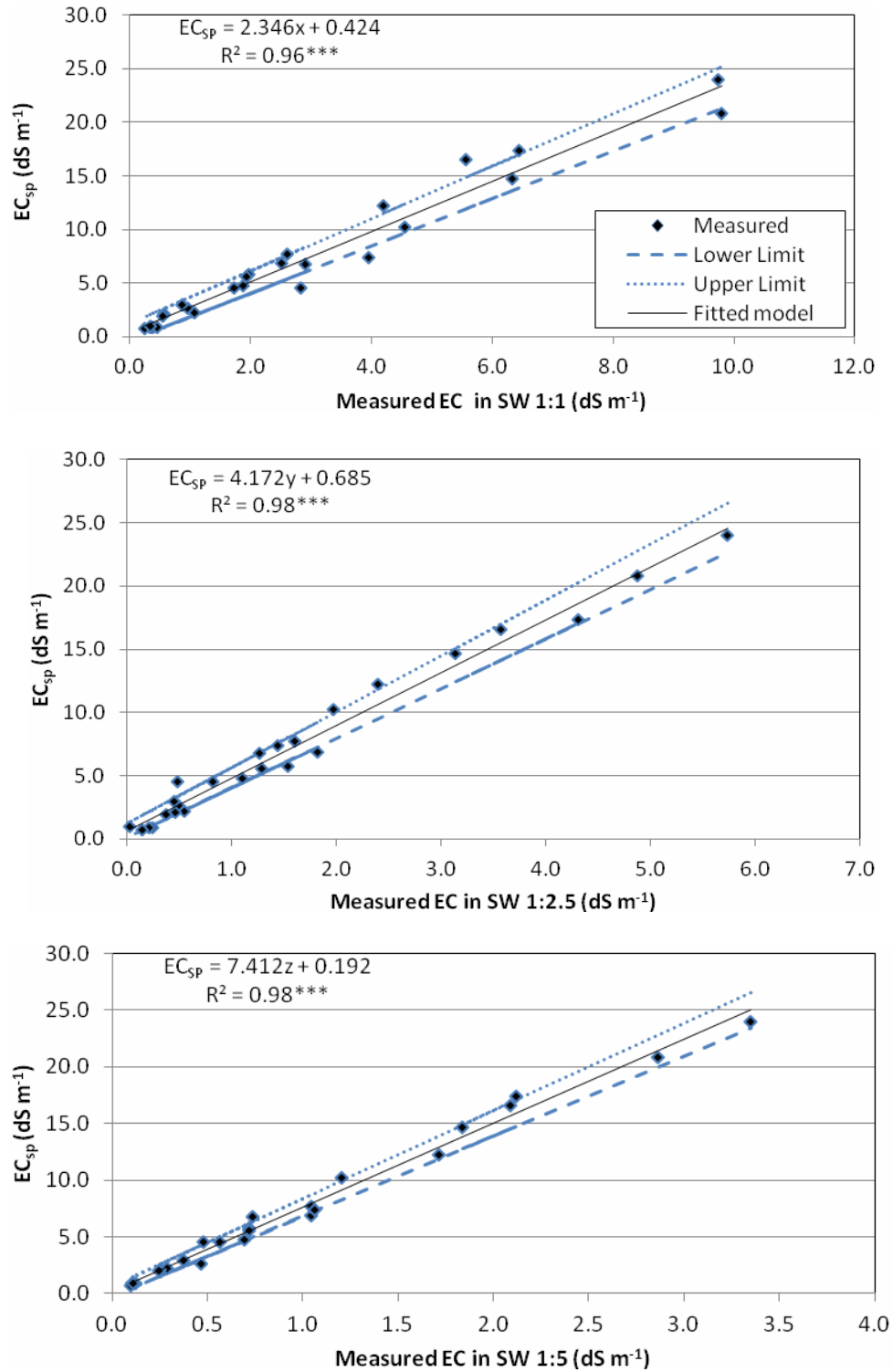
\* Significant, \*\* Highly significant, \*\*\* very highly significant, <sup>ns</sup> not significant.

The degree of correlation between soluble ions concentration of saturated paste extracts versus different soil to water ratios varies more among different ions than among soil to water ratios. Although Na and Cl ions show the highest coefficients of determination (0.92-0.99), K ion show the lowest coefficients of determination (0.47-0.84), and Ca and Mg ions show moderate coefficients of determination in CALMD soils (0.61-0.71), and high values in SANWD and CLYLA soils (0.71-0.98). Slight decrease in the slopes of the regression equations was observed after omitting the intercept for all ions in different soil to water ratios (Tables 4, 5 and 6).

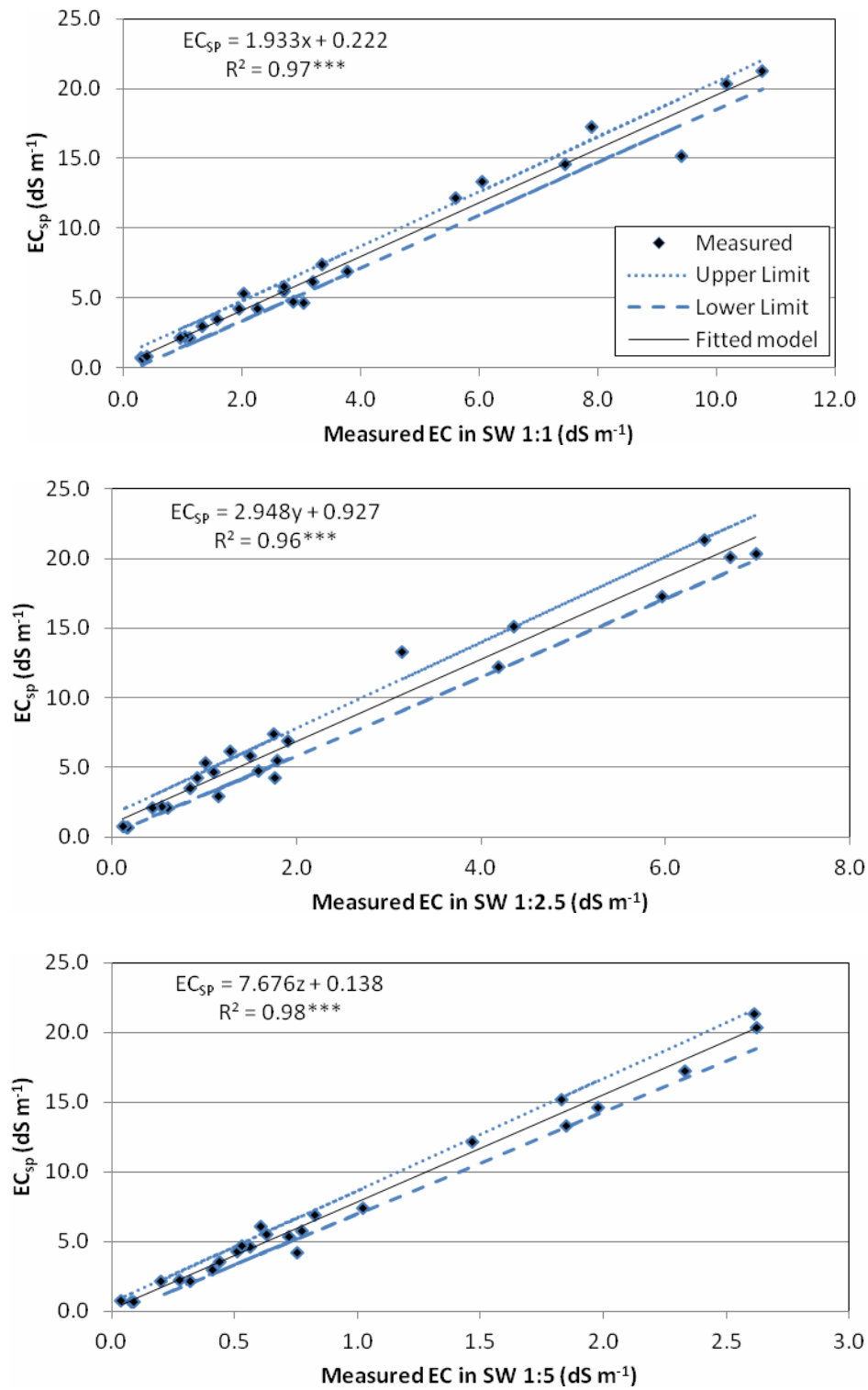
Inspection of the results of EC given in Table (3) and Figs. 1, 2 and 3 shows that the slopes for the SW1:1, SW1:2.5 and SW1:5 extracts are close to 2, 4 and 7.5, respectively, for the three soil types. This

means that the effect of dilution in the different soil to water ratios is superior to the effect of soil type. Therefore, data of the EC for each soil to water ratio were combined for the three soil types to establish

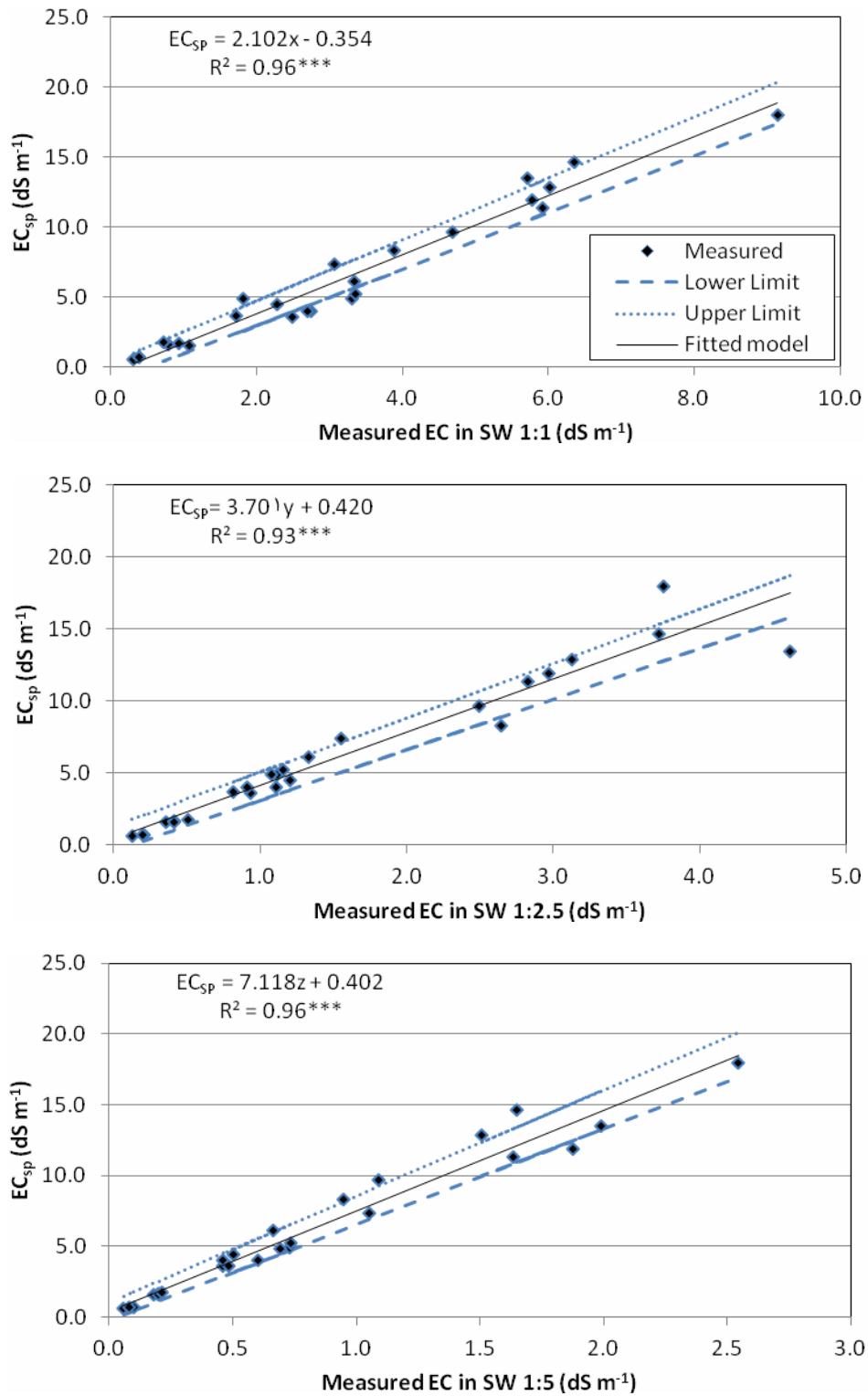
one regression line as shown in Table 7 and Fig. 4. Slopes of the regression lines without intercept of the EC are 2.12, 3.64 and 7.58 for SW1:1, SW1:2.5 and SW1:5, respectively, with slightly higher coefficients of determination than those with intercept (Table 7). Regression lines for soluble ions concentration for combined soils show generally lower coefficients of determination than the EC regression lines.



**Figure 1. Regression relationships of EC measured in saturated soil paste extracts ( $EC_{sp}$ ) versus different soil to water ratios for SANWD soils**



**Figure 2. Regression relationships of EC measured in saturated soil paste extracts (EC<sub>sp</sub>) versus different soil to water ratios for CALMD soils**



**Figure 3. Regression relationships of EC measured in saturated soil paste extracts ( $EC_{SP}$ ) versus different soil to water ratios for CLYLA soils**



**Table 4. Regression equations and coefficients of determination ( $r^2$ ) for soluble ions concentrations ( $\text{me l}^{-1}$ ) of saturated soil paste extracts versus different soil to water ratios for SANWD soils**

Parameter	Without intercept		With intercept	
	Equation	$r^2$	Equation	$r^2$
SW 1:1				
Cl <sup>-</sup>	Cl <sub>sp</sub> = 3.37x	0.95 <sup>***</sup>	Cl <sub>sp</sub> = 3.99x + 51.23	0.96 <sup>***</sup>
K <sup>+</sup>	K <sub>sp</sub> = 1.29x	0.50 <sup>*</sup>	K <sub>sp</sub> = 2.05x + 0.21	0.47 <sup>ns</sup>
Na <sup>+</sup>	Na <sub>sp</sub> = 2.52x	0.98 <sup>***</sup>	Na <sub>sp</sub> = 2.71x + 6.71	0.99 <sup>***</sup>
Ca <sup>2+</sup>	Ca <sub>sp</sub> = 3.17x	0.82 <sup>**</sup>	Ca <sub>sp</sub> = 4.85x + 34.01	0.71 <sup>**</sup>
Mg <sup>2+</sup>	Mg <sub>sp</sub> = 3.98x	0.71 <sup>**</sup>	Mg <sub>sp</sub> = 5.12x + 10.91	0.87
SW 1:2.5				
Cl <sup>-</sup>	Cl <sub>sp</sub> = 6.07y	0.98 <sup>***</sup>	Cl <sub>sp</sub> = 6.20y + 6.38	0.99 <sup>***</sup>
K <sup>+</sup>	K <sub>sp</sub> = 2.43y	0.73 <sup>**</sup>	K <sub>sp</sub> = 2.23y + 0.07	0.74 <sup>**</sup>
Na <sup>+</sup>	Na <sub>sp</sub> = 4.53y	0.99 <sup>***</sup>	Na <sub>sp</sub> = 4.51y + 0.14	0.99 <sup>***</sup>
Ca <sup>2+</sup>	Ca <sub>sp</sub> = 5.22y	0.92 <sup>***</sup>	Ca <sub>sp</sub> = 5.40y + 0.03	0.96 <sup>***</sup>
Mg <sup>2+</sup>	Mg <sub>sp</sub> = 10.61y	0.98 <sup>***</sup>	Mg <sub>sp</sub> = 10.98y + 6.78	0.98 <sup>***</sup>
SW 1:5				
Cl <sup>-</sup>	Cl <sub>sp</sub> = 10.34z	0.97 <sup>***</sup>	Cl <sub>sp</sub> = 10.74z + 13.54	0.99 <sup>***</sup>
K <sup>+</sup>	K <sub>sp</sub> = 2.96z	0.59 <sup>*</sup>	K <sub>sp</sub> = 2.55z + 0.11	0.64 <sup>*</sup>
Na <sup>+</sup>	Na <sub>sp</sub> = 8.38z	0.98 <sup>***</sup>	Na <sub>sp</sub> = 8.41z + 0.52	0.98 <sup>***</sup>
Ca <sup>2+</sup>	Ca <sub>sp</sub> = 9.81z	0.98 <sup>***</sup>	Ca <sub>sp</sub> = 10.68z + 7.39	0.99 <sup>***</sup>
Mg <sup>2+</sup>	Mg <sub>sp</sub> = 16.34z	0.96 <sup>***</sup>	Mg <sub>sp</sub> = 18.21z + 12.11	0.98 <sup>***</sup>

x, y and z are the values measured in SW1:1, SW1:2.5 and SW1:5 extracts, respectively.

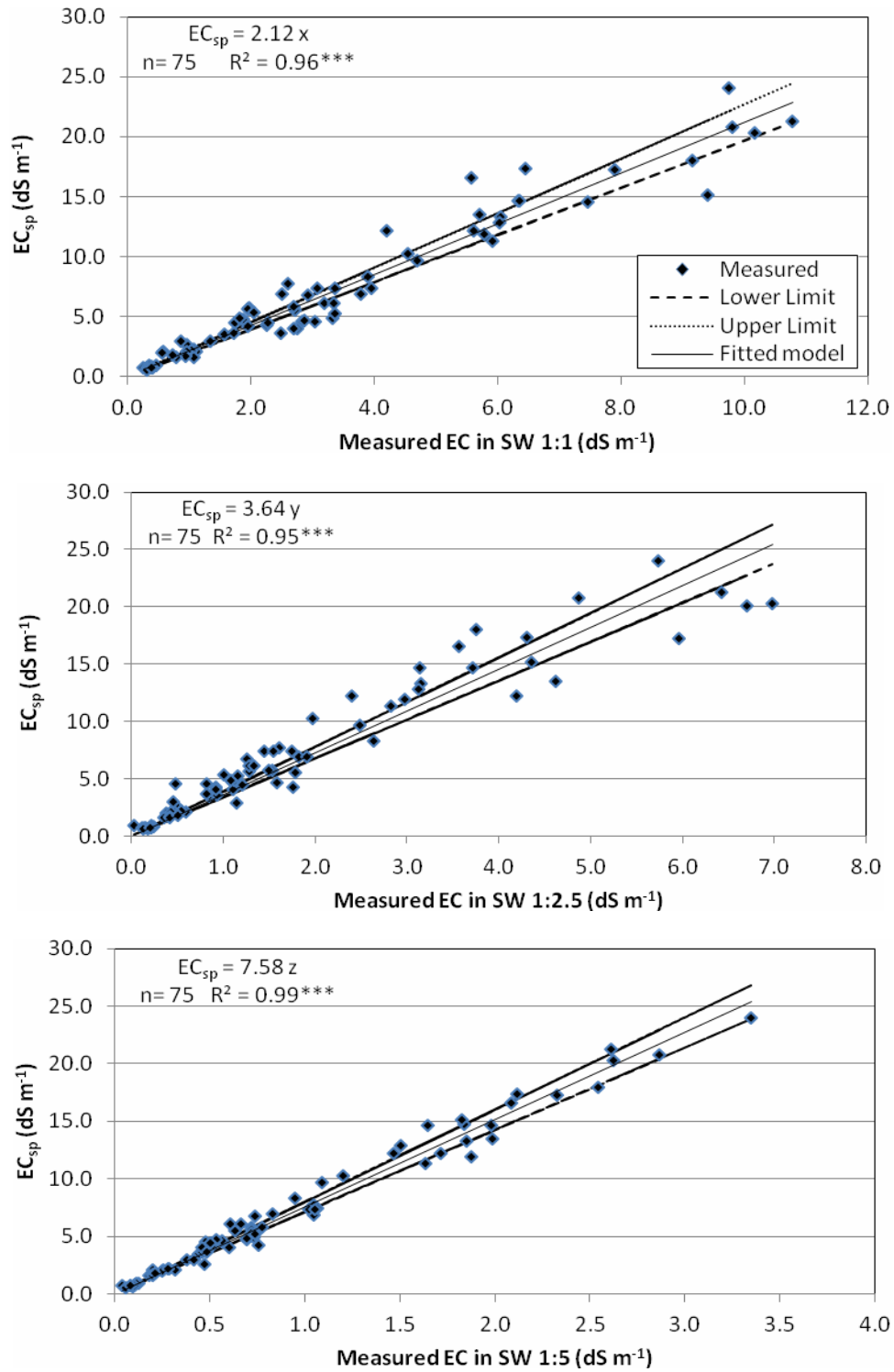
\* Significant, \*\* Highly significant, \*\*\* very highly significant, <sup>ns</sup> not significant.

**Table 5. Regression equations and coefficients of determination ( $r^2$ ) for soluble ions concentrations ( $\text{me l}^{-1}$ ) of saturated soil paste extracts versus different soil to water ratios for CALMD soils**

Parameter	Without intercept		With intercept	
	Equation	$r^2$	Equation	$r^2$
SW 1:1				
Cl <sup>-</sup>	Cl <sub>sp</sub> = 2.31x	0.98 <sup>***</sup>	Cl <sub>sp</sub> = 2.19x + 3.10	0.99 <sup>***</sup>
K <sup>+</sup>	K <sub>sp</sub> = 1.67x	0.52 <sup>*</sup>	K <sub>sp</sub> = 1.49x + 0.03	0.53 <sup>*</sup>
Na <sup>+</sup>	Na <sub>sp</sub> = 2.02x	0.99 <sup>***</sup>	Na <sub>sp</sub> = 2.02x + .05	0.99 <sup>***</sup>
Ca <sup>2+</sup>	Ca <sub>sp</sub> = 1.97x	0.68 <sup>**</sup>	Ca <sub>sp</sub> = 2.21x + 4.99	0.70 <sup>*</sup>
Mg <sup>2+</sup>	Mg <sub>sp</sub> = 1.65x	0.69 <sup>**</sup>	Mg <sub>sp</sub> = 1.41x + 9.21	0.71 <sup>**</sup>
SW 1:2.5				
Cl <sup>-</sup>	Cl <sub>sp</sub> = 5.18y	0.99 <sup>***</sup>	Cl <sub>sp</sub> = 4.89y + 6.29	0.99 <sup>***</sup>
K <sup>+</sup>	K <sub>sp</sub> = 2.46y	0.71 <sup>**</sup>	K <sub>sp</sub> = 2.11y - 0.08	0.72 <sup>**</sup>
Na <sup>+</sup>	Na <sub>sp</sub> = 3.74y	0.99 <sup>***</sup>	Na <sub>sp</sub> = 3.65y + 3.11	0.99 <sup>***</sup>
Ca <sup>2+</sup>	Ca <sub>sp</sub> = 9.65y	0.69 <sup>*</sup>	Ca <sub>sp</sub> = 4.85y + 0.81	0.70 <sup>**</sup>
Mg <sup>2+</sup>	Mg <sub>sp</sub> = 4.71y	0.68 <sup>**</sup>	Mg <sub>sp</sub> = 4.84y + 2.35	0.69 <sup>**</sup>
SW 1:5				
Cl <sup>-</sup>	Cl <sub>sp</sub> = 10.54z	0.98 <sup>***</sup>	Cl <sub>sp</sub> = 11.61z + 0.31	0.99 <sup>***</sup>
K <sup>+</sup>	K <sub>sp</sub> = 3.49z	0.51 <sup>*</sup>	K <sub>sp</sub> = 2.51z - 1.1	0.52 <sup>*</sup>
Na <sup>+</sup>	Na <sub>sp</sub> = 7.69z	0.99 <sup>***</sup>	Na <sub>sp</sub> = 8.05z - 0.91	0.99 <sup>***</sup>
Ca <sup>2+</sup>	Ca <sub>sp</sub> = 15.99z	0.61 <sup>**</sup>	Ca <sub>sp</sub> = 19.65z - 4.65	0.63 <sup>**</sup>
Mg <sup>2+</sup>	Mg <sub>sp</sub> = 10.03z	0.62 <sup>**</sup>	Mg <sub>sp</sub> = 9.85z + 15.32	0.68 <sup>**</sup>

x, y and z are the values measured in SW1:1, SW1:2.5 and SW1:5 extracts, respectively.

\* Significant, \*\* Highly significant, \*\*\* very highly significant, <sup>ns</sup> not significant.



**Figure 4. Regression relationships of EC measured in saturated soil paste extracts ( $EC_{SP}$ ) versus different soil to water ratios for combined soil types**

**Table 6. Regression equations and coefficients of determination ( $r^2$ ) for soluble ions concentrations ( $\text{me l}^{-1}$ ) of saturated soil paste extracts versus different soil to water ratios for CLYLA soils**

Parameter	Without intercept		With intercept	
	Equation	$r^2$	Equation	$r^2$
SW 1:1				
Cl <sup>-</sup>	Cl <sub>sp</sub> = 2.01x	0.96 <sup>***</sup>	Cl <sub>sp</sub> = 2.11x- 10.51	0.97 <sup>***</sup>
K <sup>+</sup>	K <sub>sp</sub> = 1.54x	0.65 <sup>**</sup>	K <sub>sp</sub> = 1.42x+ 0.01	0.66 <sup>*</sup>
Na <sup>+</sup>	Na <sub>sp</sub> = 2.38x	0.92 <sup>***</sup>	Na <sub>sp</sub> = 2.11x- 0.22	0.93 <sup>***</sup>
Ca <sup>2+</sup>	Ca <sub>sp</sub> = 2.21x	0.98 <sup>***</sup>	Ca <sub>sp</sub> = 2.61x-0.02	0.98 <sup>***</sup>
Mg <sup>2+</sup>	Mg <sub>sp</sub> = 1.89x	0.95 <sup>***</sup>	Mg <sub>sp</sub> = 2.35x-5.99	0.96 <sup>***</sup>
SW 1:2.5				
Cl <sup>-</sup>	Cl <sub>sp</sub> = 4.31y	0.98 <sup>***</sup>	Cl <sub>sp</sub> = 4.35y-13.11	0.99 <sup>***</sup>
K <sup>+</sup>	K <sub>sp</sub> = 3.44y	0.73 <sup>**</sup>	K <sub>sp</sub> = 3.48y- 0.09	0.84 <sup>**</sup>
Na <sup>+</sup>	Na <sub>sp</sub> = 4.34y	0.99 <sup>***</sup>	Na <sub>sp</sub> = 4.52y- 1.99	0.99 <sup>***</sup>
Ca <sup>2+</sup>	Ca <sub>sp</sub> = 6.61y	0.99 <sup>***</sup>	Ca <sub>sp</sub> = 6.71y- 0.99	0.99 <sup>***</sup>
Mg <sup>2+</sup>	Mg <sub>sp</sub> = 4.68y	0.96 <sup>***</sup>	Mg <sub>sp</sub> = 5.11y- 8.71	0.97 <sup>***</sup>
SW 1:5				
Cl <sup>-</sup>	Cl <sub>sp</sub> = 7.69z	0.97 <sup>***</sup>	Cl <sub>sp</sub> = 7.98z+ 1.01	0.99 <sup>***</sup>
K <sup>+</sup>	K <sub>sp</sub> = 3.25z	0.71 <sup>**</sup>	K <sub>sp</sub> = 3.32z- 0.19	0.74 <sup>**</sup>
Na <sup>+</sup>	Na <sub>sp</sub> = 6.76z	0.99 <sup>***</sup>	Na <sub>sp</sub> = 7.89z- 2.04	0.99 <sup>***</sup>
Ca <sup>2+</sup>	Ca <sub>sp</sub> = 11.21z	0.95 <sup>***</sup>	Ca <sub>sp</sub> = 12.79z- 5.84	0.96 <sup>***</sup>
Mg <sup>2+</sup>	Mg <sub>sp</sub> = 7.54z	0.93 <sup>***</sup>	Mg <sub>sp</sub> = 8.87z- 10.98	0.95 <sup>***</sup>

x, y and z are the values measured in SW1:1, SW1:2.5 and SW1:5 extracts, respectively.

\* Significant, \*\* Highly significant, \*\*\* very highly significant, <sup>ns</sup> not significant.

**Table 7. Regression equations and coefficients of determination ( $r^2$ ) for EC( $\text{dS m}^{-1}$ ) and soluble ions concentrations ( $\text{me l}^{-1}$ ) of saturated soil paste extracts versus different soil to water ratios for combined soil types**

Parameter	Without intercept		With intercept	
	Equation	$r^2$	Equation	$r^2$
SW 1:1				
EC, $\text{dS m}^{-1}$	EC <sub>sp</sub> = 2.12	0.97 <sup>***</sup>	EC <sub>sp</sub> = 2.09x+0.18	0.94 <sup>***</sup>
Cl <sup>-</sup> , $\text{me l}^{-1}$	Cl <sub>sp</sub> = 2.28x	0.91 <sup>**</sup>	Cl <sub>sp</sub> = 2.24x+1.13	0.92 <sup>**</sup>
K <sup>+</sup> , $\text{me l}^{-1}$	K <sub>sp</sub> = 1.52x	0.57 <sup>*</sup>	K <sub>sp</sub> = 1.39x+ 0.01	0.56 <sup>*</sup>
Na <sup>+</sup> , $\text{me l}^{-1}$	Na <sub>sp</sub> = 2.31x	0.94 <sup>***</sup>	Na <sub>sp</sub> = 2.33x- 1.21	0.93 <sup>***</sup>
Ca <sup>2+</sup> , $\text{me l}^{-1}$	Ca <sub>sp</sub> =2.12 x	0.84 <sup>**</sup>	Ca <sub>sp</sub> = 2.53x- 2.34	0.83 <sup>**</sup>
Mg <sup>2+</sup> , $\text{me l}^{-1}$	Mg <sub>sp</sub> = 1.70x	0.74 <sup>**</sup>	Mg <sub>sp</sub> =1.67 x+10.84	0.73 <sup>**</sup>
SW 1:2.5				
EC, $\text{dS m}^{-1}$	EC <sub>sp</sub> = 3.64y	0.99 <sup>***</sup>	EC <sub>sp</sub> = 3.35y+0.10	0.92 <sup>***</sup>
Cl <sup>-</sup> , $\text{me l}^{-1}$	Cl <sub>sp</sub> = 5.11y	0.96 <sup>***</sup>	Cl <sub>sp</sub> = 5.22y- 2.99	0.96 <sup>***</sup>
K <sup>+</sup> , $\text{me l}^{-1}$	K <sub>sp</sub> = 2.52y	0.79 <sup>**</sup>	K <sub>sp</sub> = 2.37y+ 0.03	0.80 <sup>**</sup>
Na <sup>+</sup> , $\text{me l}^{-1}$	Na <sub>sp</sub> = 4.13y	0.99 <sup>***</sup>	Na <sub>sp</sub> =4.19 y+ 0.1	0.99 <sup>***</sup>
Ca <sup>2+</sup> , $\text{me l}^{-1}$	Ca <sub>sp</sub> = 8.97y	0.91 <sup>***</sup>	Ca <sub>sp</sub> = 11.05y- 7.88	0.95 <sup>***</sup>
Mg <sup>2+</sup> , $\text{me l}^{-1}$	Mg <sub>sp</sub> = 4.79y	0.93 <sup>***</sup>	Mg <sub>sp</sub> = 5.07y- 2.31	0.94 <sup>***</sup>
SW 1:5				
EC, $\text{dS m}^{-1}$	EC <sub>sp</sub> = 7.58y	0.99 <sup>***</sup>	EC <sub>sp</sub> = 7.43y+0.23	0.98 <sup>***</sup>
Cl <sup>-</sup> , $\text{me l}^{-1}$	Cl <sub>sp</sub> = 11.02z	0.96 <sup>***</sup>	Cl <sub>sp</sub> = 11.21z-10.51	0.96 <sup>***</sup>
K <sup>+</sup> , $\text{me l}^{-1}$	K <sub>sp</sub> = 2.98z	0.55 <sup>*</sup>	K <sub>sp</sub> = 2.68z+ 0.03	0.58 <sup>*</sup>
Na <sup>+</sup> , $\text{me l}^{-1}$	Na <sub>sp</sub> = 8.31z	0.99 <sup>***</sup>	Na <sub>sp</sub> = 8.11z- 0.51	0.99 <sup>***</sup>
Ca <sup>2+</sup> , $\text{me l}^{-1}$	Ca <sub>sp</sub> = 16.11z	0.90 <sup>***</sup>	Ca <sub>sp</sub> = 18.95z- 16.31	0.92 <sup>***</sup>
Mg <sup>2+</sup> , $\text{me l}^{-1}$	Mg <sub>sp</sub> = 9.27z	0.91 <sup>***</sup>	Mg <sub>sp</sub> = 10.10z- 7.87	0.91 <sup>**</sup>

x, y and z are the values measured in SW1:1, SW1:2.5 and SW1:5 extracts, respectively.

\* Significant, \*\* Highly significant, \*\*\* very highly significant, <sup>ns</sup> not significant.

While K ion has the lowest coefficients of determination, 0.55-0.80, Na and Cl ions have the highest coefficients of determination, 0.91-0.96, and Ca and Mg ions have moderate to high coefficients of determination, 0.73-0.93 (Table 7). Snomez *et al.* (2008) reported combined regression slopes without intercepts of 2.11, 4.00 and 7.57 for (1:1), (1:2.5) and (1:5) soil to water ratios, respectively.

### CONCLUSION

This study showed that electrical conductivity and soluble ions concentrations of saturated soil paste extracts and (1:1), (1:2.5) and (1:5) soil to water ratios are obviously influenced by soil types. Soil specific and combined regression equations of the electrical conductivity, anions and cations concentrations versus those of different soil to water ratios were derived. The use of the either soil specific or combined equations is dependent on the level of data precision required, where soil specific equations can give more precise results. The three soil to water ratios studied proved to be precisely capable of estimating saturated paste extract electrical conductivity and ion concentrations. The conversion of (1:1), (1:2.5) and (1:5) soil to water ratios results to saturated paste extract equivalents has potentially great benefits. These benefits include minimum cost and less time consumption while maintaining a high accuracy and precision levels. The use of the (1:2.5) soil suspensions prepared for electrical conductivity and soluble ions concentrations measurements has more specific benefit as it can be also used in soil pH measurements, minimizing time and costs associated with soil salinity studies.

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:

.Combined Saturated Soil Paste

Soil to Water Ratios

:

Estimation

Electrical Conductivity

:

Slopes :

:

Dilution

:

Labor, Time and Cost (Na<sup>+</sup>, K<sup>+</sup>, Ca<sup>2+</sup> and Mg<sup>2+</sup>, Cl<sup>-</sup>, CO<sub>3</sub><sup>2-</sup>, and HCO<sub>3</sub><sup>-</sup>)

:

Regression Equations

Determination Coefficients

:

Specific Soil Equation :