Quantitive Assessment of Soil Degradation in some Areas North Nile Delta, Egypt

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Abstract— Most forms of land degradation are man-made problems, although there are some physical environmental factors involved, but mismanagement and misuse are still considered. Quantitative assessment of human induced land degradation and monitoring the changes in land qualities in Kafr EL-Sheikh Governorate during the period of 1963 to 2009 are the main objective of this study. Geometrically corrected physiographic-soil map was produced for the studied area. The comparison between the data extracted from the RISW reports, [1] and the data of this study were carried out to determine the rate of land degradation. Aerial photo-interpretation, Landsat ETM+ image, fieldwork and laboratory analysis data were used to produce the physiographic-soil map of Kafr EL-Sheikh Governorate. Land degradation rate, relative extent, degree, and severity level in the study area were assessed. The results indicate that the dominant active land degradation features are; water logging salinization, alkalinization and compaction. The main causative factors of human induced land degradation types in the studied area are over irrigation, human intervention in natural drainage, improper time use of heavy machinery and the absence of conservation measurements.

Keywords— Physiographic – soil map, land degradation, land qualities, North Nile Delta, Egypt.

I. INTRODUCTION

Soil degradation is defined as the process, which lowers (quantitatively or qualitatively) the current and/or the potential capability of soil to produce goods or services. Soil degradation implies a regression in capability from a higher to lower state; a deterioration in soil productivity and land capability, [2; 3; 4 and 5]. The food gap due to increasing population puts more pressure on the use of land, resulting in serious forms of land degradation. These are considered irreversible processes particularly with the severe and continued misuse and poor management. The intensification of agriculture coupled with poor management accelerates the rate of land degradation. Food supply situation will be worse in the future if the current trend of land degradation does not change drastically. The livelihoods of more than 900 million people in some 100 countries are now directly and adversely affected by land degradation [6]. Unless the current rate of land degradation is slowed and reversed, food security of humanity will be threatened and the ability of poor nations to increase their wealth through improved productivity will be impeded. Land degradation can be observed in all agroclimatic regions on all continents. Although climatic conditions, such as drought and floods, contribute to degradation, the main causes are human activities. Land degradation is a local problem in vast number of locations, but it has cumulative effects at regional and global scales. The countries of the developing world, and particularly those in the arid and semi-arid zones, are the most seriously affected [7].

The status of soil degradation is an expression of the severity of the process. The severity of the processes is characterized by the degree in which the soil is degraded and by the relative extent of the degraded area within a delineated physiographic unit [8]. Egypt could be sub-divided geographically into four distinct regions, each extending longitudinally from the Mediterranean coast in the north towards the inland of Africa in the south. Along an east-west geotraverse, these regions are the Sinai Peninsula, the Eastern Desert, the Nile Valley and the Delta, and the Western Desert [9]. About 90% of the population, which stands now at 75 millions, is concentrated in the Nile Valley and the Delta.

In parallel, most of the national socio-economic activities are concentrated in this region, which entails strenuous demographic pressure and subsequent environmental degradation [10].

The study area represents the traditional cultivation in the Nile Delta, Egypt; it includes both old cultivated and newly reclaimed soils. It is located in the north west of the Nile Delta between longitudes 30° 20' and 31° 20' and latitudes 31° 00' and 31° 40', incorporating an area of 3165.18 Km2, (Figure, 1).

This area belongs to the late Pleistocene, which is represented by the deposits of the neonile broke into Egypt sometime in the earlier part of this age and also by the deposits accumulated during the recessional phases of this river. Through its history the neonile in this region has been continuously lowering its course at a rate of 1m/1000 years [11]. Based on the Egyptian Meteorological Authority [12]data and the American Soil Taxonomy [13], the soil temperature regime of the studied area is defined as Thermic with Torric soil moisture regime.

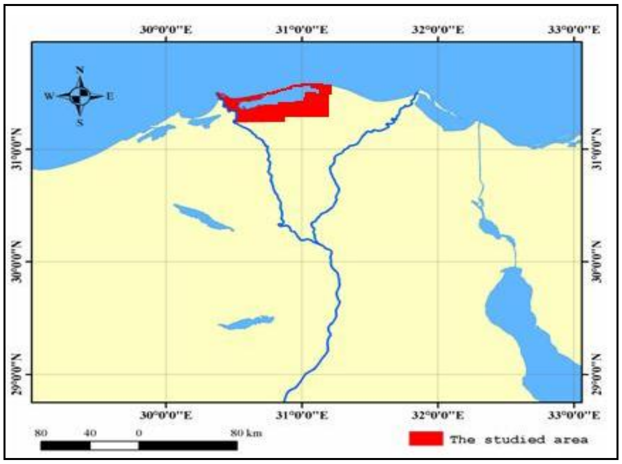

Figure (1): Location map of the studied area.

MATERIALS AND METHODS

***Physiography and soils mapping*:**

Sixty-one Panchromatic aerial photographs scale (1: 40.000) taken during the year 1991 has been used to produce the physiographic map of the studied area, the "physiographic analysis" detailed by [14], [15], [16], [17] was used for this purpose. Updating of the physiographic map was carried out using the Landsat ETM+ image (path 177, row 38) taken during the year 2003 (Figure, 2). The different mapping units were represented by 10 soil profiles and 40 min pits, the morphological descriptions of the soil profiles were carried out using FAO guidelines [18]. The laboratory analyses of the soil and water samples were carried out using the soil survey laboratory methods manual [19]. The American Soil taxonomy, [13] was used to classify the different soil profiles to sub great group level, and then the correlation between the physiographic and taxonomic units was designed, after [20]. Arc-GIS 9.2 software has been used for geometric correction and mapping as the main software of Geographic Information System.

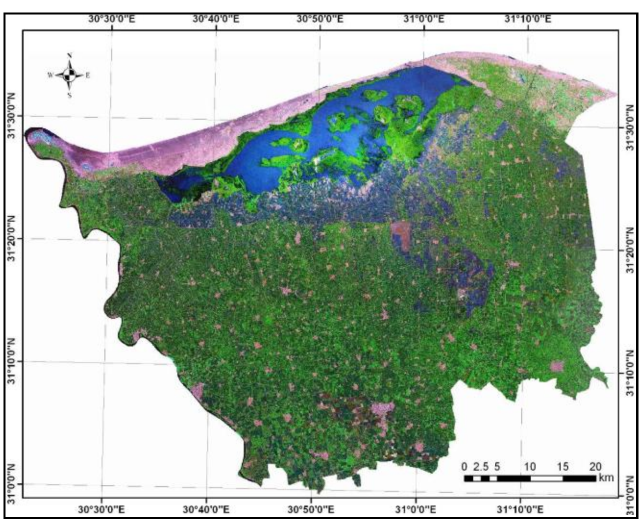

Figure (2): Enhanced Land sat ETM+ Image of the studied area.

Soil degradation assessment:

This study is based on comparing between the data extracted from RISW report, (1975) and the data resulting from this study. The FAO/UNEP [21] methodology for assessing soil degradation was used and the results were evaluated and confirmed with the physiographic units, the ratings used are presented in Tables (1 and 2).

Table (1) Soil degradation types, classes and rates

Chemical degradation	**Salinization (Cs) increase in (EC) per dS/m/year**	**Alkalinization (Ca) increase in ESP/Year**
Non to slight	<0.5	<0.5
Moderate	0.5 – 3	0.5 – 3
High	3 – 5	3 – 7
Very high	>5	>7
Physical degradation	**Compaction/increase in bulk density per g/cm^3/year**	**Water logging/increase in water table in cm/year**
Non to slight	<0.1	<1
Moderate	0.1 – 0.2	1 – 3
High	0.2 – 0.3	3 – 5
Very high	>0.3	>5

Table (2) Criteria used to determine the degree of the different degradation types

Hazard type	Indicator	**Unit**	**Hazard class**			
			Low	Moderate	High	Very high
Salinization	EC	dS/m	4	4 – 8	8 – 16	>16
Alkalinization	ESP	value	10	10 – 15	15 – 30	>30
Compaction	Bulk density	g/Cm^3	1.2	1.2 – 1.4	1.4 – 1.6	>1.6
Water Logging	Water Table level	cm	150	150 – 100	100-50	<50

Land degradation degree, relative extent, severity level and causative factors were defined and described using the UNEP, [8] approach. The relative extent of each type of soil degradation within the mapped unit is recognized as:

Category	**% of the mapping unit**
1. Infrequent	up to 5%
2. Common	6-10%
3. Frequent	11-25%
4. Very frequent	26-50%
5. Dominant	over 50%

The soil degradation severity level is indicated by the combination of the degree and the relative extent as shown in (Table ,3).

Table (3): The severity level of soil degradation:

Degree of soil degradation	**Relative extent (%)**				
	0-5	**6-11**	**11-25**	**26-50**	**50-100**
Slight	1.1	1.2	1.3	1.4	1.5
Moderate	**2.1**	**2.2**	**2.3**	**2.4**	**2.5**
Strong	3.1	3.2	3.3	3.4	3.5
Extreme	4.1	4.2	4.3	4.4	4.5

The severity classes:

Low	Moderate	High	Very high

RESULTS AND DISCUSSION

Physiographic-soils units of the studied area:

The main physiographic-soils units in the studied area are represented in (Table, 4) and (Figure,3); the obtained data indicate that the area includes the following:

- Alluvial plain: this landscape represents 71.08 % of the total area; it includes the landforms of river terraces (T1, T2, & T3), levees (L) and basins (B1, B2 & B3). The soils classifications of these units are: Typic Torrifluvents, Vertic Torrifluvents, Typic Aquisalids and Typic Natrargids sub great groups.

- Lacustrine plain: this landscape includes the dried lake bed (DL), dried fish ponds (FD) wetlands (WL), and wet sabkha (WS) landforms, and they represent 19.34 % of the total area. The main taxonomic units in this landscape are Typic Natrargids and Sodic Aquicambids.

- Marine plain: it includes the sand sheets (S1 & S2), Island (I) and seasonally submerged land (SL) and representing 9.57 % of the total area. The soils of this landscape are belongs to the Typic Torripsamments sub great group. Some chemical and physical analyses of the studied soil profiles are shown in (Table ,5).

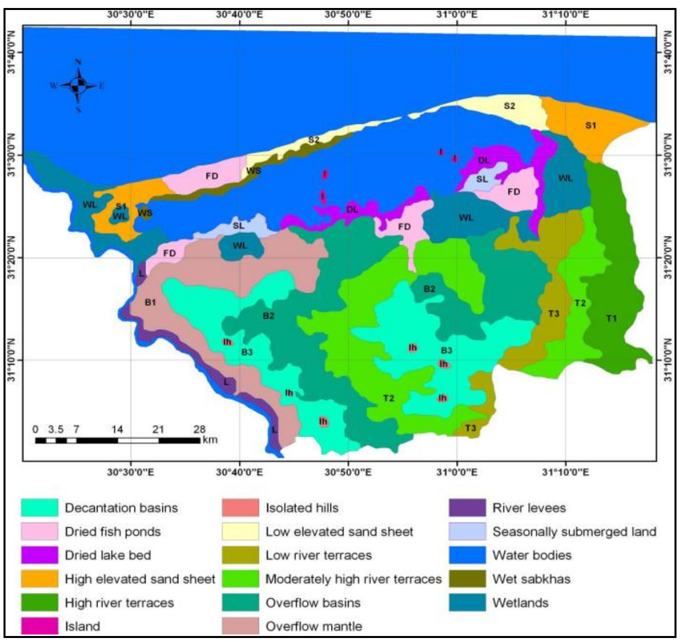

Figure (3): Physiography and soils of the studied area

Table (4) Legend of the physiographic-soils map

Physiography	Landforms	Mapping unit	Area (km^2)	Soil profile	Soil taxonomy
Flood plain	River terraces: High	T1	218.24	9	Vertic Torrifluvents
	Moderately high	T2	476.78	--	--
	low	T3	173.44	4	Typic Aquisalids
	River levees	L	50.68	10	--
	Isolated hills	I H	10.54	--	--
	Overflow mantle	B1	292.41	3	Typic Torripsamments
	Overflow basins	B2	528.57	8	TypicTorrifluvents
	Decantation basins	B3	509.67	5	Typic Natrargids
Lacustrine plain	Dried lake bed	DL	115.00	6	Sodic Aquicambids
	Dried fish ponds	FD	152.25	--	--
	Wetlands	WL	304.83	7	Typic Natrargids
	Wet sabkhas	WS	40.36	--	--
Marine plain	Sand sheet: High elevated	S1	153.96	1	Typic Torripsamments
	Low elevated	S2	88.08	2	Typic Torripsamments
	Seasonally submerged land	SL	44.96	--	--
	Island	I	5.40	--	--

Human induced soil degradation:

The soil degradation parameters (rate, degree, relative extent, causative factors and severity level) were investigated for the different soil classes to assess water logging, compaction, salinization, and alkalinization in the studied areas. The rate of land degradation was estimated by the comparison between the main land characteristics as studied in 1963 and 2009, (Table, 6). Soil degradation rates for each mapping unit are illustrated in (Table, 7). The obtained data reveal that, the rate of salinization, alkalinization, water logging and compaction, are slight to moderate, where the annual increases of EC, ESP, water table level and bulk density reaches to 0.28 dS/m, 0.27 %, 0.65 cm and from 0.02 g/cm^3 per year respectively. The hazards of the different types of soil degradation are low to high, where the present values of electric conductivity, exchangeable sodium percent, bulk density and the depth of water table are ranges between 6.91and 34.70 dS/m, 7.00 and 33.36%, 1.13 and 1.79 g/cm^3 and 60to 130 cm. respectively. The relative extent of each type of human induced soil degradation in the studied areas were estimated based upon the correlation between the physiography and soils in the different mapping units, as shown in (Table, 8). The results indicate that 643.95 km^2 of the studied area have a high degree of water logging as the soil depth ranges from 60 to 80 cm., 1733.26 km^2 have a high hazard of compaction as the bulk density are located in the range of 1.45 to 1.79 g/cm^3, 707.89 km^2 have a high degree of salinity where the EC ranges from 15.43 to 34.70 dS/m and 1848.64 km^2

have a moderate hazard of alkalinity ESP ranges from 15.00 to 33.36 %.

The severity levels of land degradation were indicated by a combination of the degree and the relative extents of the degradation types (Table 9). The severity level in the studied area varies from low to very high, where the relative extent in the different mapping units is dominant (affect over 50% of the units) while the degree of degradation varies from low to high. The high severity levels of soil degradation are associated with the landforms of clay flat, decantation and overflow basins, and over flow mantle. The soils of sandy remnants, turtle backs and river terraces are facing low severity levels of degradation.

The main causative factors of soil degradation in the studied area were observed during the fieldwork, these factors are over irrigation (i), improper use of heavy machinery (m), and human intervention in natural drainage (d) and the absence of conservation measurements (o). These factors are found in the different units in the area, where the same traditional managements are practices.

The statuses of land degradation in the different mapping units of the studied area are shown in (Table 10) and (Figure,4).

Table (6): Monitoring of the main land characteristics in the studied area:

Profile No.	Mapping unit	Water table level (cm)		Bulkdensity* g/cm^3		EC* ds/m		ESP*%	
		1963	2009	1963	2009	1963	2009	1963	2009
1	S1	110	90	1.10	1.13	10.41	18.53	6.50	7.00
2	S2	150	120	1.11	1.15	21.82	34.70	6.67	7.63
3	B1	130	100	1.18	1.25	10.31	15.43	6.18	7.00
4	T3	100	60	1.28	1.34	22.94	29.15	11.45	16.85
5	B3	150	120	1.30	1.79	7.23	9.00	10.10	17.60
6	DL	100	80	1.30	1.41	5.17	7.90	19.61	32.15
7	WL	90	60	1.28	1.38	4.82	6.91	20.19	33.36
8	B2	150	130	1.30	1.64	2.14	3.36	5.63	9.77
9	T1/T2	150	120	1.31	1.45	2.24	3.87	11.86	15.50
10	L	100	70	1.29	1.40	5.24	7.91	10.42	15.00

*Calculated till the depth to 100 cm.

Table (7) Land degradation rates in the different mapping units of the studied area

Profile No.	Mapping unit	W	C	S	A
1	S1	1	1	1	1
2	S2	1	1	2	1
3	B1	1	1	1	1
4	T3	1	1	1	1
5	B3	1	2	1	1
6	DL	1	1	1	2
7	WL	1	1	1	2
8	B2	1	1	1	1
9	T1/T2	1	1	1	1
10	L	1	1	1	1

Where:

W= Water logging, C = Compaction, S = Salinization, A = Alkalinization.

1= Low, 2= Moderate, 3= High

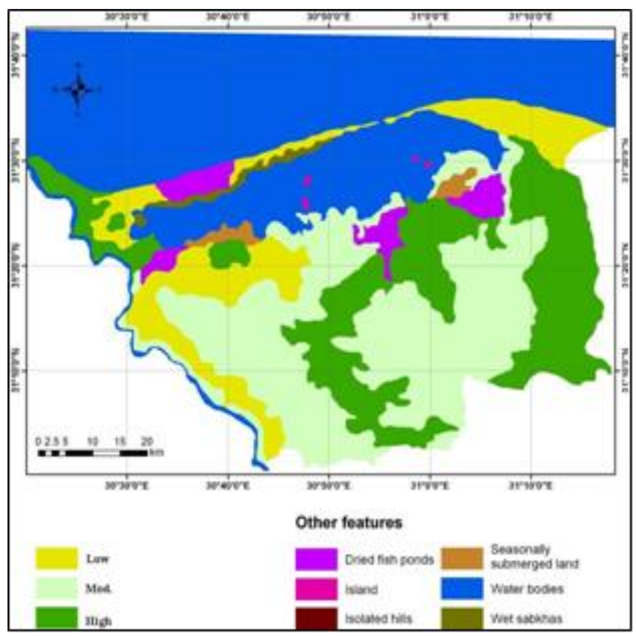

Figure (4): Land degradation statuses in the studied area.

Table (10): Land degradation status in the different mapping units:

Mapping unit	Land degradation status*
S1	(Pw i/d/o 3,5) (Cs m/i/o 4,5)
S2	(Pw i/d/o 2,5) (Cs m/i/o 4,5)
B1	(Pw i/d/o 3,5) (Pc m 2,5) (Cs m/i/o 3,5)
T3	(Pw i/d/o 3,5) (Pc m 2,5) (Cs m/i/o 3,5) (Ca m/i/o 3,5)
B3	(Pw i/d/o 2,5) (Pc m 4,5) (Cs m/i/o 2,5) (Ca m/i/o 3,5)
DL	(Pw i/d/o 3,5) (Pc m 3,5) (Cs m/i/o 2,5) (Ca m/i/o 4,5)
WL	(Pw i/d/o 3,5) (Pc m 2,5) (Cs m/i/o 2,5) (Ca m/i/o 4,5)
B2	(Pw i/d/o 2,5) (Cs m/i/o 4,5)
T1/T2	(Pw i/d/o 2,5) (Cs m/i/o 3,5)
L	(Pw i/d/o 3,5) (Pc m 3,5) (Cs m/i/o 2,5) (Ca m/i/o 3,5)

*The first two letters = degradation types where, Pw = physical degradation/ water logging, Pc= physical degradation/ soil compaction, Cs= chemical degradation/ Salinization, Ca = chemical degradation/ alkalinization. The following one or two letters= causative factors where, i = over irrigation, d = human intervention in natural drainage, m = improperly time use of heavy machinery, o= absence of conservation measurements. The first digit= degree of land degradation; the second digit = relative extent of degradatio

CONCLUSION

The soils of the studied area have a mod. rate of degradation for different types of human induced factors due to the mod. changes in the land characteristics during the period of 1963to 2009. According to present value of soil depth, bulk density, electric conductivity and exchangeable sodium percentage these soils are threatened by a low to high degree of water logging, compaction, salinity and alkalinity. The high Values of these types are due to the over irrigation, improper use of heavy machinery and the absence of conservation measurements. The severity levels of the different types of degradation in these soils are low to very high. Generally, the studied area is considered as unstable ecosystem due to active degradation resulting from climate, relief, soil properties and improper farming system.

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Table (8): Relative extent (%) of the land degradation types in the studied area:

Mapping unit	Water logging Depth of water table (cm)			Compaction (bulk density (g/cm^3))			Salinization (EC in dS/m)			Alkalization (ESP %)		
	150 - 100	100-75	75-50	<1.2	1.2 - 1.35	1.35 - 1.50	<4	4-8	8 -16	<15	15-25	25-35
S1	-	71.42	28.58	82.31	17.69	-	-	26.53	73.47	91.29	8.71	-
S2	64.20	30.67	5.13	77.16	22.84	-	-	48.38	51.62	83.45	16.55	-
B1	-	59.11	40.89	-	66.25	33.75	-	39.62	60.38	78.31	21.69	-
T3	-	81.47	18.53	-	72.36	27.64	-	34.84	65.16	16.59	83.41	-
B3	65.42	30.23	4.35	-	32.62	67.38	17.89	82.11	-	6.10	93.90	-
DL	-	54.26	45.74	-	45.63	54.37	26.60	73.40	-	-	20.78	79.22
WL	-	65.13	34.87	-	47.29	52.71	31.84	68.16	-	-	16.59	83.41
B2	72.55	27.45	-	-	29.65	70.35	83.41	16.59	-	93.50	6.50	-
T1/T2	75.30	24.70	-	-	48.78	51.22	75.62	24.38	-	25.69	74.31	-
L	-	76.11	-	-	49.82	50.18	67.44	32.56	-	23.44	76.56	-

Table (9): Land degradation severity level in the studied area:

Profile No.	Mapping Unit	Water logging			Compaction			Salinization			Alkalization		
		Degree	Extent	Severity level	Degree	Extent	Severity level	Degree	Extent	Severity level	Degree	Extent	Severity level
1	S1	3	5	3,5VH	1	5	1,5L	4	5	4,5VH	1	5	1,5L
2	S2	2	5	2,5H	1	5	1,5L	4	5	4,5VH	1	5	1,5L
3	B1	3	5	3,5VH	2	5	2,5H	3	5	3,5VH	1	5	1,5L
4	T3	3	5	3,5VH	2	5	2,5H	4	5	4,5VH	3	5	3,5VH
5	B3	2	5	2,5H	4	5	4,5VH	2	5	2,5H	3	5	3,5VH
6	DL	3	5	3,5VH	3	5	3,5VH	2	5	2,5H	4	5	4,5VH
7	WL	3	5	3,5VH	2	5	2,5H	2	5	2,5H	4	5	4,5VH
8	B2	2	5	2,5H	4	5	4,5VH	1	5	1,5L	1	5	1,5L
9	T1/T2	2	5	2,5H	3	5	3,5VH	1	5	1,5L	3	5	3,5VH
10	L	3	5	3,5VH	3	5	3,5VH	2	5	2,5H	3	5	3,5VH

L= low, H= high, VH= very high