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ASSESSMENT AND MAPPING THE SOIL DEGRADATION USING GIS AND DEGRADATION INDICES IN AL REYAD PROVINCE, KAFR EL- SHEIKH GOVERNORATE, EGYPT

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ABSTRACT: ***This study aims to assess and mapping the land capability and soil degradation in Reyad province, Kafr El-Sheikh governorate. To achieve this purpose, satellite images were interpreted and handled using GIS technique. Thirty soil profiles in addition to fifty-six minipits were chosen representing soils of the studied area.***

The soil units of the studied area were created and mapping based on the spatial variability of soil salinity and soil sodicity. The results indicated that, the largest soil unit with about 56.5% of the total studied area is "slightly saline, non-sodic soils". The second unit is the "slightly saline, sodic soils" that occupies about 5% of the studied area. In addition, "moderately saline, non-sodic soils" unit occupies 3.5% from studied area as small patches. Another "moderately saline, sodic soils" unit covers about 2.3%. The smallest unit is "highly saline, sodic soils" that covers about 1% of the total studied area. The variations between soil units are rendered mainly to the using of agricultural drainage water in irrigation.

The capability evaluation indicated that, the studied area have two classes. The first class is the "moderately suitable for agriculture" S2 that occupies 67% of the area and affected with texture as a main limiting factor. The second class is the "marginally suitable" S3 that found in 1% from the area and suffering from texture, salinity and sodicity as main limiting factors

Studied Chemical Degradation Indices (CDI) vary from very low to high. The largest class includes the moderate degraded soils that covers about 42% of the studied area. The soils having low CDI covers about 14%. About 11 % of the total studied area have a high CDI. The remaining are fishpond (29.98 %) and urban areas (2.07 %).

Studied Biological Degradation Indices (BDI) indicated that the largest area (40%) could be affiliated to the moderate Biological Degradation class that having low organic matter content because of the prevailing semiarid conditions.

Key words: ***Soil unit, land capability evaluation, suitability for agriculture, chemical & biological degradation, GIS.***

INTRODUCTION

Different forms of land degradation affect many of the old agricultural soils of Egypt. The chemical soil degradation is one from these forms noticed and revealed in the irrigated soils of the Nile Delta by many soil researchers (Abdel Kawy and Ali 2012, Shalaby *et al.* 2012, Wahab *et al.* 2010).

Land degradation is the process of reducing land suitable for agricultural purposes especially in arid, semi-arid and sub-humid areas as a result of human activities and climatic variations (Barbero-Sierra *et al.,* 2015) and eventually puts livelihoods and sustainable development at risk (Fleskens and Stringer, 2014). It is the alteration in ecological and economic functions due to

the decrease in the productivity and quality of the land (Hill *et al.,* 2005). Soil salinization is a common occurrence in semiarid and arid regions, where evapotranspiration exceeds rainfall, resulting in accumulation of salts in the root zone (Derici, 2002).

Under Mediterranean conditions, soil can lose its potential productivity mainly due to salt accumulation or sodicity. Soils with high soluble salt content or high exchangeable sodium or with a low cation exchange capacity will correspond to the soils with a higher chemical degradation. This could be rendered to natural conditions and/or human activity (De Paz *et al.* 2006). From this prospective, finding procedure to control land degradation is an urgent need. The first process of this procedure involves in identification and assessment of the land degradation status. The second is establishing a strategy to combat soil degradation. Several methods have been developed to provide a procedure for land degradation assessment. Such methods have been proposed as expert opinion, remote sensing, field monitoring, and productivity measurements as efficient for the assessment of degraded land. There is no single standardized method for assessment of soil degradation (Tetteh, 2015).

Organic matter is the main nutrient source for plants and microorganisms. Biological degradation Index (BDI) is related to the depletion of organic matter content (De Paz *et al.* 2006).

The objectives for this study are: (a) Evaluate and mapping the land capability of the studied area. (b) Assess and mapping soil degradation status in Reyad province, Kafr El Sheikh governorate.

MATERIALS AND METHODS

1. Location

The studied area is located in Al Reyad province, Kafr El Sheikh governorate located at the north of Nile delta. It is bounded by El-Burlus Lake at the North, Kafr El-Sheikh province at the south, Al Hamol province at the east and Sedi Salem at the west, with an area of about 80377 Feddans (Fig., 1).

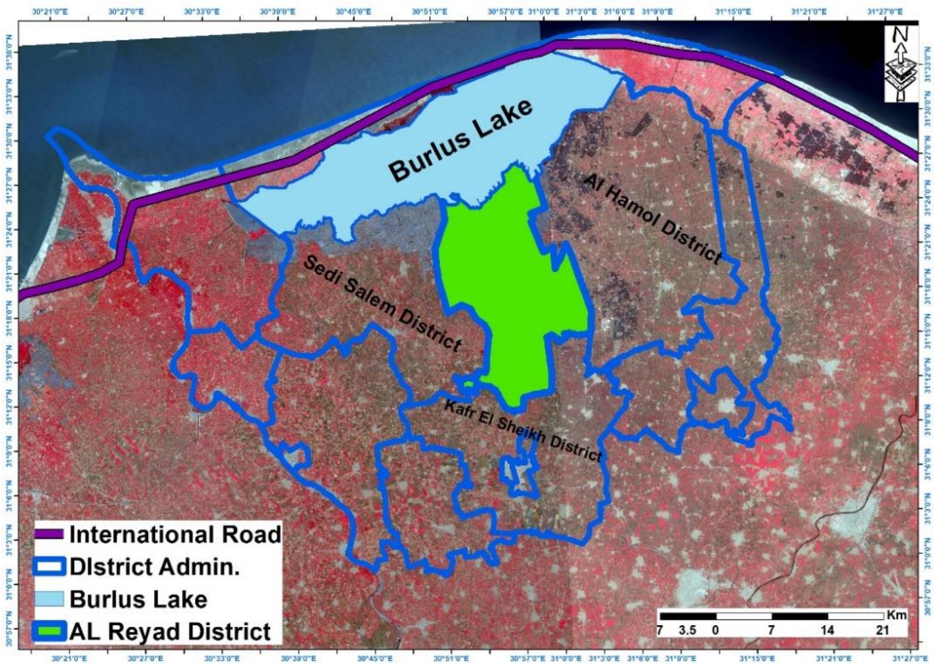

Fig. (1): Location map of the studied area.

2. Satellite data:

Data of Sentinel 2 dated in April 2018 with spatial resolution of 10 m and spectral resolution of the bands 5, 3 and 2 were used for visual interpretation of the studied area (Fig., 2).

Color enhancement operations were used to create new images which is increased the amount of information that can be visually interpreted from the data (Daels, 1986).

Universal Transverse Mercator projection (UTM) was used as a main projection of all data and output maps (Daels, 1986).

The geo-statistical analysis techniques were used to create Digital Elevation Model (DEM) using the semi-variogram parameters (Stein, 1998) of contour lines and spot heights.

3. Field Work:

Thirty soil profiles were selected and 56 minipits were collected (eighty-six soil observation sites) to represent the soils of the studied area. The soil profiles were morphological described according to FAO (2006). Soil samples were collected from different layers of soil profiles in addition to the minipits for laboratory analyses.

Water samples were collected from the 4 main drain canals in the studied area.

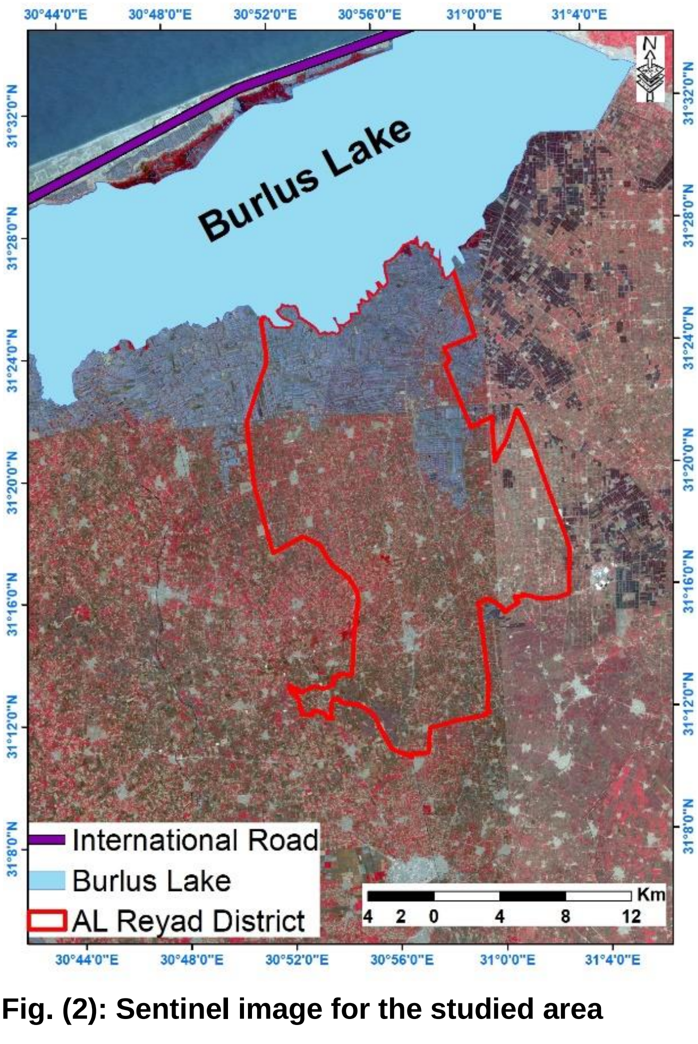

Fig. (2): Sentinel image for the studied area

4. Laboratory Analyses:

The collected soil samples were air dried, crushed and prepared for laboratory analyses, to determine soil chemical and physical properties according to Soil Survey Staff (2004). These properties were particle size distribution, soil pH, electrical conductivity (ECe) in the soil paste extract, cation exchange capacity, exchangeable sodium percentage (ESP) and organic matter content (OM).

Drainage water samples were analyses to determine some chemical properties according to Soil Survey Staff (2004). These included the electric conductivity (ECe), soluble cations and anions and SAR. Suitability of water for irrigation was determine according to the limitations outlined by FAO (1985).

5. Land Capability Evaluation:

Land capability was evaluated as suitability for agriculture according to FAO (1985), Sys and Verheye (1978) and Sys et al. (1991). The following equation was used to calculate the capability index Ci:

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

Where:

Ci = Capability index (%), t = Slope, w = Drainage status, S_1 = Texture, S_2 = Soil depth and n = Salinity and alkalinity

The capability classes were defined according to the values of this index (Sys, 1991) as follows:

Capability index (Ci) %	Capability classes	
> 75	S1	highly suitable for agriculture.
75-50	S2	moderately suitable
50-25	S3	marginally suitable
< 25	N	not suitable

6. Soil degradation assessment:

The parameters of geo-statistical approach of the surface layers (eighty-six soil samples) were dealt with Arc GIS 10.3 to produce the maps for distribution of soil salinity, sodicity and organic matter in the studied area. From the semi-variogram operation, it could be possible define which models fitted to the experimental semi-variogram values. Parameters of the best fitting model were used to interpolate the thematic soil properties based on ordinary Kriging prediction (Stein, 1998).

The degraded status is better represented by an index for each degradation process. However, these indices should be as simple as possible (De Paz *et al.* 2006). Chemical and biological soil degradation indices were selected based on the methodology developed by FAO (1980), and applied by Sanchez et al. (1998 and 1999) and De Paz *et al.* (2006) within the Mediterranean region.

Statistical analysis was done using SPSS program, version 17.0 (2008) was used to test the relation between field capacity and the clay content %, silt content %, sand content, cation exchange capacity, electrical conductivity, exchangeable sodium values of soil samples. The system provides a selection of top quality statistics and a high resolution graphics.

Chemical degradation index (CDI):

Chemical degradation index was calculated using the following equations:

$$\mathrm{CDI} = \frac{\mathrm{Salts} + \mathrm{Na}}{\mathrm{CEC}} \quad \ldots eq.1 \ (\mathrm{FAO}, 1980)$$

Salts (meq/100g) = (13.5 X EC_e X Hs)/1000 ……..…. *eq.2* (De Paz *et al.*, 2006)

Hs = 28.215 + 6.09 X OM + 0.243 X Clay (%) – 0.11 X Sand (%)… *eq.3* (De Paz *et al.*, 2006)

Where: Salts is soluble salt content (meq $100g^{-1}$), Hs is soil water content % at saturation, Na is exchangeable sodium (meq $100g^{-1}$), EC_e is soil electrical conductivity (dS m^{-1}), OM is organic matter content (%), and CEC is cation exchange capacity (meq 100^{-1} g).

The multi regression operation was used to determine the formula for the field capacity. Based on the correlation between the soil properties of profiles with the results of field capacity, multi regression formula was created to estimate the field capacity of the minipits. The linear regression model applied on this study assumes that, the M mean of the response variable Y depends on the explanatory variable X according to a linear equation. In the multiple setting, the response variable Y depends on not one but B explanatory variables. The mean response is a linear function of the explanatory variables as following:

$$M\,Y = B_0 + B_1X_1 + B_2X_2 + \ldots + BpXp$$

MY is the mean estimated field capacity, B0, B_1, B_2 and B_p are constants, X_1, $X_{2,\ldots}$ X_p are the significant of the relation analysis of soil properties.

Biological degradation index (BDI): **Biological degradation is related to the high decomposition rate of organic matter under semiarid conditions. Organic matter (OM) is one of the main nutrient sources for plants and microorganisms. It affects soil aggregation and prevents crusting (De Paz *et al.* 2006). BDI considers organic matter content alone as the main factor of biological degradation.**

$$\mathbf{BDI} = \frac{\mathbf{1}}{\mathbf{OM}} \quad \ldots\ldots\ldots eq.4 \ (\mathbf{FAO - 1980})$$

Description of the chemical and biological degradation degree was indicated according to the rating assigned in Table (1).

RESULTS AND DISCUSSION

1. Digital Elevation Model (DEM)

Fig. (3) shows that, the elevation of the southern studied area ranged from 1.3 to 4.3 meter above sea level. The areas located adjacent to Burlus Lake have low elevation between 0.0 and 0.6 meter above sea level. There are some scattered areas having relatively high elevation areas are found inside the low lands in the north and northwest parts.

2. Land cover

The visual interpretation of sentinel satellite image and field check were used to produce land cover map dated in 2018 and presented in Fig. (4) and Table (2).

Table (1): Degree and index ratings of soil chemical and biological degradation (De Paz *et al.,* 2006).

Degradation degree	Chemical degradation index	Biological degradation index
Very low	0-0.0081	0- 0.3
Low	0.0081-0.021	0.3 - 0.6
Moderate	0.021-0.046	0.6-1
High	0.046-0.085	1- 2.5
Very high	> 0.085	> 2.5

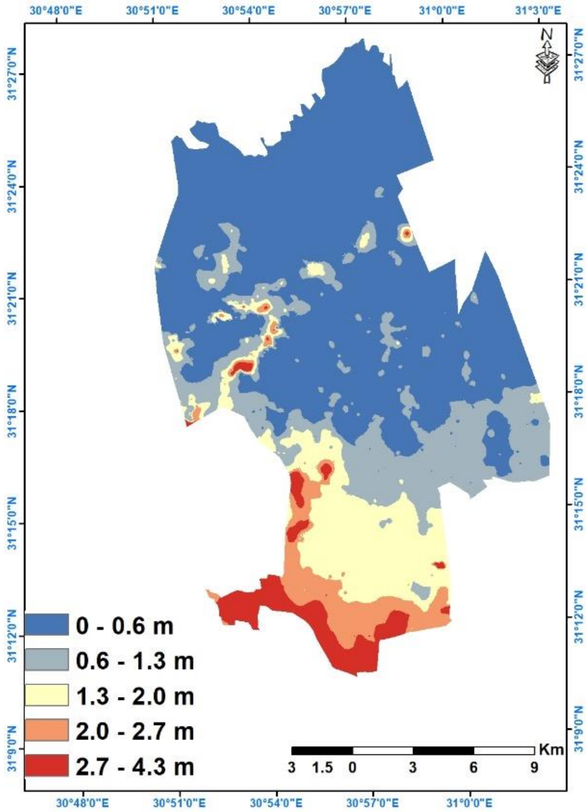

Figure (3). Digital Elevation Model (DEM) of the studied area

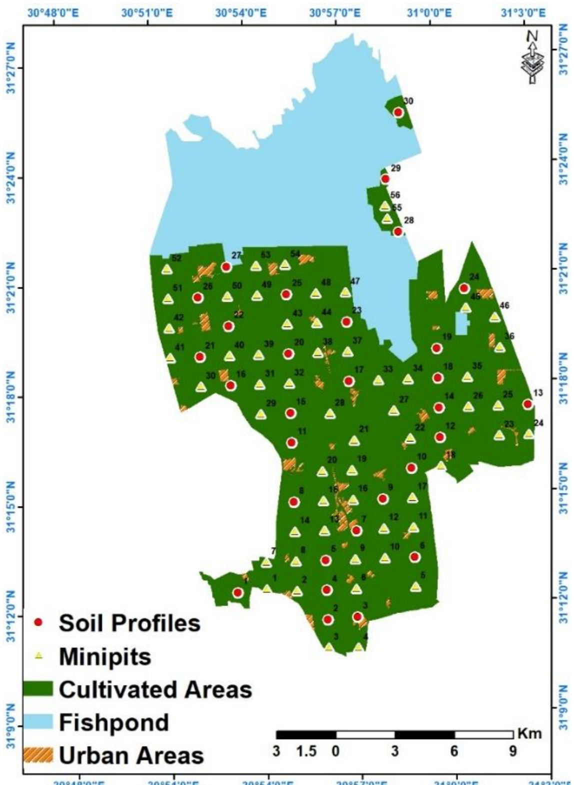

Fig. (4): Land cover map with observation soil points for the studied area

Table (2): Areas of the main classes of land cover

Classes	Area in Feddan	%
Cultivated Areas	54616	67.95
Fishpond	24096	29.98
Urban Areas	1665	2.07
Total	80377	100.00

Feddan = 4200 m^2

3. Soil characteristics

Data in Tables (3 and 4) indicated that, these soils are very deep (> 120 cm in depth). The dominant soil texture is clay as clay content ranges from 41.3 to 67.2 %. The ECe values ranged between 0.2 and 12.6 dS m^{-1} indicating that, these soils are slightly to highly saline. The soils have alkaline reaction with pH values between 7.2 and 8.6. Exchangeable sodium percentage ranged from 4 to 27%. CEC ranged between 32.4 to 58.1 meq. $100g^{-1}$. Organic matter content is vary between 0.07 and 3.5 %.

4. Produce thematic maps of the studied area:

Soil salinity map

Soil salinity map was produced using geo-statistical approach for the 86 surface layer samples of the studied area. The salinity classes of the studied soils according to Soil Survey Staff (2004) are given in Table (5) and illustrated as salinity map in Fig. (5). Accordingly, ECe values ranged from 0.2 to 12.62 dS m^{-1} with mean of 1.9. and standard deviation of 2.05 %. The slightly saline soils cover about 61 % of the total studied area. The moderately and highly saline soils represent an area of about 7% of the studied area.

Soil sodicity map

ESP values for the surface layers of the studied area (Tables, 3 and 4) are ranged between 0.84 and 29.75 with mean of 9.75 and standard deviation of 6.31 %. Accordingly, the sodicity classes of these soils are presented in Table (6) and their map is shown in Fig. (6). Data in Fig. (6) and Table (6) indicated that, the non-sodic soils have ESP < 15% cover about 60 % of the total studied area. The sodic soils having ESP > 15 cover about 8 % of the total studied area.

Organic matter map

Organic matter (OM) content of the studied surface soil samples was ranged between 0.53 % and 3.5% within average of 1.6 % (Tables, 3 and 4). The standard deviation is 0.61%. Studied soil classes according their OM contents are presented in Table (7) and illustrated in Fig. (7). The results indicated that the class of soils having low OM contents cover 55.5 % of the total studied area. The soils class having medium OM class cover 12.2 %.

5. Land capability evaluation

A land capability model for the resulted database was built using Arc GIS 10.3 software to produce the land capability classes and map based on Sys *et al.,* (1991) model (Fig., 8 and Table, 8). Accordingly, the studied soils were classified into two capability classes, i.e. S2 and S3. The soils of S2 class are moderately suitable for agriculture that affected with texture as main limiting factor. This soil class contains area of 53867 Feddans (67 % of the total area). The soils of marginally suitable S3 class occupies an area of 749 Feddans (1 %) that having texture, salinity and sodicity as main limiting factors.

Table (3): Some chemical and physical properties for soil profiles of the studied area

Prof. No	Depth	pH	ECe dSm-1	Sand %	Silt %	Clay %	Texture	FC * %	OM %	Ex Na meq $100g^{-1}$	CEC meq $100g^{-1}$	ESP
1	0-25	7.7	0.45	33.5	45.8	20.7	L	40.0	0.97	1.5	25.9	5.8
	25-50	8.1	0.44	20.4	22.8	56.8	C	75.4	0.90	2.7	48.4	5.6
	50-125	8.1	0.58	6.4	25.4	68.2	C	82.1	1.10	2.3	56.4	4.1
	125-150	8.1	0.46	6.5	28.1	65.4	C	82.1	0.58	3.5	56.4	6.1
2	0-25	7.7	0.60	13.2	34.3	52.5	C	74.0	1.36	2.5	46.5	5.4
	25-75	7.3	0.41	13.3	34.6	53.1	C	74.0	0.75	2.0	46.5	4.4
	75-150	7.6	0.51	13.7	34.7	51.6	C	74.0	0.61	3.2	45.1	7.1
3	0-25	7.7	0.52	8.8	36.9	54.3	C	74.0	1.40	3.2	49.4	6.4
	25-75	7.6	0.68	24.6	33.8	41.6	C	66	0.85	3.4	36.8	9.2
	75-130	7.6	0.90	21.9	36.6	41.5	C	66	0.75	5.0	36.8	13.6
4	0-25	7.6	1.65	24.3	34.4	41.3	C	67.0	1.36	3.8	35.9	10.6
	25-75	7.4	1.15	19.5	37.7	42.8	C	66	0.75	3.4	35.9	9.6
	75-150	7.4	1.13	25.9	32.6	41.5	C	66	0.48	3.6	35.9	9.9
5	0-25	7.9	1.06	14.4	22.3	63.3	C	81.0	1.96	2.6	55.8	4.6
	25-75	8.2	0.32	17.5	23.0	59.5	C	80.0	0.78	1.0	51.1	2.0
	75-120	8.2	0.33	17.5	25.0	57.5	C	78.0	0.42	0.8	50.9	1.5
6	0-20	7.8	0.55	24.3	34.8	40.9	C	67.0	0.98	2.2	36.7	6.1
	20-70	7.5	0.63	22.5	35.9	41.6	C	67.5	0.58	2.8	36.7	7.5
	70-130	7.7	1.13	4,50	37.8	57.7	C	77.3	0.31	6.7	51.2	13.2
7	0-20	7.2	0.53	16.8	39.0	44.2	C	69.0	0.62	1.0	39.9	2.5
	20-70	7.2	0.58	16.3	38.2	45.5	C	70.0	0.91	0.9	39.9	2.2
	70-120	8.0	0.59	14.5	39.3	46.2	C	70.0	0.53	0.9	39.9	2.2
8	0-25	7.8	3.75	14.3	25.4	60.3	C	80.0	1.87	4.1	52.3	7.8
	25-75	8.0	0.50	14.0	23.5	62.5	C	80.3	0.79	1.7	53.1	3.2
	75-120	8.1	0.89	17.3	25.4	57.3	C	79.0	0.62	2.2	50.3	4.4
9	0-20	7.9	0.34	13.2	39.1	47.7	C	72.0	0.85	0.8	41.3	2.0
	20-70	7.9	0.39	16.2	38.3	45.5	C	70.0	0.79	1.0	40.6	2.5
	70-120	7.9	0.65	18.3	37.0	44.7	C	69.0	0.59	1.2	40.6	3.0
10	0-30	7.7	1.79	13.3	34.2	51.7	C	74.0	2.13	6.0	46.7	12.8
	30-60	7.8	2.43	11.5	33.7	54.8	C	69.0	0.87	8.8	47.9	18.5
	60-90	7.7	3.46	11.6	35.8	52.6	C	69.0	0.85	12.1	46.7	25.9
	90-150	7.8	1.20	6.5	36.3	57.2	C	69.0	0.35	2.9	50.1	5.7

L = Loam, CL= Clay Loam and C = Clay   FC*= Lap. Field Capacity

Table (3): Cont.

Prof. No	Depth	pH	ECe dSm-1	Sand %	Silt %	Clay %	Texture	FC * %	OM %	Ex Na meq $100g^{-1}$	CEC meq $100g^{-1}$	ESP
11	0-30	7.7	1.06	11.2	22.2	54.9	C	69.0	2.65	4.7	47.9	9.9
	30-70	7.6	0.67	11.5	11.5	54.8	C	74.0	0.86	2.8	47.9	5.8
	70-150	7.4	0.58	11.6	11.6	52.6	C	73.0	0.65	2.3	45.9	5.1
12	0-35	7.7	1.27	9.4	34.7	55.9	C	76.0	2.46	2.7	50.1	5.3
	35-75	7.7	1.18	9.9	34.9	55.4	C	77.0	0.19	4.9	50.1	9.7
	75-150	7.7	1.43	9.5	35.7	54.8	C	75.0	0.61	7.0	50.1	14.0
13	0-30	8.7	2.10	11.4	33.7	54.9	C	75.0	1.99	9.8	50.9	19.3
	30-85	8.4	1. 04	26.5	34.7	38.8	C	64.0	0.95	4.4	33.1	13.2
	85-130	8.4	1. 04	12.5	33.6	53.9	C	74.0	1.74	6.7	50.9	13.2
14	0-30	7.6	1.40	9.7	35.8	54.5	C	70.1	1.92	4.7	50.1	9.4
	30-70	7.6	2.04	19.5	36.6	43.9	C	66.2	1.10	4.1	36.7	11.1
	70-150	7.6	1.92	9.5	35.8	54.7	C	75.0	0.53	5.0	49.1	10.2
15	0-25	7.7	1.26	11.5	11.5	52.8	C	74.2	1.41	3.7	44.7	8.2
	25-50	7.4	0.89	11.6	11.6	54.7	C	75.0	0.41	3.1	48.5	6.4
	50-100	7.6	0.90	19.4	19.4	42.8	C	66.1	0.31	2.5	37.1	6.7
16	0-30	7.8	2.78	4.3	37.9	57.8	C	77.0	1.32	14.1	50.3	28.0
	30-75	7.8	3.38	4.7	37.9	57.4	C	77.1	1.18	11.2	50.3	22.2
	75-150	7.5	3.69	13.2	34.3	52.5	C	74.1	0.77	12.1	47.6	25.5
17	0-30	7.8	0.69	13.2	34.3	52.5	C	75.2	1.68	2.5	47.1	5.3
	30-80	7.8	0.81	13.6	34.7	51.7	C	74.0	1.50	3.5	47.1	7.4
	80-150	7.9	0.81	21.9	36.6	41.5	C	65.0	0.98	4.2	36.9	11.5
18	0-30	7.7	2.48	19.3	36.8	43.9	C	67.0	1.40	5.7	36.3	15.8
	30-80	7.7	3.24	23.3	33.4	43.3	C	67.1	0.91	6.4	36.3	17.5
	80-150	7.7	3.58	25.3	33.8	41.9	C	66.9	0.77	6.7	36.3	18.4
19	0-30	7.5	1.60	25.8	33.9	41.3	C	66.1	1.56	3.5	37.1	9.5
	30-60	7.6	3.39	22.9	33.8	41.3	C	66.3	1.01	4.2	37.1	11.2
	60-100	7.8	1.97	19.3	33.8	43.9	C	67.1	0.59	3.8	37.1	10.1
20	0-30	7.8	1.54	4.4	36.9	58.7	C	79.1	1.58	6.6	51.1	12.9
	30-60	7.6	1.60	23.7	33.7	42.6	C	67.1	0.63	5.9	37.3	15.8
	60-90	7.7	1.36	25.3	33.8	40.9	C	65.1	0.80	6.1	37.3	16.4
	90-150	7.9	1.36	24.9	33.6	41.5	C	65.1	0.21	6.1	37.3	16.4
21	0-30	7.5	1.20	4.7	34.7	60.6	C	80.1	1.59	5.8	51.5	11.3
	30-80	7.4	2.40	3.7	34.8	61.8	C	80.1	1.02	2.0	51.5	3.8
	80-130	7.7	3.00	1.5	36.7	61.8	C	80.1	0.95	5.0	51.5	9.8

Table (3): Cont.

Prof. No	Depth	pH	ECe dSm-1	Sand %	Silt %	Clay %	Texture	FC * %	OM %	Ex Na meq $100g^{-1}$	CEC meq $100g^{-1}$	ESP
22	0-25	7.5	1.03	12.6	34.6	52.8	C	75.2	1.14	4.4	46.1	9.5
	25-55	7.7	4.48	19.5	37.9	42.6	C	66.2	0.83	0.6	37.2	1.6
	55-90	7.5	3.84	20.5	37.6	41.9	C	66.2	0.57	0.4	37.2	1.1
	90-120	7.6	3.95	19.3	37.9	42.4	C	66.2	0.47	0.6	37.9	1.5
23	0-35	7.7	1.23	20.5	37.6	41.9	C	65.1	1.08	2.9	35.6	8.1
	35-75	7.7	1.76	20.4	37.8	41.8	C	65.1	1.01	3.3	35.6	9.3
	75-150	7.9	1.76	4.4	36.9	58.7	C	79.1	0.77	4.5	50.9	8.9
24	0-25	8.6	11.86	12.5	34.6	52.9	C	74.2	1.43	9.7	46.9	20.7
	25-70	8.6	11.93	22.8	34.6	42.6	C	66.1	1.32	7.7	37.7	20.5
	70-130	8.4	11.56	11.4	33.9	54.7	C	75.0	1.27	11.8	48.1	24.6
25	0-30	7.4	2.65	4.4	36.9	58.7	C	79.2	0.80	9.0	51.4	17.5
	30-60	7.7	5.16	6.6	36.6	56.8	C	76.5	0.56	10.2	50.6	20.2
	60-90	7.6	3.75	12.5	33.8	53.7	C	74.0	0.28	25.1	49.7	50.6
	90-150	8.2	5.47	23.6	33.7	42.7	C	66.5	0.07	19.2	38.9	49.3
26	0-25	7.9	0.76	4.8	34.7	60.5	C	80.1	2.27	3.7	51.7	7.1
	25-70	7.9	1.01	3.4	33.9	61.8	C	80.1	0.75	6.1	51.7	11.9
	70-120	8.5	0.86	1.9	36.8	61.3	C	80.1	1.02	3.9	51.3	7.6
27	0-30	7.5	1.76	4.5	37.7	57.8	C	77.3	1.58	3.4	51.1	6.7
	30-60	7.5	2.66	6.5	37.6	55.9	C	75.1	1.10	7.4	51.0	14.5
	60-90	7.5	3.02	7.5	37.7	54.8	C	75.1	0.93	4.8	47.9	10.0
	90-150	7.4	2.82	12.5	34.8	52.7	C	74.0	0.38	7.4	48.1	15.5
28	0-30	7.7	2.94	23.2	33.4	43.4	C	67.0	2.98	11.0	36.9	29.8
	30-60	7.7	5.85	11.5	34.7	53.8	C	74.0	2.05	23.2	48.3	48.0
	60-110	7.9	2.17	12.5	34.6	52.9	C	74.0	1.82	4.1	48.3	8.4
	110-150	7.6	2.63	11.5	33.7	54.8	C	75.0	0.87	9.5	48.3	19.7
29	0-30	8.6	2.70	24.4	32.9	42.7	C	67.0	1.81	4.6	36.9	12.5
	30-60	8.5	2.80	23.5	33.6	42.9	C	67.0	1.62	6.3	36.9	17.1
	60-100	8.4	2.19	3.5	33.8	62.7	C	81.0	0.95	9.8	53.9	18.2
30	0-25	8.2	1.93	6.3	33.8	59.9	C	80.1	1.12	10.1	52.5	19.3
	25-70	8.2	10.54	4.6	33.9	61.5	C	80.1	1.10	10.2	53.7	19.1
	70-130	8.6	11.81	19.3	33.9	43.8	C	66.9	0.96	10.9	40.1	27.2

Table (4): Some chemical and physical properties for minipits in the studied area

Min. No	Depth	pH	ECe dSm-1	Sand %	Silt %	Clay %	Texture*	FC** %	OM %	Ex Na meq $100g^{-1}$	CEC meq $100g^{-1}$	ESP
1	0-30	8.3	0.66	17.6	25.4	55.8	C	75.1	1.36	1.8	50.8	3.6
2	0-30	8.2	0.74	24.6	35.4	33.0	C L	55	1.24	2.1	24.1	8.7
3	0-30	7.8	0.40	13.6	34.8	52.6	C	74	1.16	2.1	47.3	4.5
4	0-30	7.5	0.64	18.8	37.5	43.7	C	68	1.77	2.4	36.1	6.7
5	0-30	7.8	0.57	24.4	33.7	41.9	C	67	0.98	0.7	35.7	2.1
6	0-30	7.8	1.09	21.3	36.8	41.9	C	67	2.90	4.0	36.8	10.9
7	0-30	8.2	0.31	11.0	21.8	67.2	C	82	1.88	0.5	55.1	0.8
8	0-30	8.0	0.20	14.5	25.0	60.5	C	80	1.92	0.5	55.1	0.8
9	0-30	7.8	0.77	23.6	34.8	41.6	C	66	0.95	3.5	36.7	9.5
10	0-30	7.3	0.92	11.5	33.7	54.8	C	75	1.53	4.6	49.1	9.4
11	0-30	7.9	0.61	4.8	37.7	57.5	C	78	0.75	2.8	51.6	5.5
12	0-30	8.0	0.41	18.7	39.8	41.5	C	66	1.30	1.1	35.9	3.1
13	0-30	8.1	1.53	19.5	20.5	60.0	C	80	2.11	3.5	51.3	6.8
14	0-30	8.3	12.62	11.5	23.2	65.3	C	85	2.02	15.9	58.1	27.3
15	0-30	7.7	2.18	18.5	26.0	55.5	C	75	1.96	3.4	49.9	6.8
16	0-30	8.0	0.48	13.9	38.6	47.5	C	71	0.53	0.9	32.9	2.7
17	0-30	8.0	2.64	18.8	40.7	40.5	Si C	65	0.62	1.3	31.7	4.0
18	0-30	7.9	1.91	11.7	35.6	52.7	C	67	2.02	7.1	46.7	15.3
19	0-30	8.1	1.09	7.8	36.6	55.6	C	73	1.50	3.7	49.1	7.6
20	0-30	7.8	1.03	18.5	37.6	43.9	C	68	0.73	3.4	32.9	10.4
21	0-30	8.1	0.67	6.4	36.8	56.8	C	77	2.38	2.6	49.1	5.3
22	0-30	7.8	1.87	13.2	34.5	53.3	C	76	1.42	7.4	44.9	16.5
23	0-30	8.3	2.92	9.5	33.8	56.7	C	78	2.32	6.4	44.9	14.3
24	0-30	8.3	3.31	24.5	33.8	41.7	C	67	2.28	5.0	34.8	14.5
25	0-30	8.1	2.06	14.7	32.7	52.6	C	74	2.33	2.2	44.7	4.9
26	0-30	8.6	2.24	12.6	34.5	52.9	C	74	3.50	3.5	43.2	8.2
27	0-30	7.7	1.68	4.4	36.9	58.7	C	79	1.06	3.9	45.8	8.6
28	0-30	7.8	1.57	12.5	34.7	42.8	C	68	0.98	3.1	32.7	9.5
29	0-30	8.0	1.52	4.5	36.9	58.6	C	79	1.51	5.3	51.6	10.3

CL= Clay Loam, SiC = Silty Clay and C = Clay   **FC = Estimated Field Capacity

Table (4): Cont.

Min. No	Depth	pH	ECe dSm-1	Sand %	Silt %	Clay %	Texture*	FC** %	OM %	Ex Na meq $100g^{-1}$	CEC meq $100g^{-1}$	ESP
30	0-30	7.7	1.20	4.4	34.7	60.9	C	80	2.27	6.4	52.1	12.4
31	0-30	7.5	5.36	12.6	33.7	53.7	C	77	1.20	11.7	51.8	22.7
32	0-30	7.5	1.56	19.6	33.8	42.6	C	67	1.51	3.7	37.1	9.9
33	0-30	7.6	1.11	11.5	33.9	54.6	C	75	1.77	4.8	48.1	9.9
34	0-30	7.7	1.01	25.5	33.7	41.8	C	66	1.46	2.0	34.9	5.6
35	0-30	8.5	5.01	5.7	34.7	59.6	C	80	1.31	3.2	45.9	7.1
36	0-30	8.4	4.72	12.9	33.6	53.5	C	74	2.72	4.3	44.6	9.7
37	0-30	7.9	0.89	4.9	37.7	50.8	C	73.5	1.68	2.7	45.7	5.9
38	0-30	8.5	0.99	23.5	33.7	42.8	C	67	1.85	2.2	32.5	6.9
39	0-30	7.5	1.56	19.6	33.8	42.6	C	68	1.51	3.3	33.4	9.9
40	0-30	7.5	6.45	4.4	36.9	58.7	C	79	0.87	13.8	51.1	27.0
41	0-30	7.8	0.79	4.6	34.9	60.2	C	80	1.44	4.0	51.5	7.8
42	0-30	7.8	0.62	4.7	34.8	60.5	C	80	0.76	2.9	52.3	5.5
43	0-30	8.0	2.38	8.9	36.8	54.3	C	74.5	0.66	8.7	47.9	18.2
44	0-30	8.2	0.64	19.5	36.8	43.7	C	69	1.05	1.6	32.5	4.9
45	0-30	8. 03	3.42	10.8	34.5	54.7	C	75	1.76	2.1	45.4	4.5
46	0-30	8.3	1.78	11.4	33.7	54.9	C	75	1.73	2.2	45.1	4.8
47	0-30	7.8	0.88	8.5	36.8	54.3	C	74	1.85	3.3	48.1	6.9
48	0-30	7.9	1.54	23.2	33.9	42.9	C	68	1.71	2.5	32.4	7.8
49	0-30	7.3	6.45	10.3	33.9	55.8	C	76	1.41	11.1	47.9	23.3
50	0-30	7.5	4.39	23.8	34.8	41.4	C	66	0.87	0.5	33.7	1.6
51	0-30	7.6	2.30	3.9	35.7	60.4	C	80	1.13	2.2	52.1	4.2
52	0-30	7.5	1.10	4.8	34.7	60.5	C	80	2.64	2.6	51.5	5.1
53	0-30	7.6	1.18	12.5	12.5	53.7	C	74	1.82	7.5	47.7	15.7
54	0-30	8.0	1.45	25.4	33.8	41.8	C	66	2.48	4.9	33.5	14.6
55	0-30	7.8	0.89	11.6	33.6	54.8	C	75	2.95	3.3	47.7	7.0
56	0-30	7.8	1.33	23.5	34.7	51.8	C	75	1.07	5.8	46.9	12.4

Table (5): Soil salinity classes in the studied area.

Salinity classes*	ECe dS m^{-1}	Area in Feddan	%
Slightly Saline	0-4	49187	61.20
Moderately Saline	4-8	4680	5.82
Highly Saline	8-16	749	0.93
Fishpond		24096	29.98
Urban Areas		1665	2.07
Total		80377	100.00

*According to Soil Survey Staff (2004)

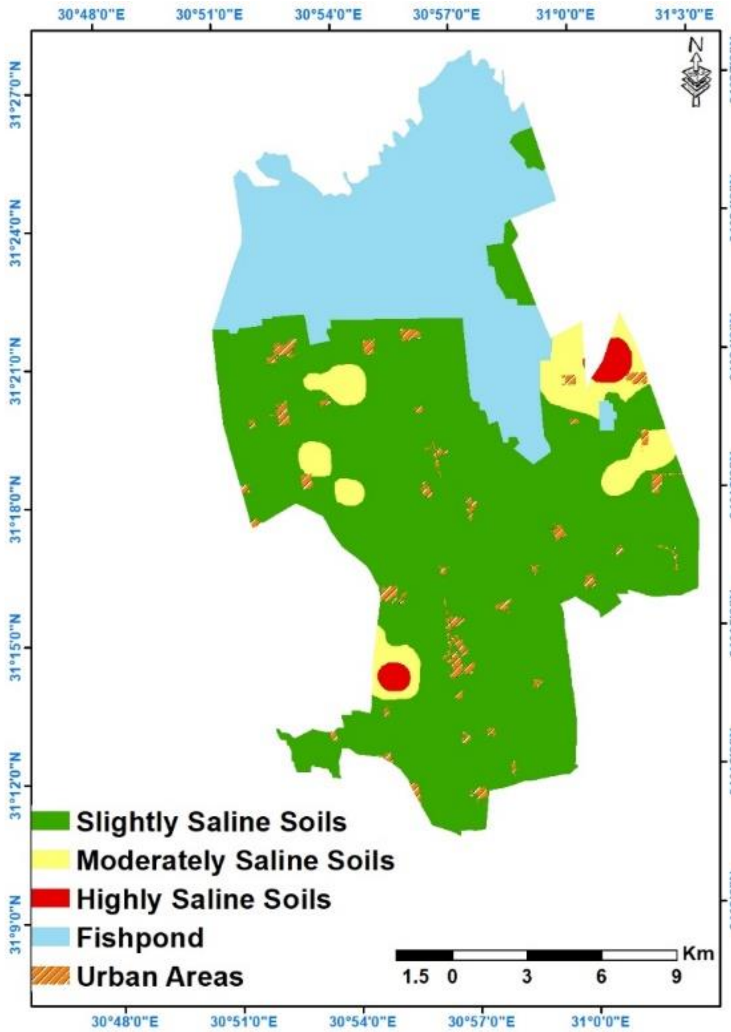

Fig. (5): Salinity map of the studied area.

Table (6): Soil sodicity classes of the studied area*.

Sodicity Classes	ESP	Area in Feddan	%
Non Sodic	< 15%	48252	60.03
Sodic Soils	> 15%	6364	7.92
Fishpond		24096	29.98
Urban Areas		1665	2.07
Total		80377	100.00

*According to Soil Survey Staff (2004)

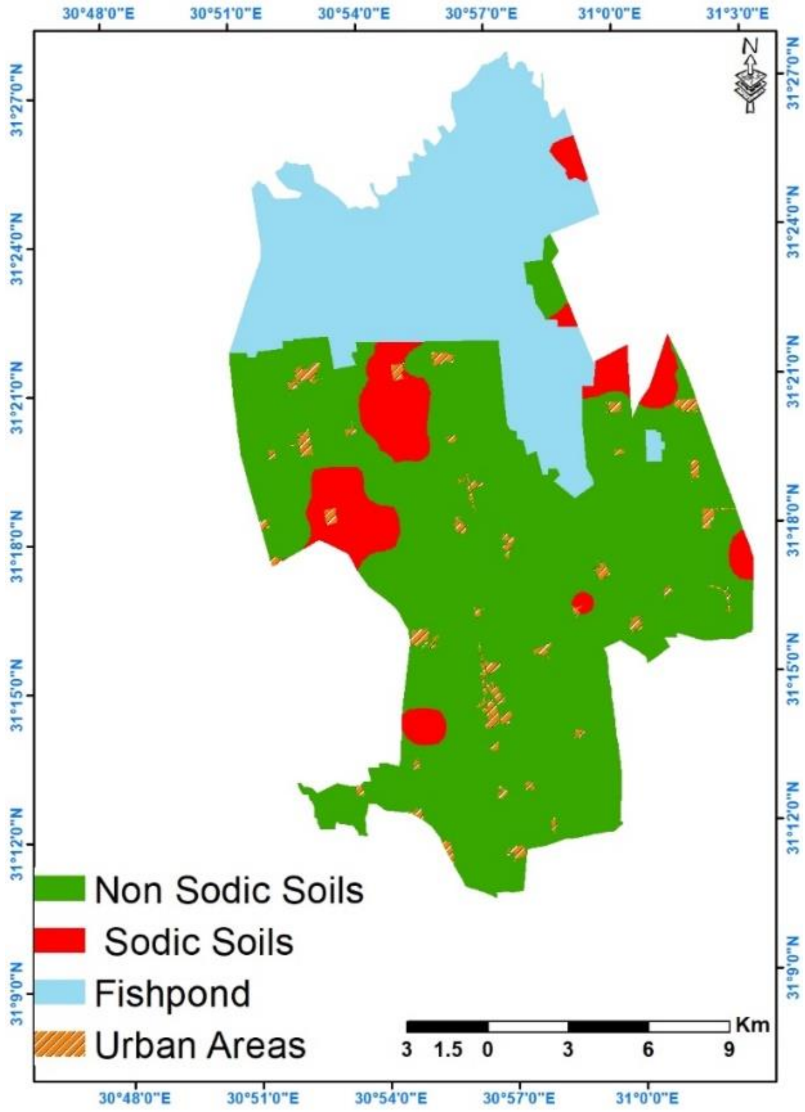

Fig. (6): Soil sodicity map of the studied area.

Table (7): Soil OM classes of the studied area*.

OM Classes	OM %	Area in Feddan	%
Very Low	< 0.7	147	0.18
Low	0.7- 2	44636	55.53
Medium	2 - 3.5	9832	12.23
Fishpond		24096	29.98
Urban Areas		1665	2.07
Total		80377	100.00

***According to Soil Survey Staff (2004)**

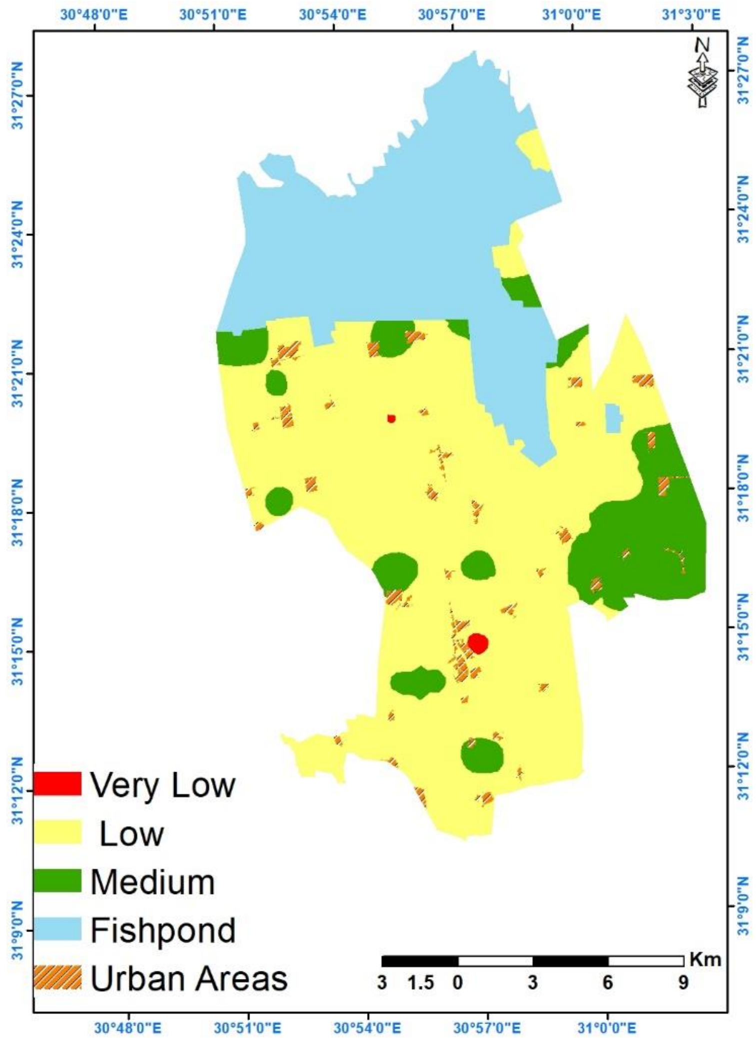

Fig. (7): Soil OM content map of the studied area.

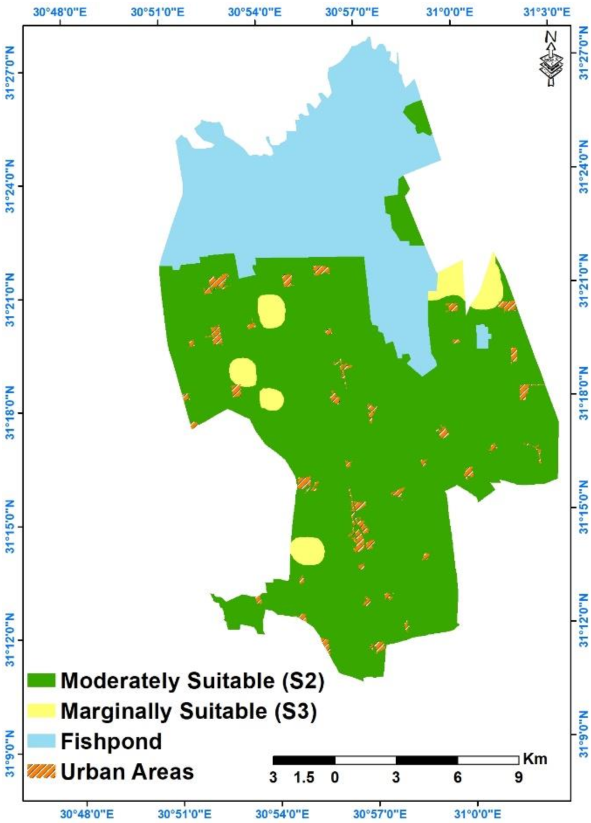

Fig. (8): Land capability map of the studied area>

Table (8): Land capability as suitability classes for agriculture*

Capability classes	Area in Feddan	%
Moderately Suitable (S2)	52000	64.70
Marginally Suitable (S3)	2616	3.25
Fishpond	24096	29.98
Urban Areas	1665	2.07
Total	80377	100.00

*According to Sys *et al.,* (1991)

6. Soil units map:

The soils map was produced based on the spatial variability of soil salinity and soil sodicity. Six units were recognized in the studied area as shown in Fig. (9) and Table (9). Results in Fig. (9) and Table (9) reveal that the "slightly saline, non-sodic soils" is the largest soil unit occupying 56% of the total studied area. The second unit is the "slightly saline, sodic soils" occupying 5% of the area and distributes in scatter areas all over the studied area. The "moderately saline, non-sodic soils" unit covers 3.5% and distributed in small patches. The smallest unit is the “highly saline, sodic soils”,that covers about 1% of the total studied area.

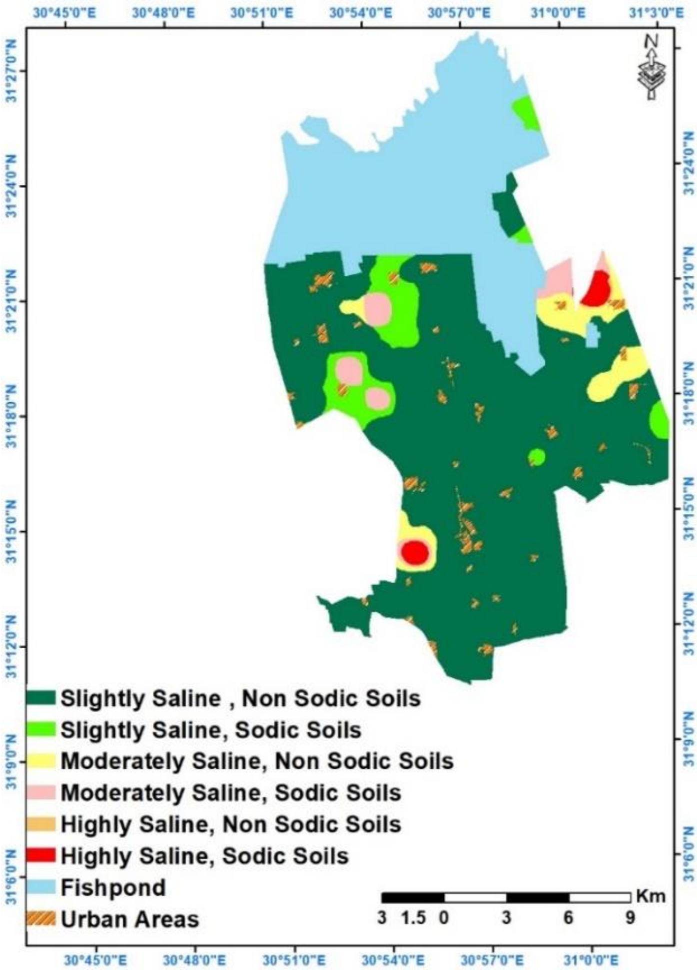

Fig. (9): Soil units map of the studied area.

Table (9): Areas of the studied soil units.

Soil units	Area in Feddan	%
Slightly Saline, Non-Sodic	45377	56.46
Slightly Saline, Sodic	3810	4.74
Moderately Saline, Non-Sodic	2813	3.50
Moderately Saline, Sodic	1866	2.32
Highly Saline, Non-Sodic	62	0.07
Highly Saline, Sodic	687	0.86
Urban Areas	1665	2.07
Fishpond	24096	29.98
Total	80377	100.00

7. Degradation assessment in the studied area

Statistical analyses

Correlation analysis

The statistical analyses of the studied soil properties indicated that, there is a very high significant positive correlation at the 0.01 level (2-tailed) between field capacity (FC) and each of clay content %, CEC as well as exchangeable sodium of soil samples. Whereas, there is a very high significant negative correlation at the 0.01 level (2-tailed) between FC and both of silt content %, and sand content % of the soil samples (Table 10).

Table (10): Correlation between lap FC, estimated FC, and soil properties (P).

Prop.	Correlations	$FC^{\$}$	$eFC^{\$\$}$	clay	silt	sand	CEC	EC	Na
$FC^{\$}$	Pearson Correlation	1	.964**	.960**	-.759-**	-.336-**	.858**	.218*	.315**
	Sig. (2-tailed)		.000	.000	.000	.002	.000	.044	.003
	N	86	86	86	86	86	86	86	86
$eFC^{\$\$}$	Pearson Correlation	.964**	1	.996**	-.799-**	-.381-**	.897**	.221*	.327**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.041	.002
	N	86	86	86	86	86	86	86	86
clay	Pearson Correlation	.960**	.996**	1	-.801-**	-.373-**	.928**	.185	.299**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.089	.005
	N	86	86	86	86	86	86	86	86
silt	Pearson Correlation	-.759-**	-.799-**	-.801-**	1	.002	-.775-**	-.105-	-.293-**
	Sig. (2-tailed)	.000	.000	.000		.982	.000	.335	.006
	N	86	86	86	86	86	86	86	86
sand	Pearson Correlation	-.336-**	-.381-**	-.373-**	.002	1	-.354-**	-.103-	-.080-
	Sig. (2-tailed)	.002	.000	.000	.982		.001	.347	.465
	N	86	86	86	86	86	86	86	86
CEC	Pearson Correlation	.858**	.897**	.928**	-.775-**	-.354-**	1	.190	.364**
	Sig. (2-tailed)	.000	.000	.000	.000	.001		.080	.001
	N	86	86	86	86	86	86	86	86
EC	Pearson Correlation	.218*	.221*	.185	-.105-	-.103-	.190	1	.647**
	Sig. (2-tailed)	.044	.041	.089	.335	.347	.080		.000
	N	86	86	86	86	86	86	86	86
Na	Pearson Correlation	.315**	.327**	.299**	-.293-**	-.080-	.364**	.647**	1
	Sig. (2-tailed)	.003	.002	.005	.006	.465	.001	.000	
	N	86	86	86	86	86	86	86	86

**. Significant at the 0.01 level (2-tailed). $FC^{\$}$ Lap. field capacity

*. Significant at the 0.05 level (2-tailed). $FC^{\$\$}$ estimated field capacity

The correlation between lap FC and estimated FC values

The results indicated that, there is a very high significant positive correlation (R^2=0.964**) at the 0.01 level (2-tailed) between estimated FC and lap FC of the soil samples. Also the results illustrated in Table (10) showed a very high significant correlation at the 0.01 level (2-tailed) between estimated FC with each of clay content %, silt content %, sand content %, CEC, EC, and exchangeable sodium of soil samples. A multi regression analysis was applied for estimation field capacity to improve the accuracy of obtained result.

Multi Regression Analysis

The capability of SPSS software was used to analyze the soil properties and produce ANOVA and Coefficients tables that used to calculate minipits field capacity. Tables (11 and 12) show the Analysis of Variances (ANOVA) and Coefficients parameters.

Degradation indices of studied area

The surface layer is a part of the soil section that controls degradation processes and affected by human activities and agricultural practices. The analyses results of the surface layer in the studied area were used to estimate the Chemical Degradation Index (CDI) and Biological Degradation Index (BDI) to assess the soil degradation extent.

The chemical and biological degradation indices (CDI & BDI) were estimated according to FAO (1980).

Table (11): ANOVA parameters

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3400.963	6	566.827	180.828	.000[a]
	Residual	247.635	79	3.135		
	Total	3648.598	85			

a. Predictors: (Constant), Na, sand, silt, EC, CEC, clay. b. Dependent Variable: FC

Table (12): Coefficient parameters

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	28.812	4.455		6.468	.000
	clay	.992	.074	1.221	13.384	.000
	silt	-.037	.055	.040	.674	.503
	sand	-.044	.046	.037	.975	.332
	CEC	.213	.071	-.250-	-3.019-	.003
	EC	.066	.125	.021	.525	.601
	Na	.087	.085	.042	1.019	.311

a. Dependent Variable: FC

7.1 Chemical Degradation

Soil data were applied to the equations 2 and 3, that checked, modified and statistical analyzed using SPSS program. The results are presented in Table (10 to 12). The modified equations are presented as follows:

Hs =28.812+(0.992*Clay%)+(-0.037*Silt%)+(-0.044*Sand%) (%) … *eq.5*

Salts (meq/100g) = (0.066 * EC_e * Hs)/1000 ………………. *eq. 6*

A correlation analysis was performed in order to identify the most influential variables effected the CDI of the studied soils. The selected variables were soluble salts, exchangeable sodium and CEC). These variables were varied within a particular range, and their effects on CDI were estimated and illustrated in Figs (10 and 11). The results in Figs (10 and 11) revealed a very strong correlation (R^2 = 0.93) between the exchangeable sodium (Na) and CDI, a weak correlation (R^2 = 0.36) between the soluble salt content and CDI, and a very weak correlation (R^2 = 0.02) between CEC and CDI. This means that any slight variations in the soluble salt content and the exchangeable sodium lead to a remarkable change in the chemical degradation degree. The high effect of Na^+ at CDI could be referred to their extreme levels which cannot be buffered by CEC. The high sodium content has a particular effect on the soil hydraulic properties and increases the rate of the salinity affected soils.

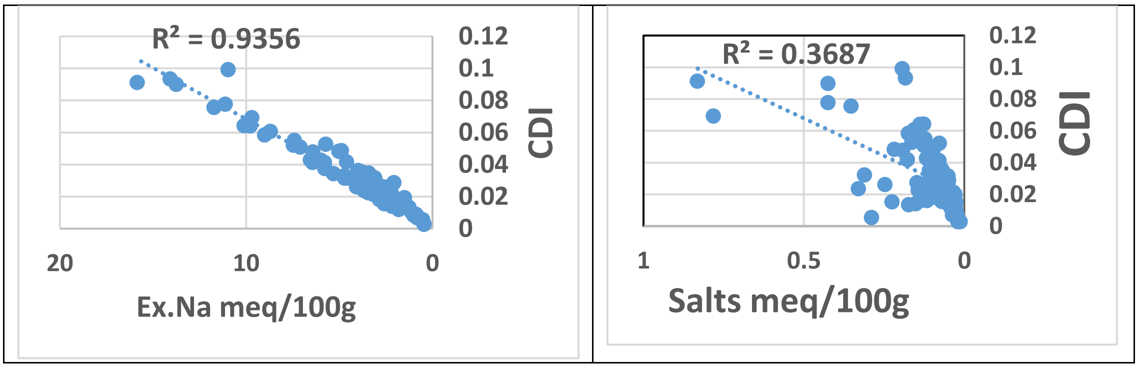

Fig. (10). Effect of exchangeable sodium and soluble salts content on CDI.

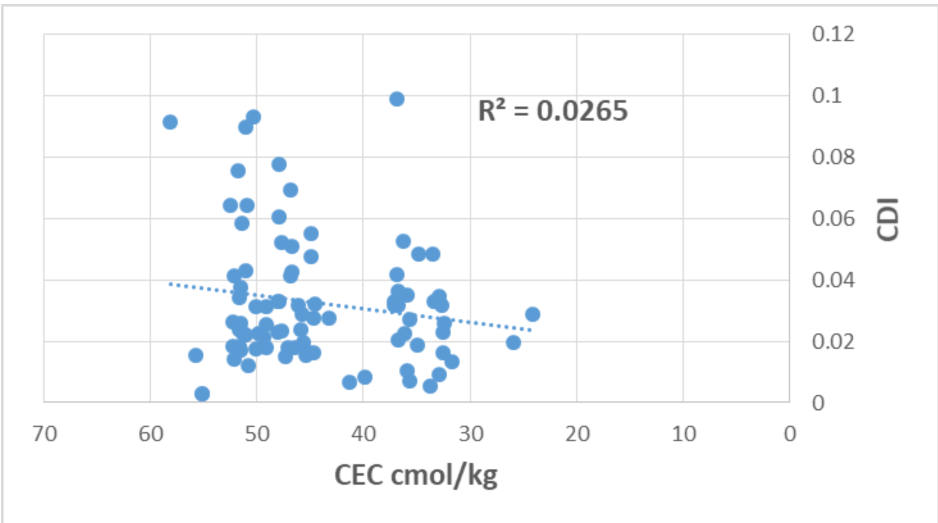

Fig. (11): Effect of cation exchange capacity on CDI.

The results of soil chemical degradation are presented in Fig. (12) and Table (13). These results indicated that, the CDI levels vary from very low to high. The largest class of the studied area (42%) have moderate index (CDI= 0.02 to 0.04). This area are represented by the soils of "slightly saline, non-sodic". The highly degraded index (CDI = 0.04-0.08) covers about 11% of the studied area and represented by the soils of "slightly saline, moderately saline and highly saline, sodic soils".

7.2 Biological Degradation

Data presented in Fig. (12) and Table (13) indicated that, the largest class of the studied area (about 40%) has a moderate biological degradation (BDI = 0,6 to 1,0). This soil degradation class referred to its low organic matter content under the prevailing semiarid conditions.

Drain Water quality

Irrigation water quality plays very important role in land degradation. The quality, particularly salinity and alkalinity (SAR) are crucial for agricultural purposes. Water samples were collected from four main drain canals in the studied area. These samples were analyzed to estimate their quality and results are presented in Table (14). The results indicated that, all water samples are very highly saline (>3 dS/m) and medium sodium (C4 – S2). This drainage water is considered not suitable for agricultural irrigation. The continues use of this drainage water for irrigation could be lead to increase of soil salinity and the chemical degradation of the soil.

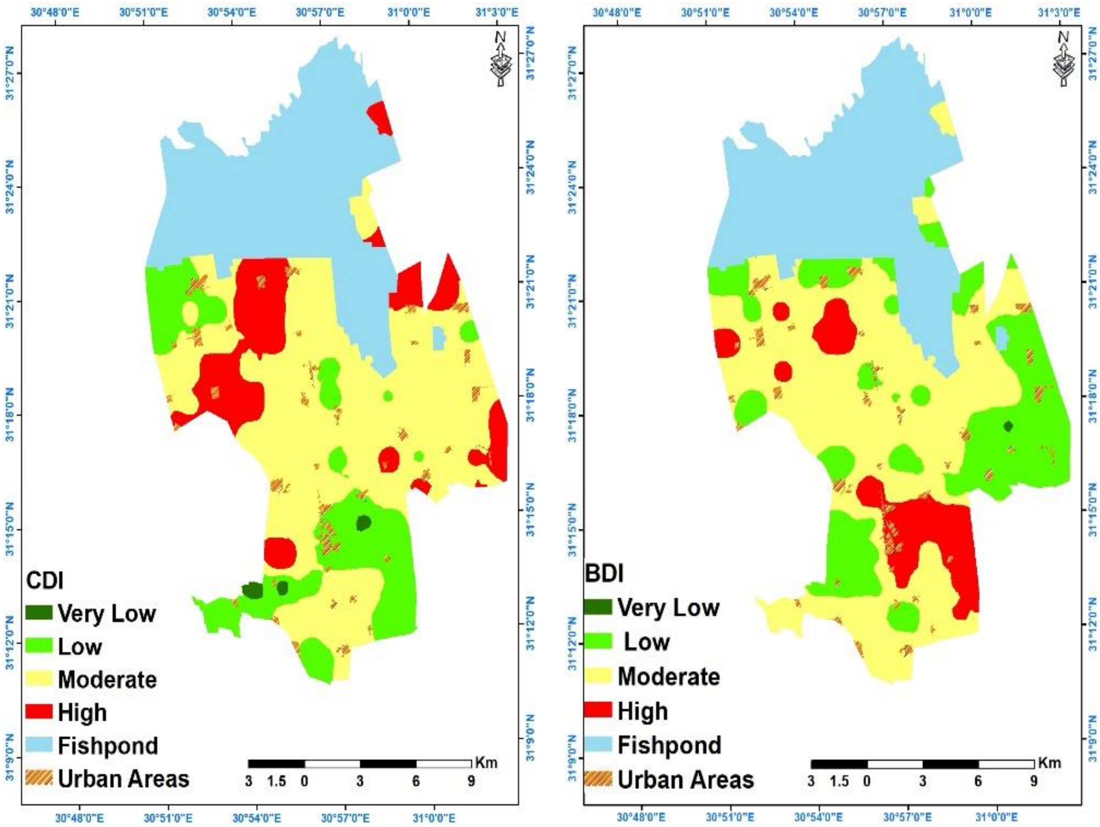

Fig. (12): Chemical (CDI) and biological (BDI) degradation status of the studied area.

Table (13): Classes Areas of (CDI) and (BDI) in the studied area.

CDI	Area in Feddan	%	BDI	Area in Feddan	%
Very Low	391	0.49	Very Low	47	0.06
Low	11409	14.19	Low	16105	20.04
Moderate	33849	42.11	Moderate	32191	40.05
High	8967	11.16	High	6273	7.80
Fishpond	24096	29.98	Fishpond	24096	29.98
Urban Areas	1665	2.07	Urban Areas	1665	2.07
Total	80377	100.00	Total	80377	100.00
Total	80377	100.00	Total	80377	100.00

Table (14): Chemical properties of drains water

Drains	EC (dS/m)	SAR	Cations (meq/l)				Anions (meq/l)		
			Na	Ca	Mg	K	HCO_3	Cl	SO_4
Nashart	7.4	14.48	51	15.8	9.0	0.8	5.5	35.7	35.4
Drain No. 8	6.5	15.46	50	12.5	8.4	0.7	5.0	30.1	36.5
Al Monshah	5.6	13.75	40.1	11.5	5.5	0.7	4.5	28.2	25.1
Drain No. 6	5.5	12.43	37.4	11.5	6.6	0.6	4.5	26.2	25.4

Conclusion

The using of integration of remote sensing (RS), geo-statistical analyses, and traditional statistics applied with geographic information system (GIS) is very helpful for studying the soil characteristics. These techniques are also very useful for mapping soil units, land evaluation and soil degradation. The using of statistical analyses include correlation operation, analyses of variances, and linear regression model are helpful to predicate the missing values of field capacity of the minipits soils. Therefore, the new model is valid in such soils under the Egyptian conditions.

One from the main reasons for soil degradation especially chemical degradation in Egyptian soils is the using of drainage water for irrigation due to the shortage of Nile Water. Continuous use of this drainage water leads to decrease the soil permeability caused by sodium accumulation in the exchange phase.

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تقييم وإنتاج خرائط تدهور الأراضي باستخدام نظم المعلومات الجغرافية وأدلة التدهور بمركز الرياض – محافظة كفر الشيخ – مصر

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الملخص العربى

تمثل منطقة الدراسة مركز الرياض بمحافظة كفر الشيخ بمساحة تقدر بحوالي٨٠٣٧٧ فدان، ويهدف هذا البحث الي دراسة خصائص أراضي تلك المنطقة، وتقييم مدى تدهورها، وتقييم كفاءتها الإنتاجية للزراعة، وذلك بإستخدام تقنيات الاستشعار عن البعد ونظم المعلومات الجغرافية، وتطبيق نموذجي تدهور الاراضي الكيمائي والبيولوجي. ولهذا الغرض تم إختيار وحفر ٣٠ قطاعا أرضيا ممثلا لأراضي المنطقة، وكذلك ٥٦ حفرة صغيرة، ولقد وصفت هذه القطاعات مورفولوجيا وجمعت عينات من طبقاتها المختلفة، بالإضافة الى عينات الحفر الصغيرة، لانتاج خرائط ملوحة وصودية التربة ، وخرائط التدهور الكيمائي والبيولوجي.

درست الصفات المميزة لوحدات خريطة التربة الناتجة، وتم التعرف على الوحدات السائدة بها كالاتي:

وحدة الاراضي منخفضة الملوحة وغير صودية التي تمثل حوالي ٥.٥٦٪ من إجمالي المساحة المدروسة، يليها وحدة الاراضي منخفضة الملوحة وصودية حيث تشغل حوالي ٥٪ من مساحة الدراسة، بينما كانت وحدة "الأراضي متوسطة الملوحة وغير صودية" حوالي ٣,٥٪ منتشرة على هيئة اجزاء صغيرة في منطقة الدراسة، ثم الأراضي متوسطة الملوحة وصودية التي تشغل حوالي ٢,٣ %، وأصغر وحدة هي" اراضي عالية الملوحة وصودية "، تغطي حوالي ١٪ من المساحة المدروسة.

وبتقييم صلاحية التربة للزراعة طبقا لنموذج Sys ، أوضحت الدراسة أن أراضي المنطقة تنتمي إلى قسمين هما متوسطة الصلاحية (S2) ومحدودة الصلاحية (S3)، وتبين النتائج أن حوالي ٦٥% من اجمالي منطقة الدراسة هي أراضي متوسطة الصلاحية (S2) وأن العامل المحدد فيها هو قوام التربة، أما الأراضي محدودة الصلاحية (S3) فهي تغطي مساحة حوالي ٣% من اجمالي منطقة الدراسة وترجعالعوامل المحددة فيها الى قوام التربة وملوحة وصودية الأرضي، بينما باقي المنطقة (حوالي ٣٢%) كانت عبارة عن مزارع سمكية ومناطق سكنية.

أظهرت نتائج مؤشر التدهور الكيميائي للتربة (CDI) أن مستوياته تختلف من منخفضة جدا إلى عالية، وكانت أكبر فئة (٤٢٪) من اجمالي المنطقة ذات مؤشر متوسط (اراضي متوسطة التدهور) ، يليها مؤشر منخفض في حوالي ١٤٪ من المساحة، أما حوالي ١١٪ من المساحة كان لها مؤشر CDI عالي، أما باقي المساحة فهي عبارة عن مزارع سمكية (حوالي ٣٠ %) ، وحوالي ٢ % مناطق حضرية.

فيما يخص التدهور البيولوجي كانت الفئة الكبرى (حوالي ٤٠ %) من اجمالي منطقة الدراسة تشير الى درجة تدهور بيولوجي متوسط ، نتيجة لسرعة تحلل للمواد العضوية بسبب الظروف المناخية الجافة والشبه الجافة.

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