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CHEMICAL FEATURES OF SOME SOIL RESOURCES IN EL-TINA PLAIN OF NORTHWESTERN SINAI, EGYPT

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ABSTRACT

El-Tina plain comprises an expansive landscape of soils that are collectively covered by the mega soil reclamation project of El-Salam/Sheikh Gaber Canal. The objective of this work is to prepare a database for some localities in the area, a prerequisite to allocative efficiency nexus for sustainable development in Egypt. A reconnaissance survey led to choosing 16 sites, each was completely described in the field and sampled for subsequent analysis. Field inspection revealed that the soils are barren with shallow watertable. Soil genesis indicates that they are derived from the defunct Pelusiac Branch of the Nile that used to run across northwestern Sinai. Particle size analysis revealed that some soils contain up to 80 % clay. Chemical analysis revealed that most soils are heavily infested with salinity and sodicity, aside from other constraints including salt crusts. Due to salinity perturbation, exchangeable sodium percentage (ESP) is not correlated with sodium adsorption ratio (SAR). The dominant soluble cation is Na^+ at 1323.34 cmole l^{-1} followed in sequence by Mg^{2+} at 867.59 cmole l^{-1}, Ca^{2+} at 386.44 cmole l^{-1}, and K at 57.85 cmole l^{-1}. The dominant soluble anion is Cl^- at 1414.41 cmole l^{-1} followed by SO_4^{2-} at 1193.90 cmole l^{-1}, whereas the HCO_3^- is below one cmole l^{-1}. The average EMgP stands at 48.85 compared with ESP at 31.75. This is confirmative evidence indicating seawater intrusion. Given these provisions, it is concluded that soil reclamation in the investigated localities for crop cultivation is dubious. An aquaculture production system may turn out to be a sagely alternative scenario.

Key words: Sinai, El-Tina plain, salinity, allocative efficiency.

INTRODUCTION

Overpopulation, demographic imbalance, urbanization, employment, and desertification are some of the intricate problems that Egypt must solemnly consider. A common factor in the analysis of these problems is that they are related to natural resources management, especially soil and water. More than often, feasible practical solutions are compromise trade-offs solutions when it comes to sector demand/completion. The contemplated development of Sinai Peninsula offers an illustrative example.

A plethora of development plans and research work on Sinai was undertaken in the last few decades as a component of a national agenda. In a historical perspective, the reports submitted by Dames and Moore (1985) are probably the first thrust to formulate a comprehensive regional plan. It was reiterated that industry, recreational tourism, and agriculture could serve as sound drivers for development. A few years later, Euroconsult (1992) classified the Mediterranean coast and hinterlands of Sinai into groups and units of terrestrial or aquatic environments within each group. The northwestern part of Sinai was presented as a priority area for agricultural development.

The suggested area consists of five reclamation blocks, most prominent of which is El-Tina plain covering some 50,000 faddans

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(0.42 hectare each). Irrigation water will be delivered by El-Salam/Sheikh Gaber Canal, which was subsequently designed to serve a mega soil reclamation project over a command area of 620,000 faddans east and west of Suez Canal. The water load of the canal emanates from two sources. The first is the River Nile taken from the tail of Damietta Branch before it reaches the Mediterranean Coast. The second is drainage water from El- Serw and Hadous drains before they reach the southern edge of Lake Manzala. The adopted mixing mechanism provides that salinity of the water mix does not exceed 1000 ppm, which implies that the water is not really pristine. Therefore, as described by Tahoun (2009), appropriate measures should be taken when using this water for irrigation, especially on heavy-textured soils.

Stanley and co-workers (1996, 1998, 2014), Dewidar and Frihy (2003) and Kaiser (2009) stipulated that El-Tina plain is about 818 km^2 in area with a concave shoreline configuration. The plain can be divided into distinct geomorphic units including sandy shore, coastal plain, marginal lagoon, Nile flood plain, sand dune belt, and sabkhas. The area is covered with Quaternary sediments of littoral nature, alluvial and aeolian origin which show variations in texture and composition ranging from unconsolidated sands to salinized silt and clay of chemical and biochemical origin. Sneh *et al.* (1986), Stanley and Warne (1998), and Quintanar *et al.* (2013) explained the nature of clay sediments in the area. They demonstrated that there was a major Nile distributary channel by the name of Pelusiac Branch that split off from the main trunk of the Nile heading northeast to the Mediterranean Sea across the northwestern coast of Sinai. The branch used to carry considerable loads of water and sediments. Based on presumed climatic and anthropogenic reasoning, the channel was chocked by sand and silt deposits from prograding beach accretion processes, and became defunct. El Gammal (2013) argued that the area of Pelusium on the Mediterranean shoreline suffered from frequent tectonic movements the latest of which occurred in 870 AD.

As far as land use is concerned, El-Shazly and Abdel-Gaphour (1990), Abdelmalik (1999), and Nawar (2009) warned from the ravage of soil salinity in El-Tina plain, as it would be a major soil limiting factor for agricultural utilization. Salt efflorescence is common in many soils across the area in the form of thin crust and rather thick pans of about 5 centimeters. Beneath the salt crust there is a sand zone rich in diagenetic saccharoidal gypsum crystals. Thin hard bands of gypsum may also occur at different levels close to the surface. Hassan (2002) described El-Tina plain as a landscape whose parent material is a mixture of alluvium deposits, and lacustrine sand deposits, sometimes inter-mixed with aeolian deposits. The water table in some cases is very shallow. Throughout the area, drainage condition is poor to imperfect. Nawar (2009) as well as Tahoun *et al.* (2011) highlighted this finding, and the prevalence of salinity and sodicity in many soils of El-Tina plain.

James *et al.* (1982), Aragüés and Tanji (2003), Shrestha (2006), and Urdanoz and Aragüés (2011) confirmed that soil salinity, whether primary or secondary, leads eventually to soil degradation, crop failure, and in extreme cases to land abandonment. It goes without saying that detailed spatial information on soil salinity is seminal for better soil management, particularly in areas allocated to large reclamation project of the dryland. The provisions of El-Salam/ Sheikh Gaber Canal project prioritize El-Tina plain for conventional agriculture. Yet the area does not have accurate databases warranted for rational resource allocation. The problem is exacerbated by the limited water resources to be shared by competitive sectors.

In this context, the current work was undertaken with particular emphasis on localities within El-Tina plain. The guiding principles are those of Grundwald *et al.* (2011) and Verhoeven (2015) who call for allocative efficiency as nexus for sustainable development. The objective of this work is two-fold. The first is to establish a data set which may identify and discern chemical features of some soils in El-Tina plain. The second is to debunk some functional relations based on the interactive links between these features. Beneficiaries and target groups of this article include relevant ministries, local administrators, sophisticated farmers, and the scientific community at large.

METHODS AND PROCEDURES

Soil Sample Collections

A reconnaissance survey of soils in El-Tina plain within northwestern Sinai was undertaken to examine the broad soil patterns, landscape features, and some of their characteristic. This was coupled with extraction of data from satellite images and Digital Elevation Model (DEM) to generate a preliminary physiographic map. The product was subsequently checked and completed through frequent field observations and description of soils on the landscape. Thereafter, a systematic scheme was developed whereby soil samples were collected from 16 sites according to morphological variations. Longitudes and latitudes were defined in the field using a Garmen Map 60 system.

The field work of this research began by excavating, morphologically describing, and sampling the sites following the guidelines of FAO (2006). In general, the area is distinguished by flat to slightly sloping surface, which may reach 5% in places. There is no evidence for severe erosion caused by either water or wind in the area. The Soil Taxonomy System (Soil Survey Staff, 2014) was consulted. Soil morphology, total salinity, clay content, and effective soil depth were used to define diagnostic soil features. Collected soil samples were air dried, crushed, and sieved through a 2 mm sieve, and then stored till needed for further work. Standard analytical procedures as given by Klute (1986) and Page *et al.* (1982) were used as standard procedures.

Physical Analysis

Particle size analysis was determined by the pipette method. Coarse sand was separated by sieving, after removing cementing agents and deflocculating aggregates. Determination of fine sand, and silt fractions was undertaken by sedimentation from aqueous suspensions. The clay fraction was determined by evaporating aliquot of clay suspensions devoid of sand and silt after elapsed time in accordance with Stokes law.

Chemical Analysis

Soil organic matter was determined by the Walkely Black method. Calcium carbonate was determined by the calcimeter. Gypsum was determined by the dilution differential method. Values of the soil pH, EC, and soluble ions were obtained from equilibrated soil saturated extract; Na^+ and K^+ by a flame photometer; Ca^{2+} and Mg^{2+} by the versenate method, Cl^- by titration with $AgNO_3$; $CO^2{}_3{}^-$ and $HCO^-{}_3$ by titration with an acid. Sodium adsorption ratio (SAR) was calculated from corresponding concentration of Na, Ca, and Mg cations in the saturated soil extract using the standard equation. Exchangeable cations were determined by displacement with ammonium acetate, and CEC by computation as sum of exchangeable Na, K, Ca, and Mg.

RESULTS AND DISCUSSION

Site Description

For the sake of avoiding unnecessary repetition under this heading, it may be reported that field inspection on a major scale of the investigated soils revealed some common features as well as specific features. Soils of all sites are barren land with no traces of vegetation. The soil depth is very shallow and the whole area shows very poor drainage conditions. The topography is flat to almost flat. Most soils seemed wet especially in the early hours of the day.

Sites localities 25, 26, 27, 30, and 31 were covered with salt crust varying in thickness from 2 to 9 cm; sites 22, 23, 24, 28, 29, 32, 33, 34, 35, 36, and 37 have no salt crust. With the possible exception of sites 25, 26, and 27 whose water table stands at 10 cm below surface, the other sites have their water table at approximately 25 cm below. The specific site features may be outlined as follows:

Site 22

Location: 32° 24′ 58″ E, 31° 04′ 26″ N; black (7.5YR 1.7/1, moist), grayish yellow brown (10YR 5/2, dry); clay; strong medium to coarse subangular blocky structure; hard, firm, very sticky, very plastic; weak effervescence with HCl; few dispersed gypsum crystals; common medium salt crystals.

Site 23

Location: 32° 24′ 16″ E, 31° 04′ 35″ N; black (7.5YR 2/1, moist), grayish yellow brown (10YR 6/2, dry); clay loam; moderate medium subangular blocky structure; moderately sticky, moderately plastic; weak effervescence with HCl; few very fine gypsum crystals; few fine salt crystals.

Site 24

Location: 32° 23′ 27″ E, 31° 04′ 25″N; brownish black (7.5YR 3/1, moist), grayish brown (10YR 5/2, dry); clay; moderate medium to coarse subangular blocky structure; sticky, plastic; weak effervescence with HCl; common fine irregular gypsum concretions; common medium gypsum crystals; common medium salt crystals.

Site 25

Location: 32° 22′ 39″ E, 31° 04′ 26″ N; black (7.5YR 1.7/1, moist), dull yellowish brown (10YR 5/3, dry); loam; weak fine subangular blocky structure; slightly sticky, slightly plastic; weak effervescence with HCl; few very fine gypsum crystals; common medium salt crystals.

Site 26

Location: 32° 22′ 37″ E, 31° 04′ 36″ N; black (7.5YR 2/1, moist), dull yellowish brown (10YR 5/3, dry); loam; weak fine subangular blocky structure; slightly sticky, slightly plastic; weak effervescence with HCl; few medium gypsum concretions; common fine salt crystals.

Site 27

Location: 32° 22′ 04″ E, 31° 04′ 27″ N; brownish gray (7.5YR 4/1, moist), grayish yellow brown (10YR 6/2, dry); clay; strong medium to coarse subangular blocky structure; hard, firm, sticky, plastic; moderate effervescence with HCl; few fine gypsum crystals; common fine salt crystals.

Site 28

Location: 32° 21′ 13″ E, 31° 04′ 32″ N; brown (7.5YR 4/3, moist), grayish yellow brown (10YR 6/2, dry); clay; moderate medium to coarse subangular blocky structure; hard, firm, very sticky, very plastic; moderate effervescence with HCl; very few very fine lime concretions; very few very fine gypsum crystals; few fine salt crystals.

Site 29

Location: 32° 20′ 32″ E, 31° 04′ 46″ N; brownish black (10YR 3/1, moist), grayish yellow brown (10YR 5/2, dry); loam; weak fine subangular blocky structure; slightly sticky, slightly plastic; few gray mottles; weak effervescence with HCl; common fine gypsum crystals; common fine salt crystals.

Site 30

Location: 32° 20′ 32″ E, 31° 05′ 05″ N; black (7.5YR 2/1, moist), black (7.5YR 2/1, dry), dull yellowish brown (10YR 4/3, dry); clay; moderate medium to coarse subangular blocky structure; hard, firm, very sticky, very plastic; weak effervescence with HCl; common medium gypsum crystals; common fine salt crystals..

Site 31

Location: 32° 20′ 25″ E, 31° 05′ 27″ N; black (7.5YR 2/1, moist), dull yellowish brown (10YR 4/3, dry); clay; moderate medium to coarse subangular blocky structure; sticky, plastic; moderate effervescence with HCl; common fine gypsum concretions; common medium salt crystals.

Site 32

Location: 32° 20′ 13″ E, 31° 06′ 18″ N; black (7.5YR 1.7/1, moist), grayish yellow brown (10YR 4/2, dry); clay; moderate medium to coarse subangular blocky structure; sticky, plastic; moderate effervescence with HCl; very few medium gypsum concretions; common medium salt crystals.

Site 33

Location: 32° 19′ 01″ E, 31° 06′ 20″ N; black (7.5YR 2/1, moist), grayish yellow brown (10YR 4/3, dry); clay; moderate, medium to coarse subangular blocky structure; sticky, plastic; weak effervescence with HCl; common fine gypsum crystals; common fine salt crystals.

Site 34

Location: 32 ° 20′ 36″ E, 31° 07′ 29″ N; black (7.5YR 2/1, moist), grayish yellow brown (10YR 4/2, dry); clay; strong medium to coarse subangular blocky structure; hard, firm, very sticky, very plastic; weak effervescence with HCl; common very fine gypsum crystals; common fine salt crystals..

Site 35

Location: 32° 21′ 09″ E, 31° 08′ 12″ N; brownish black (7.5YR 3/1, moist), dull yellow orange (10YR 6/3, dry); clay loam; moderate medium subangular blocky structure; sticky, plastic; weak effervescence with HCl; few very fine gypsum crystals; common fine salt crystals.

Site 36

Location: 32° 22′ 17″ E, 31° 07′ 57″ N; black (7.5YR 1.7/1, moist), grayish yellow brown (10YR 5/2, dry); clay loam; moderate medium subangular blocky structure; sticky, plastic; weak effervescence with HCl; common very fine gypsum crystals; common fine salt crystals.

Site 37

Location: 32° 20′ 37″ E, 31° 01′ 18″ N; brownish black (5YR 2/1, moist), grayish yellow brown (10YR 4/2, dry); silty clay; moderate medium subangular blocky structure; sticky, plastic; weak effervescence with HCl; common fine gypsum crystals; common medium salt crystals.

Reassessing site inspection on a closer scale reveals some relevant facts. First, the soil structure is often well-preserved in a subangular form, and the clayey soils show considerable plasticity. Second, in most cases soil color tended to have a tint of brown/yellow component, indicating the absence of a reducing environment. Only the soil of site 29 showed conspicuous mottling. The particular reason for this unique case is a matter of speculation. Third, most soils are salt infested where the occurrence salt crystals were evident. In this context, the calcium carbonate content of the soils is low, and only the soil of site 28 showed lime concretions. Furthermore, gypsum is often present in detectable amounts either as individual crystals or as concretions.

General Soil Properties

The complete sets of field, laboratory, and analytical results of the investigated soils are reported in the Ph.D. dissertation of Shahin (2016) which is the basic reference of this paper. Table 1 presents analytical results concordant with the objectives of this paper. Table 2 shows the results of applied multivariable correlation analysis to investigate degree of similarities and the probable interrelations among parameters. The premise is that soil quality deterioration could be detected by means of such interrelations, which may also serve as indicators of cause and effect relationships.

The average soil clay content of the sampled soil population is 51.4%. Nevertheless, the amplitude of variation is very large ranging between a minimum of 15.5% and a maximum of 79.4%. Table 2 for correlation analysis between the investigated parameters, reveals a very high negative correlation between the soils clay and silt contents. Such result sounds reasonable, since the soil contents of these two soil separates, along with sand are complementary; the increase of a given component would necessitate a proportional decrease in the other two components. Fig. 1-a graphically illustrates this relation. An unusual feature in the figure is the presence of a gap in the clay content parameter to present a divide separating the soil population into two discontinuous groups. The first group has a clay content ranging between 15.5 and 41.0 %, whereas the second group ranges between 66.5 and 79.4%. Equating this divide into a geographic field positioning does not yield distinct implication. Therefore, it is more than likely that the initial clay deposition in the area was affected by environmental particularities at the time.

The divide exists also when plotting the soil CEC as a function of soil clay content which is given in Fig. 1 b. The highly significant correlation between the two parameters is indicative of the meager soil organic content, which is shown for the corresponding analysis in Table 1. It is rather interesting to observe that these clay contents are considerably greater than that reported by Radwan (2008) for soils in the northernmost extremities of Kafr El-Sheikh and El-Behaira governorates. Such elevated clay content in some El-Tina soils of northwestern Sinai does not withstand two logical expectations. First, the soil parent material in the three localities is admittedly the same, belonging to the Nile alluvium. Second, the ambient sedimentation landscape of the three localities is seemingly the same, being almost flat allowing the river to dispose of its load of fine particles (El Gammal, 2013; Sestini, 1989, 1992; Sneh *et al.,* 1986; Stanley and Clemente, 2014).

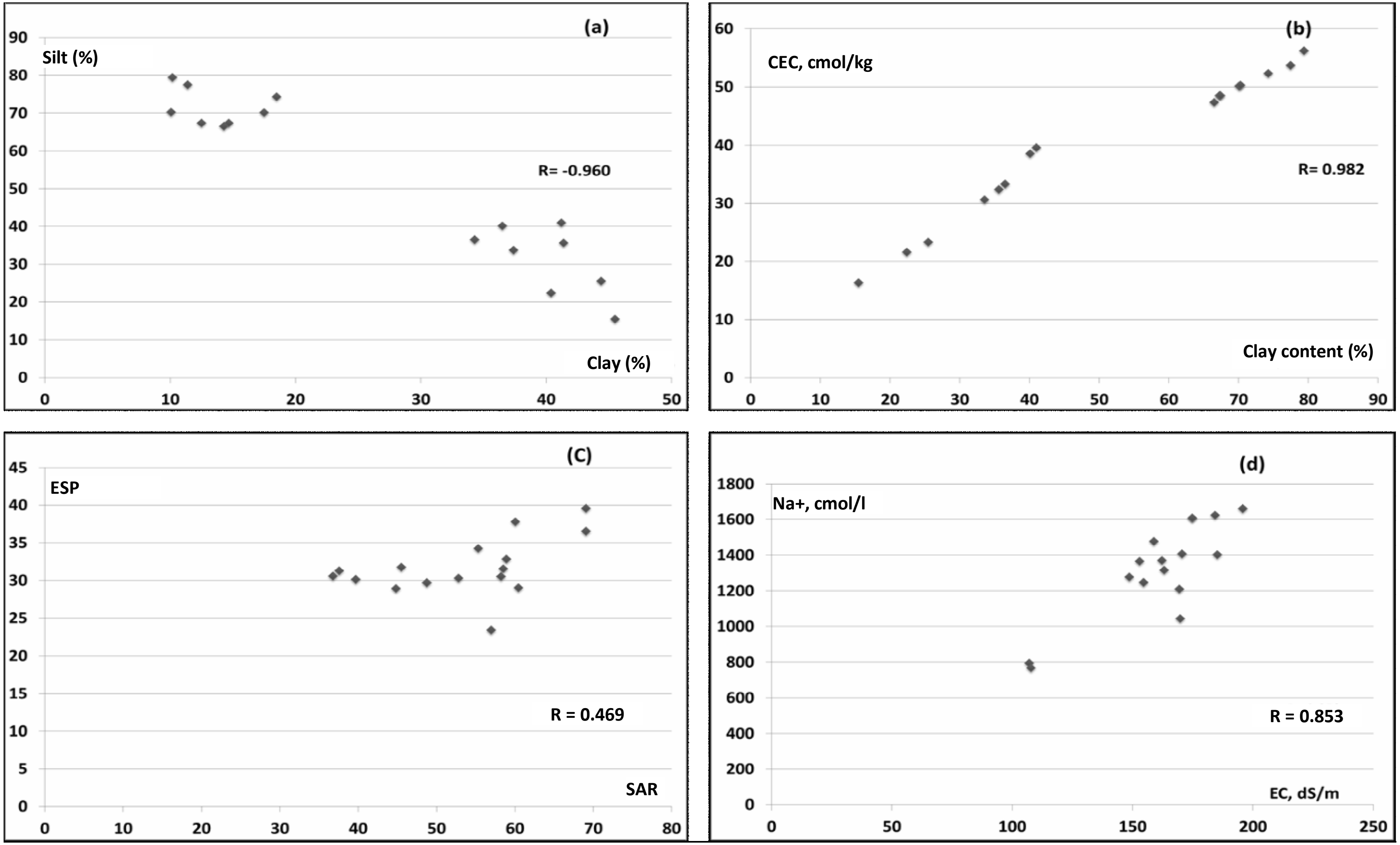

Fig. 1. Statistical relations between some soil parameters

Table 1. Some physical and chemical analytical data of the studied soils

Sample No.	Silt (%)	Clay (%)	$CaCO_3$ (%)	Gypsum (%)	OM (%)	pH_e	EC_e dS m^{-1}	Soluble cations, cmol l^{-1}				Soluble anions, cmol l^{-1}		
								Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2--}
22	10.2	79.4	2.6	4.74	0.84	7.8	195.9	1660.14	58.70	477.17	1110.40	1754.05	0.84	1551.52
23	37.4	33.6	1.2	4.86	0.91	7.4	107.1	792.99	35.01	214.20	584.45	887.01	1.00	738.64
24	12.5	67.3	1.4	5.23	0.98	7.7	163.2	1315.91	52.05	343.30	897.23	1322.30	0.96	1285.23
25	44.4	25.5	2.4	4.38	1.05	7.5	162.2	1368.9	68.15	268.13	887.11	1510.24	1.05	1081.00
26	40.4	22.4	2.5	4.98	1.00	7.5	153.0	1365.61	62.40	334.40	686.43	1464.06	0.61	984.17
27	18.5	74.3	3.1	5.23	1.05	7.6	169.4	1209.74	53.90	406.50	1050.03	1405.21	0.64	1314.32
28	17.5	70.1	3.2	4.78	1.05	7.5	107.9	767.40	41.60	322.05	511.15	901.41	0.98	739.81
29	45.5	15.5	1.3	5.11	0.98	7.5	169.8	1044.14	47.50	501.12	1110.20	1215.12	0.64	1487.20
30	10.1	70.3	1.6	5.34	1.16	7.8	170.5	1407.04	88.90	438.10	856.20	1584.13	0.94	1205.17
31	14.7	67.4	3.6	5.32	0.96	7.5	184.3	1622.56	45.40	409.03	1050.13	1656.41	0.96	1469.75
32	36.5	40.1	3.4	4.68	1.05	7.6	185.2	1401.93	33.12	608.60	1286.67	1710.32	1.05	1618.95
33	14.3	66.5	1.2	5.06	1.23	8.3	174.9	1607.83	91.00	377.32	705.14	1610.43	0.83	1170.03
34	11.4	77.5	1.4	4.91	1.00	7.6	158.9	1478.04	41.60	476.23	811.56	1394.02	0.64	1412.77
35	34.3	36.5	1.2	4.77	0.94	7.7	154.7	1246.36	51.50	323.09	984.21	1309.21	0.86	1295.09
36	41.4	35.6	1.1	4.86	1.05	7.7	148.7	1277.16	63.80	306.41	645.32	1296.24	0.96	995.49
37	41.2	41.0	1.2	5.06	1.23	8.3	174.9	1607.83	91.00	377.32	705.14	1610.43	0.83	742.18
Average	26.9	51.4	2.1	5.0	1.03	7.7	161.3	1323.34	57.85	386.44	867.59	1414.41	0.86	1193.20
Median	26.4	53.8	1.5	5.0	1.03	7.6	166.3	1367.25	52.98	377.32	871.66	1434.63	0.90	1245.63
Max.	45.5	79.4	3.6	5.3	1.23	8.3	195.9	1660.14	91.00	608.60	1286.67	1754.05	1.05	1618.95
Min.	10.1	15.5	1.1	4.4	0.84	7.4	107.1	767.40	33.12	214.20	511.15	887.01	0.61	738.64
Range	35.4	63.9	2.5	1.0	0.39	0.9	88.8	892.74	57.88	394.40	775.52	867.04	0.44	880.93

Table 1. Cont.

Sample No.	Exchangeable cations, cmol kg^{-1}				CEC, cmol kg^{-1}	SAR	ESP	EMgP
	Na^{+}	K^{+}	Ca^{2+}	Mg^{2+}				
22	18.44	2.64	6.56	28.56	56.21	58.92	32.81	50.82
23	9.22	1.11	5.43	14.84	30.61	39.68	30.13	48.50
24	14.68	1.43	5.98	26.41	48.51	52.84	30.27	54.45
25	5.46	1.31	4.99	11.54	23.31	56.96	23.43	49.53
26	6.24	1.44	4.65	9.17	21.48	60.45	29.02	42.65
27	15.14	1.66	6.18	29.32	52.32	44.83	28.95	56.06
28	15.66	1.35	6.54	26.55	50.09	37.60	31.26	52.99
29	4.98	0.67	4.22	6.43	16.27	36.79	30.55	39.45
30	17.22	1.54	6.22	25.32	50.31	55.31	34.23	50.34
31	18.31	1.45	6.41	22.33	48.51	60.07	37.75	46.04
32	12.23	1.41	5.88	18.98	38.51	45.54	31.77	49.30
33	18.71	1.32	6.14	21.13	47.32	69.11	39.56	44.67
34	16.37	1.89	6.22	29.22	53.71	58.25	30.48	54.41
35	9.88	1.62	5.36	16.44	33.31	48.75	29.67	49.37
36	10.22	1.43	5.54	15.21	32.42	58.55	31.54	46.94
37	14.47	1.24	5.66	18.23	39.59	69.11	36.54	46.04
Average	12.95	1.47	5.75	19.98	40.15	53.30	31.75	48.85
Median	14.58	1.43	5.93	20.06	43.45	56.14	30.91	49.34
Max.	18.71	2.64	6.56	29.32	56.201	69.11	39.56	56.06
Min.	4.98	0.67	4.22	6.43	16.27	36.79	23.43	39.45
Range	13.73	1.97	2.34	22.89	39.90	32.32	16.13	16.61

This incompatible result may be interpreted based on a discussion elaborated by Stanley and Warne (1998) on the old Nile Delta. They estimated that since seven millennia down to the nineteenth century, 5 to 10 x 10^6 tonnes of Nile alluvium sediments were deposited per annum in the delta proper. They added that the sediments were carried along seven Nile channels. These include the Pelusiac Branch pointing to the northeast to reach northwestern Sinai, the Sebennitic Branch to the north crossing what is now Kafr El-Sheikh Governorate, and the Canopic Branch to the northwest crossing what is now El-Behaira Governorate. There is evidence to indicate that sediments reaching the coast were reworked by marine processing in a general eastward direction along the coast. Marine waves molded the coastline so that the delta margin configuration began to resemble the modern arcuate shoreline. Therefore, it is most likely that the clay content of soils of El-Tina plain in northwestern Sinai might have been replenished by this marine processing.

One more feature of the soil clay content needs to be highlighted. It is the high correlation coefficients between, not only the CEC values, but also between the magnitudes of each of the individual exchangeable cations. But things do not seem to be that simple. When correlating clay with the saturation percentages of cations, EMgP shows significant correlation, whereas ESP fails to show significance. Further work is invited to solve the incompatibility.

The $CaCO_3$ of invariably all soils is rather small, far less than the calcareous limit; providing support to the site inspection section of this work. There is justification to believe that this phase belongs to diagenetic process. Interestingly, Table 2 does not show any significant correlation between this component and any of the determined and computed parameters. Given the elaboration of Babel and Schreiber (2014) on the genesis of calcite in soils and sediments, it may be hypothized that calcite in the studied soils was formed *via* the reaction:

$$Ca^{2+}_{(aq)}+2HCO_3^-{}_{(aq)} \rightarrow CaCO_{3(s)}+H_2O_{(l)} + CO_{2\,(g)}$$

Where (aq) is aqueous or soluble in water, (s) is solid, (l) is liquid, and (g) is gas.

Expectantly, calcite precipitation would diminish the concentration of bicarbonate in the system, as substantiated by the results of Table 1.

The case of gypsum occurrence in the investigated soils is inviting for discussion. First, it is to be noted that the gypsum content is greater than that of calcium carbonate, 5.0% *vs* 2.1%. Such presence is expected given the proximity of the area to the Mediterranean coast, promoting seawater intrusion followed by water evaporation and the subsequent separation of a series of evaporites.

When seawater intrudes open land, exposure to atmospheric conditions stimulates vaporization, which induces solution concentration, and the beginning of sequential evaporites separation. Hassan (2002), Tahoun *et al.* (2011), and Nawar (2009) reported the presence of gypsum in many soils of northern Sinai. Pedogenic horizons of gypsum containing fairly large crystals were detected by Abdel-Aal (1971) in the soils of El-Serw locality in the northern extremities of the Delta. He interpreted such presence in terms of the influence of shallow groundwater and the parent material as well as topography.

Gomis-Yagues *et al.* (2000), Boluda-Botella *et al.* (2004), and Babel and Schreiber (2014) added that gypsum crystallization begins when vaporization reduces the solution to a ratio $V_{er} = 0.2$. The first gypsum crystal usually is fine-grained. In more concentrated solutions, it appears as firm coarser-crystalline crusts commonly displaying the centimeter-to-decimeter large domal structures. The presence of a complex, living microbial community, particularly cyanobacteria, within gypsum sediments profoundly influences the geochemical micro environment, leading to increased photosynthetically produced oxygen up to concentration equal four times air saturation during the day, but that oxygen remains within the interstitial brine. The relevance of such processes to the fact that gypsum was present either as discrete crystals or concretions need further investigations.

The pH values of Table 1 show limited variation between soils. There is a case where the values are consistently high, reaching 8.3, particularly in site 33. In contrast, there are cases

Table 2. Correlation analysis (r) of multivariate studied soil parameters

		Silt (%)	Clay (%)	$CaCO_3$ (%)	Gypsum (%)	OM (%)	pH_e	EC_e, dS m^{-1}	Soluble cations cmol l^{-1}				Soluble anions cmol l^{-1}			Exchangeable cations cmol l^{-1}				CEC cmol kg^{-1}	SAR	ESP	EMgP
									Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}				
Silt (%)																							
Clay (%)		0.960-	1.00																				
$CaCO_3$ (%)		0.206-	0.258	1.00																			
Gypsum (%)		0.441-	0.366	0.088-	1.00																		
OM (%)		0.026	0.037	0.204-	0.235	1.00																	
pH_e		0.172-	0.232	0.406-	0.210	0.688	1.00																
EC_e, dS m^{-1}		0.204-	0.203	0.181	0.222	0.120	0.409	1.00															
Soluble	**Na^+**	0.283-	0.293	0.049	0.156	0.248	0.576	0.853	1.00														
Soluble	**K^+**	0.049-	0.051	0.379-	0.234	0.729	0.787	0.331	0.510	1.00													
Soluble	**Ca^{2+}**	0.238-	0.245	0.309	0.173	0.035	0.105	0.681	0.406	0.134-	1.00												
Soluble	**Mg^{2+}**	0.065-	0.047	0.383	0.038	0.308-	0.141-	0.744	0.362	0.266-	0.729	1.00											
Soluble	**Cl^-**	0.205-	0.217	0.248	0.099	0.245	0.471	0.924	0.935	0.450	0.559	0.558	1.00										
Soluble	**HCO_3^-**	0.031	0.010-	0.145	0.340-	0.025	0.057-	0.176-	0.110-	0.070-	0.246-	0.064-	0.042-	1.00									
Soluble	**SO_4^{2-}**	0.238-	0.224	0.215	0.174	0.178-	0.110	0.865	0.600	0.114-	0.837	0.906	0.685	0.220-	1.00								
Ex	**Na^+**	0.880-	0.927	0.200	0.429	0.213	0.467	0.312	0.445	0.205	0.300	0.033	0.362	0.082	0.257	1.00							
Ex	**K^+**	0.581-	0.635	0.246	0.147-	0.356-	0.108	0.356	0.476	0.004	0.224	0.228	0.437	0.078-	0.338	0.541	1.00						
Ex	**Ca^{2+}**	0.844-	0.929	0.347	0.210	0.079	0.253	0.133	0.269	0.009	0.196	0.000-	0.221	0.270	0.134	0.936	0.607	1.00					
Ex	**Mg^{2+}**	0.893-	0.971	0.263	0.284	0.013	0.192	0.153	0.223	0.032-	0.250	0.074	0.168	0.032	0.218	0.876	0.653	0.928	1.00				
CEC,cmolkg^{-1}		0.913-	0.982	0.255	0.333	0.080	0.304	0.225	0.326	0.059	0.276	0.063	0.259	0.062	0.242	0.952	0.648	0.964	0.981	1.00			
SAR		0.165-	0.184	0.194-	0.118	0.438	0.687	0.502	0.856	0.710	0.028-	0.153-	0.684	0.072-	0.124	0.357	0.318	0.187	0.099	0.212	1.00		
ESP		0.408-	0.401	0.066-	0.549	0.425	0.659	0.340	0.461	0.395	0.279	0.057-	0.372	0.024	0.194	0.692	0.031	0.470	0.281	0.449	0.469	1.00	
EMgP		0.577-	0.678	0.224	0.061-	0.135-	0.131-	0.134-	0.092-	0.243-	0.025-	0.028	0.105-	0.179	0.005	0.457	0.530	0.661	0.807	0.693	0.167-	0.278-	

where the pH values are comparatively modest at 7.5. This case is represented by sites 25, 26, 39 and 31.

Prevalence of soil salinity in all tested samples is shown by the extremely high electrical conductivity of their saturated extract, reaching 195.9 dS m^{-1}. Such values were expected given encountered salt crystals in the field inspection. In association with salinity, soil sodicity expressed either by ESP or SAR is excessively high. The electrical conductivity is correlated with the concentration of ions in the soil extract except K^+ from the cationic suite and HCO_3^- from the anionic suite. The lack of such correlation in these two particular ions might be interpreted by their deflated low concentration. Sodium ion concentration is very highly correlated with the Cl^- with a correlation coefficient of 0.935 whereas its correlation coefficient with SO_4^{2-} is modest at 0.600. Whether or not the SO_4^{2-} was depleted by the reaction with Ca^{2+} is an entertained possibility to be explored in further work. This line of argument is the apparent strong correlation between the concentration of both Ca^{2+} and SO_4^{2-} at 0.837 whereas its correlation with Cl^- is minor at 0.559.

The dominant soluble cation is Na^+ with an average of 1323.34 cmole l^{-1} followed by Mg^{2+} at 867.59 cmole l^{-1}, Ca^{2+} at 386.44 cmole l^{-1}, and K at 57.85 cmole l^{-1}. The dominant soluble anion is Cl^- with an average concentration of 1414.41 cmole l^{-1} followed by SO_4^{2-} at 1193.20 cmole l^{-1}, whereas the HCO_3^- concentration is negligible, falling below one cmole l^{-1}. As given in Table 2 and Fig. 1 (d) for Na^+ as a model, most of the soluble soil components are positively correlated with the EC.

Suarez (1981), James *et al.* (1982) and more recently Pils *et al.* (2007) and Bourrie (2014) advanced that SAR determined in saturated soil extract may be used as a substitute for the determination of the ESP. The substitution is based on two tacit assumptions. First, Ca and Mg ions have equal selectivity for exchange, and second, the exchange phase composition is fixed by the total concentrations of the exchangeable ions rather than their activities. Tahoun and co-workers (1995, 1999, 2011) substantiated experimentally this concordant relation in certain soils, but also reported discordant exceptions. It was found that the relation holds for soils with low salinity, but goes astray for soils with high salinity. Figure 1-c shows the relation for the latter case pertinent to soils of this work as an example.

The work of Pils *et al.* (2007) and Bourrie (2014) may be utilized to interpret the inconsistency. A multifaceted argument goes as follows. First, cations in soil solution have different threshold concentration, which is defined as the value of the concentration of electrolyte that results in a 10–15% decrease from its initial value during dilution. The threshold concentration for Mg^{2+} saturated clays is three times larger than that for Ca^{2+} saturated clays. Such difference is ascribed to greater hydration energy of Mg^{2+} as compared to Ca^{2+}. Second, the displacement of exchangeable Ca^{2+} by Na^+ and the reverse, shows demixing and quasi-crystals (QCs) breakup and formation. In low ionic strengths systems, demixing with monovalent cations on the external surfaces and divalent cations on the internal surfaces of QCs largely controls the average size of QCs in suspensions. In high ionic strength systems, both monovalent and divalent cations are found in the interlayers. The average size of QCs is controlled by the monovalent to divalent cation ratio, the hydration energies of the cations, and the ionic strength of the system. This is to say in a simple manner that with soils of excessive salinity, it seems that the chemical microenvironment of the soil system is perturbed to nullify the supposedly concordant relation between SAR and ESP.

It is most interesting to note that values of exchangeable Mg content given in Table 1 is far greater than the exchangeable Na counterpart in every and each soil. The average content in the soil community is 19.98 cmole kg^{-1} for Mg in contrast with 12.95 cmole kg^{-1} for Na. The corresponding values of EMgP and ESP carry the same trend. The average EMgP value stands at 48.85 compared with ESP value at 31.75. Values of soluble cations in conjunction with their exchangeable values bring two sets of complications. First, the overall average soluble Na at 1323.34 cmole l^{-1} is far dominant surpassing Mg at 867.59 cmole l^{-1} by a factor of about 2, yet the overall average of exchangeable Mg is 19.98 cmole kg^{-1} exceeds the Na at 12.95 cmole kg^{-1} by a factor of about 1.6.

In this connection, it is interesting to refer to the findings of Sayles and Mangelsdorf Jr. (1977). They investigated the equilibration of clay immersed in seawater for periods up to150 days. It was found that Mg^{2+} moved into the exchange positions in preference to Ca^{2+} and Na^{+}. Kaolinite adjusted very rapidly, but montmorillonite and mixed layer minerals were slow to reach equilibrium. In the process, reacting minerals released appreciable amounts of SiO_2, $A1_2O_3$, and Fe_2O_3 in the order: montmorillonite > illite > kaolinite > halloysite. Furthermore, Pils *et al.* (2007) investigated the effect of demixing on the breakup and formation of smectite quasicrystals (QCs). They indicated that a Ca-dominated system enhances both the formation of large QCs and flocculation. In contrast, increasing Na^{+} concentration induces the breakup of large Ca-QCs and dispersion. As large Ca-QCs breakup, monovalent cations reside primarily on the external surfaces whereas Ca^{2+} is preferentially retained in the interlayers.

General Discussion and Conclusions

The on-farm Egyptian experience in the reclamation of salt-infested soils, particularly in the northern extremities of the Nile Delta, is not only extensive, but also well-documented. However, when it comes to soils of El-Tina plain, the paucity of data is embarrassingly too little. The authors were able to encounter a single publication written by Abdel-Dayem *et al.* (2000), which deserves to be revisited.

They implemented a prototype of field trials to reclaim salt-infested soils in El-Tina plain using the prescribed conventional wisdom. Soil profiles in the area are deep, and the clay content in most cases ranges around 40%. A mimic local drain was excavated around the locality, and then individual soil reclamation processes took precedence. Such processes involved land leveling, mechanically removing salt crusts, and establishing field irrigation and drainage networks as starters. Subsequently, gypsum was applied followed by lavish soil leaching. Brackish water was used for the initial leaching stages then fresh water followed, either intermittently or continuously. After 3 long years, a considerable proportion of salinity and sodicity was removed to create an enabling environment for a viable agriculture.

The feasibility of replicating the prototype of Abdel-Dayem *et al.* (2000) to localities investigated in this work is most likely dubious. The submitted justifications are numerous. First, the considered soils have very shallow soil depth due to elevated water table reaching 10 cm below surface in places. Second, the clay content of some soils is extremely high approaching 80%. Third, the salinity and sodicity loads are overwhelming. Fourth and most important of all, is the undeniable need of mega volumes of water for leaching, in a time of extremely scarce water resources. In the circumstances, allocative efficiency as nexus for sustainable development as set by Grundwald *et al.* (2011) and Verhoeven (2015) would be grossly thwarted.

Therefore, the possibility of using soils in certain localities in El-Tina plain for crop cultivation is assuredly not recommended. In retrospect, allocating such land to establish an aquaculture production system may turn out to be a sagely resource allocation.

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السمات الكيماوية لبعض موارد الأراضي في سهل الطينة شمال غرب سيناء – مصر

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منطقة سهل الطينة هى احدى مناطق الاستصلاح الحديثة الواقعة على ترعة السلام وتوجد فى اقصى الجزء الشمالى الغربى من شبه جزيرة سيناء شرق قناة السويس و تعتبر المنطقة جزءا من دلتا نهر النيل القديمة وتتنوع التربة فى منطقة سهل الطينة و الهدف من هذا العمل هو اعداد قاعدة بيانات لبعض المواقع فى منطقة الدراسة والتى تعتبر شرط أساسى لتحقيق التنمية المستدامة فى مصر، تم اختيار 16 موقع بناءا على دراسه استكشافيه للمنطقة و تم وصفها وصف كامل فى الحقل وأخذت عينات من كل موقع لاجراء التحليل المعملى لها وكشفت الدراسه الحقلية ان التربة جرداء مع ارتفاع مستوى الماء الأرضى وأظهر التحليل الحجمى لحبيبات التربة أن بعض الوحدات تحتوي على ما يصل إلى 80% من الطين، وكشف التحليل الكيميائي أن معظم أنواع التربة ذات محتوى عالى من الملوحة والقلوية مع تكوين قشرة متصلبة من الأملاح فى بعض المواقع ، ولم نحصل على ارتباط بين قيم النسبة المئوية للصوديوم المتبادل والنسبة الإدمصاصية للصوديوم في الأراضى التي تعانى من الملوحة الزائدة و ربما يرجع ذلك إلى وجود زيادة في الأملاح التي تؤدى إلى خلل في التفاعلات الأيونية العادية التي تتم في المحلول الارضى. و قد وجد ان الكاتيون السائد هو الصوديوم بتركيز 1323.34 cmole l^{-1} متبوعا بالمغنيسيوم بتركيز 867.59 cmole l^{-1} ثم الكالسيوم عند 386.44 cmole l^{-1} ثم البوتاسيوم بتركيز 57.85 cmole l^{-1} و بالنسبه للانيون السائد كان الكلوريد بتركيز 1414.41 cmole l^{-1} متبوعا بالكبريتات عند 1193.20 cmole l^{-} بينما قل تركيز البيكربونات عن 1 cmole l^{-1}، ووجد ان متوسط النسبة المئوية للمغنيسوم المتبادل كانت 48.85 مقارنة مع النسبة المئوية للصوديوم المتبادل التى وصلت 31.75، هذا دليل واضح على تسرب مياه البحر إلى هذه المنطقة، وبناءا على هذه النتائج فان استصلاح هذه الاراضى واستغلالها فى الإنتاج الزراعى مشكوك فيه ويمكن استخدام هذه الأراضى فى إنتاج الأحياء المائية كأحد السيناريوهات البديلة .

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