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STUDY AND EVALUATE EL GABAL EL ASFAR SOILS WHICH IRRIGATED BY SEWAGE SLUDGE

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ABSTRACT

The investigated area is located to the east of the Nile Delta; it is bounded by latitudes 30° 11' 15" & 30° 14' 10" N and longitudes 31° 22' 05" & 31° 24' 20" E. According to period of irrigated by sewage effluents the soils of the area were divided into four grades. These include i) non-irrigated and barren, ii) irrigated for (24 years), iii) irrigated for (49 years) and iv) irrigated for 82 years until 2009 and after this changed to irrigated by ground water. Four soil profiles were taken to represent the soils of the area. Morphological description and soil sampling were conducted during the field work. The soil properties including texture, depth, organic matter (OM), EC, $CaCO_3$, pH, CEC, and ESP have been determined. The soils were classified as: Typic Torripsamments and Typic Torriorthents according to the American soil taxonomy. The soil capability classes ranged between (2) good and (5) very poor. The soil suitability ranged between S1 and S3. The soils of the area are suitable for field crops (Wheat, Barley, Faba bean, Sugar beat, Sun flower, Maize, Soya bean, Peanut, Cotton, Sugar Cane), vegetable (Tomato, Pepper, Watermelon, Alfalfa, Sorghum), and fruit (Citrus, Grape, Olive, Apple, Pear, Figs, Date palm). The soils are in general not suitable for Cabbage, Onion, Rice and Banana.

INTRODUCTION

The studied area located in south-eastern edge of the Qaliubiya governorate in Belbes Desert, it is bounded by latitudes 30° 11' 15" & 30° 14' 10" N and longitudes 31° 22' 05" & 31° 24' 20" E (Fig. 1).

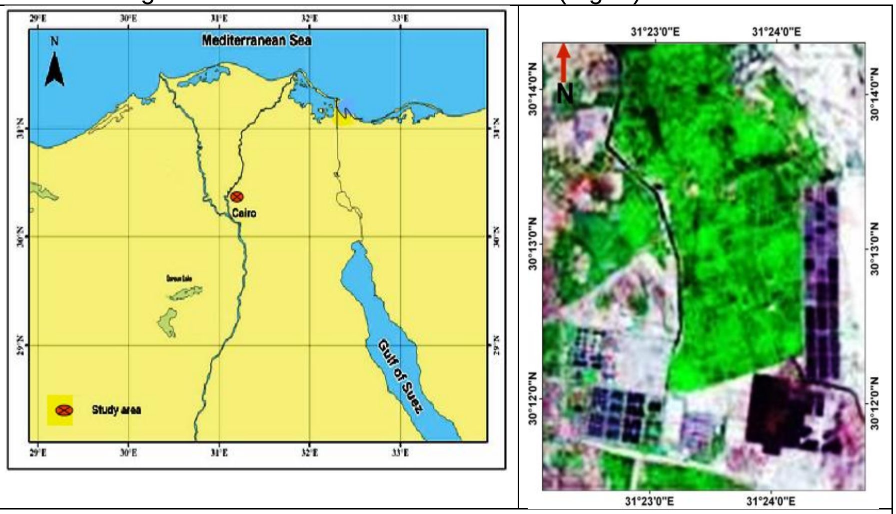

Fig. 1. Location map of the study area

The climate of the area is the same desert climate of the Cairo area, which is moderated by A proximally of the Mediterranean Sea African Development Bank (2008). The soils at El –Khanka city are classified xeric moisture regime and Aridic moisture regime and the soil temperature regime of the area is Thermic USDA (2010). According to Shata and El Fayoumy (1970), El Diary (1980). and RIGW (1989). The Pleistocene and Holocene epoch of the Quaternary period mainly cover the study area. Miocene and Pliocene sediments of the Neogene period outcrop at the eastern portions.

Since 1900, Egypt began to apply the use of sewage water in farming as unconventional source of water to reduce the water shortage and achieve the block of the food gap between the product and the overpopulation. Sewage water contains useful nutrients for the soil fertility and plants nutrition. The benefits of these nutrients depend on the concentrations of the nutrients in wastewater, the quantities of wastewater applied, the times of application, the type and the target yield of the crop grown, and the fertility of the soil (Janssen *et al.,* 2005). On the other hand it contains high percentage of heavy metals which cause toxicity of plant and a harmful effect on humans. Acording to El-Fakharany and Mansour (2009) The Quaternary aquifer classified into two hydrogeological units; the upper unit is the Holocene aquitard and the lower one is the Pleistocene aquifer.

MATERIALS AND METHODS

Four soil profiles choosing to representative the soils of the four areas non-irrigated, irrigated for 29 years, irrigated for 49 years and 82 years, were duge and detailed description were done based on USDA (2010) and collected the different samples for the different morphological layers of soil profiles for another analysis. The particle size distribution determined according dry sieving method, USDA (1991). Soil pH determined according to klute (1986). EC dS m^{-1}, $CaCO_3$ %, OM% determined according to USDA (1991), Cation exchange capacity (CEC), exchangeable sodium determined according to Robert (2008). Based on the morphological, physical, chemical and climatologically data classified the soil of the area according to USDA (2010).

Land capability and suitability Soil classes.

Based on the physical, chemical, fertility, climatologically and crops requirements according to FAO (1981). The (ASLE) software (Ismail et al, 1994) was used to producing land capability and suitability classes. The Arc-GIS 9.3 software was used for mapping the land capability and suitability of the studied area.

RESULTS AND DISCUSSION

General description of the area

The parent material of the area under investigation is Pliocene and plectocen deposits. The Relief is flat and flat to almost flat. The drainage condition is well. The land use field crops and vegetable crops.

The soil of the area was developed according to the application period of sewage effluents. The morphological features were changed with the time of the application Table (1).

The area under investigation based on period of irrigated with sewage effluent could be divided into four classes as the following:-

Non-irrrigated soils

The soils non-irrigated and barren and representative by soil profile No (4) and (fig.2).

The morphological features as colour, texture, structure, consistence, pores, effervescence with Hcl, and boundary indicated there are no changed from layer to another. From table (2) the texture class is sand, cation exchange capacity values are low and ranged between 1.12 and 0.61 mg/100g soil. ESP values are low than 15%. From table (3) pH values are ranged between 7 and8. $CaCO_3$ content is high in the surface and decrease with depth. Organic mature content is low and decrease with depth. Electrical conductivity (EC dS m^{-1}) values are high in the surface (6.62 dS m^{-1}) and decrease with to reach 1.40 dS m^{-1}.

Fig.2. Photography Image Barren Soil Profile No. (4).

1

Table 2. Particle size distribution analysis of barren soil.

profile No	Depth in cm	Corse Sand %	Fine sand %	Silt %	Clay %	Texture Class	CEC mg/100g	Cations mg/100g				ESP %
								Ca^{++}	Mg^{++}	Na^{+}	K^{+}	
4	0 – 40	64.9	34.4	0.42	0.28	Sand	1.12	0.49	0.23	0.١١	0.19	9.82
	40 – 90	76.3	22.9	0.48	0.32	Sand	0.82	0.48	0.31	0.02	0.01	2.4
	90 – 130	80.8	19.1	0.06	0.04	Sand	0.61	0.35	0.24	0.01	0.01	1.6

Table 3. Some chemical characteristics of barren soil.

Profile No	Depth in cm	PH (1:1)	$CaCO_3$	OM %	EC dS m^{-1}	Soluble Cations mq/l				Soluble anions mq/l			
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Co^{--}_3	Hco^{-}_3	Cl^{-}	So^{--}_4
4	0 - 40	7.65	6.23	0.53	6.62	20.3	12.8	30.9	2.2	0.0	15.2	36.9	14.1
	40 - 90	7.89	5.82	0.26	2.48	8.6	3.8	11.2	1.2	0.0	5.2	18.1	1.5
	90 - 130	8.01	5.96	0.15	1.40	4.1	2.9	6.0	1.0	0.0	2.1	8.2	3.7

Soils irrigated with Sewage Sludge for 29 years

The soil irrigated for (29) years and representative by soil profiles No. (1) and fig. (3). The morphological features does not changed from layer to another which indicated that there is no effects for sewage effluent. From table (4) the texture is sand, Cation Exchange capacity still low and ranged between 6.21 mg/100g soil in the surface and 0.72 mg/100g soil in the deep, ESP values are low than 15%. From table (5) pH values are ranged between 8.06 and 8.13, $CaCO_3$ content is varied from layer to another and ranged between 4.24 and 8.00. Organic mature content is moderately high in the surface and decrease with depth. Electrical Conductivity (EC dS m^{-1}) is low than another.

Fig.3. Profile No.(1).

Table 4. Particle size distribution analysis of second area.

Profile No	Depth in cm	Corse Sand %	Fine sand %	Silt %	Clay %	Texture Class	CEC mg /100g	Cations mg/100g				ESP %
								Ca^{++}	Mg^{++}	Na^{+}	K^{+}	
1	0 – 15	70.00	14.02	10.05	5.02	Sand	6.21	2.56	1.65	0.86	0.90	13.85
	15 – 40	76.8	22.1	0.66	0.44	Sand	1.35	0.52	0.43	0.11	0.19	8.15
	40 – 80	52.8	46.7	0.3	0.2	Sand	1.12	0.55	0.19	0.12	0.16	10.71
	80 -120	44.7	55.2	0.06	0.04	Sand	0.72	0.43	0.27	0.01	0.01	1.39

Table 5. Some chemical characteristics of second area

Profile No	Depth in cm	PH (1:1)	$CaCO_3$	OM %	EC dSm^{-1}	Soluble Cations mq/l				Soluble anions mq/l			
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Co^{--}_3	Hco^{-}_3	Cl^{-}	So^{--}_4
1	**0 – 15**	**8.13**	**4.65**	**2.98**	**0.68**	**2.35**	**1.05**	**2.20**	**1.20**	**0.00**	**1.33**	**3.25**	**2.22**
	15 – 40	**8.06**	**5.23**	**1.56**	**0.30**	**0.98**	**0.52**	**1.10**	**0.40**	**0.00**	**0.89**	**1.87**	**0.24**
	40 - 80	**8.11**	**4.54**	**0.89**	**0.27**	**0.79**	**0.56**	**1.10**	**0.25**	**0.00**	**0.30**	**1.32**	**1.08**
	80 -120	**8.12**	**8**	**0.65**	**0.28**	**0.88**	**0.52**	**0.91**	**0.49**	**0.00**	**0.25**	**1.15**	**1.40**

Soils irrigated with Sewage Sludge for 49 years

The soil irrigated for (49) years and representative by soil profile No. (6). From table (6) the texture class is loamy sand in the surface and changed to sand the deep layer, Cation Exchange capacity (mg/100g soil) varied from layer to another as 13.78 in the surface, 16.89 in the subsurface, 1.21 in the third layer and 0.61 mg/100g soil in the deepest layer. ESP values are low than 15%. From table (7) pH values are ranged between 7.78 and 8.22, $CaCO_3$ content is 4.01 in the surface and increase with depth to reach 5.15. Organic mature content is high in the surface and decrease with depth. Electrical Conductivity is low than another.

Table (6) Particle size distribution analysis of third area

Profile No	Depth in cm	Corse Sand %	Fine sand %	Silt %	Clay %	Texture Class	CEC mg/100g	Cations mg/100g				ESP %
								Ca^{++}	Mg^{++}	Na^{+}	K^{+}	
6	**0 – 15**	**50.20**	**18.46**	**20.56**	**10.87**	**loamy sand**	**13.78**	**7.23**	**4.30**	**1.26**	**0.99**	**9.1**
	15 – 30	**49.72**	**16.88**	**19.95**	**13.45**	**loamy sand**	**16.89**	**8.98**	**5.78**	**1.28**	**0.85**	**7.6**
	30 – 70	**82.00**	**17.80**	**0.12**	**0.08**	**Sand**	**1.21**	**0.51**	**0.31**	**0.20**	**0.14**	**6.5**
	70 – 120	**95.50**	**4.20**	**0.18**	**0.12**	**Sand**	**0.61**	**0.39**	**0.19**	**0.02**	**0.01**	**3.3**

Table 7. Some chemical characteristics of third area

Profile No	Depth in cm	PH (1:1)	$CaCO_3$	OM %	EC dSm^{-1}	Soluble Cations mq/l				Soluble anions mq/l			
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Co^{--}_3	Hco^{-}_3	Cl^{-}	So^{--}_4
6	0 - 15	7.78	4.01	5.78	0.61	2.1	1.0	2.6	0.5	0.0	2.7	3.8	-0.4
	15 – 30	8.01	4.57	3.12	0.52	1.9	0.8	2.0	0.6	0.0	1.9	2.9	0.5
	30 - 70	8.12	4.98	1.35	0.40	1.3	0.8	1.3	0.7	0.0	0.6	1.9	1.5
	70 – 120	8.22	5.15	0.98	0.30	1.1	0.9	1.1	0.4	0.0	0.2	1.0	2.3

Soils irrigated with Sewage Sludge for 82 years

The soil irrigated for (82) years and representative by soil profile No. (13) and fig. (4). From table (8) the texture class is clay loam in the surface and subsurface and sand in the deep layers, Cation Exchange capacity (mg/100g soil) varied from layer to another as 30.34 in the surface, 34.25 in the subsurface, 0.32 in the third layer and 0.30 mg/100g soil in the deep layer. ESP values are low than 15%. From table (9) pH values ranged between 7.67 and 8.01, $CaCO_3$ content ranged between 3.01 and 5.12% and increase with depth. Organic mature values high in the surface and decrease with depth and ranged between 6.79 and 0.34. Electrical Conductivity (EC dS m^{-1}) ranged between 0, 43 and 0.57dS m^{-1}.

Fig.4. Profile No. (13).

Table 8. Particle size distribution analysis of fourth area

Profile No	Depth in cm	Corse Sand %	Fine sand %	Silt %	Clay %	Texture Class	CEC mg /100g	Cations mg/100g				ESP %
								Ca^{++}	Mg^{++}	Na^{+}	K^{+}	
13	0 – 20	20.08	18.00	35.04	25.07	Clay loam	30.34	15.75	9.49	3.10	1.45	10.2
	20 – 40	19.01	15.01	37.02	28.03	clay loam	34.25	18.52	10.41	3.32	2.00	9.7
	40 – 80	75.8	24.1	0.06	0.04	Sand	0.32	0.20	0.10	0.01	0.01	3.1
	80 – 120	72.7	27.1	0.06	0.04	Sand	0.3	0.16	0.12	0.01	0.01	3.3

Generally, the climate of the area is arid led to the initial soil content of organic matter is poor and low level of cation exchange capacity that affect on soil fertility. The impact of sewage water on soil was not significant on irrigated soil for 29 years, while the effect of sewage explained on irrigated soil for 49 and 80 years old. This effect represents the high values of the organic material that contain colloidal substances have a negative active surfaces Intensify the positive elements leads to high cationic exchange capacity of the soil and the soil texture changed from sandy to loamy sand clay.

Table 9. Chemical analysis of fourth area

Profile No	Depth in cm	PH (1:1)	$CaCO_3$	OM %	EC dSm^{-1}	Soluble Cations mq/l				Soluble anions mq/l			
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Co^{--}_3	Hco^{-}_3	Cl^{-}	So^{--}_4
13	0 - 20	7.86	3.01	6.79	0.57	1.4	0.9	2.9	0.6	0.0	1.1	3.1	2.0
	20 - 40	7.67	4.32	4.23	0.50	1.5	0.9	2.0	0.6	0.0	0.8	2.6	2.1
	40 - 80	7.98	4.78	2	0.44	1.4	0.9	1.8	0.4	0.0	0.6	2.0	2.2
	80 - 120	8.01	5.12	0.98	0.43	1.3	0.8	1.8	0.4	0.0	0.6	2.1	2.0

Soil capability

The Land capability classification of the soils of the studied area was carried out according to soil depth, texture class, cations exchange capacity (CEC), available moisture content, $CaCO_3$, exchangeable sodium percentage (ESP), soil salinity (EC) and drainage condition. The results showed that land capability ranges between classes 2 (good) to class 5 (very poor) and most of it sites under class 2. The low capability class C4 and C5 is related to drainage condition, soil salinity and alkalinity, CEC and soil texture. The highly capability class correlation with highly soil fertility, improved of soil texture and highly organic matter. Land capability class enhanced with time these results showed in table (10) and fig. (5).

Table (10) the class of land capability.

Profile No.	Land capability class	Final index
1	C 4 (poor)	33.21
4	C 5 (very poor)	12.93
6	C 3 (fair)	58.18
13	C 2 (good)	79.29

Soil Suitability class

According to environmental requirements for 28 crops (Wheat, Barley, Faba bean, Sugar beat, Sun flower, Rice, Maize, Soya bean, Peanut, Cotton, Sugar Cane) as failed crop, (Onion, Cabbage, Pea, Potato , Tomato, Pepper, Watermelon, Alfalfa, Sorghum) as vegetable and forage crops and (Citrus, Banana, Grape, Olive, Apple, Pear, Figs, Date palm) as fruit trees The results showed that The most suitable crops to grow in the study area are Cotton, Date palm, Olive, Alfalfa, Barley, Wheat, Maize, Faba been, Soya been, Sugar beet, and Citrus. The suitability for Cabbage, Onion, Rice and Banana is ranges between currently non suitable to permanently non suitable. The soil suitability for Cabbage, Onion, Rice and Banana is limited in some area by soil salinity and alkalinity, exchangeable sodium percentage, drainage condition and soil texture. fig. (6).

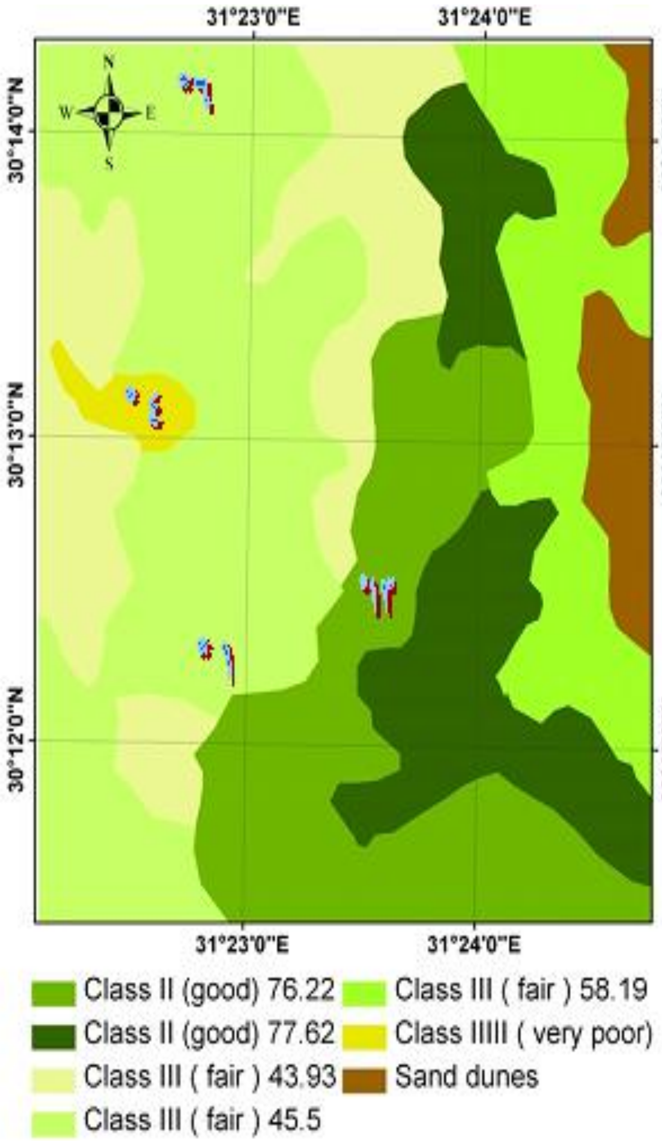

Fig.5. Land Capability Classes of the Investigated Area.

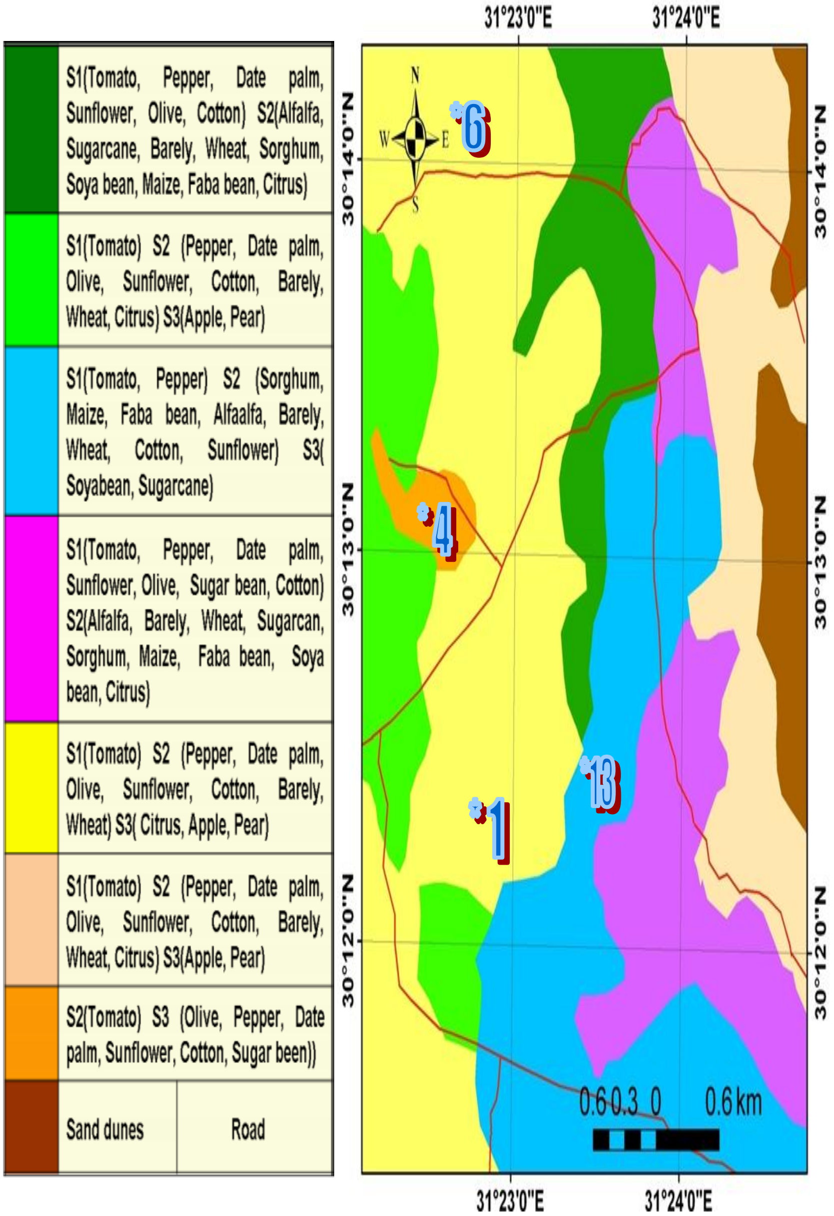

Fig.6. Soil Suitability Map.

REFERENCES

African Development Bank (2008). Gabal El Asfar Waste Water Treatment Plant – Stage II Phase 2.

El Dairy, M.D. (1980). Hydrogeological studies on the eastern part of Nile Delta using isotope techniques, M.Sc. thesis, Fac. of Sci. Zagazig Univ., 233p.

El-Fakharany, M. A. and N. M. Mansour (2009). Assessment of Water Resources Quality at the Southeastern Part of the Nile Delta, Egypt. The international conference on water conservation in arid rigons 12-14 october 2009. Jeddah

ESRI. (2008). ArcMap version 9.3 user manual. Redlands, CA, USA.

FAO, (1981). A framework for land evaluation. Soils Bulletin 32. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

Ismail, H.A.; E.M. El-Zahaby and M.E. El-Fayoumy (1994). A modify approach for land evaluation under arid condition. Applications. Mansoura University Journal of Agricultural Science, 19: 3497–3513.

Janssen, B.H.; H. Boesveld and M. J. Rodriguez (2005). Some theoretical considerations on evaluating wastewater as a source of N, P and K for crops. Irrigation and Draing, vol. 54., S35–S47

Klute, A. (1986). Methods of Soil Analysis (part–1) Physical and Mineralogical Methods. 2nd ed., Amer. Soc. of Agron., madison, wisconsin, USA.

Lindsay, W.L. and W.A. Norvell (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci. Soc. Amer. J. 42:421-428.

Qalioubia report. (2008). The environmental Profile, 185p.

Robert, W.D. (2008). Soil testing manual: procedures, Classification Data, and sampling practices. Pinted by press of Ohio.

Shata, A.A. and I.F. El Fayoumy (1970). Remarks on the regional geological structure of the Nile Delta “. Symposium hydrology of Delta, UNESCO, vol. I., 189-197.

Soil Survey Staff, (2003). Keys to Soil Taxonomy. Tenth Edition, (USDA Agriculture Handbook, 436). Washington, D.C.

SOIL SURVEY STAFF. (1975). Soil Munsul Colourcharts. U.S.D.A., Soil Conserve, Washington, D.C.

SOIL SURVEY STAFF. (2010). Key to Soil Taxonomy. Eleventh Edition, 346p, U.S.D.A., Washington, D.C.

USDA (1991). Soil Survey Laboratory Methods Manual. Soil Investigation Report, No. 42, version N.1.0, OCT. pp: 603.

دراسة وتقيم أراضي الجبل الأصفر التي تروى بمياه الصرف الصحي

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منطقة الدراسة تقع شرق دلتا النيل بين خط عرض "10 '14 °30 & "15 '11 °30 شمالاً وخط طول "20 '24 °31 & "05 '22 °31شرقاً. وفقا لفترة الري بمياه الصرف الصحي قسمت الأرض بالمنطقة إلى أربع مناطق. المنطقة الأولى غير مروية وقاحلة غير مزروعة ، المنطقة الثانية رويت (٢٩) عاما ، المنطقة الثالثة رويت (٤٩) عاما والمنطقة الرابعة رويت (٨٢) عاما من مياه الصرف الصحي،حتى عام ٢٠٠٩ وبعد ذلك تغيرت للري بالماء الأرضي. اربعة قطاعات ارضية أخذت لتمثيل ترب المنطقة .والوصف المورفولوجي خلال العمل الحقلي. صفات التربة متضمنة تحليل فيزيائي (قوام التربة) ، العمق، المادة العضوية OM ، ملوحة التربة EC ، كربونات الكالسيوم $CaCO_3$ ، درجة الحموضة pH ، السعة التبادلية الكاتيونية CEC ، نسبة الصوديوم المتبادل ESP تم تقديرهم.

البيانات التي تم الحصول عليها تشير إلى أن التربة يمثلها مجموعة كبيرة : Torripsamments Typic and Typic Torriorthents. .نطاقات التربة فئة القدرة بين الطبقة ٢ (جيد) لفئة ٥ (سيئة للغاية). ومدى ملاءمة التربة يتراوح بين S1 إلى S3 والمحاصيل الحقلية الأكثر ملاءمة هي (القمح، الشعير، الفول، بنجر السكر، زهرة الشمس، الذرة، فول الصويا، الفول السوداني، القطن، قصب السكر) ومحاصيل الخضر الأكثر مناسبة (الطماطم، الفلفل، البطيخ، البرسيم، الذرة) ومحاصيل الفاكهة الأكثر ملائمة هي (الموالح ، العنب، الزيتون، التفاح، الكمثرى، التين، النخيل)، فقط ٤ محاصيل (الملفوف، البصل، الموز والأرز) حاليا ليست مناسبة ويمكن أن تكون غير مناسبة بشكل دائم في معظم من المنطقة.

قام بتحكيم البحث

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Table 1. Morphological feature of the soil profiles of the area.

Applicat. Period (year)	Profile No.	Depth In (cm)	Land Use	Symbole	Color		Textural class	Structure	Consis -tence Dry	Efferv. With Hcl	Roots	Boundary	New formation
					Dry	Moist							
Zero	4	0-40	Barren	C1	10YR 6/2	10YR 5/3	S.	SG.	sh.	h.	N.	ms.	
		40-90		C2	10YR 6/2	10YR 5/3	S.	SG.	L.	mh.	N.	ss.	
		90-130		C3	10YR 6/2	10YR 5/3	S.	SG.	L.	mh.	N.		
29	1	0-15	After citrus	Ap	10YR 6/2	10YR 5/3	S.	SG.	sh.	m.	csm.	md.	
		15-40		C1	10YR 6/2	10YR 5/3	S.	SG.	sh.	m.	Ffm.	SS.	
		40-80		C2	10YR 6/4	10YR 5/2	S.	SG.	sh.	m.	csm.	s.	
		80-120		C3	10YR 6/4	10YR 5/2	S.	SG.	L.	mh.	N		
49	6	0-15	Alfalfa	Ap	10YR 6/2	10YR 4/3	LS.	Smmss	sh.	m.	csm.	cs	common small residual parts and humified of organic compound.
		15-30		C1	10YR 6/2	10YR 4/3	LS.	Mmssb	mh	m.	Fm	cs.	few humified of organic compound
		30-70		C2	10YR 6/2	10YR 5/3	S.	SG.	L.	m.		sd.	
		70-120		C3	10YR 6/4	10YR 5/2	S.	SG.	L.	m.			
82	13	0-20	Tomato	Ap	10YR 5/3	10YR 4/2	CL.	smlsb.	h.	m.	csmm.	cs.	common small to medium mixed from residual and semihumified organic material.
		20-40		C1	10YR 5/3	10YR 4/2	CL.	smlsb.	h.	m.	Fm	cs.	common small humified organic material.
		40-80		C2	10YR 6/2	10YR 5/3	S.	SG.	L.	m.		cs.	
		80-120		C3	10YR 6/2	10YR 5/3	S.	SG.	L.	m.			

Structure abbreviation
- **SG:** Single grains
- **smmss:** small to medium moderately strong sub angular
- **mmssb:** medium moderately strong sub angular blocky
- **smlsb:** strong medium to large sub angular blocky

effervescence with Hcl
- **h:** High
- **mh:** moderately high

Texture class
- **S:** sand
- **LS:** Loamy sand
- **CL:** Clay loam

Consistence abbreviation
- **sh:** slightly hard
- **L:** Loose
- **mh:** Moderately hard
- **h:** Hard

Boundary abbreviation
- **ms:** medium sharp
- **ss:** smooth sharp
- **md:** moderately diffuse
- **SS:** Slightly smooth
- **s:** smooth
- **cs:** clear smooth
- **sd:** slightly diffuse

Roots abbreviation
- **N:** non
- **csm:** common small to medium roots
- **Ffm:** few fine to medium roots
- **Fm:** few medium roots
- **csmm:** common small to medium mixed roots