

ORIGINAL ARTICLES

Anthropogenic Impacts on the Land and Water Quality of El-Burullus Wetlands

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ABSTRACT

The Egyptian wetlands within the Delta region have been subjected to extensive losses due to reclamation activities. They also suffered from degradation as a result of threats including chemical contamination, excess nutrients, and sediment. This study is focused on the wetlands in El-Burullus area in the Northern Delta region. These wetlands originally included El-Burullus shallow lake as well as the swamps and clay flats that surrounded the lake, in addition to the coastal saline wet sandy soils along the Mediterranean Sea. Most of these wetlands were converted into agricultural areas or fish ponds. The current wetlands area includes only the remaining parts of El-Burullus Lake and the coastal wet sandy soils. The losses of the wetland area accounted for about 59.1 % of the total wetland area and about 13.4 % of El-Burullus Lake area before the reclamation. Concerning the saline wet sandy soils, they were classified as Typic Psammaquents, Typic Aquisalids and Typic Torriorthents as they were influenced by their reclamation status. The water table depth was moderate. The subsurface layers were mostly greyish, in addition to the presence of H₂S odour. The reclamation activity is starting to affect these soils especially those which will eventually depend on low water quality in irrigation. The lake water salinity was relatively low due to the massive discharge of the drainage water into it. The trophic state of lake and content of heavy metals were influenced by their amounts in the nearby drains which discharge into the lake. The reclaimed swamps and clay flats soils were classified as Vertic Torrifluvents. This area was affected by the use of low water quality for irrigation or fish ponds.

Key words: Anthropogenic Impacts. El-Burullus Wetlands. Water quality

Introduction

Wetlands are defined as transition zones between the land and the water where the flow of water, the cycling of nutrients, and the energy of the sun meet to produce a unique ecosystem characterized by hydrology, soils, and vegetation, and making these areas very important features of a watershed (United States Environmental Protection Agency (EPA), 2002).

In spite of representing only three to six percent of the earth's land surface area, these ecosystems are ecologically and economically valuable. They are amongst the world's most productive environments and provide a wide array of benefits.

Wetlands play an indispensable role in water quality maintenance, flood flow alteration, erosion control and shoreline stabilization. They also provide habitat for thousands of species of both aquatic and terrestrial species and are crucial to the survival of many threatened and endangered species of animals and plants (Null et al, 2000).

Unfortunately, in spite of their importance wetlands continue to be among the world's most threatened ecosystems, mainly because they are exposed to pollution or the over-exploitation of their resources and the most threatening damage of all is the conversion to other land uses which has been a problem historically and continues to be to the present day.

Wetlands in the Nile Delta region of Egypt are mainly located on the northern lakes and their surrounding banks. These wetlands, specifically the lakes are subjected to high levels of pollution from industrial, domestic and agricultural activities. Furthermore, large parts of these wetlands are converted into other land uses.

The main objective of this work is to identify the anthropogenic impacts on the wetlands in El-Burullus study area and determine their current conditions. This area is occupied by one of the two Egyptian Ramsar Sites according to the List of Wetlands of International Importance. The sub main objective is to assess the current conditions of the currently reclaimed wetlands area and converted to other land uses.

Materials and Methods

El-Burullus study area is located in the northern part of the Nile Delta between longitudes 30° 30' 40" and 31° 28' 31" E and latitudes 31° 14' 34" and 31° 33' 29" N. It covers an area of about 1941 km².

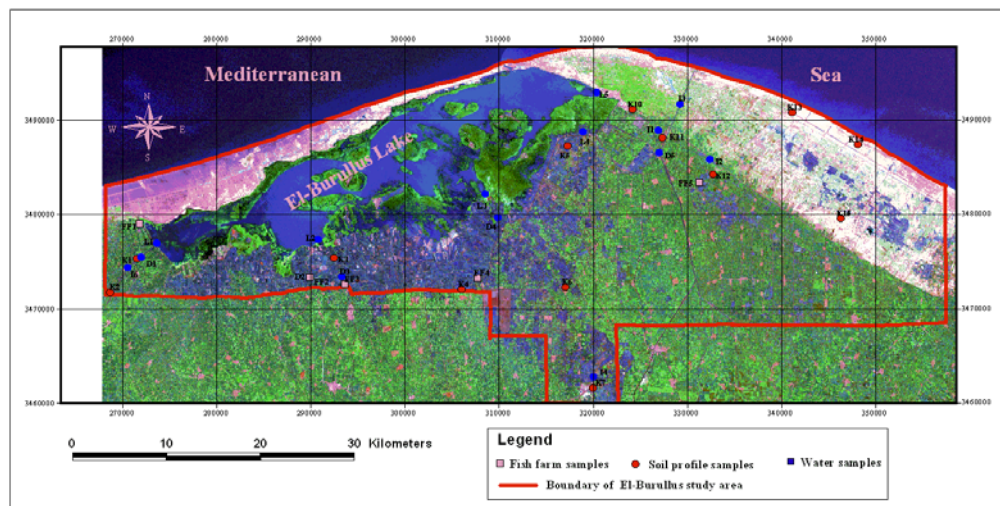
The area was suffering from water shortage, thus farmers frequently use drainage water for supplementary irrigation. The main irrigation canals were KhalijBirinbal in the west and Bahr Tira and Al-Nil Canal in the east of the study area. The water in both Bahr Tera and Al-Nil Canals were reused drainage water mixed with irrigation water. On the other hand, KhalijBirinbal, the closest to the River Nile (Rashid Branch), has been unofficially used in draining the its surrounding area in western part of the study area. In addition, a small part in the southern parts of the study area was served by Al-Zawiyah canal. These irrigation canals served the area through a network of smaller canals.

The main drainage systems in the study area were Gharbia Drain and Nashart drain systems, which are located in the eastern and middle part of the study area, respectively. Gharbia Drain discharges into the Mediterranean Sea. It is completely opened to the sea from October to March and closed during the rest of the year. This process increases the quantity of drainage water reused. Most of its drainage water is lifted by Hamul pump station into Bahr Tira Irrigation system or used unofficially by farmers. Some of the water is discharged into Al-Burullus Drain and thereafter into El-Burullus Lake. On the other hand, Nashart drain discharged into the lake completely. On its way to the lake, it collects water from Drain No. 9 and MohetFoah Shark Drain (Drainage Research Institute (DRI), 1990).

Other existing drainage systems included: Al-Burullus Drain and Tera Drain in the eastern parts of the study area, Tulumbat 7 Drain and Drain No. 8 in the middle parts and Drain No. 11 and Al-Masraf Al-Raisi in the western parts. The water is collected from their catchments and discharged into the lake. The drainage water in these drains is mainly from agricultural sources but with little amounts of industrial and sewage wastes. Due to lack of irrigation water the drainage water was commonly used for irrigation especially in the areas which were closer to the lake.

The Landsat ETM+ data acquired on 17/06/2002 was employed in this study. The data was enhanced for haze correction and noise reduction followed by a relative sun angle correction. The resolution merge was applied to produce high resolution multispectral images and finally subset of the study area was selected. The image then was subjected to image processing steps which included the principal component analysis (PCA) and image classification. A general principal components analysis was applied to all the layers of the image. Another specific PCA was applied to the short wave to thermal infrared layers to strengthen the detection ability of wet soils. The first and second layers of both PCAs were stacked into one image for each data type. Using the unsupervised classification the training sets which represent the different land use/ land cover classes were chosen. These series of training sites were verified in the field and were used in the supervised classification.

The field work place from 22/8/2006 to 13/9/2006. Thirteen soil profiles were selected and studied in the field and morphologically described to FAO (2006). The soil and water samples were collected for laboratory analyses and the soils were subsequently classified according to USDA (2006). In addition to the soils profiles, auger samples from the fish ponds were collected as well as water samples from the irrigation, drainage and lake water. The location of the soil profiles and water samples are shown in map 1.



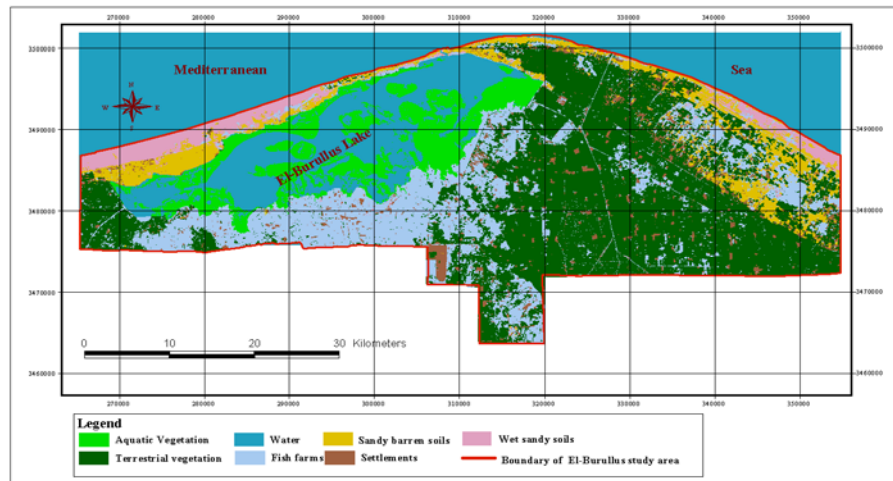
Map 1: Location of the soil profiles, fish ponds and water samples of El-Burullus study area.

The particle size distribution was determined according to Kilmer and Alexander,(1949). The organic matter, the soil reaction (pH) of the soil paste, the electrical conductivity (EC), the soluble cations and anions were determined according to United States Salinity Laboratory staff, (1954). the available heavy metals was determined according to Lindsay and Norvell, (1978).Ammonia and nitrate nitrogen were determined according to Cottenie et al., (1982). Concerning the water samples, the electrical conductivity (EC), the pH, the soluble cations and anions, phosphorus, heavy metals were determined according to American Public Health Association, (1995).The ammonia and nitrate nitrogen were determined according to Cottenie et al. (1982).

The soil fertilitywas evaluated according to Baruah and Barthakur (1997) and Bakr et al.(1999). The evaluation of water quality for irrigation was carried out according to FAO(1985). The evaluation of lake water quality followed the United Nations Economic Commission for Europe (UNECE), (1994).

Results And Discussion

The studied area included five land use/landcover classes, namely; water, barren sandy soils, vegetation, settlements and wet sandy soils. The overall accuracy of the classification was 82.7 %. The water class included El-Burullus Lake and the fish ponds, while, the vegetation class included both terrestrial and aquatic vegetation. Using a vector layer containing the lake area, the vegetation within the lake was recoded as aquatic vegetation, while outside the lake was recoded as terrestrial vegetation and the water outside the lake, was recoded as fish ponds,(Map 2).



Map 2: Land use/ land cover map of El-Burullus area

The results revealed that the terrestrial vegetation classes represented 40.7%, the settlements and wet sandy soils represented the least classes and covered 4.1 and 3.7%, respectively. The aquatic vegetation, lake water, fish ponds and barren sandy soils covered 10.4, 12.9, 20.9 and 7.2%, respectively, (Table 1).

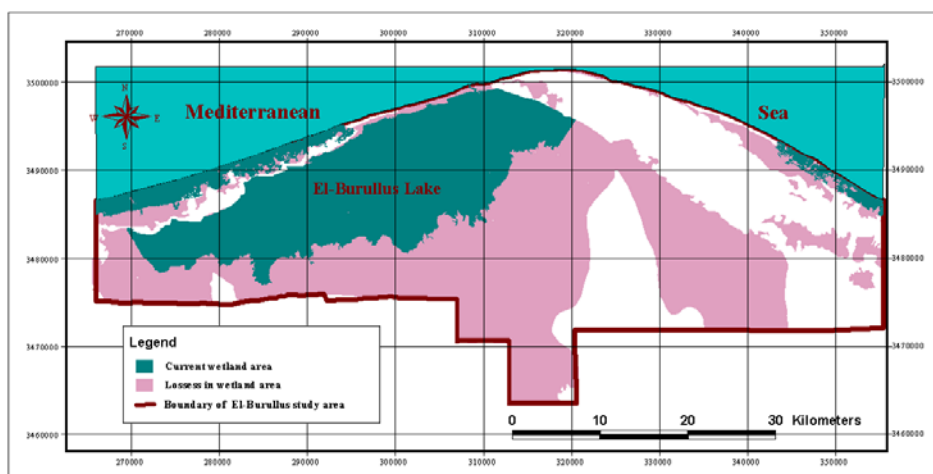
Table 1: The area of land use/ land cover unit of El-Burullusstudied area

Class	Area (km ²)	Area (%)
Terrestrial vegetation	811.9	40.7
Aquatic vegetation	207.0	10.4
Settlements	82.4	4.1
El-Burullus lake water	257.9	12.9
Fish ponds	416.2	20.9
Barren sandy soils	143.4	7.2
Wet sandy soils	74.2	3.7
Total area	1993.0	100.0

Based on these data,the current wetland area included only the remaining parts of El-Burullusshallow lake and the coastal saline wet sandy soils covering an area of only about 539 km². The lake surface area which

consisted of the lake water and aquatic vegetation classes covered about 465km² and represented most of the current wetland area.

On the other hand, the previous wetland area included El-Burullus Lake, in addition to the swamps and clay flats that surrounded the lake and the coastal saline wet sandy soils (Academy of Scientific Research and Technology, 1982). These wetlands area was about 1316 km² out of which the lake surface area covered about 539km². Most of these wet soils and part of El-Burullus Lake were converted into agricultural areas or fish ponds and were not currently considered as wetlands. Therefore, the losses of the wetland area represented about 59.1 % of the previous wetland area and the shrinkage of the lake surface area itself was about 13.4 % of the lake surface area, (Map 3), revealing the effect of this anthropogenic reclamation activity on the wetland conditions.



Map. 3: Effect of reclamation on wetland area.

1. The current wetlands:

The saline wet sandy soils:

These soils were represented by profiles K11, K12 and K13. Whereas, the soils of profiles K11 and K13 were nearly reclaimed, the area represented by profile K12 was the only area that remained as wet soils, but scheduled for reclamation as well.

The water table depth was moderate and fluctuated between 80 and 100 cm. The subsurface layers were mostly greyish in addition to the presence of H₂S odor (profile K13). The soils were classified as Typic Psammaquents, Typic Aquisalids and Typic Torriorthents for the soils represented by profiles K11, K12, K13, respectively and influenced by their reclamation status. The soils were non to moderately calcareous where the calcium carbonate content ranged from 0 to 98 g Kg⁻¹. This could be rendered to the presence of shell fragments within the soil profile. Few fine gypsum crystals were present only in the subsurface layer of profile K12. The gypsum content ranged from 0 to 1 g Kg⁻¹. The morphological description summary of the profiles is shown in table 2.

The soil texture varied between sandy and sandy loam, (Table 3a and 3b). The chemical analyses results of these soils show that these soils were slightly to strongly saline soils, EC values varied from 3.0 to 28.7 dS/m (Table 4). The pH values ranged between 7.5 – 8.1. The organic matter content ranged between 8 to 15 g Kg⁻¹.

Soils contents of available nitrogen content ranged from low to moderate. The ammonium form ranged from 18.0 to 33.9 mg Kg⁻¹ while the nitrate form ranged from 13.6 to 36.2 mg Kg⁻¹. The available phosphorus was low (0.8 – 9.4 mg Kg⁻¹). The available nitrogen and phosphorus were highest in the soils represented by profile K18, which represented the oldest reclaimed area in this unit with the highest organic matter content. The available and total heavy metals contents; iron, zinc, lead and cadmium, followed the same pattern where it were relatively low in profiles K11 and K12, while they reached the highest levels in profile K13, especially in the surface layer.

Table 2: Summary of the morphological features of the soil profiles

Profile No.	Depth (cm)	Horizons		Moisture	Color	Texture	Structure	Consistence	Permeability	Roots	Mottling	Remarks	Observations
		Top	Bottom										
K1	0-30	2A1	2B1	—	Light	Medium to coarse sandy loam	Blocky	—	—	Common	—	—	—
	30-120	2A2	2B2	—	Light	Medium to coarse sandy loam	Blocky	—	—	Common	—	—	—
K5	0-20	2A	2B	—	Light	Medium to coarse sandy loam	Blocky	—	—	Common	—	—	—
	20-65	2A	2B	—	Light	Medium to coarse sandy loam	Blocky	—	—	Common	—	—	—
K8	0-40	2A	2B	—	Light	Medium to coarse sandy loam	Blocky	—	—	Common	—	—	—
	40-115	2A	2B	—	Light	Medium to coarse sandy loam	Blocky	—	—	Common	—	—	—
K10	0-35	2A	2B	—	Light	Medium to coarse sandy loam	Blocky	—	—	Common	—	—	—
	35-115	2A	2B	—	Light	Medium to coarse sandy loam	Blocky	—	—	Common	—	—	—
K3	0-40	2A	2B	—	Light	Medium to coarse sandy loam	Blocky	—	—	Common	—	—	—
	40-45	A layer very rich in shell fragments											
FF1	0-25	2A	2B	—	Light	Medium to coarse sandy loam	Blocky	—	—	Common	—	—	—
	25-50	2A	2B	—	Light	Medium to coarse sandy loam	Blocky	—	—	Common	—	—	—
FF4	0-25	2A	2B	—	Light	Medium to coarse sandy loam	Blocky	—	—	Common	—	—	—
	25-50	2A	2B	—	Light	Medium to coarse sandy loam	Blocky	—	—	Common	—	—	—
K13	0-35	2A	2B	—	Light	Medium to coarse sandy loam	Blocky	—	—	Common	—	—	—
	35-55	2A	2B	—	Light	Medium to coarse sandy loam	Blocky	—	—	Common	—	—	—
	55-80	2A	2B	—	Light	Medium to coarse sandy loam	Blocky	—	—	Common	—	—	—

Table 3a: Particle size distribution of the soil profiles

Profile No.	Land use	Depth (cm)	Particle size %					Textural class
			Coarse sand	Fine sand	Sand	Silt	Clay	
			%	%	%	%	%	
K1	Reclaimed wetlands (cultivated soils)	0-30	38	276	314	407	279	Clay loam
		30-120	72	219	291	398	311	Clay loam
K5	Reclaimed wetlands (cultivated soils)	0-20	67	274	341	31	349	Clay loam
		20-65	21	131	152	316	532	Clay
K8	Reclaimed wetlands (cultivated soils)	0-40	46	387	433	155	412	Clay
		40-115	28	347	375	209	416	Clay
		115-140	42	361	403	193	404	Clay
K10	Reclaimed wetlands (cultivated soils)	0-35	48	333	381	308	311	Clay loam
		35-115	56	199	255	316	429	Clay
		115-140	82	325	407	147	446	Clay
K3	Reclaimed wetlands (fish ponds soils)	0-40	22	289	311	374	315	Clay loam
		40-45	A layer very rich in shell fragments					
FF1	Reclaimed wetlands (fish ponds soils)	0-25	36	304	34	213	447	Clay
		25-50	48	279	327	274	399	Clay loam
FF4	Reclaimed wetlands (fish ponds soils)	0-25	42	221	263	284	453	Clay
		25-50	48	183	231	26	509	Clay
K13	Current wetlands	0-35	12	583	652	151	197	Sandy loam
		35-55	146	544	689	44	267	Sandy clay loam
		55-80	106	558	654	164	182	Sandy loam

Table 3b: Particle size distribution of the soil profiles

Profile No.	Land use	Depth (cm)	Particle size %					Textural class	
			Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand		Silt and clay
K11	Current wetlands	0-60	11	203	665	12	0	1	Sand
		60-100	05	165	669	158	2	1	Sand
K12		0-45	03	27	474	488	4	4	Sand
		45-100	36	273	457	232	1	1	Sand

Table 4: Chemical analysis of the soil profiles

Profile	Land use	Depth	pH	EC	CaCO ₃	OM	N (mg Kg ⁻¹)		P (mg Kg ⁻¹)	Cd (mg Kg ⁻¹)	Pb (mg Kg ⁻¹)	Zn (mg Kg ⁻¹)	Fe (mg Kg ⁻¹)
No.		(cm)		(dS/m)	g Kg ⁻¹	g Kg ⁻¹	NH ₄	NO ₃	Ava	Ava	Ava	Ava	Ava
K1	Reclaimed wetlands (cultivated soils)	0-30	7.8	2.3	73	29	29.3	25.2	8.3	0.18	0.86	2.09	44.6
		30-120	7.7	5.0	323	31	21.1	20.0	10.5	0.30	0.48	2.97	52.3
		0-20	7.4	23.2	45	18	50.3	49.8	10.7	0.44	2.13	3.94	39.3
K5		20-65	7.8	11.5	22	21	37.5	45.9	13.3	0.36	1.88	4.12	23.6
		65-120	7.8	11.5	29	18	29.3	37.5	12.7	0.36	1.02	3.51	16.6
		0-40	7.9	3.7	114	24	41.6	33.4	8.8	0.14	0.38	1.88	35.1
K8		40-115	8.1	2.4	165	26	30.1	57.9	7.4	0.14	0.26	1.15	36.5
		115-140	8.2	2.2	185	16	25.2	49.8	4.3	0.13	0.24	0.65	16.9
		0-35	7.6	2.8	114	26	29.3	33.4	5.3	0.28	0.58	3.23	47.0
K10		35-115	7.7	2.6	110	12	25.2	37.8	3.0	0.26	0.44	2.02	29.6
		115-140	8.4	2.0	273	16	29.3	25.2	7.5	0.25	0.49	1.76	11.5
		0-40	8.1	3.5	75	12	45.2	51.4	11.7	0.23	0.68	3.43	60.8
K3	Reclaimed wetlands (fish ponds soils)	40-45	A layer very rich in shell fragments										
		45-150	7.9	6.1	137	36	45.2	51.4	13.9	0.30	0.56	5.15	58.8
		0-25	7.1	8.5	0	61	44.0	40.1	13.0	0.36	1.77	14.12	185.5
FF1		25-50	7.5	9.9	5	53	57.5	34.9	11.1	0.26	1.34	14.74	150.3
		0-25	8.0	5.7	145	26	43.1	39.8	10.3	0.36	0.80	5.23	55.0
		25-50	8.1	7.1	164	25	39.0	31.4	11.7	0.32	0.86	4.72	53.2
FF4		0-60	7.8	3.0	55	9	18.0	27.5	0.9	0.06	0.09	0.60	6.6
		60-100	8.1	8.5	85	12	23.6	24.5	0.9	0.11	0.15	0.21	13.5
		0-45	8.0	7.8	11	10	25.8	16.2	1.0	0.10	0.12	0.31	6.1
K11		45-100	8.1	28.7	98	8	21.6	13.6	0.8	0.05	0.05	0.60	15.1
		0-35	7.5	26.0	11	15	31.1	29.0	19.4	0.22	0.24	5.23	20.9
		35-55	7.9	12.3	0	13	33.9	36.2	7.7	0.14	0.15	2.37	13.9
K13	55-80	8.0	12.1	0	14	19.3	29.0	4.5	0.11	0.18	1.16	9.0	

*. Ava: Available

El-Burullus Lake:

The water chemical analyses results of El-Burullus Lake are shown in table 5. The data revealed that the water salinity differed from 4.1 to 5.9 dS/m, while the pH ranged from 7.6 to 8.3. The relatively low salinity was due to the discharge of massive amounts of drainage water into the lake.

The phosphorus content differed from 0.12 to 0.17 mg L⁻¹. The nitrogen in the ammonium and nitrate forms varied from 0.50 to 0.75 mg L⁻¹, from 0.45 to 0.60 mg L⁻¹, respectively.

Table 5: Water chemical analysis of El-Burullus Lake

Sample	pH	EC	P	N-NH ₄	N-NO ₃	Cd	Pb	Zn	Fe	P
Location		(dS/m)	(mg L ⁻¹)	(mg L ⁻¹)	(mg L ⁻¹)	(mg L ⁻¹)	(mg L ⁻¹)	(mg L ⁻¹)	(mg L ⁻¹)	(mg L ⁻¹)
L1	7.9	4.2	0.13	0.75	0.60	0.01	0.01	0.02	0.55	0.13
L2	8.3	4.1	0.12	0.50	0.45	0.00	0.00	0.01	0.26	0.12
L3	7.6	4.4	0.15	0.60	0.55	0.02	0.03	0.04	0.48	0.15
L4	7.6	5.9	0.17	0.71	0.57	0.02	0.03	0.02	0.46	0.17

When evaluating the lake quality for maintenance of aquatic life, it could be considered mostly as class III concerning the nitrogen level. On the other hand, it falls in class IV concerning the phosphorus level. High levels of ammonium and nitrate in surface waters affect the predators (such as fish). Also, the lake trophic state corresponded highly to phosphorus levels in water. Phosphorus is considered the main reason for eutrophication in lakes, which are subjected to point source pollution from sewage, (Silva and Uchida, 2000). Accordingly, the lake classified as eutrophic concerning its trophic status. This is verified by the presence of algae blooms and invasive plant species including *Phragmites australis* (common reed), *Typhadomigensis* (reed maca), which were present all over the lake (Plate 1). This eutrophic condition is highly detrimental to the lake water quality (Smith, 2009). The presence algal blooms will limit the sunlight available to bottom-dwelling organisms and when dissolved oxygen levels decline significantly, fish and other marine animals suffocate and die off, (Horrihan et al, 2002). Eutrophication also causes shifts in the species composition of ecosystems such as the presence of competitive species to invade and out-compete original inhabitant species, (Shumway, 1990). The cadmium, lead, copper, zinc and iron ranged from 0.00 to 0.02, from 0.00 to 0.03, from 0.01 to 0.04, and from 0.26 to 0.55 mg L⁻¹, respectively. The lowest amounts of cadmium, lead, and iron were in L3, which is the outlet of Drain No. 8 the least polluted drain.



Plate 1: The eutrophic condition of El-Burulluslake

2. The reclaimed wetlands:

These soils were located in the swamps and clay flats that surrounded El-Burullus Lake in addition to parts of the lakes that were drained out, mainly the eastern and western fringes of the lake. This area was converted either to agricultural area or fish ponds. The cultivated soils were represented by profiles K1, K2, K4, K5, K6, K7, K8, K9 and K10, while the fish ponds were represented by profile K3 and five auger samples at depths 0-25 and 25-50 cm. The parent materials of these soils were fluvio-lacustrine deposits.

The soils had deep to very deep profile with water table depth ranging from 110 to more than 120 cm. The structure was mostly moderate to strong, medium to coarse sub-angular blocky. Fine to wide cracks were present on the soil surface. In most of the profiles, slickensides and gleyzation in the subsurface layers were observed. Few fine light gray mottles were noticed in addition to, few fine to medium reddish brown and very dark reddish brown mottles in some areas. Fine red and brownish red hard irregular concretions were also observed locally. The soils also contained few to common fine gypsum crystals. The presence of few to common, fine to medium hard irregular white lime concretions was common. Few to many shell fragments were also found within the profile and occasionally noticed on the soils surface. The soils were classified as Vertic Torrifluvents. A summary of some of these soil profiles morphological description is given in table 2. The particle size distribution revealed that the soil texture ranged from clay to clay loam (Table 3a).

The cultivated soils ranged mostly from non to extremely calcareous with calcium carbonate content ranging from 22 to 323 g Kg⁻¹. The fish pond soils were non to strongly calcareous and their calcium carbonate content was somewhat lower than the cultivated soils and ranged from 0 to 164 g Kg⁻¹.

The soils chemical analyses are shown in table 4. The EC values of the cultivated soils ranged from 2.0 to 23.2 dS/m, therefore, the soils mostly fluctuated between slightly and moderately saline except for the area represented by profiles K5 and K9 which were considered as strongly to extremely saline and were not used. The EC values of the fish pond soils ranged from 3.5 to 9.9 dS/m and were considered slightly to strongly saline but mostly moderately saline soils. The soil pH was slightly higher in the cultivated soils and fluctuated between 7.4 and 8.4 but differed from 7.0 to 8.1 in the fish ponds.

On the other hand, the organic matter content was higher in the fish pond soils and varied from 12 to 61 g Kg⁻¹ while in the cultivated soils it differed from 9 to 38 g Kg⁻¹. The available nitrogen ranged from moderate to high in the cultivated soil. The ammonium form ranged from 21.1 to 60.3 mg Kg⁻¹ while the nitrate ranged from 20.0 to 66.1 mg Kg⁻¹ in the cultivated soils. In the fish ponds, the ammonium ranged from 32.4 to 71.2 mg Kg⁻¹ while the nitrate ranged from 26.8 to 51.0 mg Kg⁻¹.

The available phosphorus fluctuated between low and moderate (3.0 to 14.7 mg Kg⁻¹) in the cultivated soils. The available phosphorus content of the fish ponds moderate to high and ranged from 10.3 to 28.2 mg Kg⁻¹.

In the cultivated soils, the available iron was high ranging from 11.5 to 64.0 mg Kg⁻¹. The available zinc varied between moderate and high and ranged from 0.65 to 4.12 mg Kg⁻¹. The available lead ranged between 0.20 and 2.13 mg Kg⁻¹. The available cadmium varied from 0.10 to 0.44 mg Kg⁻¹. The lowest amounts of cadmium, lead and zinc were found in the area represented by profile K7 the most distant profile from the lake and irrigated from the least polluted irrigation source in the study area, namely Al-Zawiyah Canal. The remaining profiles are whether lacking irrigation system (profiles K4 and K6) and therefore unofficially using drainage water or using water sources of low quality such as Al-Nil canal (profile K10) and Bahr Tera canal (K8) and Khalij Brinibal canal (profiles K1 and K2).

The available iron content of the fish ponds soils was high and varied from 43.5 to 185.5 mg Kg⁻¹. The available zinc was high and ranged from 3.4 to 14.7 mg Kg⁻¹. The available cadmium differed between from 0.23 and 0.40 mg Kg⁻¹. The available lead fluctuated from 0.51 to 1.83 mg Kg⁻¹. The highest amounts of total and available cadmium, lead and zinc were found in location FF1 which used the water of Al-Mafrat Al-Raisi which contained relatively higher amounts of these heavy metals. On the other hand, location K3 contained the lowest amounts and used water from Drain No 8 the least polluted drain in the area.

3 Irrigation and drainage water:

The salinity of the irrigation water ranged from 1.1 to 2.2 dS/m which means a slight to moderate problem when used in irrigation. Based on the EC values and the SAR, which varied from 2.8 to 6.9, no infiltration problem is expected. The pH values differed from 7.2 to 7.8, which was in the normal range, (Table 6).

The EC of the drains varied from 2.0 to 7.2 dS/m indicating a moderate to severe problem when used in irrigation. The pH ranged from 7.2 to 7.9, which was in the normal range for irrigation. The SAR values were from 3.2 to 9.3 and when considering these values with the EC values, this reflects no water infiltration problem when used.

Concerning the specific ion toxicity which affects only sensitive crops and under surface irrigation and based on the content of sodium sodium showed no problem in Al-Zawiyah canal and a slight to moderate problem in the other irrigation canals. Chloride showed no problem in Al-Zawiyah canal as well while it showed moderate to severe problem in the other canals. Slight to severe problem is expected from drainage water while a moderate to severe problem is expected with chloride (Table 6).

In the irrigation water, phosphorus content was in the range of 0.41 to 0.60 mg L⁻¹ and the ammonium and nitrate varied from 0.8 to 1.2 mg L⁻¹ and from 0.9 to 1.3 mg L⁻¹, respectively. Therefore, no problem or adverse effect is expected from the nitrate when this water is used for irrigation. In the drainage water, phosphorus content varied from 0.41 to 1.00 mg L⁻¹. The ammonium and nitrate ranged from 1.1 to 2.0 mg L⁻¹ and from 1.1 to 1.6 mg L⁻¹, respectively. Concerning the nitrate content no problem is expected when this water is used in irrigation.

The cadmium, lead, zinc, and iron contents of the irrigation water ranged from 0.01 to 0.03 mg L⁻¹, from 0.01 to 0.02 mg L⁻¹, from 0.01 to 0.03 mg L⁻¹ and from 0.17 to 0.81 mg L⁻¹, respectively. This means that only the cadmium content will cause problem and prevent using this water, while all other studied heavy metals were within the maximum limits recommended for irrigation water.

Table 6: Chemical analysis of the irrigation and drainage water

Sample Location	Sample Code	pH	EC	SAR	P	N-NH ₄	N-NO ₃	Cd	Pb	Zn
			(dS/m)		(mg L ⁻¹)	(mg L ⁻¹)	(mg L ⁻¹)	(mg L ⁻¹)	(mg L ⁻¹)	
KhalijBrinibal canal	I1	7.8	1.7	5.7	0.60	1.0	1.3	0.03	0.02	0.03
Al-Zawiyah canal	I2	7.2	1.1	2.8	0.41	0.8	0.9	0.01	0.01	0.01
Al-Bassar canal	I3	7.5	1.5	3.9	0.50	0.9	1.1	0.01	0.01	0.01
Bahr tera canal	I4	7.3	1.7	6.2	0.57	0.9	1.0	0.02	0.02	0.03
Al-Nil canal	I5	7.5	2.2	6.9	0.57	1.2	1.3	0.02	0.02	0.02
Al-Masraf Al-Raisi drain	D1	7.3	7.2	9.2	0.75	1.2	1.1	0.04	0.03	0.05
Drain No 11	D2	7.3	2.9	4.4	0.91	1.8	1.2	0.01	0.03	0.01
Nashart drain	D3	7.2	2.2	3.2	0.60	1.3	1.3	0.02	0.02	0.03
Drain No 8	D4	7.6	4.1	8.7	0.69	1.2	1.4	0.01	0.01	0.01
Tulumbat 7 drain	D5	7.9	4.6	6.1	0.63	1.3	1.4	0.03	0.02	0.05
Tera drain	D6	7.8	4.3	7.1	0.41	1.0	1.2	0.02	0.02	0.02
Al-Burullus drain	D7	7.5	3.3	5.4	1.00	2.0	1.6	0.03	0.04	0.06
Gharbia drain	D8	7.7	2.0	3.3	0.64	1.2	1.3	0.03	0.03	0.04

In the drainage water, cadmium, lead, zinc and iron they ranged from 0.01 to 0.04 mg L⁻¹, from 0.01 to 0.04 mg L⁻¹, from 0.01 to 0.06 mg L⁻¹ and from 0.21 to 1.17 mg L⁻¹, respectively. Accordingly, these elements were below the maximum limits recommended for irrigation water except for cadmium which was higher than the recommended limits in some samples.

The quality of the irrigation water gets poorer as we approach the lake because its mixture with the drainage water whether officially or non-officially.

When evaluating the use of drainage water in aquaculture, the pH values of all locations were suitable because they were in the recommended suitable water pH. The nitrogen and the phosphorus content of these

waters revealed their suitability for use in aquaculture as they exceed the recommended level of 1.5 mg L⁻¹ and 0.4 mg L⁻¹, respectively. Below these levels they would become unsuitable in increasing the productivity of fish ponds. Furthermore, the P:N ratio is considered very important in defining the suitability of water for aquaculture and a healthy P:N ratio of 1:4, in water is recommended. The P:N ratio of the samples ranged from 0.19 to 0.33 revealing that a slight problem may occur when using these waters. Therefore, it is recommended to use phosphate fertilizers to increase both the phosphorus content and the P:N ration, especially the studied soils contained mostly low to moderate amounts of available phosphorus. The nitrite content is suitable in all locations because it did not exceed the recommended amount of 0.1 mg NO₂/L.

The cadmium, zinc, and iron, contents revealed that the water in all locations exceeded the recommended maximum permissible concentrations for use in aquaculture.

Conclusion:

The results of this study revealed that the studied area is severely affected by the use of low water quality in irrigation. The reclaimed wetlands are more affected by this low water quality regime than its origin. The remaining wetland, mainly El-Burullus Lake is subjected to sever impacts resulting from the discharge of the enormous amounts of low quality drainage water into it. This resulted in the eutrophic status of the lake, which is currently suffering effects resulting from that impact. This included the shifts in the species population of the fish in the lake and could have serious impacts on the biological diversity of the ecosystem and degrading its environmental quality. Therefore, it is recommended that a sustainable management strategy should be applied in the area that relies on environmental impact assessment studies of the current human activities.

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