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The use of geographic information systems for monitoring some soil properties: case study Damanhur District, El-Beheira Governorate - Egypt

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Abstract

The main objective of this study is to integrate GIS and field work to assess monitor some soil properties in the period 1980 – 2017, field work involved digging pits and carrying out morphological examination and obtain samples. Updating the digital soil maps were generated using the database collected from field work and lab analysis. Soil salinity showed that highly saline soil decreased from 6583.3 ha (15669 Fed.), 16.4% to 5063.8 ha (12050 Fed.) 12.6%. Such improvement was due to soil reclamation. Decision makers should continue carrying out reclamation operations an area of 3895 ha (9270 Fed.) 9.7% from total area prone to salinization. An area of 3284.4 ha (7817Fed.) 8.2% suffer from shallow water table. Attention must be paid to 19778 ha ((47072 Fed.) 49.1% to prevent water table from rising. these soils showed no alkalinity for 50.2 ha (119.5 Fed.) Which need to improvement urban encroachment on the fertile soils affected 4.2 to 6.5% of the whole area in 1980 and 2017 respectively.

Key words: Soil salinity, monitoring, GIS, water table depth, alkalinity, Damanhur, Egypt

Introduction

The soil of Nile Delta is the most fertile and finest Egyptian Territory; it was formed over thousands of years of deposits through the Nile River. The Nile Valley and Delta are of the oldest agricultural areas in the world. These were under continuous cultivation for at least 7000 years. The deltaic lands, worldwide are fine texture mainly with poor drainage, and many have intrusion of sea water and arise in the ground water table. Therefore these soils are threatened by degradation. Land degradation processes are clearly observed also in different regions under arid and semi-arid climatic conditions. The Nile Delta is one of these regions which are threatened by water logging, soil compaction, salinization and alkalinization. Delta is receives surface water irrigation, causing a rapid rise in water tables and increasing soil salinity (Abul-Ata, 1977; Kishk, 1986; White, 1988; Scott, 1993),this decreases soil suitability and capability. The soil properties deteriorate in absence of efficient management to improve the production capacity. Therefore, the process is urgent to know the behavior give recommendations to stop the deterioration of soils. A availability of data in a digital form and the use of computers to handle large amounts of data and allows them to create attributes useful in soil improvement. Spatial mapping involves interpolation and extrapolation of point data across land surfaces. Geographic Information System (GIS) is considered an organized collection of computer hardware, software. spatial and non-spatial data that can help capturing, storing, updating, manipulating, analyzing and managing the geographic information. The GIS software work on links of digital maps with database. Features on the map (which represent objects in the real world) are linked to records in the database. The digital maps and databases serve as a storehouse of information. The map stores physical features and the database stores information about the soils. The result of having these two components linked is that both spatial data and attribute data can be queried and retrieved. This is important for planners, who rely on geographic data. Additional mathematical functions can allow statistical analysis of data, create new data and create predictive models (Mahmoud, 2002**).** Damanhur district in El-Beheira governorate located in the north central part of Nile Delta was selected for the current study as representative of the territory of the Nile River Delta.

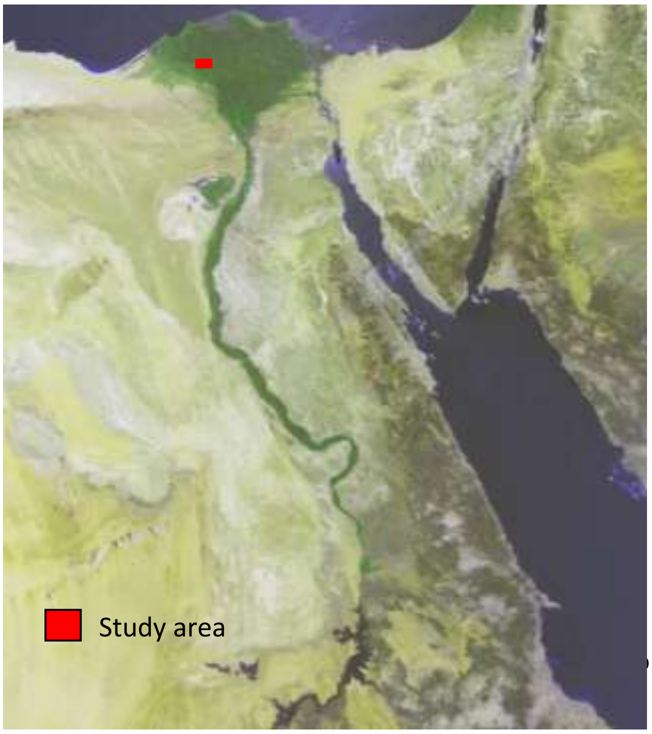
Materials and methods

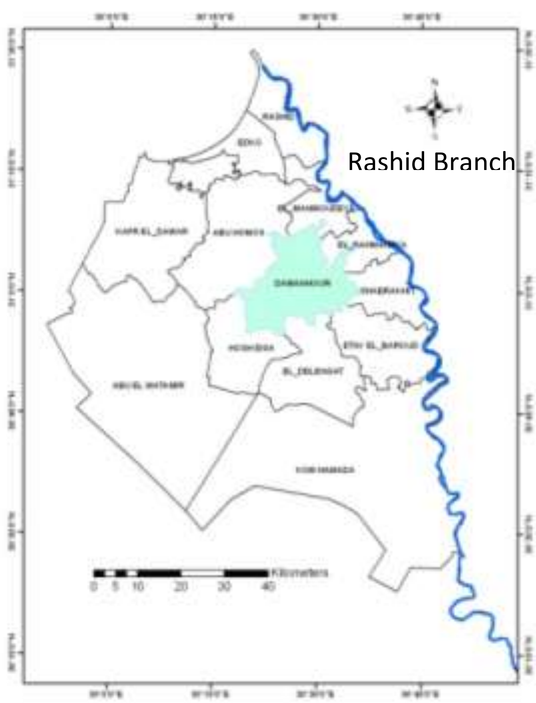
Location of study area

The study area (Fig.1) is located in El-Beheira Governorate between longitudes 30° 17' 54.42′′and 30° 36' 27′.96′′East and latitudes 30° 54' 51′.1′′and 31° 7' 59.34′′North (Figs. 1). The mean minimum and maximum annual temperature in the study area are 12.6 °C and 26.2 °C respectively (EMA 1996), which indicates Thermic temperature regime and the annual precipitation is 83.7 mm, indicating Torric moisture regime (USDA, 2006)

Geographic Information Systems (GIS)

The GIS was used for analytical and data management features including data input for reprocessing and output for final maps and useful arrays of digitizing operations. All vector layers were imported into GIS and used used for design spatial modeling of the soil properties of study area .The average weight values were calculated for each property. Soil survey map was done by the Soil, Water and Environment Research Institute in1980 (SWERI 1980). A total of 25 soil profiles were done to represent the different soil maps units. The basic soil physical and chemical analyses were done. Identifying soil properties of the study area was based on geographic database of Damanhur soil area, depending on the data inputs.





Raster and vector data

Hard copy of soil survey map produced by SWERI 1980 were converted to digital copy by high quality scanning, subsetting. To unify the georeferance of subjects, the early maps were geometrically corrected and projected to the ETM (Egyptian Transfer Mercator) projection. Geometric corrections were done on these maps to deal with the GIS programs and vectorization on screen digitizing carried out to create and extract the layers of soil properties. The hardware used to carry out the work are: PC with configuration, GPS, scanner, and printers.

Field work and laboratory analysis

The field work was carried out in the area which was homogeneous as a physiographical unit (flat Nile alluvial deposits), Twenty five soil profiles were taken to cover all area using the global positioning system (GPS) (Fig. 2).the Profile pits were dug to 150 cm depth or to impervious layer or a permanent water table, morphologically described (FAO, 2006), classified, and sampled for laboratory analysis.

The soil samples were air dried, crushed, sieved through a 2-mm diameter sieve and subjected to laboratory analyses using methods cited by Black etal (1965). Particle size distribution was carried out using the pipette. the pH were determined in the saturated soil paste and the paste extract salinity and soluble cations and anions were determined in saturated soil paste. Gypsum content was determined by precipitation with acetone. Total carbonates were determined volumetrically using the Calcimeter, sodium adsorption ratio (SAR) was calculated (Black eta 1965)

Land Capability:

Land evaluation for the purpose of the agricultural capability was assessed according to FAO (1985), Sys and Verheye (1978) and Sys et al. (1991) according to the following equation:

$$Ci = \frac{t}{100} \times \frac{w}{100} \times \frac{s_1}{100} \times \frac{s_2}{100} \times \frac{s_3}{100} \times \frac{s_4}{100} \times \frac{n}{100} \times 100$$

Where:

Ci=Capability index (%)	S_2 = Soil depth
t = Slope	S_3 = $CaCO_3$ content
w = Drainage conditions	S_4 = Gypsum content
S_1 = Texture	n=Salinity and alkalinity

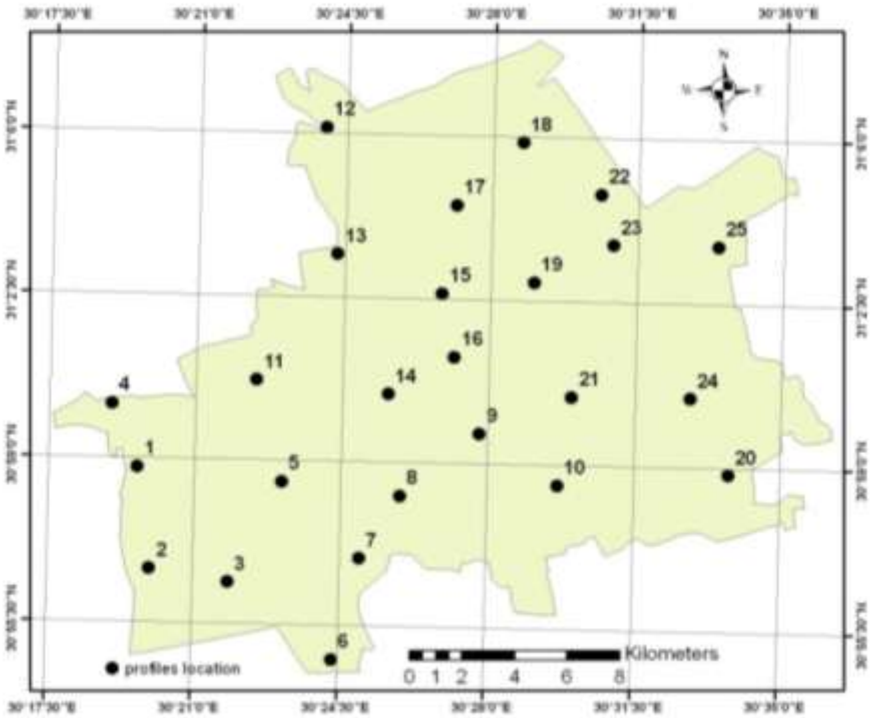


Fig.2: profiles location of studied area

Capability classes arbitrary defined according to the value of the index as follows:

Capability class	Land index (Ci) %	Definition
S1	> 75	Soils are highly suitable for cultivating all crops.
S2	75-50	Soils are moderately suitable for agriculture
S3	50-25	Soils are marginally suitable for agriculture
N	< 25	Soils are not suitable for agriculture

Results and Discussion

1-Soil salinity

Regarding soil survey map produced by of the SWERI in 1980 (Figure 3and table 1), the areas of normal saline soils with EC < 4 dSm^{-1} affected 20812.2 ha (49533 Fed.), 51.7% of total studied area whereas. Soils has moderately saline values from 4-8 dSm^{-1} reached 11173.5 ha (26593 Fed.), 27.8% of total area. Highly saline soil of between 8-12 dSm^{-1} covering **an** area 3898.3 ha (9278 Fed), 9.7%.Very highly saline soil (12-16 dSm^{-1}) occurred in 2685.3 ha (6391 Fed.), 6.7%. The present results of 2017(Table2) of the study area reveal an area of 28689.1 ha (68280 Fed.), 71.3 of non-saline to moderately saline soils was in the eastern part of study area 3895.0 ha (9270 Fed.), 9.7%. Highly saline soils cover an area of 3970.2 ha (Fed. 9449); 9.9%. The very highly saline soil was in southwest of area1092.9 ha (2601 Fed.), 2.7%.

In general soil salinity status between 1980 and 2017 decreased. This may be mainly to drainage networks and government efforts in reclaiming these soils. However very highly saline soils would need more reclamation.

Table 1. Soil salinity classes of Damanhur district

		1980			2017			Change
No	Class	Area/ha.	Area/Fed.	%	Area/ha.	Area/Fed.	%	%
1	Normal saline soil	20812.2	49533	51.7	28689.1	68280	71.2	19.6
2	Moderately saline soil	11173.5	26593	27.7	3895.0	9270	9.7	-18.1
3	High saline soil	3898.3	9278	9.7	3970.2	9449	9.9	0.2
4	Very high saline soil	2685.3	6391	6.7	1092.9	2601	2.7	-4
5	Urban	1677.3	3992	4.2	2599.6	6187	6.5	2.3
Total		40246.6	95787	100	40246.6	95787	100	

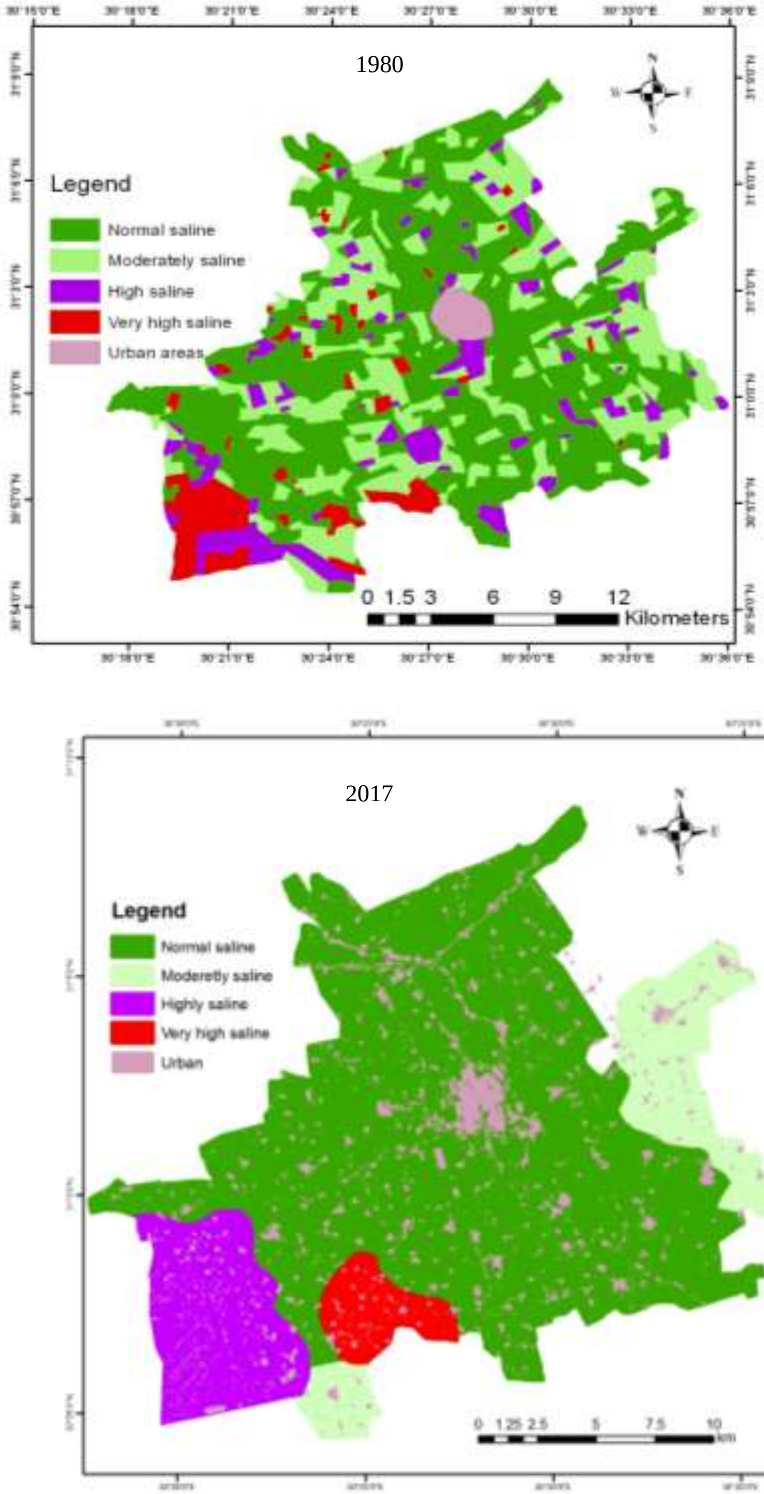


Fig. 3: Soil salinity maps of study area in years 1980 and 2017 respectively

Table 2. Physical and chemical properties of the representative soil profiles of the studied area

Profile No.	Depth, cm	Particle size distribution (%)				Textural class	pH	EC dS.m-1	Gyp. g.kg	OM. g.kg	$CaCO_3$ g.kg	SAR
		Course sand	Fine sand	Silt	Clay							
1	0-35	10	12	30	48	clay	7.4	10.9	0.5	2.81	5.8	8.7
	35-80	11	12	32	45	clay	7.5	12.3	0.2	0.9	9.6	6.5
	80-115	12	11	33	44	clay	7.7	8.9	0.35	0.65	6.4	12.4
2	0-35	7	20	30	43	clay	7.3	2.6	1.6	2.08	6.6	2.3
	35-85	10	15	30	45	clay	7.5	14.19	1.2	2.7	10	15
	85-150	5	15	33	47	clay	7.3	9.31	1.5	2.5	10	8.1
3	0-35	19.7	32.6	23.5	24.2	Sandy clay loam	8.0	11	1.2	1.3	4.2	10.5
	35-80	28.9	38.7	20.5	11.9	Sandy loam	7.6	2.2	0.95	0.65	6.5	3.1
	80-150	20.6	55.7	13.8	9.9	Sandy loam	7.8	1	0.75	0.66	5.1	2.5
4	0-30	6.3	31.95	16	45.75	clay	7.7	3.2	0.02	2	10.5	5.3
	30-50	9	16.5	19.25	55.25	clay	7.7	2.4	0.01	1.75	10	4.1
	50-70	7.75	19.9	20.35	52	clay	7.7	3.2	0.1	0.6	13	4
	70-150	2.6	23.85	17.65	55.9	clay	7.7	2.2	0.15	0.2	12	3.9
5	0-30	3.15	28.85	20.65	47.35	clay	7.9	1.5	1.1	1.75	1.95	2.1
	30-70	2.15	27.85	19.75	50.25	clay	7.8	1.55	0.5	0.5	1.75	2.3
	70-150	1.65	26	20	52.35	clay	7.4	1.7	0.1	0.2	1.55	4.2
6	0-25	6.25	43.75	17.65	32.35	Sandy clay loam	7.5	5.38	0.95	1.45	6.15	10.1
	25-50	2.45	34.05	25.25	38.25	Clay loam	7.9	3.87	0.7	0.4	6	7.7
	50-90	1.35	23	20.45	55.2	clay	7.2	3.16	0.25	0.1	5.35	8.8
	90-150	1	19.45	21.4	58.15	clay	7.6	3.09	0.2	0.1	5	4.3
7	0-25	2.45	34.65	25.25	37.65	Clay loam	7.3	15.5	0.6	2	5.25	12.4
	25-50	1.3	38.8	21.45	38.45	Clay loam	8.1	1.4	0.4	1.35	4.75	2
	50-150	1.1	34.5	29.15	35.25	Clay loam	8.1	1.6	0.1	0.3	4	3.8
8	0-30	6.35	18.75	25.25	49.65	clay	7.8	1.85	0.65	1.7	7.35	1.8
	30-70	4.35	24.55	19.65	51.45	Clay	7.9	2.56	0.3	1.25	6.15	5.7
	70-150	2	19	20.75	58.25	clay	7.9	5	0.1	0.25	5.45	13.2
9	0-40	6.35	23.85	21.45	48.35	clay	7.2	1.55	0.45	1.85	7.45	2.8
	40-80	3.15	20.9	20.75	55.2	clay	7.7	1.51	0.3	0.8	7.15	5.4
	80-150	2.1	19.9	19.65	58.35	clay	7.6	2.63	0.1	0.2	7	7.1
10	0-40	4.75	24.7	20.25	50.3	clay	7.5	2.91	0.7	1.15	6.45	11.1
	40-80	2.15	23.45	21.8	52.6	clay	7.1	1.39	0.3	0.65	7	2.6
	80-120	2	22.15	20.45	55.4	clay	7.2	3.73	0.35	0.4	7.15	7.2
	120-150	1.8	19.6	21.35	57.25	clay	7.6	1.89	0.25	0.35	7.5	4.7
11	0-30	4.9	35.3	15.2	44.6	clay	7.1	3.77	1.1	2.6	5.2	3.97
	30-90	4.1	11	22.4	62.5	clay	7.1	3.95	0.9	1.4	3.3	6.8
	90-150	4.5	8.3	25.3	61.9	clay	7.2	2.46	2.4	3	2.9	4.2
12	0-25	5.35	30.49	10.88	53.28	clay	7.0	6.6	1.5	1.7	4.5	7.5
	25-90	2.4	4.3	24.7	68.6	clay	7.8	3.39	2.3	2.6	4.5	6.6
13	0-20	7.7	22.4	13.5	56.4	clay	8.2	3.37	1.2	2.3	5.3	6.4
	20-70	2.1	5	21.3	71.6	clay	8.1	3.5	1.3	2.2	4.6	7.3
	70-100	7.95	18.88	6.93	66.24	clay	7.7	4	1.9	1.9	3.1	4.9
14	0-25	3.1	17.82	27.18	51.9	clay	7.7	2.2	1.2	1.7	7.1	4.97
	25-90	6.2	8.4	24.8	60.6	clay	7.7	1.2	1.1	2.9	4.8	3
15	0-30	9.5	10.2	30.7	49.6	clay	7.0	0.96	1.8	2.45	3.1	1.25
	30-100	0.8	6.66	27.84	64.7	clay	7.5	4.9	1.3	1.2	2.9	6.8
	100-150	0.8	7.1	26.4	65.7	clay	7.6	2.8	2.1	2.8	2.5	6.9
16	0-30	9.9	11.6	17.9	60.6	clay	7.6	2	0.9	3.1	3.4	5.3
	30-90	5.6	9.5	19.1	65.8	clay	7.4	3.5	1.2	1.3	4.8	5
	90-150	4.1	6	22.7	67.2	clay	7.6	2.1	0.6	2.9	3.1	2.9
17	0-25	10.3	17.6	20.4	51.7	clay	7.3	1.65	1.1	1.5	5.3	0.93
	25-80	6.3	8.3	22.3	63.1	clay	7.4	1.2	1.4	2.4	5	1.38
	80-150	5.1	8.2	21.9	64.8	clay	7.4	1.3	1.4	3.1	2.9	1.76

Table 2 cont.

Profile No.	Depth, cm	Particle size distribution (%)				Textural class	pH	EC dS.m-1	Gyp. g.kg	OM. g.kg	$CaCO_3$ g.kg	SAR
		Course sand	Fine sand	Silt	Clay							
18	0-25	8.1	13.1	28.2	50.6	clay	7.7	3.3	0.9	2.1	5	6.3
	25-80	3.5	9.4	23.7	63.4	clay	7.8	1.04	1.2	2.4	4.7	1.6
	80-120	3.2	7.7	23.9	65.2	clay	7.8	1.5	0.7	2.7	3	2.3
19	0-30	7.3	5.8	26.1	60.8	clay	7.7	1.25	1.1	1.3	4.9	2.13
	30-80	4.8	7.1	24.6	63.5	clay	7.6	1.9	1.6	0.9	3.2	3.77
	80-110	2.9	6.6	23.8	66.7	clay	7.7	2.65	1.3	2.4	2.7	3.91
20	0-25	7.79	16.89	21.28	54.04	clay	7.9	3.24	1.55	2.14	5.48	5.04
	25-75	5.54	13.87	20.94	59.65	clay	7.8	2.32	1.51	1.62	2.49	4.43
	75-150	3.17	16.75	22.89	57.19	clay	7.7	2.48	2.63	0.77	3.97	6.03
21	0-25	3.75	8.69	26.77	60.79	clay	7.6	1.1	2.91	2.32	2.67	3
	25-70	2.16	9.82	24.12	63.9	clay	7.7	1.27	1.39	1.16	1.85	3.8
	70-150	3.08	6.83	23.87	66.22	clay	7.7	1.44	3.73	0.84	1.42	2.1
22	0-25	4.74	9.23	28.66	57.37	clay	7.5	0.5	1.89	1.79	3.94	0.4
	25-70	3.98	7.44	30.32	58.26	clay	7.6	0.5	0.7	1.41	2.87	0.8
	70-120	2.15	5.93	29.51	62.41	clay	7.8	0.6	0.25	0.95	1.55	1.3
23	0-30	4.1	11.11	31.18	53.61	clay	7.4	1.1	0.2	2.33	3.36	3.7
	30-80	4.2	7.61	33.72	54.47	clay	7.7	0.95	0.6	1.63	3.12	2.4
	80-110	3.63	8.55	30.63	57.19	clay	7.9	1	0.4	0.77	1.25	2.2
	0-30	5.2	15.71	27.32	51.77	clay	7.1	1.93	2.3	0.57	3.6	2.1
24	30-75	4.66	14.83	27.45	53.06	clay	7.1	1.72	1.6	2.14	3.12	3.5
	75-120	3.8	13.3	29.02	53.88	clay	7.7	2	2.1	1.66	2.4	5.6
	120-150	2.6	12.64	28.54	56.22	clay	7.5	2.48	0.9	0.58	0.68	4.3
25	0-30	4.86	14.64	27.44	53.06	clay	7.1	2.09	0.85	1.65	4.14	3.4
	30-80	3.36	13.68	29.12	53.84	clay	7.1	4.92	0.75	2.4	3.18	13.5
	80-130	3.02	12.07	30.66	54.25	clay	7.1	11.02	0.96	0.98	1.45	14.5

2-water table depth

The Water table depth is shown in Fig. 4 and table 3 Indicates that in year 1980 deep water table class covers an 24557.1 ha (58446Fed.), 61%, whereas the moderately deep covered 12613.9 ha (30021fed.) 31.3%, and the shallow water table (mainly in south east and south west) covered 1397.1 ha (3325 fed.) 4.2%. In 2017 the deep water table covered 32371.0 ha (77043 fed.) 80.4%, whereas the moderate water table covered 5276.1 ha (12557 fed.) 13.1 %, there was no shallow the deep water table area increased to become 80.4% of the area. Decision makers must remedy the situation regarding the moderate water table and offer adequate solutions to decrease, the high ground water table.

Table 3. Water table level of Damanhur district

		1980			2017			Change
No	Class	Area /ha	Area/Fed.	%	Area /ha	Area/Fed.	%	%
1	Deep water table	24558.1	58446	61.0	32371.0	77043	80.4	19.4
2	Moderately water table	12613.9	30024	31.3	5276.1	12557	13.1	- 18.4
3	shallow water table	1397.1	3325	3.5	---	----	---	
4	Urban	1677.3	3992	4.2	2599.3	6187	6.5	2.3
	Total	40246.4	95787	100	40246.4	95787	100	

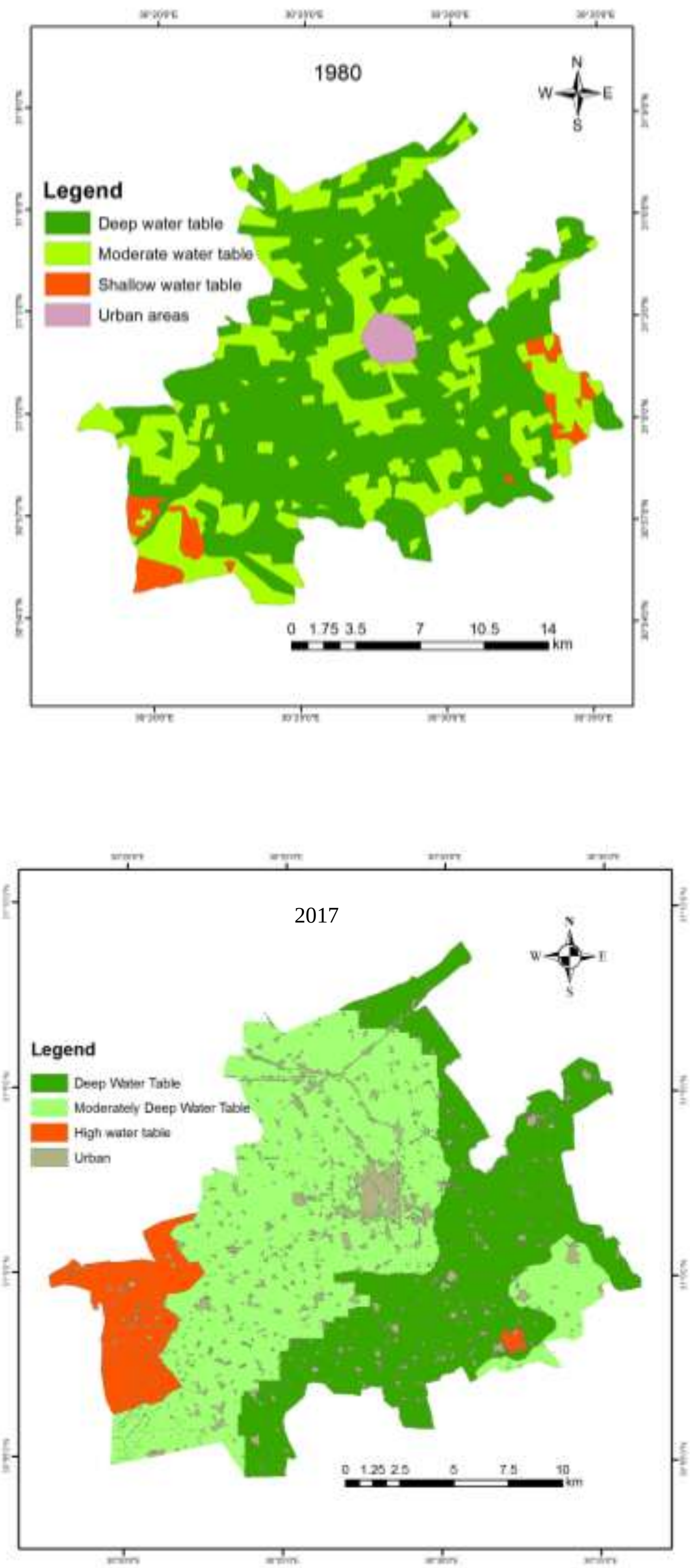


Fig. 4: Water table maps of study area in years 1980 and 2017 respectively

3- Soil alkalinity:

The data shown in table and alkaline map (Table 4 and Fig.5). The study area does not suffer from alkalinity (Table 4) since 2017 on area of 35210.5 ha (83801 fed.) 87.5% was non-alkaline and 2386.1 ha (5679 Fed.) 5.9% was moderately alkaline. Compared with 1980 there was an area of 37678.2 ha (89674 fed.), 93.6% moderately alkaline and 891.2 ha (2121 fed.), 2.2% non-alkaline. This indicates that the soils improved. A small part in east of the study area of 119.5 fed. suffer from alkalinity and 5679 Fed are susceptible to alkalinity.

Table 4: Alkalinity of Damanhur district

		1980			2017			Change
No	class	Area/ha	Area/Fed.	%	Area/ha	Area/Fed.	%	%
1	Non alkaline	891.2	2121	2.2	35210.5	83801	87.5	85
2	Moderately alkaline	37678.2	89674	93.6	2386.1	5679	5.9	- 88
3	Alkaline	-----	-----	-----	50.2	119.5	0.1	0.1
4	Urban	1677.3	3992	4.2	2599.6	6187	6.5	2.3
Total		40246.4	95787	100	40246.4	95787	100	

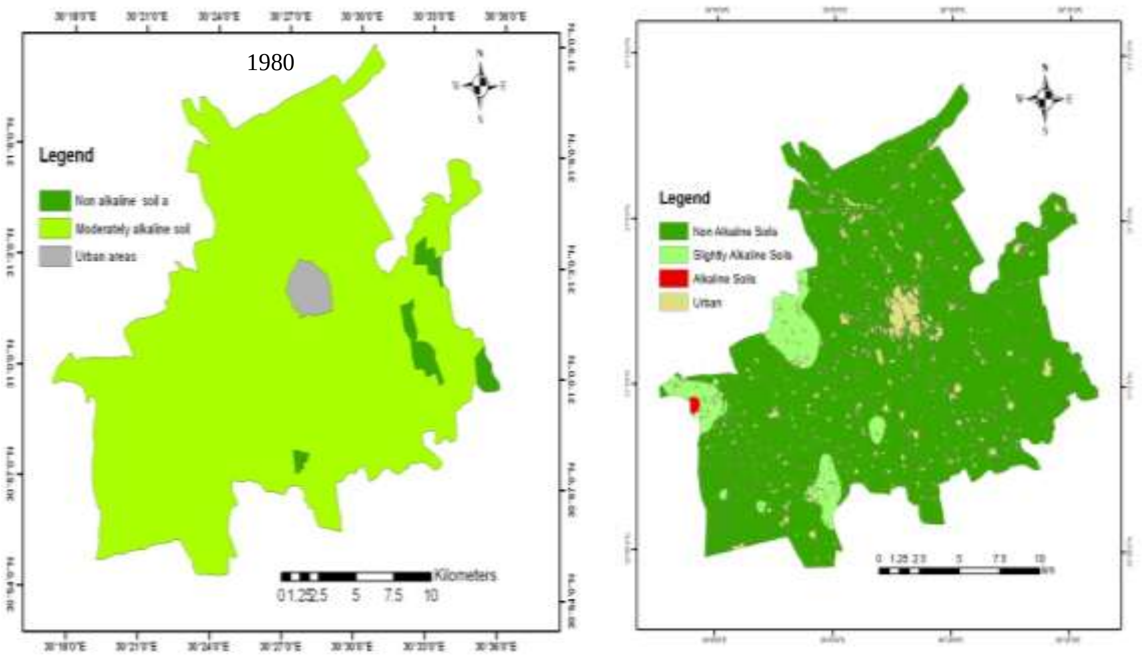


Fig. 5: alkalinity maps of study area in years 1980 and 2017 respectively

4-Land capability assessment (2017)

The land capability model was built using Arc GIS 2017 10.4 software (database) and the resulting tables were used Arc GIS to produce the capability map. Based on the Sys model as shown in Table 5 and Figure (6) there are 3 capability class: S_1, S_2, and S_3, the highly suitable S_1 has no any limitation for agriculture crops, while the moderately suitable S2 class has moderate limitations of texture and salinity. The marginally suitable S3 class has moderate to severe limitations of salinity and moderate water table.

Table 5. Land capability classes of the studied area

Class	**Area/ha**	**Area/Fed.**	**%**
Highly suitable	8264.3	19670	20.5
Moderately suitable	25451.4	60545	63.2
Marginally suitable	3943.3	9385	9.8
urban	2597.4	6187	6.5
Total	**40256.4**	**95787**	**100**

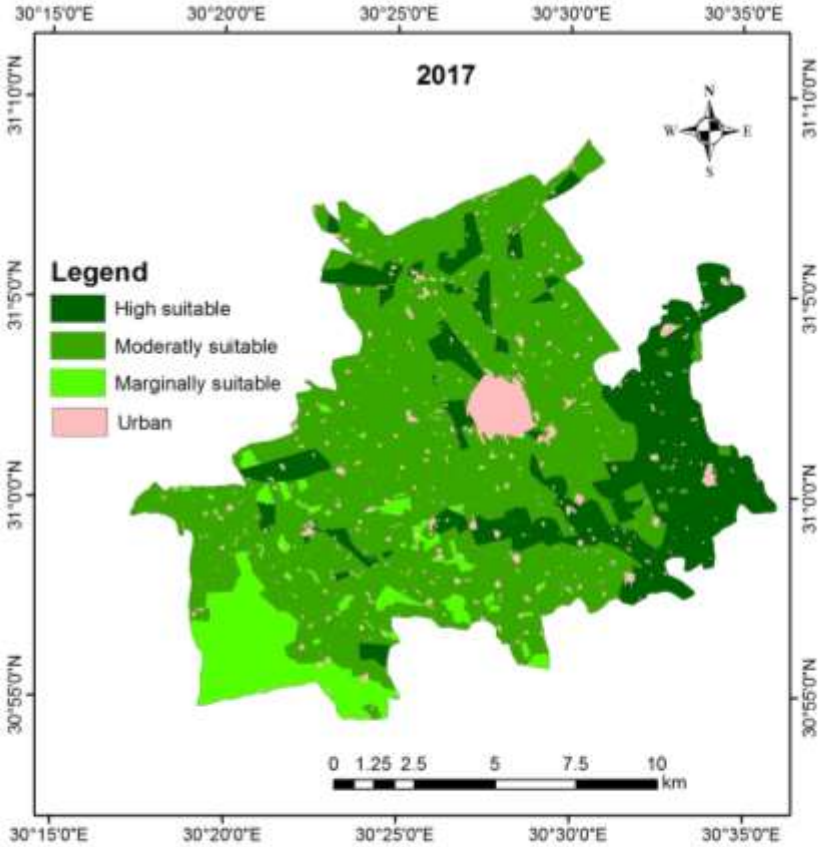


Fig. 6. Land capability map of the studied area

Conclusions and Recommendations

The general trend of the area under study shows improvement in soil salinity and water table level the study gives appropriate geographic database. These technologies were successfully used to generate integrated soil maps which can supply the decision makers with information and help for planning priorities for soils managements. The study recommends general improvement to be done.soils should be improved by constructing drainage networks and adding soil conditioners to avoid soil degradation.

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استخدام نظم المعلومات الجغرافية لدراسة التغيرات فى بعض خواص التربة –مركز دمنهور– مصر

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يقع مركز دمنهور بمحافظة البحيرة على الناحية اليسرى لنهر النيل بفرع رشيد بين خطى طول ″30° 17' 54.42 ، ″30° 36' 27′.96 شرقا وخطى عرض ″30° 54' 51′.1 ، ″31° 7' 59.34 شمالا وقد تم اختياره ليمثل اراضى الدلتا الرسوبية القديمة لنهر النيل.

تتاثر خواص التربة باختلاف الظروف المحيطة بها والعوامل البيئية ومن ثم تتاثر القدرة والكفائة الانتاجية لهذه التربة وقد قام معهد بحوث الاراضى والمياه والبيئة من خلال قسم بحوث حصر الاراضى بدراسة نصف تفصيلية لمحافظة البحيرة فى الثمانينات من القرن الماضى وتضمنت هذه الدراسة معظم صفات التربة الطبيعية والكيميائية وبمرور الزمن وباختلاف العوامل الطبيعية من مستوى الماء الارضى والملوحة وغيرها من الصفات فان خواص التربة تتغير بالتدهور فى حالة عدم اجراء عمليات تحسين للتربة او تزداد قدرتها الانتاجية بالعمل على الحد من المعوقات مثل عمق القطاع الارضى ومستوى الماء الارضى وتركيز الاملاح بالتربة لذا فان العمليه اصبحت ملحة للوقوف على التغيرات التى طرات على التربة ومعرفة سلوك القطاع الارضى باختلاف خواصة ووضع التوصيات الازمة فى حالة حدوث تدهور لتلك الصفات او الاستمرار فى عمليات التحسين.

وكان الهدف الرئيسي من هذه الدراسة هو دمج نظم المعلومات الجغرافية ونتائج التحليلات المعملية لرصد بعض خصائص تطور التربة في الفترة (1980 – 2017)، استخدمت بيانات خرائط التربة السابقة ذات الصلة وتحليلها مع تقنيات نظم المعلومات الجغرافية وتم التعامل معها وتحويلها الى قاعدة بيانات وربطها مع البيانات التي تم جمعها من الحقل والمعمل. وتبين انه انخفضت ملوحة التربة من منطقة الدراسة من 15669 فدان. (16.4٪) إلى 12050 فدان. (12.6٪)، وهذا التحسن النسبي في ملوحة التربة لمنطقة الدراسة بسبب الجهود المبذوله لتحسين التربة من خلال تحسين نظام الصرف الحقلى المغطى، ولا بد ان يواصل صناع القرار في عمليات الصيانة خاصة أن هناك مساحة حوالي 9270 فدان (9.7٪) عرضة للتملح ومساحة 12557 فدان (13.1٪) معرضة لارتفاع منسوب المياه الجوفية. كما تبين ان التربة لا تعاني من القلوية فيما عدا مساحة صغيرة حوالى119 فدان تحتاج الى عمليات تحسين.