ISSN : 0974 - 7451 Volume 9 Issue 10

Environmental Science
An Indian Journal

Current Research Paper

ESAIJ, 9(10), 2014 [325-344]

Soil spatial variability in arable land south of Lake Idku, North-West Nile Delta, Egypt

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ABSTRACT

Lake Idku (or Idku lagoon) is the third largest coastal water body northwest of the Nile delta located within El Beheira Governorate. Since mid 1950s, over 30% of Lake Idku was dried to create new agricultural lands. The project was extended in 1960s to include areas west of the delta and south of the new/old reclaimed lands. The first study concerning the quality of soil within the study area, south of Lake Idku, was conducted in 1960 and since then, no updates were undertaken to evaluate the effect of the ongoing agricultural/human activities and land use upon the quality of these reclaimed soils. The main objective of this study is to evaluate the change in soil quality in the area relative to the availed analytical data, chemical composition of irrigation water used and crops cultivated during the fall (2010/2011). The impact of different land uses and activities upon the soil quality in the study area, South of Lake Idku, was determined using multivariate analysis (Hierarchal Clustering) in order to identify similarity in patterns and classifying relationships among the measured soil variables.

INTRODUCTION

Salinity of agricultural soils and water resources is a worldwide problem in irrigated areas that causes land degradation. Salt affected soils are found under a wide range of environmental conditions, however, they are more pronounced in the arid and semi-arid regions[1]. Because of dry arid climate, most of the agricultural soils in these regions are saline and have low productivity because of the dominance of the soluble salts[2,3]. Overcoming this problem requires the use of excess water to leach salts from plant root zone as well as the cultivation of salt tolerant crops to reduce soil salinity[2,3]. On the other hand, there is an increased demand in irrigation water requirements in arid and semiarid regions which cannot be met by the scarcity of surface water resources therein[2]. This necessitates the use of low quality drainage water in irrigation. However, this may limit crop growth under these severe climactic conditions[3,4]. As well, salts may concentrate in the upper horizon through evaporation of these clayey soils.

Lake Idku (or Idku lagoon) is the third largest coastal water body northwest of the Nile delta (Figure 1[5]) located within El Beheira Governorate. The lagoon's margin is along its northern border and its eastern margin is bounded by Idku drain[6]. The main drainage systems feeding this lake are Idku drain, which covers the northeastern part of the Western Delta, and Umoum drain, located between Idku drain and Nubaria canal nearby in the western desert[7]. Water in this lagoon is generally characterized as being brackish with a marked variation in its salinity because of the fresh discharge it

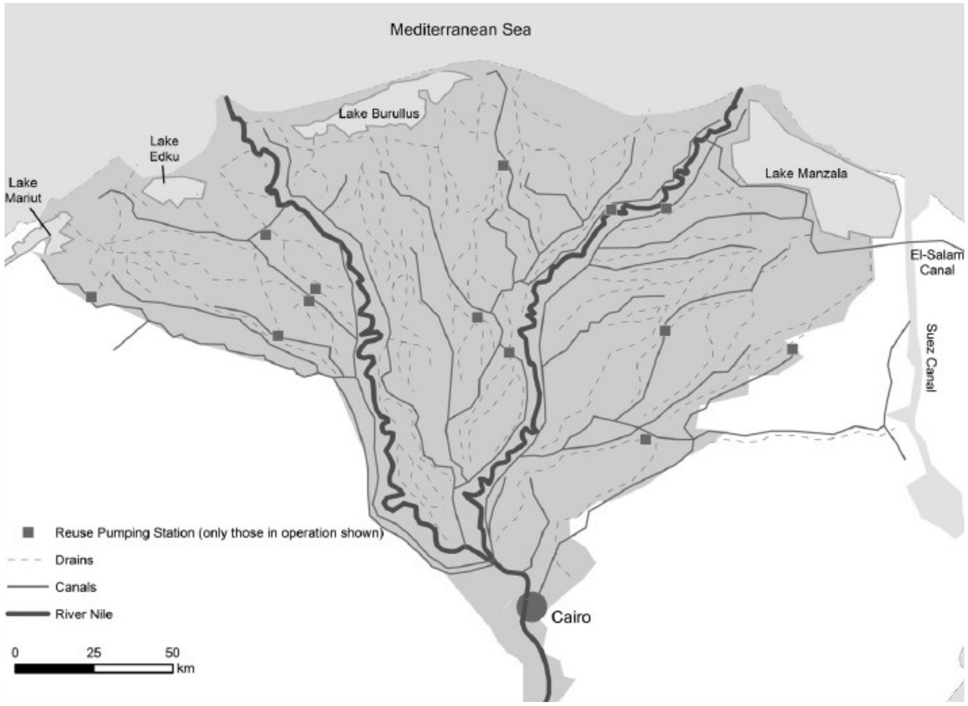

Figure 1 : Geographic location of the study site, south of Lake Idku, north-west of the Nile delta, Egypt[5]

receives from Idku drain[6].

In Egypt, land reclamation projects in the northern part of the delta started as early as 1948[8]. Since that time, parts of Lake Idku (30%) were dried to create new agricultural lands[8,9]. The project was completed by 1950 and the lands were turned over to the land reclamation authority to continue with land reclamation procedures in 1955. Throughout this process, the main water sources used were drainage waters from Idku drain in the western delta and the Gharbia main drain in the middle delta. This resulted in the reclamation of 7700 feddans east of the lake. In the early 1960s, an extension of this project was made in west of the delta and south of the new old reclaimed lands (sandy soils with high % $CaCO_3$). This exerted an increased demand for irrigation water in El-Beheira Governorate to sustain agricultural activities on these desert soils[1]. Furthermore, while good quality irrigation water from the Nile was being diverted more towards the new reclaimed soils south at Nubaria area, the old land with clayey soils received lower quality waters for irrigation. More specifically, during this period, farmers were obliged to irrigate with salty drainage waters in order not to lose their crops[1].

The first study concerning the quality of agricultural soils within the study area, south of Lake Idku (Figure 2), was conducted in 1960 and since then, no updates were undertaken to evaluate the effect of the ongoing agricultural/human activities and land use upon the quality of these reclaimed old soils. The main objective of this study is to evaluate the change in soil quality in the area relative to the availed analytical data, chemical composition of irrigation water used and crops cultivated during the fall (2010/2011).

MATERIALS AND METHODS

Study site and sampled profiles

The study area is located south of Lake Idku, El-Beheira Governorate, and it compromises two localities: Kafr El-Dawar and Abu Hommos. The soil in this area is characterized as clayey soils with the newly reclaimed sandy soils located further to the west. Soil samples were collected during the fall of 2010/2011. Seventeen soil profiles (Figure 3) and twenty eight augers soil samples were collected based upon the reference points selected during the 1960 study (Figure 2). Soil samples were obtained to represent different depths: 0–30 cm, 30–60 cm, 60-90 cm and 90-120 cm. It has to be noted that in some cases, samples below 100 cm were not obtained due to the rise in water table level. During the sample collection program, a

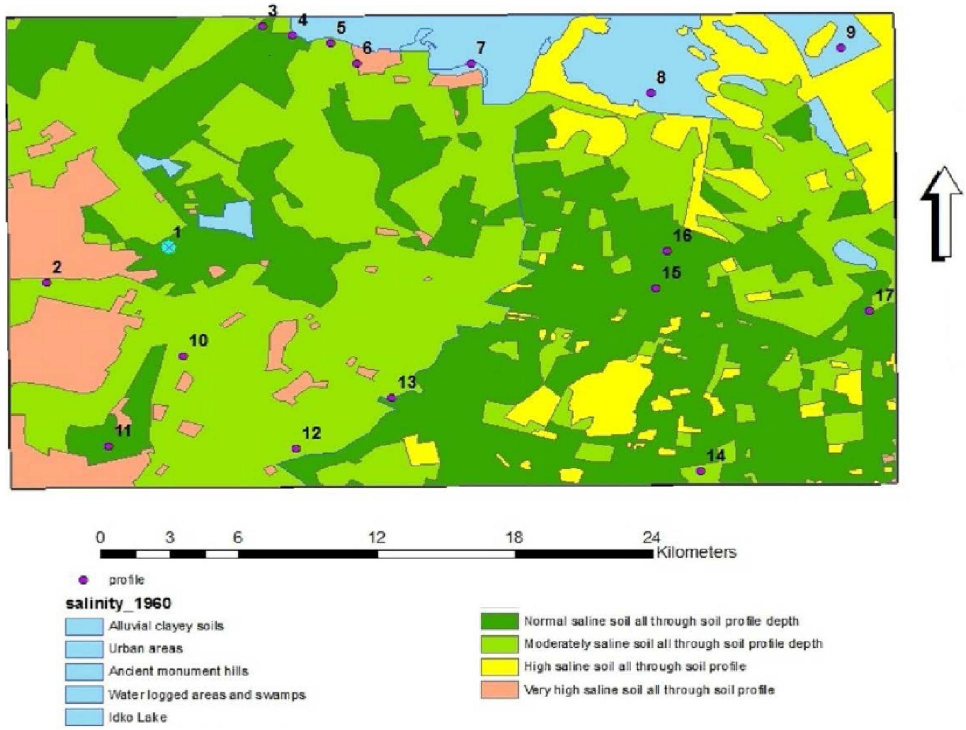

Figure 2 : Graphical salinity representation for the survey conducted in 1960 in the area of study, south of Lake Edku, indicating the location of the 17 profiles

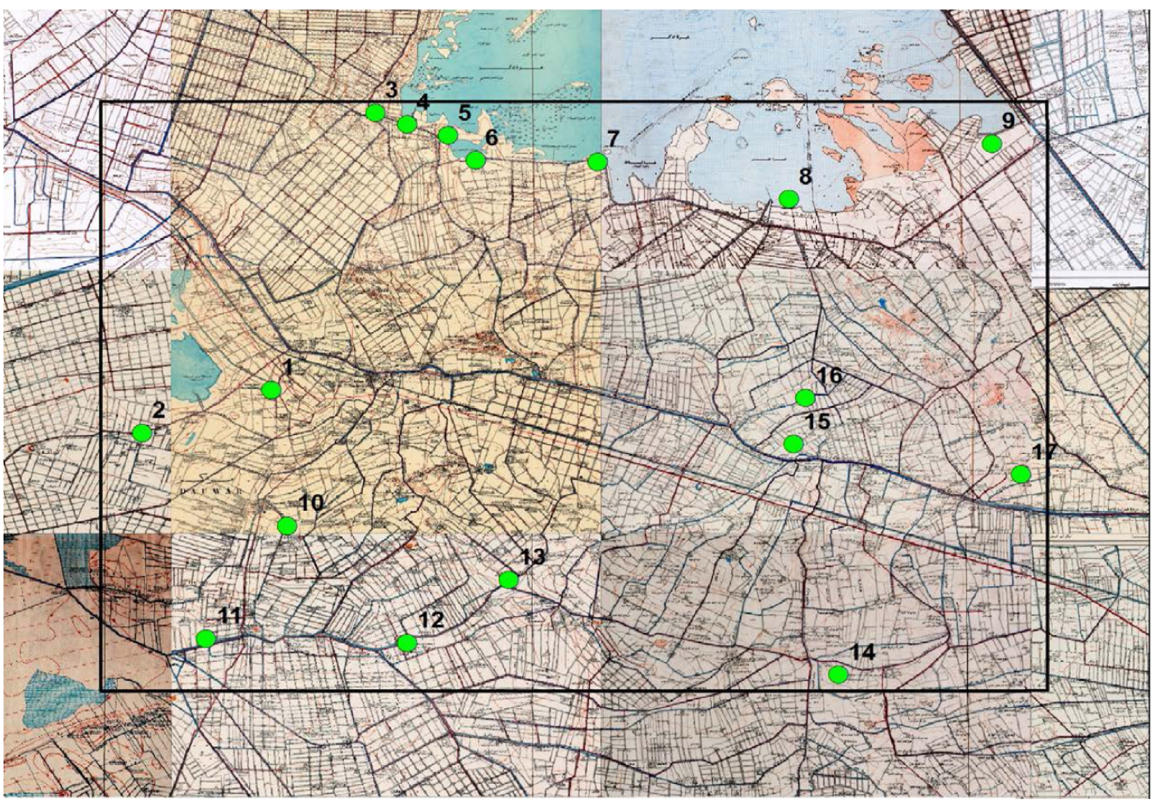

Figure 3 : Location of the 17 profile studied during the period of 2010/2011, south of Lake Edku, Egypt (Topographic map scale 1: 25000)

survey of the current land activities, agricultural crops cultivated within the area as well as irrigation water sources (canals and drains) within the vicinity of these profiles were recorded.

Soil physical and chemical characterization

Physical and chemical characteristics of the collected profile soils were determined according to standard methods[10] (TABLE 1). Soil physical characteristics determined were: particle size distribution, texture, organic matter % (OM), gypsum% and $CaCO_3$%. The measured chemical parameters include: pH, electrical conductivity (ECse), saturation percentage (SP); calcium, magnesium, sodium, potassium, chloride, sulfates, carbonates and bicarbonates. Soil micronutrients (Cu, Fe, Mn, and Zn) were determined using ICP (TABLE 2). SAR was determined according to the method of Miller and Curtin[11]. The quality of the available water streams (canals and drains) was determined according to standard methods and the results are shown in TABLE 3.

Statistical analysis

Statistical analysis of data was carried out using 'StatistiXL 1.8' incorporated within the Microsoft Excel 2007 (Microsoft ® Windows 2007) software program. Cluster analysis was performed using Ward's method for minimum variance and the similarity coefficient used was the Square Euclidean distance function. Hierarchal clustering was performed using soil chemical and physical characteristics, soil depths and other variables analyzed per profile. The results produced included the distance matrix, clustering strategy report and dendograms, based upon which the data was interpreted accordingly.

RESULTS AND DISCUSSION

Soil characterization

TABLE 1 provides a summary of the main chemical and physical characteristics of the studied profiles. Generally, 15 out of 17 profile are old cultivated lands with groundwater table levels depth between 120-130 cm, which is deep, except for profiles 4 (100 cm) and 10 (80 cm) that had a moderate depth level. Overall, the majority of the 17 profiles have high clay texture (47.60 – 69.00%) except for profile 6, 10 and 16 which exhibit sandy clay loam texture (41.40 -52.20%). It was reported that the old reclaimed cultivated lands in the north of Egypt had a fine textured (clay loam to clay) and deep ground water table between 100 and 150 cm[12,13]. The clay content of these soils was reported to increase going towards the Mediterranean Sea[14]. Moreover, it was reported that soils in arid and semi-arid regions were characterized by their slightly alkaline pH (7.8–8.6) as they exhibit elevated accumulation of calcium- and magnesium-carbonates and sulfates[10]. Soils of the northwestern coast were reported to be highly calcareous due to the nature of the parent material from which these soils were formed and the insufficient and limited leaching[15]. As well, the prevailing of the arid climactic conditions may have contributed to the formation of zones or horizons because of the limited translocation of carbonates. Overall, these profiles have low gypsum % content (0.10 -1.45%), $CaCO_3$ % content (0.35%-2.30%) and an organic matter content at the top layer that ranged between 1.35- 2.45%, all of which are comparable to fluvio-marine plain soils in the region[16]. It was reported that reclaimed soils within the Beheira governorate that has been irrigated with drainage waters since the 1960s have a soil texture that ranged from sandy, silty loam to clayey, had a calcium carbonate content between 2 - 20 % and a very low in organic matter[17]. Nonetheless, the organic matter content of these soils as obtained was indicated to be sufficient for agricultural production under the prevailing arid conditions[13]. The discussion to follow will subdivide the profiles according to the location, whether inland or coastal, as well as they will be grouped according to their proximity to each other.

Inland profiles: 1, 2, 10-17

Concerning the west inland profiles 1, 2, 10-13, these are old reclaimed lands with clayey texture (33-65%) and a non saline character all through the profiles (EC $\leq$ 4.0 dS/m) which may be because of the fact that they are old flood plain soil[13]. These profiles have a relatively deep water table except for profile 10 that has a moderate level (80 cm) which may be attributed to poor drainage[12]. As well, this profile has a second sandy-clay-loam level. The pH of these inland profiles ranged between 7.21 and 8.04 with the near alkaline pH recorded at the lower levels of profile 12 and 13. Profiles 14-17 to the east also have a predominant clayey texture (53.40 – 67.70%) with profile 16 having a sandy clay loam upper layer. The pH of these profiles

TABLE 1: Location, crop, ground water depth (cm) and chemical and physical analysis of soil at the 17 soil profiles studied south of Edku Lake, North western Delta grouped according to proximity of location with each other (1, 2,10, 11, 12,13), (3,4,5,6,7,8,9) and (14,15,16,17)

Profile No.	Area location	Depth of Ground water (cm)	Crop	Depth (cm)	pH	EC dS/m	SP	Anions (meq/L)				Cations (meq/L)				SAR	Gypsum %	OM %	$CaCO_3$ %
								CO_3^{2-}	HCO_3^-	Cl^-	$SO4^{2-}$	Ca^{++}	Mg^{++}	Na^+	K^+				
1	Kafr El-Dawar	120 (Deep)	Potatoes	0-30	7.4	3.37	60	0	4.2	11.82	18.18	7.53	14.69	11.43	0.55	3.43	1.1	2.15	2
				30-70	7.6	1.91	70	0	3.4	9.09	7.77	7.68	2.22	10.15	0.21	4.56	0.6	1	1.75
				70-100	7.66	1.82	75	0	3.4	8.18	6.94	4.61	1.81	11.74	0.36	6.55	0.2	0.7	1.4
				100-120	7.61	0.75	60	0	1.6	2.73	3.23	3.07	0.39	3.8	0.3	2.89	0.1	0.2	0.6
2	Kafr El-Dawar	120 (Deep)	Artichokes	0-30	7.49	4.02	60	0	4	19.99	17.22	15.36	6.87	18.28	0.7	5.49	1.45	1.75	1.79
				30-65	7.49	1.47	58	0	4	6.36	5.26	5.12	0.8	9.36	0.34	5.44	0.75	0.65	2
				65-90	7.4	1.23	55	0	3.6	4.54	4.64	4.61	1.81	6.09	0.27	3.4	0.6	0.45	0.65
				90-130	7.66	1.59	51	0	1.6	8.18	7	5.12	0.8	10.32	0.54	6	0.1	0.3	0.4
10	Kafr El-Dawar	80 (Moderate)	Onions	0-30	7.43	3.91	67	0	2	27.27	12.13	13.83	6.93	18.41	2.23	5.71	1.05	1.95	3
				30-60	7.84	1	45	0	2	4.54	3.67	2.56	0.9	6.45	0.3	4.9	0.7	0.75	2
				60-80	7.21	0.91	47	0	3.2	2.73	3.89	3.58	0.87	4.87	0.5	3.26	0.35	0.25	1.8
11	Kafr El-Dawar	130 (Deep)	Artichokes	0-30	7.5	1.86	68	0	4.2	9.09	5.9	4.1	2.42	12.06	0.61	6.68	1	2.3	2.4
				30-70	7.41	3.35	60	0	4	22.7	10.21	8.71	4.63	22.85	0.72	8.85	0.8	0.6	1.3
				70-100	7.7	2.72	26	0	3	20.91	4.69	12.66	2.82	12.3	0.82	4.42	0.6	0.3	0.7
				100-130	7.77	5.4	35	0	2	28.18	27.47	14.66	7.27	34.9	0.82	10.54	0.25	0.2	0.6
12	Kafr El-Dawar	120 (Deep)	Wheat	0-25	7.71	3.27	65	0	4.6	9.1	20.65	7.33	4.28	22.2	0.54	9.21	1.15	2.1	2.65
				25-60	8.02	2.43	105	0	4	13.64	8.23	3.99	3.11	18.4	0.37	9.77	0.3	0.8	1.15
				60-90	7.92	2.12	95	0	3	13.64	5.72	5.33	2.41	14.12	0.5	7.18	0.5	0.4	1.2
				90-120	7.84	3.37	75	0	4	18.18	13.19	6.66	6.24	21.9	0.57	8.62	0.1	0.15	0.9
13	Abu Homos	130 (Deep)	Wheat	0-25	7.6	1.95	55	0	2	5.45	13.39	9.33	6.17	4.84	0.5	3.53	1.15	2.15	3.45
				25-60	7.93	1.82	75	0	2.4	4.54	12.22	4.66	4.37	9.84	0.29	4.63	0.6	0.75	1.35
				60-90	8.02	1.8	95	0	3.6	5.45	9.85	3.99	3.75	10.8	0.36	5.49	0.5	0.35	1
				90-130	8.04	1.85	65	0	2	6.36	11.06	5.33	3.05	10.63	0.41	5.19	0.2	0.4	0.6
3	Kafr El-Dawar	120 (Deep)	Citrus trees	0-30	7.47	1.76	60	0	1.4	5.45	11.53	7.68	0.71	8.56	1.43	4.18	1.05	2	2.45
				30-70	7.5	0.94	55	0	3	4.54	1.86	3.06	0.31	5.39	0.64	4.15	0.5	0.7	1.15
				70-100	7.66	0.89	68	0	2.2	4.54	2.16	3.6	0.51	4.52	0.27	3.15	0.2	0.45	0.55
				100-120	7.58	1.71	65	0	4.4	10.9	2.67	7.68	1.21	8.65	0.43	4.1	0.3	0.4	0.5
4	Kafr El-Dawar	100 (Moderate)	Wheat	0-30	7.43	2.62	50	0	5.2	16.36	5.95	9.22	5.6	12.26	0.43	4.51	1.4	1.79	2.85
				30-70	7.46	1.85	60	0	4.4	9.09	5.65	5.12	3.27	10.32	0.43	5.04	0.85	0.6	1.1
				70-100	7.78	1.94	60	0	2	14.45	3.46	4.61	2.31	12.38	0.61	6.66	0.25	0.2	0.7
5	Kafr El-Dawar	120 (Deep)	Guava trees	0-30	7.3	9.66	63	0	3.6	218.8	27.43	28.68	20.72	200	0.43	40.24	1.1	2.45	2.42
				30-60	7.55	6.15	60	0	3.2	23.63	44.87	12.8	12.4	46.21	0.29	13.02	0.6	0.75	2
				60-90	7.61	6.81	65	0	2.4	36.36	34.06	14.34	8.88	49.2	0.4	14.44	0.45	0.4	1.7
				90-120	7.64	4.59	67	0	3	29.09	15.52	5.12	3.27	38.88	0.34	18.98	0.5	0.25	0.6
6	Kafr El-Dawar	130 (Deep)	Fish farm	0-30	7.11	24.15	40	0	2.8	274.5	33.79	36.88	77.74	193.6	2.87	25.57	1.1	2.45	2.42
				30-70	7.94	13.61	45	0	4.4	118.8	27.85	19.46	20.06	109.5	2.03	24.63	0.6	0.75	2
				70-100	7.9	5.37	43	0	3	29.1	24.3	13.83	11.86	28.96	1.75	8.08	0.45	0.4	1.7
				100-130	7.18	1.71	37	0	4.6	7.27	5.66	5.12	3.27	8.32	0.82	4.06	0.5	0.25	0.6
7	Abu Homos	130 (Deep)	Desert shrubs and bare land	0-30	7.88	81.06	47	0	5.3	909.1	656.06	51.2	106.9	1409.2	3.16	158.5	1.25	1.75	2.3
				30-60	7.92	46.21	40	0	3.4	436.4	90.86	56.34	7.89	463.4	3.03	81.77	0.7	0.7	1
				60-100	7.93	34	40	0	2.6	336.4	34.39	26.64	32.66	311.1	2.99	57.13	0.25	0.2	1.6
				100-130	7.69	29.51	63	0	3	245.5	76.48	26.64	22.76	272.9	2.68	54.91	0.1	0.15	0.7
8	Abu Homos	130 (Deep)	Sugar Beet	0-30	7.56	56.35	57	0	2.8	818.2	24.73	56.34	31.36	755.4	2.63	114.08	1.1	2.45	2.7
				30-60	7.58	12	90	0	4	99.99	34.01	15.36	24.16	96.8	1.68	21.78	0.65	0.8	1.8

Profile No.	Area location	Depth of Ground water (cm)	Crop	Depth (cm)	pH	EC dS/m	SP	Anions (meq/L)				Cations (meq/L)				SAR	Gypsum %	OM %	CaCO3 %
								CO_3^{2-}	HCO_3^-	Cl^-	$SO4^{2-}$	Ca^{++}	Mg^{++}	Na^+	K^+				
				60-100	7.75	7.58	75	0	3.3	31.81	46.87	16.39	9.3	54.75	1.54	15.28	0.25	0.3	0.6
				100-130	8.81	6.24	80	0	2.3	25.45	38.45	12.3	6.47	46.02	1.41	15.02	0.15	0.1	0.25
9	Abu Homos	130 (Deep)	Barseem (alfalfa)	0-30	7.14	52.11	50	0	4	618.2	137.96	66.6	91.5	596.7	5.36	67.11	1.45	2.1	2
				30-70	7.42	14.64	67	0	4.6	132.7	26.69	15.36	19.22	127.5	1.91	30.66	0.6	1	1.1
				70-100	7.55	51.6	75	0	4.4	454.5	339.71	66.6	106.3	622.1	3.61	66.91	0.4	0.25	0.7
				100-130	7.54	38.55	75	0	3.4	357.5	120.25	5.63	8.69	463.4	3.43	173.18	0.25	0.1	0.3
14	Abu Homos	130 (Deep)	Wheat	0-30	7.53	16.91	95	0	3.4	138.18	95.81	58.66	60.04	115.85	2.84	15.04	1	1.75	2.6
				30-70	7.95	7.99	105	0	2.6	33.64	48.44	21.33	23.83	38.88	0.64	8.18	0.7	0.9	1.25
				70-100	7.71	6.55	90	0	2	31.8	34.88	19.99	4.51	43.64	0.54	12.47	0.3	0.4	0.75
				100-130	7.82	5.43	90	0	2.2	27.3	27.49	14.66	12.44	29.35	0.54	7.97	0.1	0.1	0.6
15	Abu Homos	130 (Deep)	Barseem (alfalfa)	0-25	7.78	3.24	75	0	4.8	6.36	22.87	17.33	8.48	7.77	0.45	2.16	0.75	1.35	2.15
				25-70	7.99	1.58	90	0	3.2	4.55	8.67	5.33	1.12	9.84	0.13	5.48	0.4	1	1.45
				70-110	8	2.69	100	0	3.2	9.1	15.95	5.99	0.46	21.6	0.2	12.03	0.2	0.6	0.6
				110-130	8	1.95	120	0	4.4	11.82	4.06	3.99	1.17	14.92	0.2	9.29	0.2	0.2	0.2
16	Abu Homos	130 (Deep)	Barseem (alfalfa)	0-30	7.64	6.14	50	0	4	25.45	34.62	23.99	12.78	26.66	0.64	6.22	1.2	2.7	3
				30-60	7.81	4	80	0	4.4	15.45	22.58	7.99	2.97	30.94	0.53	13.22	0.65	1.15	1.7
				60-100	7.69	9.37	75	0	2.2	8.18	89.13	39.33	16.17	42.85	1.16	8.13	0.25	0.7	1.3
				100-130	7.67	9.12	80	0	3	8.18	85.52	33.33	20.87	41.3	1.2	7.93	0.1	0.3	0.6
17	Abu Homos	130 (Deep)	Barseem (alfalfa)	0-30	7.21	11.88	65	0	4.4	74.54	57.68	54.33	30.17	51.6	0.52	7.94	1	2.1	2.7
				30-60	7.23	12.1	70	0	4.2	74.54	60.46	54.66	32.44	51.6	0.5	7.82	0.75	1.25	1.45
				60-100	7.33	10.82	90	0	3.2	67.3	53.93	31.99	32.51	58.7	1.23	10.34	0.4	0.6	1.6
				100-130	7.36	23.26	75	0	4	85.45	201.33	29.33	170.6	88.87	1.98	8.89	0.15	0.45	2.45

was within the range of (7.21- 8.0) with profiles 14 and 15 having lower alkaline levels. The EC range obtained for these profiles indicate that they were moderately affected by salinity[12] with the lower level of profile 17 recording the highest EC value of 23.26 dS/m. Previous studies within El-Beheira Governorate lands indicated that the pH (soil reaction) of calcareous soils and some reclaimed sandy soils west of the Nile delta was alkaline (7.5 to 8.5)[12,13,18,19]. Thus, the alkaline soil pH of the lower layers within some of these inland profiles may be due to the nature of the parent material from which these lower layers of soils are formed[15].

Abdel Hamid and Shrestha[12] previously reported that EC values for old reclaimed cultivated lands may reach 15 dS/m. As well, fluvio-marine plain soils to the north of Egypt were reported to have an EC ranging between 2.24- 25.09 dS/m[16]. These values were comparable to the EC of clayey agricultural soils north of the delta (flood plains) that had salinity values ranging between 1.6 to 20.5 dS/m[13,20]. Overall, there was a noted increase in salinity at the lower levels of profiles 11, 12, 15, 16 and 17. This event may be explained by the upward movement of salts from lower layers during dry period or between irrigation intervals and during the non irrigation period at the end of the season[8]. In addition, the increase in soil salinity values may be due to the loss of moisture from top layers through evaporation which may be accompanied by the capillary rise of saline waters from the shallow water table in some areas[21].

Coastal profiles: 3-9

Concerning the coastal profiles 3-9, the majority of these coastal lands had a clayey texture (27.4- 63.0%) with the exception of profile 6 that exhibited a sandy-clay-loam texture throughout. Profiles 3 and 4 are less affected by salinity (EC ≤ 4.0 dS/m) while profiles 5-9 were highly saline[13]. The pH of these profile vary from top layer to lower level with the top layer soil reaction being near neutral (pH=7) for profiles 6 and 9. However, alkaline pH was observed throughout the remainder of the profiles and it reached the value of 8.81 at

TABLE 2 : Available Cu, Fe, Mn, and Zn concentrations (mg/kg) in the studied 17 soil profiles

Profile	Depth (cm)	Cu	Fe	Mn	Zn
1	0-30	3.46	17.32	1.38	0.20
	30-70	2.18	5.98	0.92	0.22
	70-100	2.38	5.66	2.88	0.18
	100-120	3.00	10.30	1.30	0.30
2	0-30	1.40	3.90	0.70	0.30
	30-65	1.50	3.90	0.70	0.20
	65-90	1.40	3.80	1.30	0.20
	90-130	1.90	5.30	1.10	0.40
3	0-30	1.70	2.80	1.00	0.20
	30-70	1.40	6.20	1.10	0.20
	70-100	1.50	5.00	2.00	0.30
	100-120	3.40	40.50	1.70	0.40
4	0-30	2.10	10.50	1.40	0.20
	30-70	1.70	6.90	1.60	0.20
	70-100	2.20	4.50	8.00	0.30
5	0-30	3.00	14.10	1.00	0.30
	30-60	1.30	8.10	1.40	0.18
	60-90	1.50	5.20	1.10	0.30
	90-120	1.20	9.80	1.50	0.20
6	0-30	1.10	18.60	1.30	0.20
	30-70	1.60	3.80	1.30	0.20
	70-100	1.80	2.30	1.20	0.16
	100-130	1.50	6.40	1.60	0.19
7	0-30	1.40	5.50	1.10	0.20
	30-60	1.10	6.40	1.90	0.20
	60-100	1.20	5.30	1.30	0.30
	100-130	1.80	5.60	1.10	0.30
8	0-30	1.40	3.60	1.10	0.18
	30-60	1.30	4.00	1.60	0.12
	60-100	1.40	15.60	1.50	0.30
	100-130	1.20	13.30	1.20	0.20
9	0-30	1.60	13.00	1.30	0.20
	30-70	1.80	9.90	1.20	0.30
	70-100	1.20	9.80	1.40	0.20
	100-130	2.30	24.30	2.70	0.60
10	0-30	1.20	10.20	1.30	0.30
	30-60	1.10	5.60	1.80	0.30
	60-80	1.50	17.20	1.30	0.20
11	0-30	1.40	4.10	1.20	0.15
	30-70	1.90	9.50	1.50	0.12
	70-100	1.10	28.40	1.30	0.20
	100-130	1.20	21.10	1.30	0.30
12	0-25	1.40	6.10	1.10	0.30
	25-60	1.10	8.30	1.40	0.20
	60-90	1.50	18.50	1.40	0.50
	90-120	1.10	3.80	1.10	0.30
13	0-25	1.30	13.80	1.80	0.30
	25-60	1.40	3.80	1.40	0.20
	60-90	1.10	2.20	1.10	0.20
	90-130	1.40	9.30	1.40	0.12
14	0-30	1.00	2.10	2.20	0.11
	30-70	1.10	6.20	1.50	0.20
	70-100	1.80	5.50	1.60	0.17
	100-130	1.60	5.60	1.80	0.22
15	0-25	1.50	3.10	1.20	0.16
	25-70	1.10	3.90	1.90	0.14
	70-110	1.10	6.30	1.30	0.16
	110-130	1.80	5.40	1.00	0.20
16	0-30	1.00	2.10	1.10	0.10
	30-60	1.30	5.80	1.30	0.28
	60-100	2.10	10.10	1.50	0.70
	100-130	2.10	10.80	1.40	0.20
17	0-30	1.50	7.70	1.60	0.40
	30-60	1.10	6.30	1.30	0.21
	60-100	2.20	25.70	2.10	0.36
	100-130	2.40	43.20	2.00	0.53

100-130 cm of profile 8. Profile 7, on the other hand, is a natural unreclaimed desert soil which exhibited an alkaline soil reaction (pH) throughout its four layers. These findings are in accordance with previous reports made by Abdel Hamid and Shrestha[12] in which they indicated that formerly reclaimed soils and coastal area soils had pH range of 7.9-8.5. As well, Abdel Kawy and Ali[13] indicated that lake reclaimed soils had a soil reaction (pH) that was slightly alkaline (8.0-8.31). However, soil pH above 8.70 was reported to be an indication of the dominance of $CaCO_3$ and presence of $MgCO_3$ or Na_2CO_3 in these soils[22]. From another perspective, this increase in pH may be attributed to lake water intrusion at these profiles. Previous studies of Lake Idku waters indicated that its water pH varied between 8.26 and 9.04[23], 7.6 - 9.5[24] and 7.89 - 8.04[25]. Okbah and El-Gohary[23] reported that the near alkaline pH of these waters was obtained during the winter season, which coincides with the current study period. This increase in pH was related to the photosynthesis activities which increased the dissolved carbon dioxide content within the lake waters and in turn increased its carbonate content[23,24]. As well, the increment of salinity exhibited within some of these profiles may be due to intrusion of seawater and/or seepage from the low quality lake water as well as poor drainage[16].

Overall, profiles 7, 8 and 9 showed higher EC values which may be due to the fact that these clayey soils adjacent to the lake had a low permeability[21]. Higher EC values for the top level of these profiles may be an indication of water logging by intruding seawaters[14]. However, the barren natural lands north of Egypt such as profile 7 were reported to have a soil salinity that ranged between 6.5 to 31 dS/m[20]. As well, Abdel Hamid and Shrestha[12] reported that the EC values of some newly reclaimed alluvial/marine soils near northern lakes may reach 30 dS/m. This increase in soil salinity may be attributed to the fact that these soils were exposed to lake seawater for long time. Furthermore, the lake is shallow and has a depth range between 10-140 cm, the maximum of which was recorded in the central and eastern parts of the lake[9,25]. On the other hand, higher TDS and EC values were reported for Lake Idku waters during the winter season[9,25] which may affect the water table around this lake area. Fur-

TABLE 3 : Irrigation water quality in canals and drains within the proximity of the studied profiles

Profiles	Sourece	pH	EC ds/m	Anions (meq/L)			Cations (meq/L)			
				HCO_3^-	Cl^-	$SO4^{2-}$	Ca^{++}	Mg^{++}	Na^+	K^+
1 and 2	Canal	6.16	0.63	3	2.73	0.56	3.27	1.02	1.8	0.21
	Main Drain	6.57	2.59	5.4	11.82	8.68	10.13	12.5	2.63	0.64
3, 4, 5, 6, 7,8 and 9	Canal (close to sea)	6.18	0.93	4.6	4.55	0.15	5.24	1.98	1.71	0.37
	Drain (close to sea)	6.7	3.82	10	25.5	2.7	14.25	19.97	3.36	0.62
10-17	Canal	6.55	0.65	2.4	2.73	1.37	3.73	1.45	1.05	0.27
	Drain (Umoum Drain)	6.7	1.33	5	6.36	1.94	8.58	3.61	1.33	0.45

thermore, it was reported that shallow saline water table may result in the movement of water-containing salts by capillary rise and through evapotranspiration, it may lead to salt accumulation in the top soil[14,20,21]. As well, the low leaching capacity and salinity of these soils may be a result of the high groundwater table[1]. Moreover, it was reported that high contents of Mg^{2+} reflected the fact that these soils were mostly marine in origin[22].

From another perspective, profile 9 showed a pronounced reversed downward flux that was coupled with an upward flux of saline ground waters at the two lower depths. This was attributed to the fact that this area may be used for rice growing and, because it received insufficient irrigation water at the beginning of the growing season, the profile may be subject to re-salinization in the two lower layers during this period[14]. This process was indicated not to be easily reversed during the growing season even with the availability of a sufficient supply of irrigation waters as the accumulated salts were not leached during the peak growth period of rice cultivation. Soil salinity build-up on the top soil of profiles 5 and 8 rather than the lower parts may be attributed to the upward movement of salts from lower layers during dry period or between irrigation intervals and during the non irrigation period at the end of the season[8]. As for profile 6, the prolonged fish farming using seawater was reported to increase top soil salinity, soil acidity and degrade soil quality[20]. This water logged profile soil exhibits an increase in soil salinity which may be due to seepage from the fish ponds supplied with low water, improper drainage system or complete submerging of the soil under water[1,16].

Water resources and its effect on soil quality

Suitability of any irrigation water for agriculture depends mostly upon its chemical composition and the conditions of use[3]. The main factors determining the conditions of use are soil texture, total water salinity, crop to be irrigated, climate, management practices and the skill of the water user. Concerning the quality of irrigation waters applied at these profiles, the pH of the waters in the surveyed canals was found to be more acidic than those in the adjacent agricultural drains. Essentially, fresh Nile waters was reported to have a pH between 7.4- 8.4[16,18]. In the past, it was reported that the irrigation water coming from the Nile was generally of a good quality and had an average EC of 1.4 mS[1]. A more recent survey of the Nile fresh water pH indicated that it was alkaline pH (8.36 and 8.10) and had an EC value between 0.52 and 0.37 during the year 2009 and 2010, respectively[26]. As well, it was noted that there was an increase in Nile water salinity as the river flowed north and this was exhibited by the increase in its sodium bicarbonate, sodium sulfate and sodium chloride contents[16]. The use of fertilizers and soil amendments was reported to reduce the Nile surface water pH[5,26]. Furthermore, soil EC was reported to increase with the increase in irrigation water salinity after plant harvesting and with the decrease in calcareous soil moisture[3,27]. More specifically, the increase in irrigation water salinity from 0.58 to 3.67 dS/m was reported to increase the total soil salinity from 1.87 to 24.83 dS/m. Moreover, such a practice did affect the EC of the top soil (0-100 cm) more than the subsoil (100-180 cm) layer[3]. Overall, a study of the effect of different salinity irrigation waters upon the soil EC concluded that the rate of salt decrease in soil was related to the EC of the applied irrigation water and that the use of poor water quality increased of soil salinity and caused by the build-up of the salts throughout the soil profiles[3].

Effectively, it was reported that in Beheira Governorate, farmers have been using recycled drainage water since 1960s[1,17]. However, as the EC of irrigation/agricultural drainage waters in the canals may reach up to 4.5 dS/m, mixing of these waters with fresh Nile water at pumping stations in this region was practiced to reduce water salinity to EC $\leq$ 1.0 before land application[5,8,17]. Moreover, to increase water resources in some areas in Egypt, tapping of water from branch drains and its discharge into the tail ends of branch canals was been practiced[5]. Nonetheless, these canals/drains represent an outlet not only for the disposal of agricultural drainage and unused water but also untreated sewage and industrial effluents[5]. Thus, these soils may be subject to low quality waters and acidic waters as indicated in TABLE 3. In this aspect, it was reported that the continued use of sewage wastewaters for irrigations decreased the pH of sandy soils from alkaline to acidic[29]. This decrease was accompanied by a decrease in soil $CaCO_3$ content and an increase in the drainage water bicarbonate content, a similar observation noted comparing the content of bicarbonates in canal and drain waters within the study area. Also, it was reported that the occurrence of carbonates in these waters was dependent upon pH and the salinity[27]. This may also be accompanied by an increase in Ca, Mg and Na content of the resulting drainage wastewaters. Overall, prolonged periods of sewage waters use was reported to increase the solubility of ions, namely: Ca, Mg, Na, K, HCO_3, Cl and SO_4 in soil[29], an observation affirmed by the increase of these ionic contents in the examined drain waters. As well, wastewaters when used for surface irrigation may lead to cation exchange where Na^+ becomes adsorbed on clay minerals and Ca^{2+} and Mg^{2+} are released to the liquid phase[30], which was affirmed by the analysis of the drain waters.

From another perspective, irrigation with low level of saline water (0.46 dS to 2.44 dS m) was reported to decrease soil salinity throughout the profile due to leaching[3,31]. The decrease in salinity with depth could be attributed to the increase effect of irrigation water salinity on the top soil compared to the lower depths. The concentration of salts in the upper horizon may be due to evaporation of water from the salts applied in the irrigation waters. As well, the increase in soil salinity indicates that the use of poor quality water caused a buildup of salts throughout the profile. Also, soil EC values were found to increase with increasing salinity of irrigation water which acted to decrease soil moisture depletion in calcareous soil in northern Egypt[31]. Moreover, saline soils in the northern part of Egypt were reported to be affected by brackish water intrusion from the sea, the northern lakes and tidal marches[32]. As well, it was reported that as salty water drainage water are kept in the drain, it can infiltrate the surrounding areas resulting in a saline and higher ground water TABLE[1]. This may affect salinity of soils as it may cause low leaching and increase the risks of lower profile salinization.

In order to understand the relationship between the quality of water resources in both feeding canals and resulting drain channels, cluster analysis was performed using the data obtained in TABLE 3. The resulting dendogram is provided in Figure 4 which indicates the splitting of these measured parameters into 8 main clusters that were grouped into two major groups. Essentially, the measured variables of bicarbonates, pH, calcium, magnesium and chloride ions were grouped into one group. Within this first group, the data revealed the dependency of the measured water pH upon its HCO_3^- content, both of which were strongly related to the calcium ion content of these waters. The concentration of Mg^{2+} ions was dependent upon the chloride ion concentration and this cluster was dependent on the bicarbonate- pH – calcium cluster. The second major group contained the measured variables of Na^+, EC, K^+ and SO_4^{2-}. A strong dependency of measured water EC on its Na^+ content was indicated that was related to the K^+ content, all of which were strongly dependent upon the measured sulfate content. As well, according to the clustering strategy, it may be concluded that the dominant salts present within these waters were $Ca(HCO_3)_2$, $MgCl_2$, Na_2SO_4 and K_2SO_4. After irrigation, there was a noted increase in their drained ionic content, which is in accordance with the findings of El-Ashry et al.[29] and Elewa and El-Nahry[16]. From another perspective, Elewa and El-Nahry[16] indicated that a significant sodium sulfate concentration was detected in the surface waters of the Rosetta Nile Branch. The data also revealed that the pH was dependent more on the concentration of bicarbonates in water while the water salinity, indicated by EC, was dependent upon the increase in Na^+ primarily and on K^+ and sulfate ions.

Land activities and soil characteristics

With respect to the agricultural activities in the area and its impact on the soil chemical and physical properties, it has to be noted that the majority of agricultural lands in Egypt are cultivated twice a year and may be left to fallow during one season either due to soil water logging or due to insufficient water resources[14]. Crops are cultivated according to a 3-year crop rotation (winter season: November-May and the summer season: May-October) depending upon water availability and aridity or climatic conditions, with a marginal season is observed (Nili season) during late summer (August-October). These rotations are beneficial to agricultural soils with respect to nutrition and essential element recovery. Generally, the main winter crops include wheat, barley and barseem (Egyptian clover), broad beans and vegetables and the main summer crops include cotton, rice and maize and onions may be inter-planted with cotton. There are two types of rotation undertaken namely: rice and no rice or cotton only rotation. Desalination of newly reclaimed or salinized soil may be achieved by cultivating rice at the initial stage at it is tolerant to salinity. Overall, El Beheira Governorate produces 50% of the rice grown in the country[14]. This may be achieved by cultivating places with high water table in the governorate as the crop requires moist soil and[1].

Egyptian clover (or barseem) is the major winter forage crop cultivated after rice and cotton in both rotation cycles[33]. Its cultivation is said to nourish the soils, suppress weeds and provide a disease break in cereal-dominated crop rotations. During the rotation, salt removal from the crop root zone may be achieved by soil leaching through water application either as pre-irrigation or as additional water supply during the irrigation season[14,20]. However, insufficient irrigation waters may cause an upward flux of saline groundwater. Clover cultivation was reported to help in soil de-salinization especially when planted after cotton. However, in some cases soil resalinization may occur after the clover is ripe and water and salts may be pushed upwards through capillary effect[14]. As well, salinity may increase in top soil by the upward moving of salts form the lower layers during the period between irrigation and non-irrigation at the end of the season[13]. This was observed in the case of profiles 9, 15, 16 and 17 where barseem was planted and it was indicated by an increase in EC values of the two lower levels.

Wheat is a common and low water consuming winter crop in Egypt that can be grown on a wide range of soils preferably medium texture in both the Delta lands and new reclaimed lands[34]. However, it is preferred to grow wheat in heavy, deep, humus rich well aerated soils with a high water capacity and a pH between 5.5 - 7.5[35]. Wheat is a relatively salinity tolerant crop; however, precaution must be made that the ECe does not exceed 4dS/m in the upper soil layer during germination in order to insure limited crop loss[34]. This crop requires from 5-6 irrigation events and this helps to leach salts but also nutrients in reclaimed soils[35,36]. However, research has shown that if wheat was planted in fine textured soils, the addition of gypsum and increasing soil organic matter during the growing period increased crop yield as well as improved the soil water holding capacity and aeration[37,38]. Another observation made after harvesting wheat in newly reclaimed soils has been that it helped to decrease soil salinity and improve soil fertility status[36]. In this study case, it was observed that there was an increase in the calcium and sulfate ions at the top of profiles 4, 12, 13, and 14 on which wheat has been planted, which may be attributed to the addition of gypsum to soil during the process of crop cultivation. As well, while the increase in irrigation water salinity may induce higher soil salinity (up to 24.83 dS/m)[3], human induced soil degradation through water logging caused by over irrigation, improper use of heavy machinery and absence of conservation measurements was reported to increase the salinity of soil up to 37.7 dS/m in old and newly reclaimed soils in Egypt[39].

Potatoes (planted in profile 1) are the most important vegetable commodity in Egypt in terms of planted area and crop value[19]. It was reported that availability of water and nitrogen supply in potatoes cropping systems was essential in controlling production in arid and semi-arid regions[19]. Thus, this crop is heavily irrigated to meet quality standards demanded by the fresh vegetable market. Potassium is the nutrient taken up by potato in the greatest quantity from the soil as well as nitrogen and appreciable amounts of phosphorus, calcium, magnesium and sulphur[40]. Therefore, while the application of potassium fertilization has been identified as one of the most important factors affecting the growth and yield of potato, the increase in soil moisture was reported to facilitate the availability of K^+ and its uptake by the plant with the increased irrigation.

Onions (Profile 10) are considered one of the most important vegetable crops in Egypt that is inter-planted with other major crops[41,42]. Onions are considered a shallow–rooted crop (18-30 cm) and shallow rooted crops are generally more difficult to irrigate and have lower irrigation efficiency values than deep-rooted crops[41]. While it was recommended to grow onions on slightly acid-neutral soils, its cultivation was reported to increase soil EC (from 0.3- 3.0 dS/m) and changed the soil pH from acidic to neutral[43]. Furthermore, during the production of onions nutrients amendments such as potassium nitrate, potassium sulfate, calcium nitrate and potassium chloride or calcium chloride as a foliar spray are used to better crop quality[44]. As well, it was reported that KCl and K_2SO_4 whether applied to soil or as a foliar spray during growth enhanced the final product dry weight and vitamin C content[45].

Artichoke's cultivation areas are known to be the coastal and sub-coastal regions in the Mediterranean basin, (profiles 2 and 11). Although artichoke is a moderately salt-tolerant crop, the salinization of irrigation water is an increasingly concerning issue especially during the vegetative stage[46]. However, artichoke productivity has been reported to be strongly affected by the amount of irrigation water applied[46]. The use of saline water in its cultivation requires more frequent irrigation/ applications relative to the use of fresh water because salts in the water and soil increases the osmotic potential of the soil paste, which makes water uptake by the plant roots more difficult[46]. On the other hand, artichokes were reported to develop root system down to 90-120 cm[47]. This may enhance its access to more water resources in the case the decrease in water supply.

Citrus trees (profile 3) occupy a prominent position in the fruit industry in Egypt[48]. About 30% of citrus orchards in Egypt are located on poor soils and newly reclaimed areas. Citrus trees are known to be salt sensitive[4]. As clay soils have high capacities and K^+ ions tend to bind to it and show little response when K fertilizers are applied to soil, foliar application of KCl, KNO_3 and K_2SO_4 have been useful in enhancing yield and quality[45]. Guava (*Psidium guajava L.*) (profile 5) is one of the major horticultural crops throughout the tropical and subtropical zones. In Egypt, guava is a popular fruit, cheap and rich source of vitamin C. Furthermore, guava is one of the leading fruit trees planted in new reclaimed soil in Egypt because of its high adaptability as well as it thrives in these soils[47]. To enhance acidity and fruit quality, foliar KCl and K_2SO_4 were reported to be applied to guava trees[45].

Sugar beet is considered to be the second source for sugar production in Egypt. This crop has the ability to grow in the new soils that usually suffer from salinity and poor quality of irrigation water[50]. While this crop was reported to tolerate soil salinity and soil water stress, it was indicated that sugar yield of sugar beet may be affected by salinity above 7dSm[50]. On the other hand, sugar beet plants were reported to develop deep root system that enables them to use soil water from as deep as 6 feet[51]. However, if water is abundant, sugar beet will satisfy the majority of their water requirements from the top 2 feet of soil. K application (as potassium sulfate) is important for this crop as it was reported to improve upon the quality of sugar beet roots whether irrigated with saline water or with good quality water.

Profile 6 is a fish farm and this activity is widespread in the northern coasts of Egypt[20]. Fish farming is practiced instead of traditional agriculture as a means to increase profits from saline affected land due to high soil salinity and decline in agricultural yield[20]. However, agricultural activities were noted to decrease soil salinity in coastal lands by 70% as it involves land washing 6 months before cultivation. On the other hand, fish farming was reported to increase soil salinity significantly as well as the prolonged use of seawater increased soil salinity, acidity and degrades soil quality while depleting the soil's organic matter content. Moreover, fish residue and mud were noted to cause water logging of these soils as they accumulate on the top soil surface. Nonetheless, while agriculture and crop rotation decreases soil salinity and enhances soil nutrients state, there has been no evidence cited to instate that fish farming did enhance soil properties.

Micronutrients and soil additives

The reclamation of saline soils uses different methods for improvement of soil quality. These include physical amelioration such as deep ploughing, sub-soiling, sanding, profile inversion; chemical amelioration which includes amending soil with various reagents such as: gypsum, calcium chloride, limestone, sulfuric acid, sulphur, iron sulfate) as well as electro-reclamation (treatment with electric current)[52]. Generally, potassium plays a key role in crop quality as it improves size of fruit, stimulates root growth and provides resistance against pest, diseases and drought as well as frost stresses[44]. Potassium is added to the soil in the form of soluble salts such as potassium chloride and potassium nitrate. However, potassium is soluble and the deficiency appears, in particular, on the lower leaves of the plants and spreads to the top when the deficiency becomes imminent[53]. Thus, potassium nitrate, potassium sulfate or thiosulfate are either applied to soil or sprayed as foliar depending upon the $CaCO_3$ content of the soil[48]. Calcium may be added to soil as a pre- or post-harvest treatment to increase postharvest quality or to control postharvest diseases in many crops[44].

Micronutrient deficiency is considered a problem and a major cause of the declining land productivity in calcareous soils of arid and semi arid regions[10]. Generally, it has been recognized and well documented that most of crops in Egypt suffer from micronutrient deficiencies, which results in lowering of yields[54]. The continuous loss of nutrients from soil, especially micronutrients, is governed by many factors; mainly: removal or uptake by crops, cultivation of high yielding cultivars and common fertilization practices. A study of the levels of available micronutrients in different areas of loamy, sandy and calcareous soil types in Egypt found that Fe, Zn and Mn were mostly insufficient (low or deficient). This was attributed to growing of high yielding varieties and/or absence of using manures or organic matter. Metals in the soil can occur either in water-soluble fraction, exchangeable, bound to carbonates, bound on oxides and hydroxides of Fe and Mn, bound to soil organic matter or bound to structural matrix of minerals (residual)[55]. As well, clay minerals interact with almost all contaminant and may act as a short-term sink for heavy metals in soils because of their adsorptive properties[56].

Generally, the micronutrients content in the studied soil samples indicated the dominance of Fe ions followed in most of the profiles by Cu then Mn ions. The value for Zn content was the least within these soil profiles ranging between 0.11- 0.70 ppm. Essa and Farragallah[56] stated that the order of micronutrients in soils irrigated with fresh Nile water was Fe>Mn>Cu>Zn (averaging 12.94, 7.49, 1.80 and 0.83 ppm, respectively). This order changed to Mn>Fe>Cu>Zn (ranging between 14.46-18.86, 7.77 – 11.61, 2.41-2.78 and 0.58-1.26 ppm, respectively) if these soils were irrigated by sewage and agricultural drainage contaminated Nile water. Irrigation of sandy soils with sewage contaminated waters was reported not only to increase the surface Fe content but also to enrich the soil with extra organic matter at varying rates[29]. However, Zayed et al.[57] reported that soils with low organic matter content suffered from Fe, Zn and Cu deficiencies. From

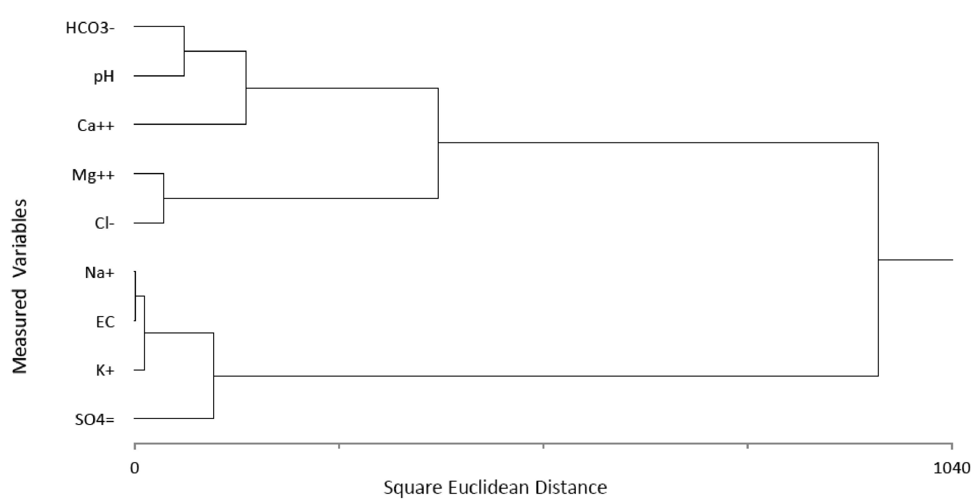

Figure 4 : Dendogram depicting the relationship between measured water resources variables using Ward's methods for minimum variance

another perspective and in Egypt, high averages of Fe were observed in the soils containing low calcium carbonate[58]. It was reported that the bicarbonate levels present in soils or in irrigation water were the most important parameter that induced lime-induced Fe deficiency (chlorosis)[58]. Iron deficiency is caused by imbalance of metallic ions as Cu and Mn[57]. Furthermore, it was reported that the levels of micronutrients in soil were depleted due to the continuous growing of high yielding crop varieties and the non addition of new organic matter to soils.

Zinc (Zn) is one of the micronutrient required for normal plant growth[48]. Zinc deficiency is widespread in Egypt and the application of $ZnSO_4$ was reported to significantly increase the final yield through increasing fruit set efficiency and decreasing fruit drop and preharvest drop[48]. In soils with very high pH and very low in which organic matter, the availability of Zn to plant roots were reported to be extremely low. As well, the amount of calcium carbonate present was reported to potentially control Zn availability in soil via the adsorption of Zn on its surface and Zn precipitation in little available form[58]. The decrease in Mn availability in the presence of $CaCO_3$ was reported to be a result of adsorption and precipitation mechanisms caused by the dilution effect of $CaCO_3$ as inert material. Zn and Cu were reported to reduce Fe uptake in soils as well as it was reported that Mn antagonized Fe absorption and distribution in plants[58]. However, when Mn reaches toxic levels, it can cause excess Fe uptake by plants to accumulate in the roots in the inactive form. Moreover, foliar sprays applications are being widely used to administer micronutrients, especially iron and manganese, for many crops[57]. Soluble inorganic salts are generally as effective as synthetic chelates in foliar sprays. Foliar spray such as $FeSO_4$, $MnSO_4$ and $ZnSO_4$ are applied to help in partially minimizing the salt-induced nutrient deficiency, increase photosynthesis and dry matter accumulation[57].

On the other hand, the high concentration of Fe at the coastal profiles may be attributed to the fact that the magnitude of the ionic content in lake Idku waters and sediments was Fe>Mn>Zn>Cu[59]. Thus, irrigation or use of these waters may increase the Fe content in these profiles, an observation that was made at the top soil of the flooded profile 6 (fish farm). The increase in Fe content in other profiles (such as profile 1 and 10) may be attributed to the fact that potatoes and onion require ample amount of water and a number of irrigation events during growth. As well, the relatively high contents of Fe in the deepest layers were reported to be associated with the sedimentation regime rather than the effect of weathering processes[22]. Essa and Farragallah[56] stated that there was a significant increase of Fe content in clay soils irrigated with sewage contaminated Nile water as well as for Fe, Cu and Zn in soils irrigated with agricultural drainage contaminated Nile water. On the other hand, the ions of Cu, Zn, and Mn, were re-

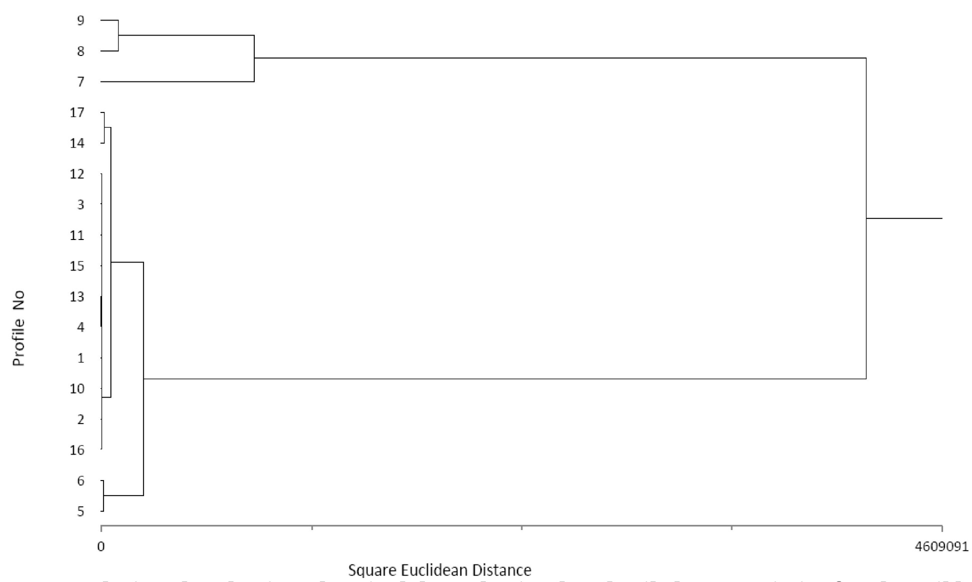

Figure 5 : Dendogram relating the physico-chemical data obtained and soil characteristics for the soil horizons of the 17 Profiles studied using Ward's methods for minimum variance

ported to be found in pesticides or in fertilizers, more specifically, copper has been associated with a fungicide (Mancozeb) used as a common treatment of mildew (common fungus) on potatoes[60].

Statistical analysis of data

The impact of different land uses and activities upon the soil quality in the study area, South of Lake Idku, was determined using multivariate analysis to identify similarity in patterns and classifying relationships among the measured soil variables. Multivariate analysis offers techniques for classifying relationships among measured variables[61]. Cluster analysis attempts to identify relatively homogenous groups of cases based on selected characteristics even from evenly distributed data. Hierarchical Cluster Analysis (HCA) has been described as "an efficient means to recognize groups of samples that have similar chemical and physical characteristics"[7]. Ward's method calculates the distance between two clusters as the sum of squares between the two clusters added up over all the variables[62]. This method is regarded as very efficient and the results were represented by dendograms the represents the sequence and the distance at which the observations are clustered. In this study, cluster analysis was performed separately using the physical data and another time using the chemical analysis data obtained for these 17 profiles. This was deemed necessary in order to identify factors affecting soil quality and similarity in patterns. Moreover and in order to correlate both set of parameters together, two characteristics of the measured soil, namely: EC and pH were used as reference points during clustering of both data sets. The discussion to follow will be based upon the findings of the hierarchal clustering (HC) of the respective sets of data and the relationships noted between the relative soils' characteristics for each profile. However, before exploring these correlations between the two sets of analytical data, and explanation is deemed necessary of the results obtained for the physical parameters.

HC of physical data (SP, Clay %, Coarse sand (CS)%, Fine Sand (FS) %, Silt%, CaCO3%, OM%, gypsum %, EC and pH)

Generally, hierarchal clustering (HC) of the physical data obtained provides information about the soil texture and its variability patterns. The analysis of the physical parameters obtained for these 17 profiles indicated that they were divided up into 10 clusters that were grouped into two main groups. The clustering strategy revealed the prevalence of the following common relationships. In all profiles, except for profiles 6 and 7, the results revealed that the measured soil SP was more dependent upon the clay content, both of which were varied by depth within each profile. Another cluster observed in all profiles, except for profile 6, has been that relating the silt content to the fine sand %. Both parameters were closely grouped with the clusters containing $CaCO_3$%, coarse sand%, OM%, gypsum %, EC and pH. This may indicate that both silt and fine sand emanated from the coarse sand/ calcareous minerals present in the soils of the current study. As well, it indicates that the $CaCO_3$ % content in these soils was not directly related to its clay fraction and minerals. It was reported that calcareous soils had a higher diûusivity due to greater aggregation and this effect varied depending on the total content and size distribution of $CaCO_3$[63]. Alternatively, the presence of the carbonate in the clay fraction was reported to decrease this diffusion ability, an observation which may be explained by examining the data for profile 6. This profile is a fish farm and the clustering strategy of its physical data indicated the presence of two clusters relating clay to silt content and fine sand% to SP. This may due to the fact that during fish farming, layers of mud (most probably silt) was deposited and accumulated on the top layer which significantly reduced the soil permeability[20]. This compaction of top soil layer was reported to decrease porosity and inhibit water entry into the soil[63].

On the other hand, the strong dependency of its CaCO3 % upon the coarse sand% available within each level, suggests that while the weathering of the carbonate-rich parent material was relatively slow, the texture of these soils remained fairly constant and was not altered by management practices[63]. Effectively, it was reported that the while the coarser fragments in black soils responsible for $CaCO_3$, these calcium carbonate particles helps in binding soil particles and causing a greater cohesion between soil particles[64]. As well, this accumulation of $CaCO_3$ in soils may be due to semi-arid climatic conditions and drainage problems in the area[65].

Other relationships noted were those linking the organic matter % within some of the studied profiles with its gypsum% (except profiles 8, 9, 11, 12, 15 and 16). This positive correlation may be attributed to the fact that they may have resulted from the same source and that they have mutual effects on soils. First, the term OM is generally used to represent the organic constituents in soils including undecayed plant and animal tissues, their partial decomposition products, and soil biomass that result from the decay and transformation of plant residues (roots, twings, leaves) and other unaltered material[63,66]. As well, organic matter may be added to soils through the application of sewage contaminated irrigation waters[29]. Organic matter helps to retain a greater amount of moisture as well as form soil aggregates that protect it from decomposition thus helping soil to rebound against compaction[67,68]. Gypsum, on the other hand, may accumulate in soil through a process similar to carbonate accumulation in the presence of significant $NaSO_4$ content in irrigation waters[16]. However, gypsum deposits are generally found in drier climates where very little leaching occurs since $CaSO_4.2H_2O$ is more soluble than $CaCO_3$ and sulfate (SO_4^{2-}) is not as abundant as carbonate[63]. In semiarid and arid areas, clay swelling and dispersion increases as the soil solution increases in the exchangeable sodium percentage –ESP- and decreases the electrolyte concentration[69]. To counter this effect, gypsum may be added to soil to limit clay swelling and dispersion and thus improve soil structural stability by means the release of electrolytes to the soil surface[69]. On the other hand, statistical clustering relating calcium carbonate with OM% and gypsum was noted in profiles 8, 9, 11, 12, 15, and 16. This may be attributed to the fact that the plant residues and roots while they may contributed to the soil organic matter, however, upon decomposition, they release organic acids that solubilizes inorganic calcium carbonate which may negatively affect the amount of $CaCO_3$ in the soil[69]. Eventually, this may affect the reaction forming or precipitating gypsum in soil.

It has to be noted that the measured physical properties excluding clay content, SP and depth, were grouped with soil pH and EC. This may indicate that the variation in these two parameters was more dependent upon the nature of the calcareous soil which contained calcium and magnesium ions and not the clay minerals that was deposited over during the stages of reclamation. As well, it emphasizes the role of these grouped parameters in the release of electrolytes to the soil surface as previously mentioned[69]. However, for profile 7 (barren land), there was a relationship between the SP and clay content of this profile which was further related to the EC of soil past and depth, accordingly. This is in accordance with the findings of Goossens et al.[1] indicating that there was a relationship between EC of soil paste and depth in recently reclaimed lands and uncultivated lands.

HC of chemical parameters (soil ionic content, micronutrients, SAR, pH and EC)

Hierarchal clustering (HC) of the chemical data obtained provides information the variability of its ionic content with respect to activity and quality of irrigation water used. Generally, the results of HC analysis of the data for the 17 profiles were divided up into 13 clusters that were grouped into two main groups. Predominantly, clustering of the ionic content of Na and Cl (the salinity indicator) was noted within 11 profiles (1, 2, 4- 9, 11, 12, 17). However, it was noted that for the coastal profiles (4-9), such a relationship was distantly related to the other parameters which affirms the analytical data (TABLE 1) indicating high salinity of these profiles may be affected by seawater. In addition, it was reported that soils deposited in a marine environment contained higher concentrations of sodium chloride[70]. This increase in soil salt content may affect the low permeability of these clayey soils in the Northern part of Egypt. On the other hand, this relationship between Na and Cl was affected by the addition of extra $CaSO_4$ to the soil of profiles (1-3 and 10-17). This was indicated by the correlation between Na and Ca and its dependency upon SO_4 ion which did impact the soil pH or reaction. This relationship was also affirmed by previous study on sodic soils in Egypt which indicated that the calcium in the gypsum replaces the sodium at the adsorption surface of the clay particles[70].

Two other relationships identified were the dependency of Zn ion on K ion in 13 profiles (1, 2, 4-8, 11-13 and 15-17) and for Cu dependency upon the Mn ionic content in 14 profiles (2 and 5-17). Effectively, these ionic contents were grouped either with the HCO_3 content of soil (5, 6, 7, 8, 9, 10, 14, 16, and 17), the HCO_3 content and EC of soil (1, 2, 3, 11, 12, 13) or with EC alone (4, 15). Essentially, the main source of micronutrients in soil is mostly the parent material[22]. As well, it was reported that the availability of micronutrients in soil increased significantly with the increase in the finer fractions (silt and clay) because these fractions improve upon soil structure and aeration which are favorable conditions for increasing their availability[65]. However, the forces binding metal ions to soils were reported to decrease with the increase in pH of the soil environment above 6[66]. It was also reported that high clay containing Egyptian lacustrine soils sorbed more Cu to its surface because of the appreciable total calcium carbonate content. As well, the type of minerals in this clay soils was noted to play an important role in Cu adsorption as they have a relatively strong affinity for Cu and other heavy metals[71]. However, the adsorbed Cu on the clay surfaces was more readily released than the adsorbed Cu on the organic-matter surfaces. As well, the statistical analysis in this study indicated that Cu content was more significantly correlated to the Mn oxide rather than Fe oxide clay minerals, which is in accordance with the findings of Shaheen et al.[71]. On the other hand, a positive correlation between Zn and K ionic content was reported by Sayed[22] during the study on NW Coast soil in Egypt. This was explained by the fact that both potassium and zinc in these soils have been a component of its silicates[22]. Overall, the availability of these micronutrients decreased with high pH. Moreover, The dependency of Cu, Mn, Zn and K on bicarbonate ion and its clustering with Ca and Mg indicates that they are most probably associated with soil parent materials[72].

Another observation noted has been a strong and direct relationship between Fe and pH in (2,6,7, 8, 9, 12, 14, 16) and more distantly, Fe was linked to other soil elements and parameters (Mg, Ca, Cl, SO4, HCO_3, SAR, EC). This indicates that most of the iron was associated with clay minerals and other silicates, and may be associated with the silt, clay or coarse sand fractions depending upon the soil whether cultivated or not[22]. As well, in these soils, the concentrations of dissolved inorganic Fe are greatly affected by high pH values[22]. Moreover, a positive relationship between Fe, pH and other metal ions indicate that the potential of hydrous iron for providing the main sorption surfaces for the accumulation of these metals in soils[73]. Metals may become fixed to solid substances as a result of adsorptive bonding, co-precipitation by hydrous iron and Mn oxides.

HC of the 17 profiles characteristics

Hierarchical cluster analysis was performed to identify groups of soil horizons of similar characteristics with regard to different parameters (elemental contents and physico-chemical characteristics) and soil properties. The resulting dendogram is shown in Figure 5. From this figure, it was shown that the data was split among two main groups with the following grouping of soil horizons being observed. The larger main group A comprised of sub groups that arranged the studied profiles as follows: (3, 11, 12 and 15); (1, 4, and 13); (2, 10 and 16); and (14 and 17). This may be explained not only by the similarities in soil properties, salinity and chemical elements but also by the fact that each of these grouped profiles were reclaimed in the same manner within the same time frame or period. As well, prior to commencing agricultural activities, these lands may have been washed 6 months before cultivation with the availed same quality irrigation waters. Separation of profiles 5 and 6 from this main agglomerate may indicate the fact that they are within the same proximity and potentially the same source of water was being used to support the ongoing activities therein. The other main group B found was to link profiles 7, 8 and 9. Separation of profiles 7, 8 and 9 from the other profiles may indicate the fact that profiles 8 and 9 were still being recently reclaimed and that their soil characteristics and parameters still resembled more the un-reclaimed soil of profile 7 more than the other old reclaimed profiles. As well, they may be affected by the same factors such as seawater intrusion and seawater salinity.

In conclusion, soils may vary in space and time due to the combined effects of physical, chemical, and biological processes that operate at different scales and with different intensities. Characterizing spatial variability of soil properties and crop parameters by inventorying them is needed to evaluate the effectiveness of their management. Also, characterizing their temporal variability by monitoring them is important in order to compare different management systems for sustainability and environmental quality. In addition, an understanding of the spatial and/or temporal variability can provide a framework for developing effective sampling schemes for future site management and efficient experimental designs for research approaches. Due to the spatial and/or temporal variability of soil properties, numerous samples need to be taken and the measurements need to be repeated as conditions change or to determine the magnitude of change and actions to options to counter it.

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