SPATIAL MONITORING OF SOIL SALINITY AND PROSPECTIVE CONSERVATION STUDY FOR SINNURIS DISTRICT SOILS, FAYOUM, EGYPT

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ABSTRACT

Mapping, updating and managing soil salinity are considered difficult tasks due to the large spatial and temporal variability of the salinity phenomena. GIS and field studies are integrated in the present study to monitor soil salinity development through 7 years (2002 – 2009) in Sinnuris District soils, Fayoum, Egypt. Areas with soil salinity problems were decreased from 42.57% to 29.5% out of 22018.9 hectares of investigated arable land within the studied period. The relative improvement of soil salinity in the region is attributed mainly to the applied subsurface drainage networks system and soil reclamation activities. The recorded saline soils were classified as, Typic Aquisalids, Typic Haplosalids and Typic Salitorrerts. Based on the updated studies for soils, ground water and Digital Elevation Models (DEM), a strategic future management plans supported with GIS spatial maps were suggested to improve salinity conditions and to overcome the future challenges of water scarcity in the area. Semi-detailed GIS maps were provided for the different main soil characteristics. Future prospective GIS model were produced to simulate drainage condition, ground water level and to improve salinity conditions in the study area. The study is considered of vital importance for decision makers and for the management of natural resources in Fayoum Governorate.

Key words; Soil salinity, GIS, Soil conservation, Sinnuris Soils and Salinity spatial monitoring, spatial simulation.

1- INTRODUTION

El-Fayoum Governorate is a natural depression occurs in the Eocene limestone plateau that located at about 90 km south-west of Cairo. Its floor is covered mainly by Fluvio-lacusrine deposits that belong to Pleistocene/Holocene periods. The depression is joined to Nile River by Bahr Yousef canal which leaves the Nile near Dayrute town , Assuit Governorate. At the depression bottom, Lake Qarun occurs which covers an area of about 210 km^2 of salty water of average 33.9–37.6 g/l (FWMP, 1999). The lake receives the majority of drainage water in the depression and its water level is maintained to not exceed -43.5 MSL. The storing capacity of the lake and its salinity are considered main limiting factors for agriculture development in Fayoum Governorate. Because of its international importance as feeding and rest place for migratory birds, Lake Qarun has been declared a natural protectorate in 1989. Sinnuris District is located in the eastern-north part of Fayoum depression and covers an area about 55726 hectares that fall within latitude $29^o20'$ and $29^o30'$ N and longitude $30^o43'$ and $30^o56'$ E, Figure 1.

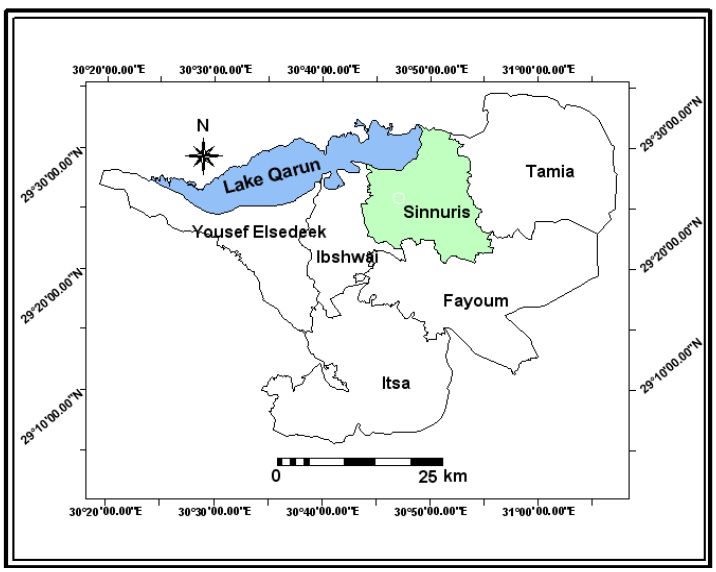


Figure 1. Location map of the study area.

The study area is characterized by a hot and dry climate in general with scanty rainfall drops that may occurs between December – April with annual average of 8 mm/year, whereas the evaporation rates average ranging between 3.5 to 10 mm/day. The minimum temperature values usually recorded in January and the maximum ones in July with an average temperature value of 22º. Adjacent to southern and eastern shores of Lake Qarun, i.e. the depression bottom, saline soils with low permeability and clayey texture are commonly developed, Figure 2.

	
Clayey saline soils	Salt crust on soil surface
	
Salicornia fruticosa, L.	Cressa cretica, L.

Figure 2. Saline soils and halophytic plants occurred south of lake Qarun.

The present study aims to;

- Monitor soil salinity in Sinnuris District within the period (2002 – 2009).
- Define strategic priorities for agricultural drainage improvement in areas suffering from salinity problems.
- Prepare guidelines for prospective development, improvement and conservation plans to manage soils salinity of the study area.

2- MATERIAL AND METHODS

The present study had been conducted in the following stages:

1- Conducting a semi-detailed soil survey in year 2002 and GIS data preparation.

2- Conducting a semi-detailed soil/water table survey in year 2009 and GIS data preparation.

3- Laboratory analysis and coding of soil database attributes.

4- GIS Monitoring analysis and prospective improvement/conservation planning.

2.1. Conducting a semi-detailed soil survey in year 2002 and GIS data preparation.

A semi detailed soil survey is conducted for Sinnuris District soils in year 2002. The survey is aided with the interpretation of aerial photographs dated 1956 and enhanced Landsat TM Satellite image dated 2001. The geopedolological approach (Zink, 1989) was basically applied to carry out the interpretation of the aerial photographs. To increase the purity of map units, the interpretation map was crossed with the soil slope, and then crossed also with the detailed soil texture classes made by Soil, Water and Environment Research Institute (1998) using ILWIS 3.3 GIS capabilities. A total number of 117 soil profiles were integrated together to represent the different soil map units, (Abdel Fattah, 2002). The basic soil physical and chemical analysis were done for soil samples of the representative soil profiles and stored as attribute data for different map units. The exact location of soil profiles integrated in the present study is indicated in Figure 3. The final soil map and its main attribute data are given in Figure 4 and Table (1 and 2).

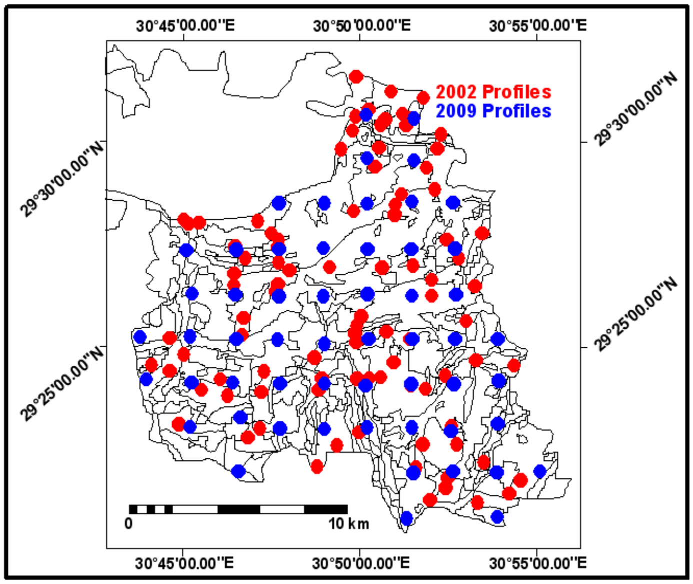


Figure 3. Location map of soil profiles for years 2002 and 2009.

2.2. Conducting a semi-detailed soil/water table survey in year 2009 and GIS data preparation.

Fifty six soil profiles and the occurrence of ground water table were tested to investigate salinity status in year 2009. The investigation points were planned on a grid system with lag distance of two kilometers. The regular spacing of data collection is planned to facilitate average interpolation, geostatistics and future monitoring. The exact locations were registered with the help of GPS (Global Positioning System) and imported to ILWIS GIS as point map. In each investigation point, soil profiles and ground water table were tested and sampled for laboratory analyses. The analyses data were stored as attributes for the point map.

2.3. Laboratory analysis and coding of soil database attributes.

The following analyses were conducted for the collected soil and water samples;

2.3.1 Analysis of soil samples.

The collected disturbed soil samples were air dried ground gently, and sieved through a 2 mm sieve, whereas the undisturbed soil samples were used directly. The following physical and chemical analyses were examined:

2.3.1.1 Physical analyses

- Particle size distribution using the pipette method, Piper (1950).
- Soil bulk density using undisturbed soil cores according to Black (1965).
- Hydraulic conductivity coefficient is determined using undisturbed soil cores, using darcy law (Richards, 1954).

2.3.1.2 Chemical analyses

- Calcium carbonate using the Collin's Calcimeter method, Wright (1939).
- Organic matter using Walkely and Black method, Jackson (1967).
- Soil paste extract was prepared for each soil sample, where the following determinations were carried out according to Jackson (1967).

a. Electrical conductivity (ECe).

b. Soluble anions, i.e., carbonate, bicarbonate and chloride.

c. Soluble cations, i.e., calcium, magnesium, sodium and potassium.

d. Soluble sulfate was calculated by subtracting the total soluble anions from the total soluble cations.

- Soil pH was measured in the soil paste according to Richards (1954).

- Exchangeable cations (Ca^{++}, Mg^{++}, Na^{+} and K^{+}) and cation exchange capacity (CEC) were determined using ammonium acetate according to Richards (1954).

2.3.2 Analysis of Water samples

In each observation point the exact location is registered using GPS, and then the depth of the ground water table is recoded and sampled. The collected ground water table samples were filtered through wattman filter papers No. 42 and stored in clean dry plastic bottles in a refrigerator, where the following analyses were done;.

- Water pH using pH meter , U.S. Salinity Lab. Staff (1969).
- Electrical conductivity (ECw), using a conductivity bridge, U.S. Salinity Lab. Staff (1969).

The analyses results were coded to ILWIS GIS as attributes data for all tested points. Moving average interpolation method was used to generate the ground water depth and ground water salinity.

2.4. GIS Monitoring analysis and prospective conservation planning.

The interpolation capabilities of ILWIS GIS was used to establish a Geographic Information System for the soils and ground water in the study area. Crossing capability between maps of different dates was also used to monitor the studied characteristics.

3. RESULTS AND DISCUSSION

3.1. Soils of Sinnuris District

The geopedological map and its legend are shown in Figure (4) and Table (1). As shown in the legend, it is clear that each map unit name contains information about landform, slope percentage and textural class. Three main soil orders were recorded in the area; Vertisols, Entisols and Aridisols, Table 1 and Figure5. The recoded areas of Great Groups soils were as following; 9786.9 hectare for Haplotorrerts , 9680 hectare for Torrifluvents, 303.9 hectare for Torripsamments, 636.3 hectare for Aquisalids, 1149.9 hectare for Haplosalids, 224.7 hectare for Haploargids and 236.8 hectare for Haplocampids. The physical and chemical soil characteristics are indicated in Table 2.

3.2. Monitoring of soil salinity

3.2.1 Soil salinity of year 2002

According the soil survey held in year 2002, Figure 6, the areas of saline soils with salinity values (> 4dS/m) reached to 9371.5 hectare, whereas soils of high salinity values (> 6 dS/m) reached to 1785.98 hectare. They are located mainly adjacent to Lake Qarun where poor drainage conditions, shallow saline ground water and clayey soils with low permeability occurred. In the east-north of the study area, soils are also very saline despite that the soils exhibit lighter textural classes due to sand encroachment from the sand sheets and dunes occurred in the north of the area. Areas, beside the down stream connection of El_Bats main drain with Lake Qarun., the high soil salinity values are enriched mainly through evaporation from the capillary rise shallow saline water table. It is expected that, lowering down the ground water depth, sub-soiling and gypsum application will improve salinity and drainage conditions in the area.

3.2.2 Soil salinity of year 2009

As indicated in Figure 7, a pronounced improvement in soil salinity condition is achieved. The total saline areas with salinity values (> 4dS/m) reduced only to 7972.1 hectare. No high salinity values (> 6 dS/m) were recorded. The highest salinity values were recoded in the area beside the down stream connection of El_Bats main drain with Lake Qarun. A small area of 521.6 hectare, 0.5 km. east of Matartares Town, in the south-east part of the study area showed a deterioration in salinity conditions, which may indicate the needs for drainage improvement in the area.

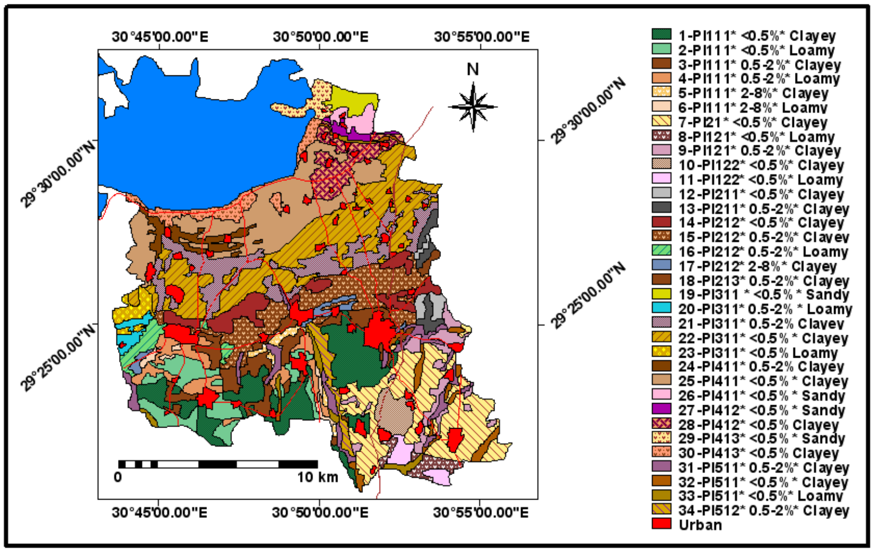


Figure 4. Geopedological soil map of the study area.

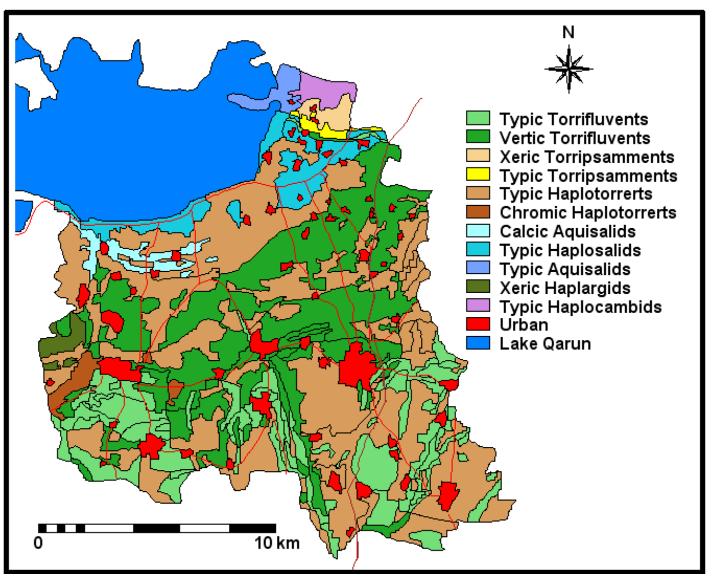
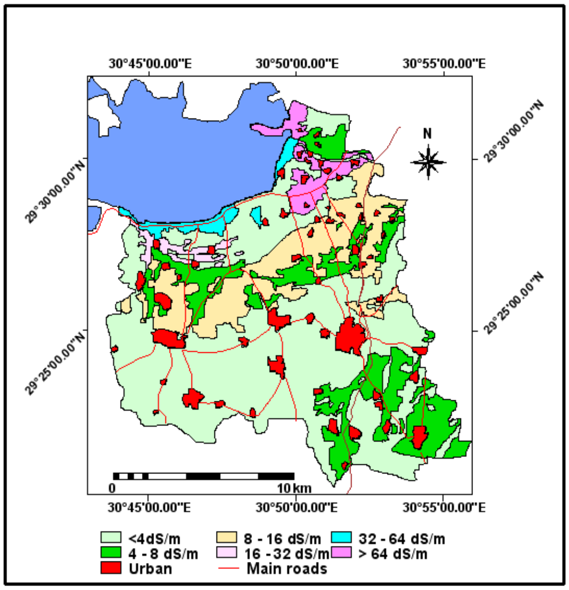
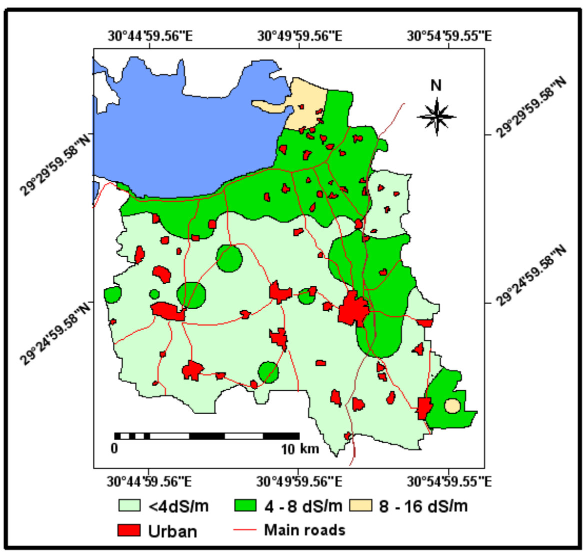


Figure 5. Soil Classification map.



Salinity class	Area (Hectare)
<4	12647.63
4-8	3960.36
8-16	3625.17
16-32	378.07
32- 64	522.47
>64	885.44

Figure 6 . Soil salinity map of year 2002.



Salinity class	Area (Hectare)
<4	14046.56
4-8	7372.12
8-16	600.0

Figure 7 . Soil salinity map of year 2009.

3.2.3 Salinity monitoring between 2002 – 2009 period

Using crossing capability of ILWIS GIS, the raster salinity maps were crossed together to monitor the salinity development in the area, Figure 8. The improved salinity conditions areas reached to 7475.26 hectare. The main improvement area was a pelt of about 2 km width north of Sanhour Town.in the form of terraces south of Lake Qarun with about 3.5 km.. The improvement is attributed mainly to the applied subsurface drainage networks system and soil reclamation activities. An area of about 4141.79 hectare showed a trend of degradation by increasing salinity values. The main degraded area is located adjacent to Lake Qarun with an area of 1974.37 hectare. Another degraded area appeared east of Sinnuris Town with an area of about 1308 hectare. A small area of 521.6 hectare, 0.5 km. east of Matartares Town, showed also a deterioration trend in salinity conditions. The resulted map is considered of a vital importance to decision makers as it could be a suitable base for planning priorities for soils and drainage improvement.

An attempt was made also to investigate the possible contribution of Lake Qarun elevation and its salinity on the soil salinity and ground water level in Sinnuris District. It is known that, the storing capacity of Lake Qarun and its salinity plays a prim strategic role on the development of Fayoum Governorate in general. Many studies referred to the siltation occurred on the lake bottom and its effects on shallowing up of the bottom of the lake and affect its storing capacity, Dardir and Wali (2009). In Table 3, FWMP (1999) provided important data to link between the lake level, its volume and its area. The data of FWMP (1999) was used beside the digital elevation model resulted in the present study after integrating the limited available spot heights of lake bottom included in the topographic map scale 1:100000, EGSA (1956). A simulation model was applied to simulate the effect of digging the lake bottom with 30 cm on the improvement of drainage condition in Sinnuris District soils. The simulation model indicated that, we need to remove 64.5 million m^3 to lower down the lake water level with 30 cm. The simulation results only limited improved area of about 105.83 hectare south of the lake. It is expected that the simulation results could be enhanced after the availability of semi detailed recent survey data for the lake bottom levels.

3.3. Ground Water Studies and Soil Salinity

The depth of ground water table is presented in Figure 9. The resulted ground water depth map indicated clearly that soils located in the eastern parts of Lake Qaroun are generally the most suffered areas from the shallow ground water. The ground water depth map showed an area of 707.29 hectare, east of Lake Qaroun, possess water level shallower than 1 m. which clearly match with the results for soil salinity of that area. As indicated in Figures 9 and 10; the ground water depth varied from 31 cm to 200 cm below soil surface with an average of 117 cm below soil surface. The comparison of the digital elevation model of soil surface (DEM) with the digital elevation model of the ground water depth (GW DEM), indicated that the ground water elevation is running in a clear harmony with the soil elevation values, Figure 10. The comparison between the spatial variability of soil salinity values with soil elevation, depth of ground water, salinity of ground water, soil hydraulic conductivity and ESP values showed insignificant simple correlation with all studied characteristics (Table 4) and indicated a very complex relationships that needs to be explored with more detailed studies to clarify the contribution rule of the different characteristics on soil salinity .

4. Conclusions and Recommendations

Improvement trend in soil salinity was recorded in Sinnuris soils. The study provided a suitable geographic database that can be used for planning priorities for soils improvement. The study recommends;

- The continuous monitoring of soil salinity, ground water level and ground water salinity to make the suitable intervention needed to prevent deterioration of soil resources.
- To apply the suggested simulation model dealing with Lake Qarun storing capacity after updating the lake bottom levels and to study the economic aspects and the cost/benefits of the applied scenario.
- To study simulation models on the effects of using mixed irrigation/drainage water to overcome the future challenges of water scarcity and to study the effects on soil salinity, ground water depth and water/salts balance in Lake Qarun.
- To extract salts from Lake Qarun as much as possible.

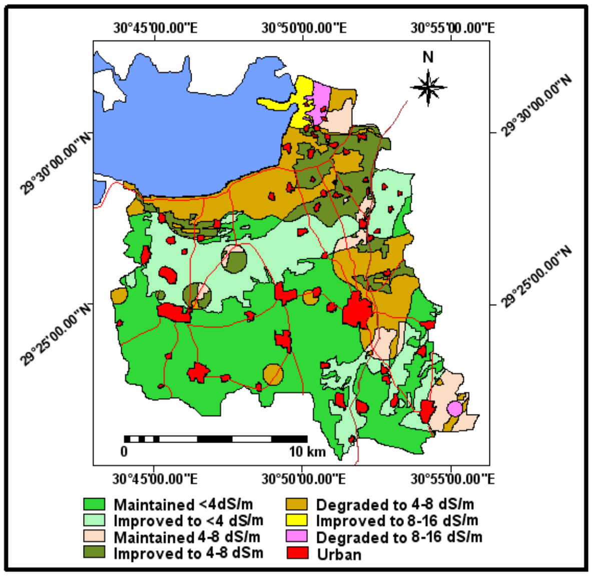


Figure 8 . Salinity monitoring between 2002 – 2009 period.

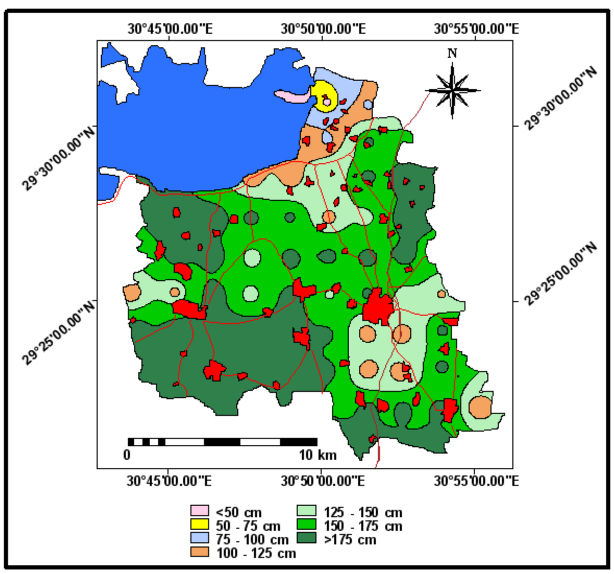


Figure 9. Ground water depth map 2009.

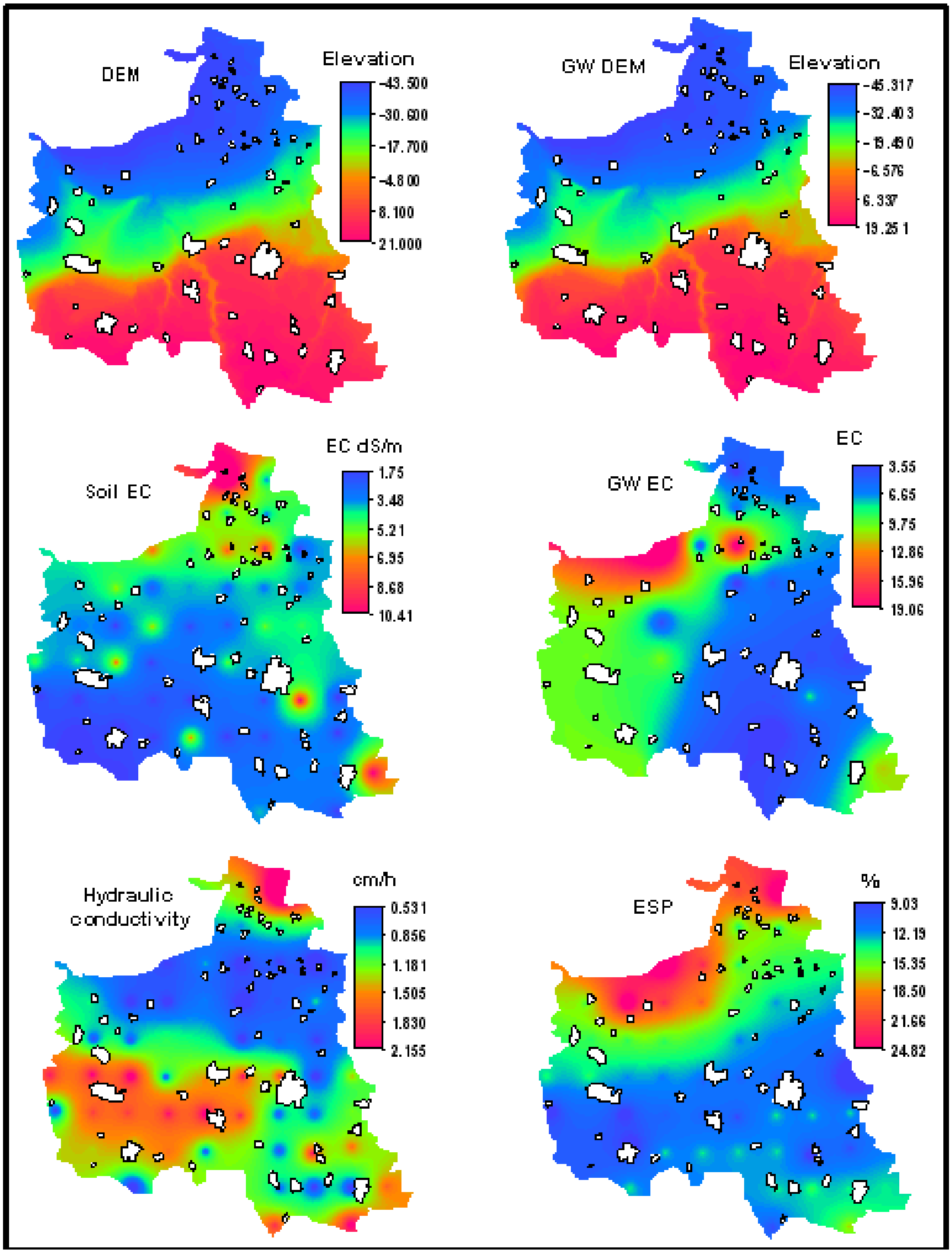


Figure 10. Relationship between soil salinity and DEM, GW GEM, GW salinity, hydraulic conductivity and ESP values.

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الرصد المكانى لملوحة التربة ، ودراسة مستقبلية للمحافظة على أراضى مركز سنورس – الفيوم – مصر

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الملخص

يعتبر رسم خرائط ملوحة التربة، وتحديثها وإدارتها من المهام الصعبة نظرا للتغيرات المكانية الكبيرة التى تحدث لظاهرة الملوحة مع الزمن. وفى هذه الدراسة فقد تم إدراج نظم المعلومات الجغرافية والدراسات الميدانية لرصد تطور ملوحة خلال فترة سبع سنوات (٢٠٠٢ -- ٢٠٠٩) وذلك لأراضى مركز سنورس – الفيوم – مصر. وقد أظهرت الدراسة إنخفاض المناطق التى تعانى من مشاكل ملوحة التربة وذلك من ٤٢,٥٧ ٪ إلى ٢٩,٥ ٪ من إجمالى ٢٢٠١٨,٩ هكتار من الأراضي الصالحة للزراعة والتي شملتها الدراسة. هذا ويعزى التحسن النسبي فى ملوحة التربة أساسا إلى تطبيق نظام شبكات الصرف المغطى وأنشطة استصلاح التربة بالمنطقة . وقد تم تصنيف التربة المالحة بمنطقة الدراسة إلى Typic Aquisalids، Typic Haplosalids ، Typic Salitorrerts. ، وبناءا على دراسات التربة الحديثة ودراسات الماء الأرضي ونماذج الإرتفاعات الرقمية الارتفاع (DEM) فقد تم إقتراح خطط مستقبلية للإدارة الاستراتيجية لأراضى المركز لتحسين ظروف الملوحة بها والتغلب على التحديات المستقبلية من ندرة المياه في المنطقة. هذا وقد تم إنتاج خرائط نصف تفصيلية لخصائص التربة المختلفة من خلال نظم المعلومات الجغرافية. وبالإستعانة بنظم المعلومات الجغرافية فقد تم إنتاج نموذج ترقب مستقبلى لمحاكاة حالة الصرف ولتحسين ظروف الملوحة في منطقة الدراسة. هذا وتعتبر هذه الدراسة ذات أهمية حيوية لمتخذى القرار لإدارة الموارد الطبيعية في محافظة الفيوم.

الكلمات الدالة : ملوحة التربة ، نظم المعلومات الجغرافية ، المحافظة على التربة ، أراضى مركز سنورس ، رصد التغيرات المكانية ، نظم المحاكاة المكانية.

Table 1: Legend of the geopedological soil map.

Landscape	Relief	Lithology	Landform	Mapping Unit	Symbol	Soil Classification	Area (fed.)
Plain Pl	Higher terraces (Pl 1)	Nile alluvial deposits (Pl 11)	Nearly level terrace tread (Pl 111)	Slope <0.5% & Clayey	Pl 1111	Typic Haplotorrerts	4453.29
				Slope <0.5% & Loamy	Pl 1112	Typic Torrifluvents	2079.00
				Slope 0.5-2% & Clayey	Pl 1113	Vertic Torrifluvents	2385.86
				Slope 0.5-2% & Loamy	Pl 1114	Typic Torrifluvents	1549.07
				Slope 2-8% & Clayey	Pl 1115	Typic Haplotorrerts	397.29
				Slope 2-8% & Loamy	Pl 1116	Typic Torrifluvents	308.14
		Fluvio-lacustrine deposits (Pl 12)	Gently sloping terrace tread (Pl 121)	Slope <0.5% & Clayey	Pl 1211	Typic Haplotorrerts	5037.86
				Slope <0.5% & Loamy	Pl 1212	Typic Haplotorrerts	562.93
				Slope 0.5-2% & Clayey	Pl 1213	Typic Torrifluvents	1191.43
			Basin (Pl 122)	Slope <0.5% & Clayey	Pl 1221	Typic Torrifluvents	772.07
				Slope <0.5% & Loamy	Pl 1222	Typic Torrifluvents	490.29
	Moderately high terraces (Pl 2)	Alluvial deposits (Pl 21)	Nearly level terrace tread (Pl 211)	Slope <0.5% & Clayey	Pl 2111	Typic Haplotorrerts	405.64
				Slope 0.5-2% & Clayey	Pl 2112	Typic Haplotorrerts	565.50
			Sloping terrace tread (Pl 212)	Slope <0.5% & Clayey	Pl 2121	Typic Haplotorrerts	1802.79
				Slope 0.5-2% & Clayey	Pl 2122	Vertic Torrifluvents	3666.64
				Slope 0.5-2% & Loamy	Pl 2123	Chromic Haplotorrerts	657.21
				Slope 2-8% & Clayey	Pl 2124	Vertic Torrifluvents	422.14
			Basin (Pl 213)	Slope 0.5-2% & Clayey	Pl 2131	Typic Haplotorrerts	127.07

Table 1: Cont.

Landscape	Relief	Lithology	Landform	Mapping Unit	Symbol	Soil Classification	Area
Plain Pl	Moderately low terraces (Pl 3)	Fluvio-lacustrine deposits (Pl 31)	Gently sloping terrace tread (Pl 311)	Slope <0.5% & Sandy	Pl 3111	Typic Haplocambids	563.57
				Slope 0.5-2% & Loamy	Pl 3112	Typic Haplotorrerts	384.21
				Slope 0.5-2% & Clayey	Pl 3113	Typic Haplotorrerts	3663.21
				Slope <0.5% & Clayey	Pl 3114	Vertic Torrifluvents	6830.57
				Slope <0.5% & Loamy	Pl 3115	Xeric Haplargids	535.50
	Low terraces (Pl 4)	Fluvio-lacustrine (Pl 41)	Nearly level to gently sloping terrace tread	Slope 0.5-2% & Clayey	Pl 4111	Calcic Aquisalids	901.07
				Slope <0.5% & Clayey	Pl 4112	Typic Haplotorrerts	5251.50
				Slope <0.5% & Sandy	Pl 4113	Xeric Torripsamments	460.29
			Basin covered with sand sheet (Pl 412)	Slope <0.5% & Sandy	Pl 4121	Typic Torripsamments	264.21
				Slope <0.5% & Clayey	Pl 4122	Typic Haplosalids	1491.00
			Marches (Pl 413)	Slope <0.5% & Sandy	Pl 4131	Typic Aquisalids	613.71
				Slope <0.5% & Clayey	Pl 4132	Typic Haplosalids	1248.64
	Incisions (Pl 5)	Alluvial deposits (Pl 51)	Vales (Pl 511)	Slope 0.5-2% & Clayey	Pl 5111	Typic Torrifluvents	1333.50
				Slope <0.5% & Clayey	Pl 5112	Typic Torrifluvents	839.36
				Slope <0.5% & Loamy	Pl 5113	Vertic Torrifluvents	530.36
			Overflow-mantle	Slope 0.5-2% & Clayey	Pl 5121	Vertic Torrifluvents	633.64

Table 2: Land map units characteristics.

No.	LMUs Symbol	Available water (FC.WP)[1]	CEC cmolc/kg	$CaCO_3$ (%)	Drainage conditions[2]	EC " dS/m"			ESP			Soil depth (cm)	Soil texture[3]	Soil pH	Organic matter (%)
						0 – 30 cm	30-90 cm	30- 125 cm	0 – 30 cm	30-90 cm	30- 125 cm				
1	**Pl111 1**	34.11	42.33	4.59	W	1.52	1.32	1.39	13.85	14.77	14.92	150	C	7.98	1.46
2	**Pl111 2**	20.71	29.74	1.64	W	2.77	1.50	1.17	13.96	14.06	13.6	150	SCL	7.47	1.44
3	**Pl111 3**	24.69	21.79	1.52	W	1.43	1.85	1.85	10.38	9.71	9.71	80	SCL	7.77	0.80
4	**Pl111 4**	18.82	35.12	2.62	W	1.29	1.17	1.24	6.44	6.31	6.58	150	SCL	8.1	-
5	**Pl111 5**	18	29.60	2.58	MW	1.17	5.05	5.61	13.72	13.72	13.72	150	CL	8.31	1.05
6	**Pl111 6**	19.5	29.48	2.89	W	0.76	0.74	0.73	11.02	11.02	11.02	150	SCL	8	1.36
7	**Pl121 1**	17.69	40.59	4.02	W	4.02	4.89	4.55	13.74	14.34	14.29	150	C	7.81	1.04
8	**Pl121 2**	20	25.85	5.69	W	1.12	1.62	1.73	19.34	19.34	19.34	150	SCL	8.2	1.31
9	**Pl121 3**	9.02	12	1.76	W	1.16	0.88	0.85	2.92	3.33	3.85	150	SCL	8.19	-
10	**Pl122 1**	20.12	16.45	5.47	W	1.75	1.7	1.7	6.62	6.17	6.17	100	SCL	7.44	0.82
11	**Pl122 2**	20.5	29.02	4.65	MW	1.76	3.3	3.16	17.12	17.12	17.12	150	SL	8.4	0.95
12	**Pl211 1**	19.5	38.32	5.39	W	1.66	2.27	2.29	12.53	12.53	12.53	150	C	8.06	1.23
13	**Pl211 2**	20	38.97	10.62	MW	1.69	3.08	3.34	29.47	29.47	29.47	150	C	8.38	1.25
14	**Pl212 1**	22.9	40.31	10.34	MW	11.67	8.16	7.20	14.58	14.58	14.63	110	C	7.70	1.12
15	**Pl212 2**	24.13	32.79	4.46	W	1.72	1.5	1.49	11.6	12.68	13.16	110	C	7.75	1.3
16	**Pl212 3**	16.75	33.31	3.26	W	1.17	1.23	1.26	7.66	9.25	9.68	150	C	7.73	1.17
17	**Pl212 4**	18.5	33.59	3.07	W	1.04	1.52	1.43	11.02	11.02	11.02	120	CL	8.06	1.42

1. F.C. = moisture content at field capacity, W.P. = moisture content at wilting point.

2- W = well, MW = moderately well, IM= imperfectly drain, EW = excessively well drain, SWE = somewhat excessive, P = poorly drained, SWP = somewhat poor.

3- C= Clay, CL= Clay Loam, SCL= Sandy Clay Loam, SiL = Silty Loam, GS= Gravely Sand, SL= Sandy Loam L= Loam, SC = Sandy Clay, LS= Loamy Sand, HC= Heavy Clay.

Table 2: Cont.

No.	LMUs Symbol	Available water (FC.WP)[1]	CEC cmolc/kg	$CaCO_3$ (%)	Drainage conditions [2]	EC " dS/m"			ESP			Soil depth (cm)	Soil texture[3]	Soil pH	Organic matter (%)
						0 – 30 cm	30-90 cm	30- 125 cm	0 – 30 cm	30-90 cm	30- 125 cm				
18	**Pl213 1**	19	37.85	9.57	MW	1.61	2.23	2.85	14.93	14.93	14.93	150	C	8.39	1.41
19	**Pl311**	18.5	6.42	1.4	EW	3.5	4.39	6.07	11.99	13.15	15.28	205	S	7.8	0.03
20	**Pl311 2**	18.5	33.71	6.15	MW	1.45	1.31	1.25	28.39	28.39	28.39	120	SCL	8.46	1.25
21	**Pl311 3**	19.5	38.13	6	MW	6.68	3.23	3.44	12.18	17.16	16.18	130	C	7.92	1.53
22	**Pl311 4**	20.65	26.34	10.84	W	9.09	8.16	8.5	14.19	16.19	16.46	100	C	7.71	1.02
23	**Pl311 5**	18.5	35.25	4.95	MW	1.74	4.13	4.29	14.14	14.06	13.95	110	CL	7.99	1.32
24	**Pl411 1**	23.95	25.78	11.20	P	22.93	19.08	19.8	31.8	31.26	31.26	80	C	8.55	0.91
25	**Pl411 2**	21	50.66	5.28	MW	2.18	2.28	2.19	23.54	38.7	37.89	170	C	8	1.17
26	**Pl411 3**	17	13.07	5.09	W	4.98	7.58	8.03	31.83	54.51	51.83	125	LS	8.26	2.48
27	**Pl412 1**	17	16.75	4.68	SWE	4.93	8.73	9.64	19.39	19.39	19.39	120	LS	8	0.66
28	**Pl412 2**	21	33.03	7.63	P	80.98	29.03	22.17	13.57	13.47	12.58	120	C	7.73	0.84
29	**Pl413 1**	20	22.13	7.6	P	145.93	31.33	31.33	21.01	26.25	26.25	50	L	7.59	1.27
30	**Pl413 2**	16.8	47.46	9.8	P	37.48	40.91	40.77	33.88	32.62	32.05	115	C	7.9	1.1
31	**Pl511 1**	28.1	26.99	1.53	SWE	1.25	1.35	1.26	6.28	9.69	10.24	135	SCL	7.63	0.95
32	**Pl511 2**	19	32.21	3.97	W	0.81	0.86	0.85	9.47	9.47	9.47	140	SCL	8.08	0.74
33	**Pl511 3**	26.34	26.05	1.53	W	1.38	1.31	1.38	8.29	8.07	7.96	110	SC	7.5	1.49
34	**Pl512 1**	20.37	26.99	3.34	W	2	1.4	1.4	9.1	8.15	7.95	110	CL	7.74	1.15

Table 3: Relationship between lake level , water volume and lake area.

(After FWMP, 1999)

Lake level (MSL)	Water Volume million m^3	Lake area Km^2
Z= -42 m	1251.7	219.5
Z= -43 m	1027.1	216.0
Z= -44 m	809.9	208.4
Z= -45 m	605.5	194.9
Z= -46 m	420.0	173.0
Z= -47 m	2.66.0	130.4
Z= -48 m	158.1	88.7
Z= -49 m	86.1	56.6
Z= -50 m	39.0	38.3
Z= -51 m	10.8	18.1
Z= -52 m	1.0	3.6
Z= -53 m	0.04	0.03
Z= -54 m	0.0	0.0

Table 4: Simple correlation between soil salinity and GW depth, GW salinity, hydraulic conductivity and ESP values.

Simple Correlation (r)	**G.W Depth**	**G.W ECe**	**Hydraulic conductivity**	**ESP**
Soil ECe	**-0.308**	**0.247**	**0.029**	**0.245**