Chapter 46
Innovations in Soil Chemical Analyses: New ECs and Total Salts Relationship for Abu Dhabi Emirate Soils

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Abstract Soil analysis is important to understand composition of soils for many reasons including developing soil management options for sustainable agricultural activities. There exists a relationship between total soluble salts (meq l^{-1}) and ECs (dS m^{-1}) developed in 1954 and published in the USDA Handbook 60. In the present study, an attempt has been made to correlate total soluble salts and ECs values from a range of soils from Abu Dhabi Emirate to test the validity of USDA relationship to local soils. The USDA ratios (TSS/ECs) of 10 and 16 exist for ECs 1 and 200 dS m^{-1}, respectively ($R^2 = 0.9577$). Whereas TSS/ECs ratio from Abu Dhabi Emirate soils was found to be 10 and 11.38 for ECs 1 and 200 dS m^{-1}, respectively, and for ECs 500 dS m^{-1} a ratio of 12 was found ($R^2 = 0.9711$), the USDA does not present such a ratio for ECs more than 200 dS m^{-1}. The present study has rejected the hypothesis that same relationship exists between TSS/ECs on soils of Abu Dhabi Emirate as that of USDA and, therefore, this relationship cannot be used for Abu Dhabi Emirate conditions. This chapter presents a new ratio for Abu Dhabi soils to avoid misinterpretation of soil analytical data for quality assurance (QA) purposes and to formulate soil management options. The newly developed relationship was

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validated by measuring sodium adsorption ratio (SAR) by various methods, that is, using Na derived by difference between TSS and Ca + Mg and through measured Na and Ca + Mg values from Abu Dhabi Soil Survey. The SAR calculated by using Na derived from newly developed relationship fits close to the SAR values from actually measured Na and Ca + Mg contents; these SAR values deviate to those measured from USSL and USDA relationships. In the light of present finding, it is recommended that other regions where soil and environmental conditions are similar to Abu Dhabi Emirate, a similar relationship most suited to their local conditions should be developed or the results to be correlated with that established from Abu Dhabi soils for validation.

Keywords Abu Dhabi Emirate • ECs • Handbook 60 • Salt concentration • UAE

46.1 Introduction

Irrigated agriculture has faced the challenge of sustaining its productivity for centuries. One of the major threats to irrigated agriculture productivity is soil salinity, which is developed either through high water table, capillary rise, and subsequent evaporation or through using alternative irrigation water sources where the quality of irrigation water is often low (variable salinity) and there is variable ionic composition in these solutions. Salinity can cause various salt stresses such as physiological drought (salt-induced drought), potential nutrient and element toxicities or management problems, nutrient imbalances and induced deficiencies, and inhibition of soil water and oxygen due to soil structure breakdown.

Salinity is a measure of the concentration of all the soluble salts in soil or water. It is expressed as deciSiemens per meter (dS m^{-1}) or milliSiemens per centimeter (mS cm^{-1}). Understanding soil salinity levels and the ionic composition across irrigated fields and landscapes is essential for better management. Salinity may exhibit considerable spatial and in depth variability (i.e., salt levels vary from one location to another and in depth) across the agricultural fields because of water movement, infiltration rate, runoff, and evapotranspiration patterns (Shahid and Rehman 2011; Shahid et al. 2010). Among other soil parameters, salinity measurement is one of the simplest and least expensive tools.

The measurement of electrical conductivity (EC) is an indirect way of salinity diagnosis. This can be accomplished by using routine EC meter and/or modern equipment (EM38). The EC meters are not difficult to use and eliminate the guesswork. There are different makes and models of salinity meter to suit a range of budgets and uses. If brackish or saline water is used for irrigation, then an EC meter is a valuable asset.

The choice of equipment/procedure depends upon the purpose of salinity determination, size of the area being evaluated, the depth of soil to be assessed, the number and frequency of measurements needed, the accuracy required, and the availability of manpower. For many reasons, soil scientists still believe that electrical conductivity of soil saturation extract (ECs) is the most common technique for assessing soil salinity and other potential hazards. This is due to the fact that the amount of water that a soil holds at saturation (saturation percentage) is related to a number of soil parameters, such as texture, surface area, clay content, and cation-exchange capacity. The lower soil-water ratio (1:1 or 1:2) makes extraction easier, but cautioned, as less related to field moisture condition than the saturated paste.

Soil sodicity is measured either as sodium adsorption ratio (SAR) or through measurement of exchangeable sodium percentage (ESP) using SAR values or exchangeable Na and cation-exchange capacity values using standard calculation procedures. The SAR requires soluble sodium to be determined in the soil extract from saturated soil paste; this can be achieved by analyzing the extract for Na using flame photometer or atomic absorption spectrophotometer (AAS), or soluble Na can be determined by difference, in samples where soluble K is either absent or present in negligible quantities. The latter requires the ECs as well as total soluble salt (meq l^{-1}) values to find soluble Na by difference. This is usually determined using USDA (Richards 1954) graph (Fig. 4 page 12 Handbook 60), which may suit to US local conditions, but may or may not be suitable for Abu Dhabi Emirate soils.

In this chapter, a new relationship between TSS/ECs is developed that differs from earlier ones developed by USDA (Richards 1954). This has been done through testing a hypothesis.

46.2 Hypothesis to Be Tested

The present study uses same approach as used by the United States Salinity Laboratory Staff (Richards 1954) to develop ECs and salt concentration relationship (Fig. 46.1). The hypothesis to test is that same relationship exists between ECs and total salts on soils of Abu Dhabi Emirate as that of USDA (Richards 1954) and, therefore, relationship as developed earlier (Richards 1954) can be used confidently in the soils of Abu Dhabi Emirate. If this hypothesis is supported, then a separate relationship for Abu Dhabi soils will not always be required and QA on ECs and total soluble salt concentration can be made confidently using the existing USDA relationship (Richards 1954). If however the relationship on ECs and salt concentration on Abu Dhabi Emirate soils does not match with that of USDA (Richards 1954), then QA of ECs and salt concentration is to be made using the developed relationship and recommendations made for sodicity appraisals and salinity management in Abu Dhabi Emirate.

46.3 Study Area

Abu Dhabi is the largest of the seven emirates of United Arab Emirates, accounting for 87% of the country's area. The emirate lies between latitude 22° 29′ N and 24° 53′ N and longitude 56° 10′ E and 51° 37′ E. Abu Dhabi Emirate is subjected to a tropical desert climate with typically high temperatures and low rainfall.

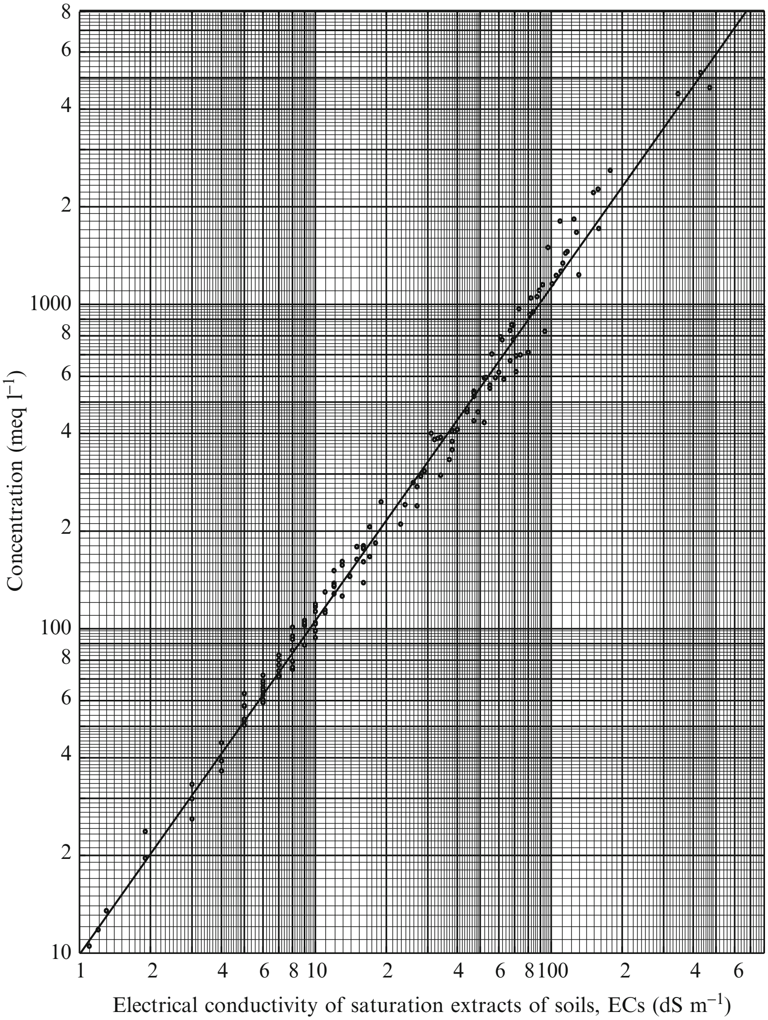

Fig. 46.1 Relationship between electrical conductivity of soil saturation extract (dS m^{-1}) and total salts concentration (meq l^{-1}) from Abu Dhabi Emirate soils

The climatic conditions are arid with extremely harsh and dry summers, when temperatures regularly exceed 45°C, and mild to warm winters with very little, sporadic rainfall, with two distinct seasons: a prolonged dry summer of very high summer temperatures between April and November and a winter of mild to warm temperatures with little rainfall between December and March. The soil temperature regime of most of Abu Dhabi can be regarded as hyperthermic (the mean annual soil temperature is 22°C or higher, and the difference between the mean summer and mean winter soil temperature is more than 6°C either at a depth of 50 cm from the soil surface or at a densic, lithic, or paralithic contact, whichever is shallower) as per Soil Survey Staff (2010). The landscape of the emirate is diverse, ranging from level coastal plains and sabkha to undulating desert sandplain; extensive areas of linear, transverse, and barchan sand dunes; and a single mountainous rocky outcrop, Jabal Hafeet.

46.3.1 Soils of Abu Dhabi Emirate

Recent Soil Survey of Abu Dhabi Emirate (EAD 2009) revealed variety of soils. The objective of this chapter is not to detail these but to give a general overview of the soils. The reader is referred to EAD (2009) and Shahid et al. (2013) for further details on the soil description. At the great group level, the soils are Haplocalcids (0.4%), Petrocalcids (0.04%), Calcigypsids (0.24%), Petrogypsids (2.88%), Aquisalids (3.07%), Haplosalids (6.53%), Torriorthents (0.59%), and Torripsamments (81.09%), whereas rock outcrops account for 0.57% only and the miscellaneous area 0.97% (urban, military, private areas, refilled, dumps, rubbish tips, quarries). This explains that sandy soils (Torripsamments) are the dominant soils in Abu Dhabi Emirate. They occur in the form of sand sheet and various types of sand dunes. These native sandy soils are poor in physical and chemical properties and in inherent soil fertility and, therefore, require significant efforts for economical agriculture.

46.4 ECs and Total Soluble Salts

The ECs values are related to total salt concentration in the liquid phase (solution chemistry) when expressed in meq l^{-1}. In the year 1954, United States Salinity Laboratory Staff published a historical book on Diagnosis and Improvement of Saline and Alkali Soils as Agriculture Handbook 60 (Richards 1954). Later much work has been done on salinity aspects worldwide; however, soil scientists around the world still believe this book to be a foundation to most of the salinity-related work. Among others, this book presents relationships between EC (millimhos cm^{-1} or new unit dS m^{-1}) and single salts ($CaSO_4$, Na_2SO_4, $NaHCO_3$, NaCl, $MgSO_4$, $CaCl_2$, and $MgCl_2$) and related salt concentration in meq l^{-1}. However, soil is a complex natural system consisting of a number of salts from various sources including parent material on which soil developed through a combination of five soil-forming factors (climate, parent material, living organisms, topography, and time). Therefore, an ECs from soil extract represents all salts, and their contribution to EC appears as weighted average conductivities of all salts that the soil is containing. The USDA (Richards 1954) in the historical book published such a relationship as Fig. 4 on page 12 of the Agriculture Handbook No 60. This relationship was developed on soils from widely separated areas in Western United States, which shows higher concentration of salts with respect to EC compared with those curves developed on single salt concentrations.

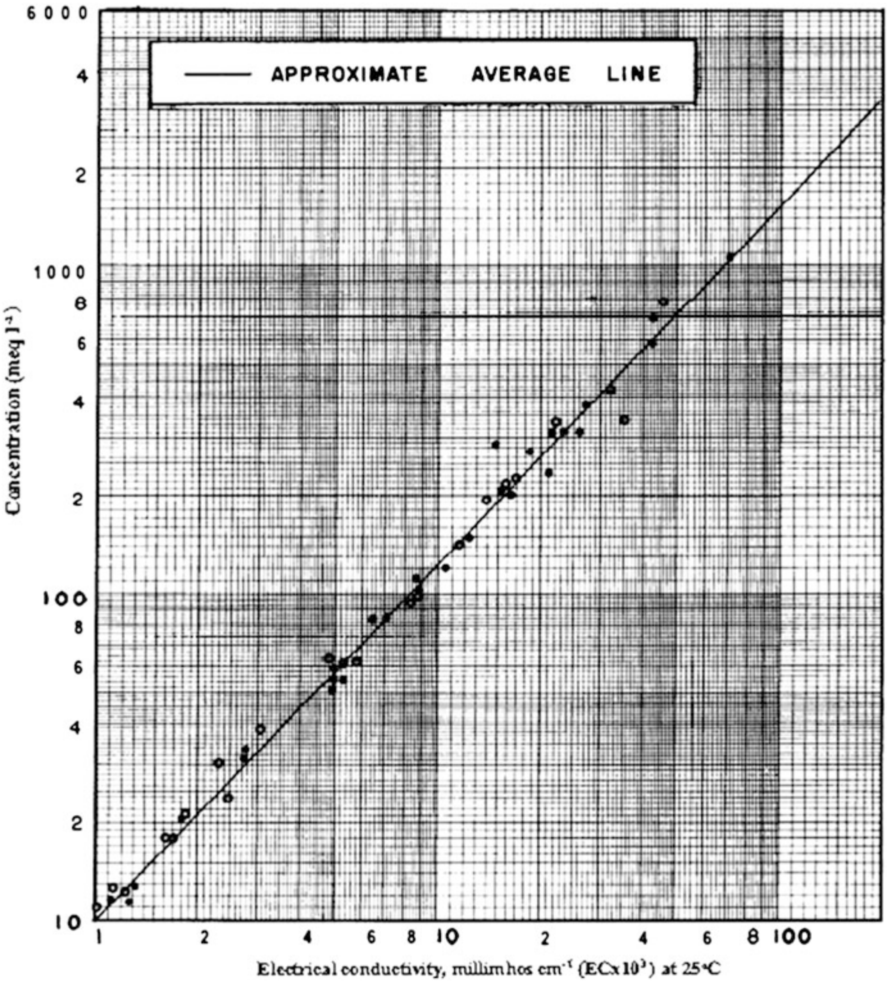

Fig. 46.2 Concentration of saturation extracts of soils in milliequivalents per liter as related to electrical conductivity (cf. Fig. 4, page 12, USDA Handbook 60)

This USDA relationship (Figs. 46.2 and 46.3) has been used intensively around the world by soil scientists and other professionals working on soil salinity issues to assess the quality of the data (ECs, anion and cation concentrations) in saturation extracts for further predictions of sodium adsorption ratio (SAR) which is then used for sodicity assessment (exchangeable sodium percentage – ESP), and to prepare salinity management plans on high ECs level soils.

Soils are heterogeneous, and great difference in soil characteristics occurs within short distances; this has been proved worldwide and recently in Abu Dhabi Emirate (EAD 2009), where a uniform-looking desert landscape presented 62 different soil types at the family level of USDA Soil Taxonomy hierarchy (Soil Survey Staff 1999, 2010).

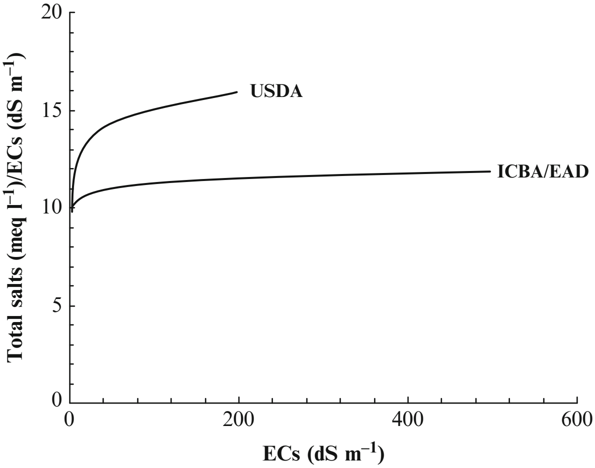

Fig. 46.3 Comparative representation of relationship between ECs and total soluble salts from *USDA* (Richards 1954) curve versus soils of Abu Dhabi Emirate (*ICBA/EAD* curve)

These desert soils are different to those in Western America, and therefore, it is hypothesized that different relationship may exist between total soluble salt concentrations and ECs in Abu Dhabi Emirate soils.

46.4.1 Importance of ECs in Crop Yields

The plant physiologists determine salinity tolerance of plants using the ECs of the root zone and crop yields. Plants can tolerate salinity up to certain levels without a measurable loss in yield (this is called threshold level). At salinity levels greater than the threshold, crop yield reduces linearly as salinity increases. Using the salinity values in a salinity/yield model developed by Maas and Hoffman (1977), predictions of expected yield loss can be made. Typically, plant growth is suppressed when a threshold value of root zone salinity is exceeded. Maas and Hoffman expressed salt tolerance of many plants by this relationship: $\mathrm{Yr} = 100 - s(\mathrm{ECs} - t)$, where Yr = percentage of the yield of plants grown in saline conditions relative to that obtained on nonsaline conditions, t = threshold salinity level where yield decrease begin, and s = percent yield loss per unit increase of ECs (dS m^{-1}) in excess of t. The ECs is the electrical conductivity of soil saturation extract. In this model, it is assumed that crops respond primarily to the osmotic potential of soil solution, and specific ion effects are of secondary importance. Therefore, soil salinity assessment is essential for plant selection growing in salinized fields and to take necessary management actions for better yields. Salinity monitoring helps understand the root zone salinity levels, whether below or above threshold level of crop in the field. The latter will require extra water to be applied based on the leaching fraction to maintain the root zone salinity below threshold salinity.

Soil salinity is a widespread limitation to agricultural production and a feature of land degradation in semiarid and arid region soils throughout the world. The accumulation of soluble salts in the soil profile curtails crop growth by increasing the osmotic potential of the soil solution and inducing specific ion toxicity or nutrient imbalances. Soil structure is affected by salinity and sodicity. A number of approaches have been devised to characterize soil salinity. Most conventional methods employ aqueous or direct extraction of the soil solution and subsequent analysis of salt concentrations. The standard way of establishing soil salinity is through the measurement of electrical conductivity of the soil saturation extract (ECs).

46.4.2 Why Total Salt/ECs Relationship Is Required

There are two main reasons to develop total salt/ECs relationship:

1. Many soil analytical laboratories carry detailed solution chemistry analysis and measure cations and anions in soil saturation extract. Major cations in arid and semiarid region soils are Na^+, K^+, Ca^{2+}, and Mg^{2+}, and anions are CO_3^{2-}, HCO_3^-, Cl^-, and SO_4^{2-}; however, heavily fertilized soils do contain other cations (NH_4^+) and anions (NO_3^-, PO_4^{3-}). In the desert soils of Abu Dhabi Emirate, other ions were mainly undetectable, or their amounts were insignificant compared with major anions and cations. Once the laboratory analytical data is available, the next step is to conduct quality assurance to develop confidence on data quality.

   Soil saturation extracts collected from saturated soil pastes are electrically neutral, and, therefore, the total charges on the cations and anions reported in the analysis should be equal. These total cations and anions have relationship with associated ECs values of the saturation extracts. Therefore, the relationship between total salts and ECs is essential to confirm the quality of the analytical data. This QA test is usually performed in many laboratories by determining total salts (meq l^{-1}) against respective ECs (dS m^{-1}) values using already established relationship by USDA (Richards 1954). Any difference between the reported values and the USDA relationship is taken as guidelines to predict the quality of analytical data (Shahid and Ahmad 2004).
2. In many developing countries, the analytical laboratories lack sufficient modern analytical facilities to determine total cations and anions separately. These laboratories use routine titration procedures (Ca and Mg), and some of the parameters are obtained through difference between total salts as predicted from USDA total salt/ECs relationship (Richards 1954). The common ions determined through difference are Na^+ and SO_4^{2-}. Na is obtained through the following relationship, where K is considered as insignificant quantities in arid and semiarid region soils, for example, the absence of K-containing minerals (mica and microcline feldspar) in Abu Dhabi Emirate soils. This compromise is made in many laboratories to make the analyses affordable, rapid, and cost effective (Bresler et al. 1982).

$$\mathrm{Na} = \left[(\text{Total soluble salts}) - (\mathrm{Ca} + \mathrm{Mg})\right]$$

Na is then used in the following relationship to determine sodicity hazards (sodium adsorption ratio – SAR), which is then used to calculate exchangeable sodium percentage (ESP):

$$\mathrm{SAR} = \mathrm{Na} / \left[(\mathrm{Ca} + \mathrm{Mg}) / 2\right]^{0.5}$$

$$\mathrm{ESP} = \left[100\,(-0.0126 + 0.01475\mathrm{SAR}) / 1 + (-0.0126 + 0.01475\mathrm{SAR})\right]$$

where Na and Ca + Mg concentrations are in milliequivalents per liter and SAR is expressed as (mmol l^{-1})$^{0.5}$.

Firstly, by determining Na through difference, any quantity of K is added into Na, which is overestimated; secondly, the total salts obtained from USDA curve developed from Western American soils may or may not be representative to the study area in the country. Such a practice leads to overestimate sodicity hazard in waters or in saturation extract of soils leading to wrong prediction and management options. Therefore, for each area, total salt/ECs relationship is essential to be developed for correct land management decisions.

46.5 Materials and Methods

For a wider coverage and representation of emirate soils and landscapes, soil samples were collected from the entire emirate (excluding offshore islands) and from different landscape positions, and their GPS coordinates (latitude and longitude) recorded. The present study is part of the major Soil Survey of Abu Dhabi Emirate undertaken between 2006 and 2009 (EAD 2009). The Soil Survey of Abu Dhabi Emirate was jointly conducted by Environment Agency-Abu Dhabi (EAD) and International Center for Biosaline Agriculture (ICBA) through an international contractor, GRM International Pty. Ltd. The survey mapped 62 soil types in the entire emirate at the soil family level of the USDA-NRCS soil hierarchy (Soil Survey Staff 1999, 2010). A total of 22,000 sites have been investigated to a 200-cm depth. Additional 500 sites were studied through typical soil profiles of representative soil families and soil samples collected for physical, chemical, engineering, and mineralogical investigations. The detailed description of soil families (site and morphological description and associated soil analyses) mapped in Abu Dhabi Emirate is reported in Volume I of the soil survey reports (EAD 2009). Reader is referred to these reports for further reading of Abu Dhabi soils. The objective of this study is not to repeat what has been reported in detailed reports. However, the soil analytical results required for this study have been extracted and further analyzed.

To establish the chemical characteristics of the soils, the representative soil samples are subjected to standard routine chemical determinations. To obtain these results, the soil samples are used to prepare standard saturated soil pastes to collect saturation extract under vacuum. The saturation extract is analyzed for the measurement of electrical conductivity, (ECs) for salinity establishment, and for anions (CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}, NO_3^-, PO_4^{3-}) and cations (Na^+, K^+, Ca^{2+}, Mg^{2+}).

Cation and anion contents provide information about the inorganic constituents of the soil solution that impact the soil's suitability for plant growth and many physical and chemical properties. Analyses of soil extracts were carried out using the standard USDA procedures (Burt 2004). The saturation extract was obtained from saturated soil paste through vacuum extraction and filtration and analyzed for soluble Ca^{2+}, Mg^{2+}, Na^+, and K^+ using inductively coupled plasma-atomic emission spectrometry (ICP-AES). Soluble HCO_3^- were determined by titration with 0.011N H_2SO_4 in the presence of methyl orange indicator and CO_3^{2-} by titration with 0.011N sulfuric acid in the presence of phenolphthalein indicator and soluble Cl^-, NO_3^-, PO_4^{3-}, and SO_4^{2-} by ion chromatography.

The analyses were performed at the Central Laboratory Unit (CLU) of the United Arab Emirates University and the Central Analytical Laboratory (CAL) of the Dubai-based International Center for Biosaline Agriculture. The CLU is an accredited laboratory under ISO/IEC 17025:2005. The ionic composition in the saturation extract is expressed on equivalent weight basis rather than on their actual weight basis. Equivalent is a large value and is not expected in soil solutions, and, therefore, a small value as milliequivalent (meq) is used per liter basis. Having measured the cations and anions, according to the above rule, theoretically, the anions must equal cations when expressed on a meq l^{-1} basis and, therefore, is one basis for quality assessment of the chemical soil data through ion balance assessment. Many laboratories accept up to 5% ion balance error (IBE) between total cations and anions as shown by Shahid and Ahmad (2004).

46.5.1 Correlation Curves

Correlation between total soluble salts (meq l^{-1}) and ECs (dS m^{-1}) from the soils of Abu Dhabi Emirate was developed by using SigmaPlot graphing software from Systat. The log-log graph (two-dimensional graph of numerical data that uses logarithmic scales on both the horizontal and vertical axes) was used for plotting ECs and total soluble salt values (Fig. 46.1), and simple scatter regression was used to develop total salt/ECs correlation.

46.5.2 Total Salt and ECs Relationship of USDA (Richards 1954) and Soils of Abu Dhabi Emirate

Recent publication (Burt 2004) reported the use of ECs (EC saturation extract) to estimate the total cation or anion concentration (meq l^{-1}) of the solution (Richards 1954) as total cations = 10 × ECs (mmhos cm^{-1}) and total anions = 10 × ECs (mmhos cm^{-1}),

Table 46.1 The ECs, associated total salts, and total salts/ECs relationship

USDA Richards (1954)			Soils of Abu Dhabi Emirate EAD (2009)		
ECs (dS m^{-1})	Associated salt concentration (meq l^{-1})	Total salts/ ECs	ECs (dS m^{-1})	Associated salt concentration (meq l^{-1})	Total salts/ ECs
1	10.0	10.00	1	10	10.00
2	21.0	10.50	2	20	10.00
3	32.7	10.90	3	30	10.00
5	56.0	11.20	5	52	10.40
8	96.0	12.00	8	83	10.38
10	123.0	12.30	10	105	10.50
15	190.0	12.67	15	150	10.00
20	262.0	13.10	20	215	10.75
25	330.0	13.20	25	270	10.80
30	405.0	13.50	30	330	11.00
35	480.0	13.71	35	390	11.14
40	560.0	14.00	40	450	11.25
45	635.0	14.11	45	490	10.89
50	710.0	14.20	50	550	11.00
60	870.0	14.50	60	670	11.17
70	1,025.0	14.64	70	790	11.29
80	1,200.0	15.00	80	900	11.25
90	1,370.0	15.22	90	1,000	11.11
100	1,520.0	15.20	100	1,120	11.20
150	2,350.0	15.67	150	1,720	11.47
200	3,200.0	16.00	200	2,275	11.38
			250	2,900	11.60
			300	3,450	11.50
			350	4,050	11.57
			400	4,700	11.75
			450	5,200	11.56
			500	6,000	12.00

where ECs is at 25°C. We believe this relationship is for general prediction of total salts; however, different relationship exists between ECs and total soluble salts at lower end, that is, ECs 1 dS m^{-1} gives TSS 10 meq l^{-1} (1:10), whereas at the upper end, ECs 200 dS m^{-1} gives TSS 3,200 meq l^{-1} (1:16) (Richards 1954).

Using the total salt concentration (meq l^{-1}) and ECs (dS m^{-1}) relationship from United State Salinity Laboratory Staff (Richards 1954) (Fig. 46.2), and similar results from the soils of Abu Dhabi Emirate (Table 46.1), correlation lines were developed. Table 46.1 clearly illustrates that total salt/ECs relationship from USDA curve (Richards 1954) ranges between 10 at 1 dS m^{-1} and 16 at 200 dS m^{-1}, which has also been shown in Figs. 46.3 and 46.4. The ICBA/EAD curve shows better correlation between ECs and total soluble salts ($R^2=0.9711$) compared with that of USDA for same parameters ($R^2=0.9577$). No values reported above 200 dS m^{-1} ECs values in USDA log-log graph. The total salt/ECs relationship ranges between 10 at 1 dS m^{-1} and 12 at 500 dS m^{-1} in the soils of Abu Dhabi Emirate (Figs. 46.3 and 46.4).

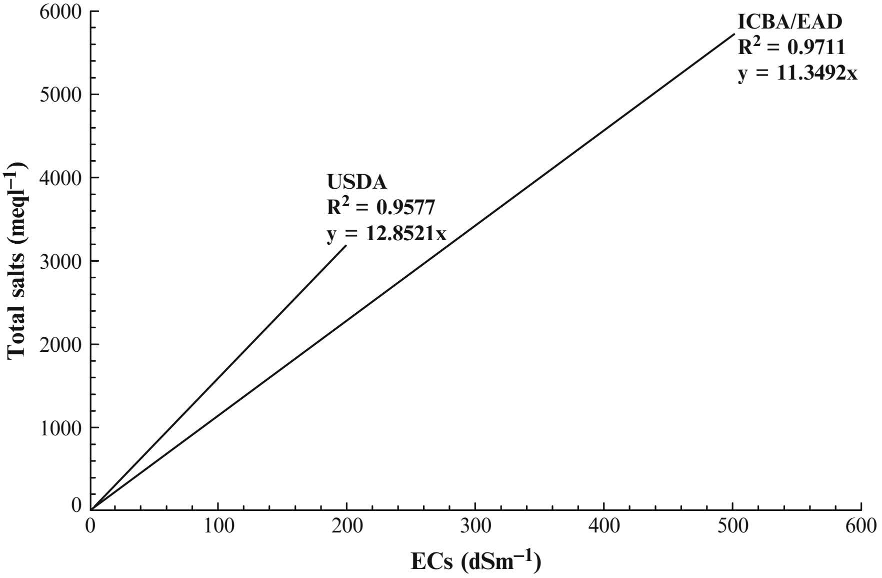

Fig. 46.4 Average lines showing relationship between ECs and total salts from *USDA* (Richards 1954 line) versus soils of Abu Dhabi Emirate (*ICBA/EAD* line)

The nonmatching of both curves confirms that USDA curve as such cannot be used in Abu Dhabi Emirate soils for predictions such as total salts from ECs values and for further quality assurance of soil data or to determine soluble sodium through difference. The USDA curve may be site specific, and relevant to original site from where it was constructed, and could be used where such soils and similar composition of salts may be existing elsewhere in the world.

The soils of Abu Dhabi Emirate present negligible quantities of K in the soil saturation extracts; this can be explained by the absence of K-bearing minerals (mica and microcline feldspar – $KAlSi_3O_8$) in the Abu Dhabi soils; however, minor to major quantities of plagioclase group containing both albite ($NaAlSi_3O_8$) and anorthite ($CaAl_2Si_2O_8$) were detected in most of Abu Dhabi soils (EAD 2009). This also supports that the curve developed in the present study can be confidently used to determine soluble Na by difference to calculate SAR values and consequently the ESP values.

46.5.3 Validation of New ECs and TSS Relationship (ICBA-EAD) Through Measuring SAR

In order to validate the newly developed relationship between ECs and TSS on Abu Dhabi soils, we made an attempt to calculate SAR by following ways (Table 46.2).

Table 46.2 Measurements of SAR in different soils by various methods[a]

Horizon	Depth	ECs	Ca	Mg	Na	K	SAR			
							$(\text{mmol l}^{-1})^{0.5}$			
	cm	dS m^{-1}	meq l^{-1}				[b]EAD	[c]USSL	[d]USDA	[e]ICBA/ EAD
Ck2	60–110	5	25	5	23	0.6	5.90	7.23	5.16	5.68
Ckz	45–60	10	46	42	306	4	23.60	30.08	22.71	24.18
Bky2	80–130	10	25	3	84	1	22.40	25.92	19.24	20.58
Bkyz	15–50	51	50	38	480	9	72.40	95.28	63.62	69.65
2Ckz	90–135	55	47	37	480	6	74.10	98.91	71.91	73.45
2Ckyz1	80–110	101	66	103	990	14	107.70	155.67	91.49	104.00
Ckz1	8–45	101	25	47	1,063	22	177.20	254.67	156.33	175.50

[a,b]EAD: We used actual values of Na and Ca + Mg from EAD (2009) to calculate SAR

[c]USSL: We determined TSS against ECs (Figure 4 page 12 Handbook 60), and Na was obtained by difference [Na = TSS − (Ca + Mg)]. Ca + Mg were taken from EAD (2009)

[d]USDA: We determined TSS against ECs by using factor of 10 (TSS = ECs × 10), and Na was obtained by difference [Na = TSS − (Ca + Mg)]. Ca + Mg were taken from EAD (2009)

[e]ICBA-EAD: We determined TSS against ECs using ICBA-EAD curve (Fig. 46.1), and Na was obtained by difference [Na = TSS − (Ca + Mg)]. Ca + Mg were taken from EAD (2009)

Table 46.2 illustrates SAR values from four methods of calculation. The comparison shows that the SAR values calculated by using newly developed relationship between ECs and TSS (ICBA-EAD curve) give close values as to EAD, confirming negligible quantities of potassium in Abu Dhabi Emirate soils.

The SAR values determined by USSL method are higher relative to those measured by EAD and through using ICBA-EAD newly developed curve; however SAR values calculated by USDA relationship are lower. This implies that a factor of 10 (TSS = ECs × 10) as given by USDA cannot be used on all ranges of ECs; this factor works well at lower ECs level. From above it is concluded that ICBA-EAD curve can be confidently used to obtain TSS against ECs and to calculate Na by difference. This will avoid analysis of Na in the laboratory, saving precious time and resources, and also will help determine quality of laboratory results of solution chemistry. Notably, this curve is applicable to soils where potassium is either absent or present in insignificant amount.

46.6 Conclusions

The present study on relationship between total salts and ECs from the soils of Abu Dhabi Emirate and its comparison with standard USDA relationship has rejected the hypothesis that same relationship exists between ECs and total salts on soils of Abu Dhabi Emirates as that of USDA and, therefore, relationship as developed earlier by USDA cannot be used for Abu Dhabi Emirate conditions. Therefore, a separate relationship developed through present study is recommended to avoid misinterpretation of soil analytical data for QA purposes and soil management. In the light of present study, it is recommended that other regions, where soil and environmental conditions similar to Abu Dhabi are occurring, develop similar relationship most suited to their local conditions.

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