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Assessment of soil Quality in some areas of the Nile Delta, Egypt, using GIS and remote sensing

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Abstract

This study aims at assessing Soil Quality Index (SQI) works interactively, comparing the values of the characteristics of the land unit with the Levels set designated for each quality class. Soil quality is based on analysis of edaphic factors which affect the quality. The following steps explain the mechanism of Soil Quality Index (SQI):drainage (D); rock fragments (R); slope (S), soil texture (T), soil depth (P), parent material (M) salinity (EC), sodicity (ESP), pH and calcium carbonate (O). The study area includes the following three governorates (Kafr El-Sheikh, Gharbia, Dakahliea) The studied area lies between 31° 36' 50.2″ and 30° 34' 35.4″ N and 30° 21' 59.5″ and 32° 18' 15.8″ E, and covers 9995 km^2 (999500 ha).The area includes three landscapes: flood plain, aeolian plain and lacustrine plain. Thirty soil profiles representing Two Quality classes were defined class II "moderate quality" covering 2.24 % of the area (22440.32 ha), in mapping unit CF1 and class III "Moderate-low quality" covering 80.76% (701517.64 ha) of the area in units decantation basins (DB), overflow basins (OB), overflow mantle (OM), high river terraces (RT1), moderate river terraces (RT2) low river terraces (RT3), sand sheets (SS) , relatively low clay (CF2) and wet sabkha (WS).

Keywords: Soil Quality Index, Nile Delta, Remote sensing and GIS

Introduction

Soil quality is defined as "the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation **(Doran and Parkin, 1994; Karlen and stott,1994; Soil Science Society of America, 1995; Karlen et al., 1997; Wander et al. 2002; Toth et al., 2007; Novak et al., 2010; Atanu and Lal 2014; Liu et al., 2016 and Abdel Rahman and Tahoun 2019).** Soil physical and chemical properties can be used as indicators for soil quality assessments and determine the sustainability of farming systems **(Lal, 1994 and Shukla et al., 2004).** Soil quality can be assessed by using national land resource or soil survey inventories **(MacDonald et al., 1995; Soil Survey Staff, 2000).** Soil quality concepts include physical, chemical and biological properties all of which account of the soil's ability to provide ecosystems and social services **(Doran et al., 1994, Karlen et al., 1997, Seybold et al., 1997, Wang and Gong, 1998, Southorn and Cattle, 2004; Wienhold et al., 2004 and Shukla et al., 2006).** Physical, chemical, microbiological and biochemical properties need to be integrated to establish such quality **(Papendick and Parr, 1992; García et al., 1994; Halvorson et al., 1996; Karlen et al., 1997; Arshad and Martin 2002; Allen et al., 2011; Rahmanipour et al., 2014).** Soil quality cannot be measured directly, but through soil indicators that are sensitive to management **(Larson and Pierce, 1991).** Remote sensing and digital image classification, in particular is the fast advancing field, which provides access to spatial information and spatial data analysis. Remote sensing techniques have been applied in many disciplines including biology, geography, geology, geomorphology, hydrology, ecology, and agriculture **(Lillesand and Kiefer, 2003; De Jong and Van Der Meer, 2005; Hord, 2006 and Schowengerdt, 2007).** Remote sensing datasets and methods are the main choices for modeling and assessment of land degradation because of their accessibility for quick and efficient assessment over large regions **(Jong, et al 2011; Higginbottom, and Symeonakis, 2014).** Remote sensing and GIS are a precisely accurate and low-cost technique **(Abdel Hamid and Hongg, 2020).**

Remote sensing and GIS were the main tool for producing maps of soil quality for the study area. Using GIS to produce the spatial variation of the soil quality for the study area.

Materials and Methods

The Study area:

The study area is located between latitudes 31° 36' 50.2″ and 30° 34' 35.4″ N, and longitudes 30° 21' 59.5″ and 32° 18' 15.8″ E, Figure (1). The total area of the study area is 9994.55 km^2 (999455.83 ha). The total mean rainfall is 6.9 mm/year and the mean minimum and maximum annual temperatures are 8.7and 35.5°C, respectively. It is Egypt's economic and financial heart, it includes the most fertile arable land in Egypt , and has the most populated as governorates in Egypt. The Nile Delta houses around 50% of the population **(Haars et al., 2016).** The study area includes the following three governorates (Kafr El-Sheikh, Gharbia and Dakahliea).Elevation in Nile Delta vary between 0 and 20 m above sea level (asl).and belongs to the late Pleistocene era **(Hagag, 1994 and Said, 1993).** The major geomorphic units in the Nile Delta, are: young deltaic plain, old deltaic plain and young Aeolian plain **(EI-Fayoumy, 1968).**

According to **CONOCO (1987)** it is characterized by the following geological units: Neonile deposits, Nile silt deposits, Prenile deposits, Protonile deposits, Sabkha deposits and Quaternary marine deposits

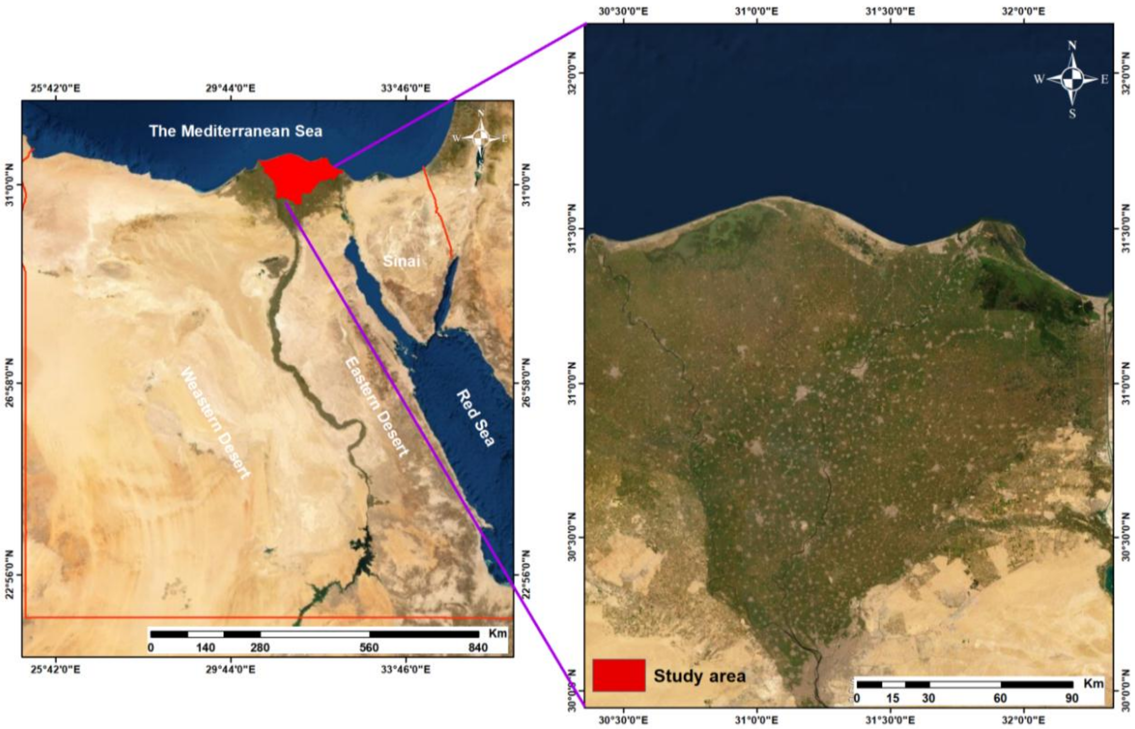

Fig.1 Location of the studied area

Field work and laboratory analyses

A semi A field survey was done in order to determine soil quality index (SQI). Ground Position System (GPS) was used for locating the site of each profile (latitude and longitude) (Fig.2). Mapping units were represented by 30 soil profiles, described according to **FAO (2006)** and classified on basis of USDA Soil Taxonomy **(USDA, 2014)**. Representative soil samples were collected and analyzed using the soil survey laboratory methods manual **(USDA, 2014 and Bandyopadhyay, 2007).**

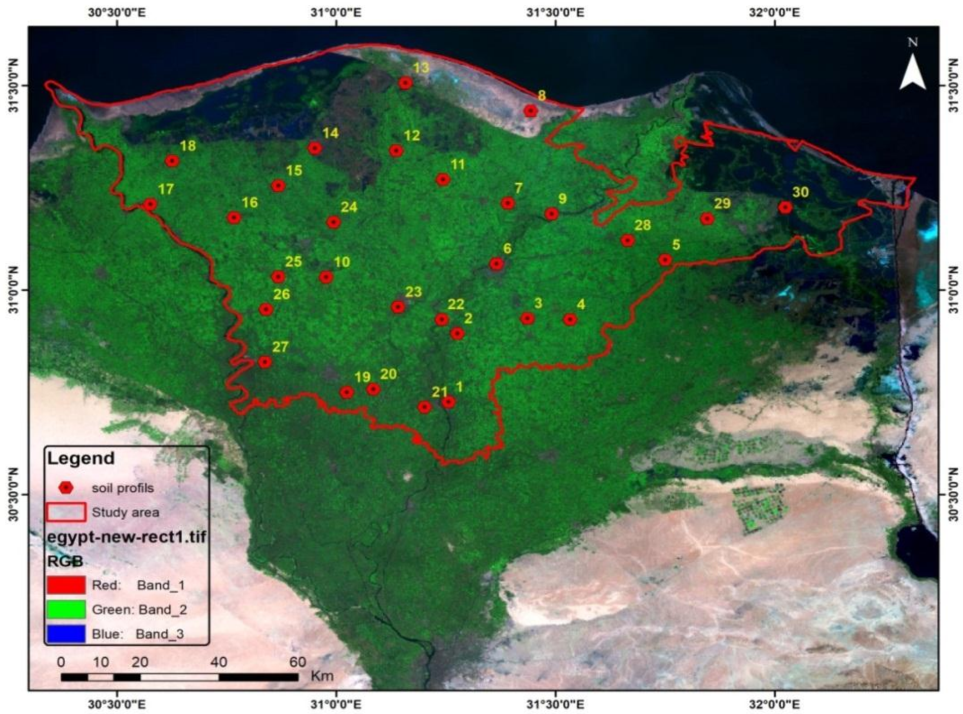

Fig 2: Location of soil profiles in the studied area.

%), soil texture class (T), soil depth (P), and parent material (M).

The chemical soil quality parameters electrical conductivity (EC), calcium carbonite $CaCO_3$, cation exchange capacity (CEC), pH and as diagnostic criteria.

The SQI) was determined by the model of **Kosmas *et al.* (1999) and Sepehr *et al.* (2007)** according to the following equation:

Soil quality Index (SQI) = (T×M×D×P×S×R×H×C×E×O) $^{1/10}$

Each factor is rated on a scale from 1 to 2 and the resultant index, lies between 1.2 and 1.5, set against a scale placing the soil in one three quality classes. The rating of soil quality of the soils was done according to the grading system in Table 1.

Image processing and Software used:

Only one type of Landsat images was used; Landsat-8. The study involved Evaluation Soil quality indicators. Geomorphologic map was prepared using Path / Row: 176 / 38 and Path / Row: 177 / 39. All further digital image processing and analyses in addition to geometrically corrector were executed using the standard approaches provided by the ENVI 5.1 and the Arc-GIS 10.2 software.

Soil quality assessment:

This procedure was designed based on soil physical and chemical properties. Suggested in the models of **Kosmas et al. (1999) and Sepehr et al.(2007).** Soil Quality Index (SQI) works interactively, to compare characteristics of the land unit with the levels of sets designated for each quality class. Soil quality model is based on analysis of soil factors which affect the quality. The physical soil qulity parameters include drainage (D) Rock fragments (R %); slope gradient (S

Table 1. Class and rating limit of Soil Quality Index (SQI).

	Range	**Definition**	**Class Rating**
Soil quality index	< 1.2	High quality	I
	1.2 - 1.25	Moderate quality	II
	1.25 - 1.5	Moderate low quality	III
	> 1.5	Low quality	IV

Results and Discussion

Digital Terrain Model (DTM):

The DTM is a topographic model of the bare Earth that can be manipulated by computer programs such as software Arc Map. The data files contain elevation data of the terrain in a digital format which relates to a rectangular grid. DTM generated with the aid of contour maps (5 m interval) and spot heights of the map scale (1.50000) using the deterministic thin-plate spline interpolation and software Arc Map 10.2 **(Wahba 1990),** as shown in Figure 3.

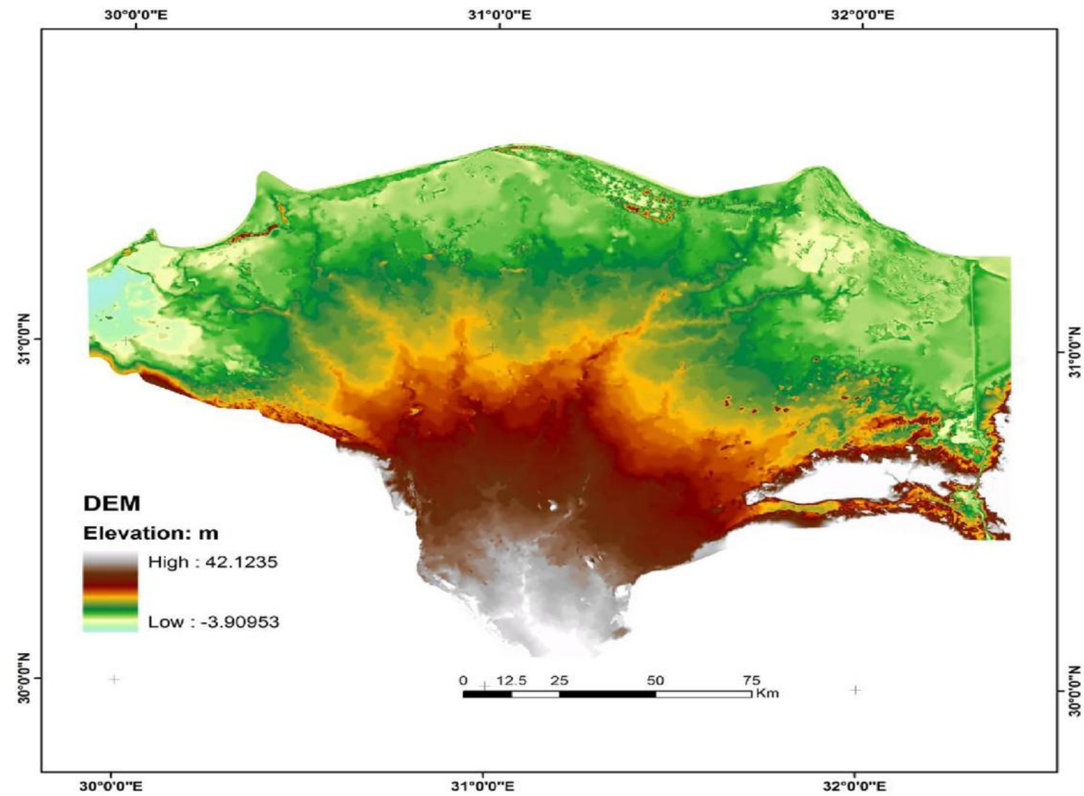

Fig 3: Topography of the study area in the Nile Delta, after El Bastawesy et al (2017).

Geomorphologic features.

The main geomorphologic units in the study area can be divided into three landscapes as follows:

1- **Flood plain:** 65.80 % of the total area; and includes decantation basins (DB), overflow basins (OB), overflow mantle (OM), high river terraces (RT1), moderate river terraces (RT2), low river terraces (RT3) and levees (L) (Table 2 and Figure 4).

2- **Aeolian plain:** 6.84 % of the total area; and includes sand sheets (SS), hummock areas (H) and costal sand bar (CSB).

3-**Lacustrine deposits:** 15.63 % of the total area; and includes relatively high clay (CF1), relatively low clay (CF2), wet sabkha (WS), dry sabkha (DS), swamps (S).

Table 2. Geomorphic units, soil profile, landforms, their areas and percentages of the total study area**.**

geomorphologic unit	**Landform**	**Mapping unit**	**Profile No.**	**Area (ha)**	**% of total area**
Flood plain	Decantation basins	DB	3,24,28 and 29	136374.14	13.64
	Overflow basins	OB	1,7,10,16,20 and 25	177624.92	17.77
	Overflow mantle	OM	2 and 6	33278.71	3.32
	High river terraces	RT1	9,11,20 and 21	93112.37	9.31
	Moderate river terraces	RT2	14,15,17,18 and 19	103797.03	10.38
	Low river terraces	RT3	4,12,23,26and 27	106155.11	10.62
	Levees	L		7674.61	0.76
Aeolian plain	Sand sheets	SS	8	56412.61	5.64
	Hummock areas	H		4772.11	0.47
	Costal sand bar	CSB		7339.50	0.73
Lacustrine deposits	Relatively high clay	CF1	30	22440.32	2.24
	Relatively low clay	CF2	5	47852.72	4.78
	Wet sabkha	WS	13	53065.14	5.30
	Dry sabkha	DS		7726.24	0.77
	Swamps	S		25470.35	2.54
Other features	Water bodies	WB		95186.87	9.52
	Fish bonds	FB		14053.22	1.40
	Nile river			7119.86	0.71
	Total area			**999455.83**	**100.00**

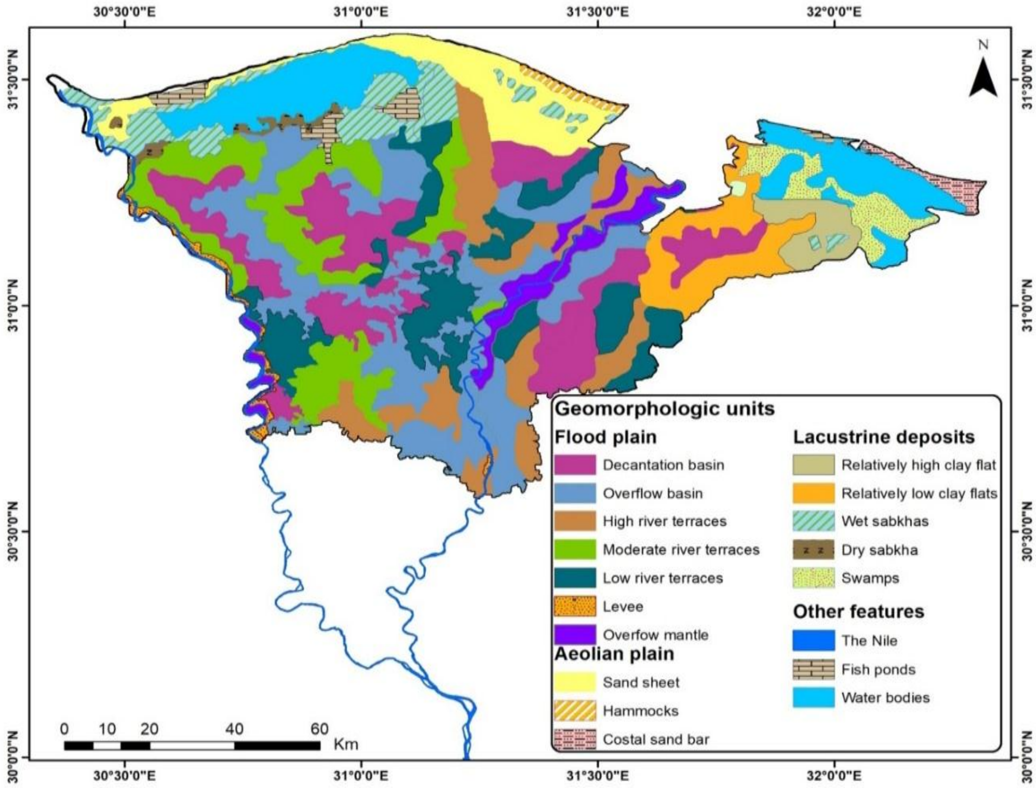

Fig. 4: Geomorphologic map of study area.

Soil quality assessment:

There are ten effective physical and chemical factors for assessing soil quality as follow:

Parent material (a

The study area is located in two classes; the first part is clay and the other is sandy.

b) Texture

Whole of study area is Clay texture, except for the unit sand sheet is sand texture and unit wet sabkha is Loamy Sand and Loamy.

a) Depth

The soils of the study area were moderately deep to very deep. The variety in depth was attributed to the depth of the ground water level

d) Slop

The slope of the study area is more close to a gentle slope which is more suitable for cultivation.

e) Rock and Fragments

The area is occupied by very small gravel class having. Its ratio is less than<20 percentage

f) EC

Salinity is one of the main limiting factors for agriculture. EC values for weight average of different profiles ranged from 0.31 to 100.38 dsm^{-1} which indicates that these soils are non-saline in except in some areas, that determines the quality of study area for different agricultural crops.

g) ESP

It is expressed as: ESP = [exchangeable sodium (meq /100 g soil) / cation exchange capacity (meq / 100 g soil)] x 100. ESP values ranged from 3.21to 20.96 which indicate that these soils are non-saline in natu Except in some areas.

h) pH

Results of lab analyses showed that soil pH is moderately.

Table: 4 Values of the factors of soil quality index of the studied of some areas in the Nile Delta

Mapping unit	Depth	slope	Rock fragments	Drainage	Texture	Parent material	EC(ds m^{-1})	ESP	pH	$CaCO_3$ (gkg-1)
DB	122.5	Very gentle	Slightly stony	Imperfectly Drainage	Clay	Alluviums deposits	2.47	8.13	7.02	33.32
OB	95.8	Very gentle	Slightly stony	Imperfectly Drainage	Clay	Alluviums deposits	1.45	7.44	7.17	23.75
OM	120	Very gentle	Slightly stony	Imperfectly Drainage	Clay	Alluviums deposits	0.99	7.44	7.09	22.54
RT1	100	Very gentle	Slightly stony	Imperfectly Drainage	Clay	Alluviums deposits	2.10	5.33	7.12	27.63
RT2	100	Very gentle	Slightly stony	Imperfectly Drainage	Clay	Alluviums deposits	3.77	9.10	7.25	28.52
RT3	98	Very gentle	Slightly stony	Imperfectly Drainage	Clay	Alluviums deposits	3.46	5.40	7.16	30.42
SS	150	Very gentle	Slightly stony	Well Drainage	Sand	Sand stone	0.31	20.96	7.52	6.56
CF1	150	Very gentle	Slightly stony	Imperfectly Drainage	Clay	Marinelimestone	2.98	3.21	7.09	48.45
CF2	80	Very gentle	Slightly stony	Imperfectly Drainage	Clay	Marinelimestone	1.19	8.65	7.16	34.55
WS	85	**Moderately**	Slightly stony	Well Drainage	Loamy Sand	Marinelimestone	100.38	4.91	6.80	33.53

Table 5. Soil characteristics of the investigated area

Mapping unit	Depth	Slope	Rock fragments	Drainage	Texture	Parent material	EC(dsm-1)	ESP	pH	$CaCO_3$(gkg-1)
DB	P1	S1	R3	D2	T3	M3	C1	E1	H2	O1
OB	P1	S1	R3	D2	T3	M3	C1	E1	H2	O1
OM	P1	S1	R3	D2	T3	M3	C1	E1	H2	O1
RT1	P1	S1	R3	D2	T3	M3	C1	E1	H2	O1
RT2	P1	S1	R3	D2	T3	M3	C1	E1	H2	O1
RT3	P1	S1	R3	D2	T3	M3	C1	E1	H2	O1
SS	P1	S1	R3	D2	T3	M3	C1	E1	H2	O1
CF1	P1	S1	R3	D2	T3	M3	C1	E1	H2	O1
CF2	P1	S1	R3	D2	T3	M3	C1	E1	H2	O1
WS	P1	S1	R3	D2	T3	M3	C1	E1	H2	O1

Assessment of Soil Quality Index (SQI)

Tables 6 and 7 and Figure.5 illustrate the general characteristics, classes and scores of the soil quality index (SQI). The moderate quality index (II) represents 2.24 % of the total area (22440.32 ha) in CF1 mapping unit. Most of the study area (80.76%, 701517.64 ha) was a moderate quality class (III) mainly presented in DB, OB, OM, RT1, RT2 RT3, SS , CF2 and WS mapping units.

Table 6. Assessment of soil quality index of the study area

Mapping unit	Depth	Slope	Rock fragments	Drainage	Texture	Parent material	EC (ds/m)	ESP	pH	$CaCO_3$ (g/kg)	Soil Quality Index (SQI)	Grade
DB	1.00	1.00	2.00	1.20	1.60	2.00	1.00	1.00	1.33	1.00	1.26	III
OB	1.33	1.00	2.00	1.20	1.60	2.00	1.00	1.00	1.33	1.00	1.29	III
OM	1.00	1.00	2.00	1.20	1.60	2.00	1.00	1.00	1.33	1.00	1.26	III
RT1	1.33	1.00	2.00	1.20	1.60	2.00	1.00	1.00	1.33	1.00	1.29	III
RT2	1.00	1.00	2.00	1.20	1.60	2.00	1.00	1.00	1.33	1.00	1.26	III
RT3	1.33	1.00	2.00	1.20	1.60	2.00	1.00	1.00	1.33	1.00	1.29	III
SS	1.00	1.00	2.00	1.00	2.00	1.00	1.00	2.00	1.33	1.00	1.39	III
CF1	1.00	1.00	2.00	1.20	1.60	1.66	1.00	1.00	1.33	1.00	1.23	II
CF2	1.33	1.00	2.00	1.20	1.60	1.66	1.00	1.00	1.33	1.00	1.27	III
WS	1.33	1.33	2.00	1.00	1.00	1.66	2.00	1.00	1.00	1.00	1.27	III

Table 7. Distribution of soil quality index of the study area

(SQI)	Grade	Class	Mapping unit	Area (ha)	Area %
> 1.2	I	High quality	———	———	———
1.2 - 1.25	II	Moderate quality	CF1	22440.32	2.24
1.25 - 1.5	III	Moderate low quality	DB, OB, OM, RT1, RT2 RT3, SS , CF2 and WS	701517.64	80.76
> 1.5	IV	Low quality	———	———	———

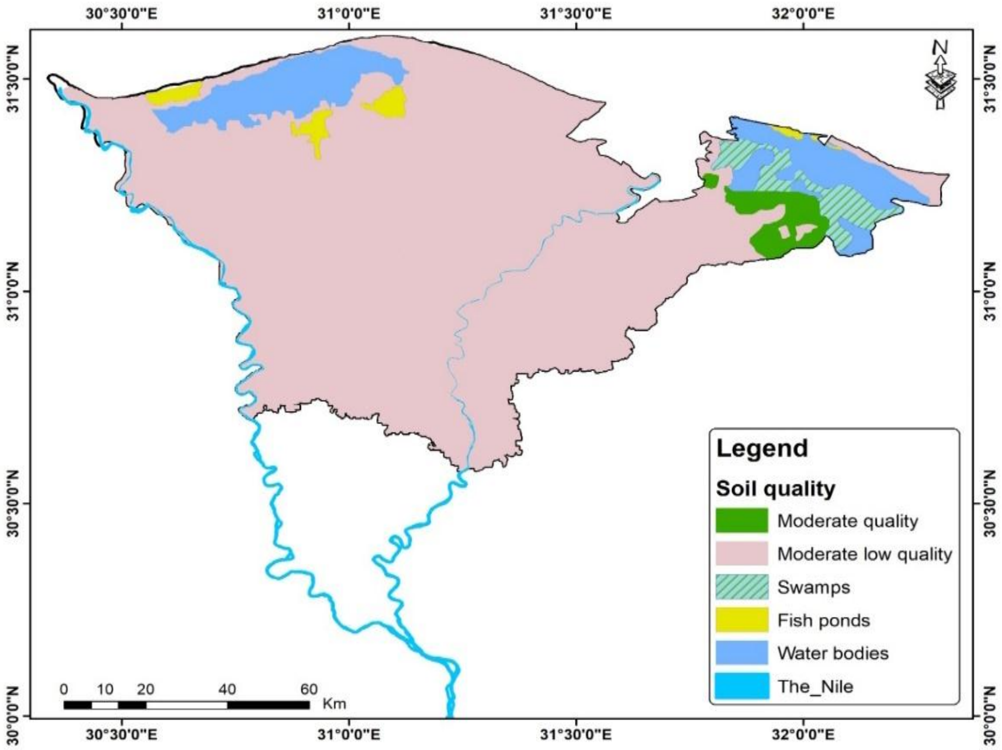

Fig 5: Soil quality map of the studied area.

Conclusion

Soil quality index (SQI) depended on 10 factors :drainage (D); Rock fragments (R); slope (S), soil texture (T), soil depth (P), parent material (M) salinity (C), sodicity (E), pH (H) lime (O mgkg^{-1}). The area was 999455.83 ha in 5 governorates: Gharbia, Dakahliea, Kafr-El-Sheikh, Monofiya, and Damietta. The main activity in the study area is agriculture. The area included three landscapes; Flood plain, Aeolian plain and Lacustrine deposits . Thirty soil profiles were dug to represent some areas of the Nile Delta soils. Two classes were outlined; (Class II) representing 2.24 % of the total area, represented in mapping units CF1and (Class III) covering 80.76% of the total area, DB, OB, OM, RT1, RT2 RT3, SS , CF2 and WS mapping unit. Remote sensing and GIS were the main tool for producing maps of soil quality for the study area. Using GIS to produce the spatial variation of the soil quality for the study area.

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تقييم جودة التربة في مناطق مختلفة من دلتا النيل بمصر باستخدام تقنيات نظم المعلومات الجغرافية والاستشعار عن بعد.

محسن محمد علي منصور– على احمد عبدالسلام – هبة شوقى عبدالله راشد عمر حسينى محمد الحسينى .

قسم الأراضى و المياه– كلية الزراعة– مشتهر– جامعة بنها– مصر.

تهدف هذه الدراسة إلى تقييم مؤشر جودة التربة في بعض مناطق دلتا النيل من خلال عشرة عوامل تعتمد علي (حالة الصرف– كمية الحصي– الأنحدار – قوام التربة– عمق التربة –مادة الأصل للتربة– التوصيل الكهربي – نسبة الصديوم المتبادل– الرقم الهيدروجيني – كربونات الكالسيوم) تقع منطقة الدراسة بين دائرتي عرض 31 ° 36' 50.2 ″و 30 ° 34' 35.4 ″ شمالاً وخطي طول 30 ° 59.5'21″ و 32° 18' 15.8″ شرقا ، وتبلغ مساحة منطقة الدراسة 9994.55 كيلومتر مربع. (999455.83 هكتار). تقع دلتا النيل بين فرعي رشيد ودمياط ،وقد اشتملت المنطقة على ثلاث مناظر طبيعية السهل الفيضي والسهل الريحي والترسيبات البحرية و تم حفر 30 قطاع ارضي لتغطية جميع الوحدات الخرائطية في منطقة الدراسة. تم تحديد درجتين لجودة التربة (الدرجة الثانية) تمثل 2.24٪ (22440.32 هكتار) من المساحة الإجمالية ، ممثلة في وحدة ترسيبات بحرية من الطين ذات منسوب مرتفع (CF1) ، (الدرجة الثالثة) تمثل 80.76٪ (701517.64 هكتار) من المساحة الاجمالية ، ممثلة في الوحدات الخرائطية الرفوف الفيضية (OM), الأحواض الفيضية (OB)، الأحواض التجمعية (DB) ، الشروفات النهرية (RT) ومنها (المرتفعة (RT1) – المتوسطة (RT2) – المنخفضة (RT3)، الفرشات الرملية (SS)، السبخات الجافة(WS) ، ترسيبات بحرية من الطين ذات منسوب منخفض (CF2).