Use of Satellite Data and GIS for Soil Mapping and Capability Assessment

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Abstract: This study aims to use the satellite data and Geographic Information System (GIS) to produce the soil map and use the spatial analysis technique to assess the soil capability. The soils adjacent to El-Manzala Lake east of the Nile Delta, Egypt were chosen for this application. To achieve this objective the land surveying, and satellite data (Landsat ETM and SRTM images) were used in a Geographic Information System to delineate the landforms of the studied area. The correlation between landforms and soil taxonomic units were worked out. The results indicated that the area was dominated by flood plain (33.48 % of the total area), the lacustrine plain (21.52 % of the total area) and the marine plain (3.13 % of the total area). The Water bodies and urban areas exhibit 41.86 % of the total area. The soil properties such as $CaCO_3$ content, texture class, soil depth, salinity, alkalinity, CEC and drainage condition were linked with the different landforms of the studied area. The thematic layers of these data were created in Arc-GIS 9.2 software using the spatial analysis function, and then these layers were matched together to assess the soil capability. The data obtained from the thematic layers indicate that the main limiting factors in the studied area were soil depth, drainage conditions, soil salinity, soil texture, alkalinity and calcium carbonate content. The limiting factors; $CaCO_3$ %, soil depth, drainage condition, salinity and alkalinity were associated with the lacusrtine plain, while the soil texture and CEC were the main limiting factors in the marine plain. The soil depth, drainage condition and soil salinity were the dominating limiting factors of the flood plain. [Nature and Science 2010;8(8):104-115]. (ISSN: 1545-0740).

Keywords: spatial analyses, landforms, soil mapping, thematic maps, soil capability, remote sensing, GIS.

1. Introduction

Until recently, there has been only one small-scale soil map with global coverage, the Soil Map of the World, at a scale of 1:5,000,000. (In this work, the term ‘‘small scale’’ refers to all the continental- and global-scale databases at spatial scales of less than 1:500,000). FAO and UNESCO produced this map between 1960 and 1980, [1]. The map contains polygons representing soil associations. Attributes provided for each mapping unit include the dominant soil type, the list of associated soils, the textural class and the slope class of the soil association. FAO prepared a map of World Soil Resources at a scale of 1:25,000,000 and also created a generalized version at a scale of 1:100,000,000 [2]. Both the Soil Map of the World and the World Soil Resources maps are available from the FAO in digital format, [3]. Landsat-MSS / TM , SPOT and IRS - LISS-I / II /III etc., were employed to map soils at different scales ranging from 1:250,000 to 1:50,000 [4].

Today there is great demand for accurate soil information over large areas from environmental modellers and land use planners (both urban and rural) as well as more traditional agricultural users of soil resource inventories. All these users want interpreted information; that is, soil properties or behaviour directly relevant to their application. The soil information so generated was interpreted for various purposes like land capability classification, land irrigability assessment, crop suitability studies, management of watersheds, prioritization of watersheds etc. [5].

In recent years thematic mapping has undergone a revolution as the result of advances in geographic information science and remote sensing. For soil mapping archived data is often sufficient and this is available at low cost. [6] stated that integration of Remote Sensing within a GIS database can decrease the cost, reduce the time and increase the detailed information gathered for soil survey. Particularly, the use of Digital Elevation Model (DEM) is important to derive landscape attributes that are utilized in land forms characterization [7 & 8].

A DEM is an electronic model of the Earth’s surface that can be stored and manipulated in a computer [7]. It provides greater functionalities than the qualitative and nominal characterization of topography. A DEM can be manipulated to provide many kinds of data that can assist the soil surveyor in mapping and giving a quantitative description of landforms and of soil variabilities. By itself the DEM can yield maps of slopes, aspects, rate of change of slope, drainage network on catchments areas [7 & 9].

Information derived from a DEM, such as elevation, slope and aspect maps can also be used with the images to improve their capabilities for soil mapping [10].

A Study by [11] indicated that slope class maps produced from 10 m DEM appear to have great potential use for soil survey and land use planning. With information on geology and surface deposits a DEM could be used to predict soil types, [12].

In his research [13] applied digital soil mapping to create a reconnaissance soil map to assess clay and soil organic carbon contents in terraced maize fields. Soil spatial variability prediction was based on environmental correlation using the concepts of the soil forming factors equation. The results were confirmed by cross-validation and provide a significant improvement compared to the existing soil survey.

In the same filed [3] stated that the use of digital data sources, such as digital elevation models (DEMs) and satellite data can speed up the completion of digital soil databases and improve the overall quality, consistency and reliability of the database. Soil information is needed for a wide range of environmental and agricultural applications. Knowledge of soils, combined with climatic and ecological data, is essential for understanding recent and future changes in ecosystems.

In the parallel, [14] reported that the principal manifestation is soil resource assessment using geographic information systems (GIS), i.e., the production of digital soil property and class maps with the constraint of limited relatively expensive fieldwork and subsequent laboratory analysis.

Moreover, many researches have done previous research and investigations and demonstrate them results on using remote sensing data and the profitable utilities of GIS applications for soil survey, mapping and land degradation in the Nile Delta area [15 to 22].

The studied area is located in the eastern part of the Nile Delta, and covers an area of about 2247.37 km^2, (Figure, 1). Two main landscapes were distinguished east of the Nile Delta: I) the fluvoi-marine plain and II) the river terraces, both of them are originated from fluvial and deltaic origin. Between these two landscapes, there is a wide transitional zone, strongly affected by wind action and consisting of nearly flat plains, gypsiferous sandy soils, wind blown sand soils, with dunes or hummocky relief and small strip of transitional soils. The area in general has fairly flat relief except the river terraces and sand dunes, which have an undulating or hummocky relief [23]. Geologically; the studied area is characterized by Nile deposits, Quaternary deposits, sabkha deposits, sand dunes and Wadi deposits [4].

The lands to be reclaimed around El-Manzala Lake east of the Nile Delta are potentially promising, this area has a good agricultural potentiality and the major constraints determining the present low production capacity of the soil are salinity, sodicity, poor internal drainage and impervious compact soil structure [25]. The soil mapping and capability assessment for this area is therefore, an essential action in order to maintain the sustainable development of effort and investment as well as the sustainable usage of the soils.

Interpreting soil qualities and site information for the agricultural use and management practices is integrated using Geographical Information System [26 & 27].

The spatial analysis was used in this study, it can be defined as the analytical techniques associated with the study of locations of geographic phenomena together with their spatial dimensions and their associated attributes [28]. The use of this techniques in evaluating the soil capability, allow producing multi-thematic maps and outlining the limiting factors, accordingly suitable suggestions could be attained to understanding how to deal with these soils for sustainable agricultural use.

The main goal of this research was to use digital elevation model (DEM) and Landsat TM imagery for a detailed Soil Mapping and Capability Assessment of the studied area.

2 - Materials and Methods

The studied area is located in the eastern part of the Nile Delta, and extended from longitudes 31° 45` and 32° 11` E and latitudes 31° 05` and 31° 32` N (Figure, 1), it covers an area of (2247.37 km^2) including land (1306.7 km^2), water bodies (921.62 km^2) and urban areas (19.05 km^2).

The delineation of the landform units from the satellite data needs a high spatial resolution images; therefore the spatial resolution of the used Landsat ETM+ was enhanced through the data merge process. This process is commonly used to enhance the spatial resolution of multi-spectral datasets using higher spatial resolution panchromatic data or single band (band 8). In this study merged data were performed using multi-spectral bands (28.50 m) as a low spatial resolution with panchromatic band 8 of ETM+ satellite image as a high spatial resolution (14.25 m) resulting in multi-spectral data with high spatial resolution (14.25 m). The landforms map has been generated from the SRTM (30 m) and enhanced Landsat ETM+ images using the ENVI 4.7 software [29].

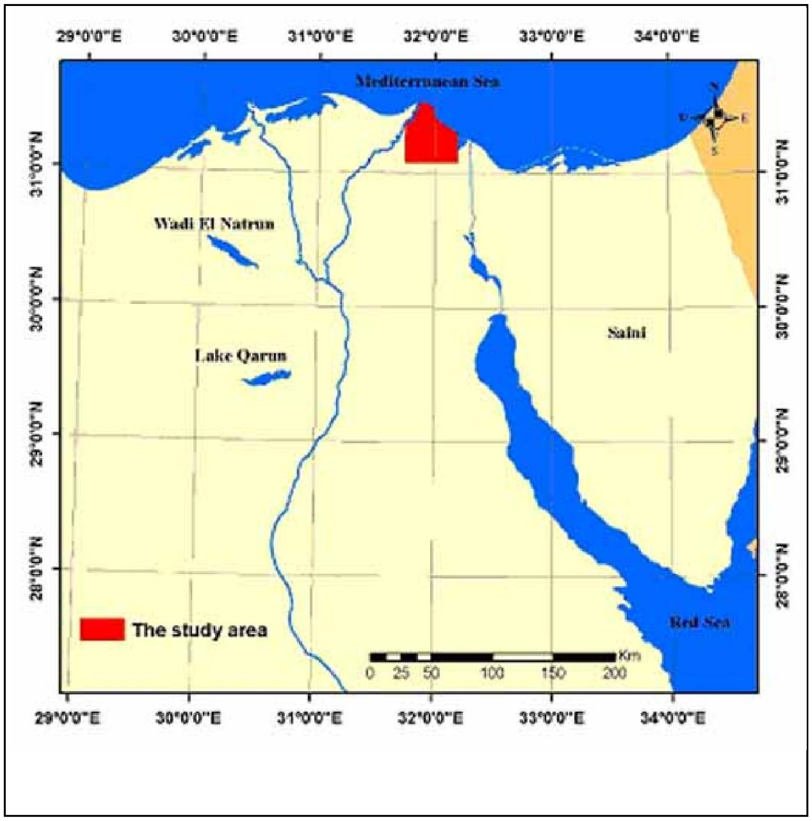

Figure (1) Location of the studied area

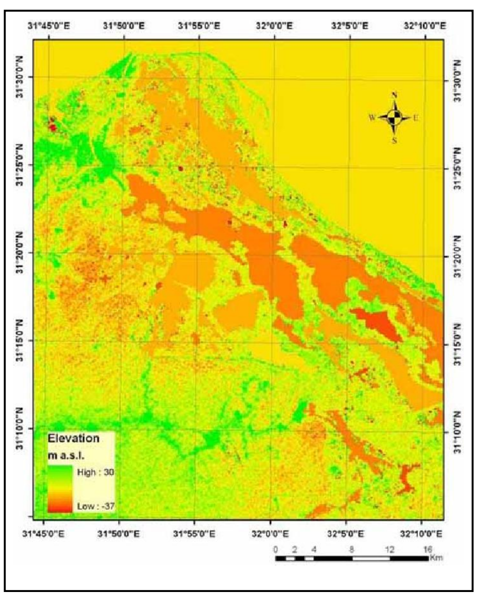

Figure (2) Surface elevation of the studied area

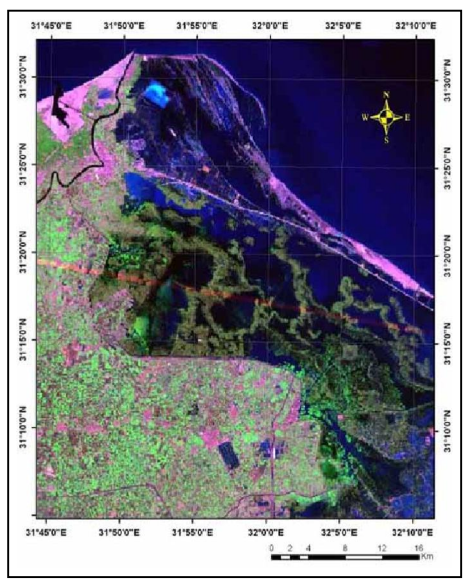

Figure (3) ETM^{+} image of the studied area

The data extracted from the ETM+ image depend upon the image texture, parceling, pattern, shape, size, color, site and situation. The SRTM data has been used in conjunction with controlled ETM+ to provide a better visualization of the terrain, where the topographic features (i.e. surface elevation, slope, aspect, shaded relief and convexity) were extracted using ENVI 4.7 software. The origin of soil deposits were extracted from geological map of the study area [24]. The boundaries of the produced map were adapted during the field work. Then, the landform units were defined and classified in orders, and then the map legend was established according to [30].

Digital Elevation Model (DEM) of the study area has been generated from the Shuttle Radar Topographic Mission (SRTM) image (Figure 2); and using Arc-GIS 9.0 software. The Landsat ETM+ image (path 176 row 38) taken during the year 2003 (Figure 3) was grouped and processed with Digital Elevation Model in ERDAS Imagine 8.7 software to extract the different landforms of the studied area [29 & 30]. The extracted data generates a preliminary geomorphologic map which was checked and completed through field observation.

A semi detailed survey was done throughout the investigated area in order to achieve more detailed information of the soil patterns, land forms and characteristic of the landscape. Fourteen soil profiles were selected to represent different mapping units; the morphological description of these profiles was carried out according to the guidelines edited by [31]. Representative disturbed soil samples have been collected and analyzed using [32].

The American Soil taxonomy [33] was followed to classify the different soils of the studied area at the sub great group level. Then the correlation between the physiographic and taxonomic units, were identified [34].

The obtained data were imported in a GIS database; the digital geomorphologic map was used as base map in the database. The spatial analyses function in Arc-GIS 9.0 was used to create the thematic layers of $CaCO_3$ content, texture class, soil depth, salinity, alkalinity, CEC and drainage condition. The thematic layers were overlapped to produce the soil capability map; the land capability classes were defined using the rating and procedure after [27 & 35].

3. Result and Discussion

According to [33] and [36] the soil temperature regime of the studied area is Thermic and the soil moisture regime is Torric.

Physiography and soils:

Based on the Landsat ETM+ images, the Digital Elevation Model (DEM) and the field check, the physiography of the studied area was identified. The obtained results reveal that, the main physiographic unites in the studied area are; the flood plain, the lacustrine plain and the marine plain, (Table 1 and Figure 4).

The flood plain is the main landform in this area. This landform dominated the eastern and southern parts of the studied area, covering an area of 752.46 km^2 (i.e. 33.48 % of the total area). This landscape was resulted from the Nile deposits, during the flood periods. It is characterized by alluvial sediments, which belong to Holocene Era. Relief types in the flood plain are flat, almost flat and gently undulating. The different land forms of this landscape are river terraces (444.70 km^2), river levees (6.01 km^2), overflow basins (182.41 km^2), decantation basins (108.68 km^2) and swales **(**10.66 km^2),

The lacustrine plain dominates the eastern parts of the area; where it covers an area of 483.74 km^2 (i.e. 21.52 % of the total area). This landscape was formed from the interaction between the Nile River and the lacustrine deposits during the flooding periods. The lacustrine plain in the studied area is characterized by the lacustrine sediments, which belongs to Holocene Era. The dominant relief type in this plain is flat or almost flat to gently undulating except small areas of convex slope, which are undulating and belongs to the old deltaic deposits. This landscape includes fish ponds and dried fish ponds as land use with an area about 126.95 km^2, dry and wet sabkhas (9.06 km^2), salt marches, swamps and dried lake bed (347.73 km^2) as landform units.

The marine plain was formed the northern part of the area and covered an area of 70.50 km^2 (i.e. 3.14 % of the total area). It includ areas of flat to almost flat and gently undulating topography, which represented by the landforms of coastal sand sheets (58.01 km^2), hummocks (1.24 km^2) and sand dunes (11.25 km^2).

The water bodies and urban areas exhibited 41.86 % of the total area.

Each landform was representing by a soil profile, the analytical data of the studied profiles are shown in table (2). The correlation between landform and taxonomic units were worked out as given in table (3), consequently, the main soils sets in the area were identified, (Figure 4). The given data indicate that the flood plain soils can be classified as *Vertic Torrifluvents*, *Typic Torrifluvents* and *Typic*

Table (1): Legend of the physiographic map of the studied area

Landscape	Origin	Relief	Land forms	Land use	Mapping unit	Area km^2	Area %
Flood plain (F)	Alluvial deposits (1)	Flat to gently undulating (1)	High terraces	Cultivated	F111	156.38	6.96
			Moderately high terraces	Cultivated	F112	178.11	7.93
			Low terraces	Cultivated	F113	110.21	4.90
		Gently slope (2)	River levees	Cultivated	F121	6.01	0.27
			Swales	Cultivated	F122	10.66	0.47
			Overflow basins	Cultivated	F123	182.41	8.12
			Decantation basins	Cultivated	F124	108.68	4.84
Lacustrine plain (L)	Lacustrine deposits (1)	Almost flat (1)		Dried fish ponds	L111	5.38	0.24
				Fish ponds	L112	121.57	5.41
			Sabkhas	Barren	L113	9.06	0.40
			Salt marches	Barren	L114	6.50	0.29
			swamps	Barren	L115	319.91	14.23
			Dried lake bed	Barren	L116	21.32	0.95
Marine plain (M)	Aeolian deposits (1)	Almost flat (1)	Coastal sand sheet	Barren	M111	58.01	2.58
		Undulating (2)	Hummocks	Barren	M121	1.24	0.05
			Sand dunes	Barren	M212	11.25	0.50
Water bodies and urban areas						940.65	41.86

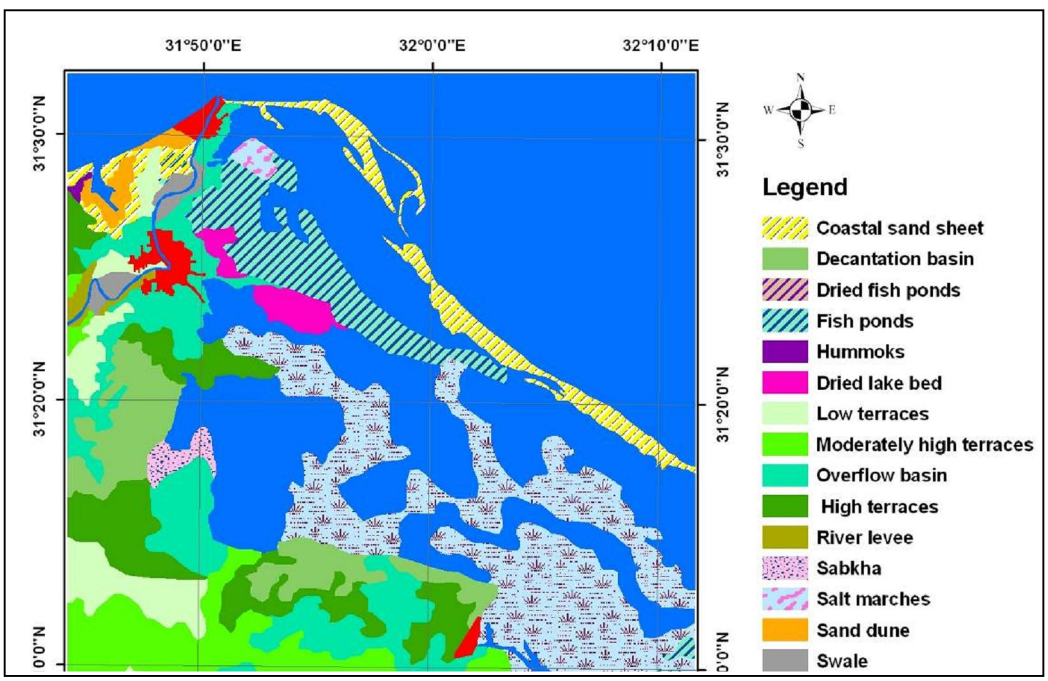

Figure (4) Landforms of the studied area

Table (2): Some chemical and physical characteristics of the studied soil profiles.

Mapping unit	Profile No.	Depth (cm)	Coarse sand %	Fine sand %	Silt %	Clay %	Textural class	CEC meq/100 g soil	ESP %	EC dS/m	pH 1: 25	O.M %	$CaCO_3$ %	Gypsum %
F111	2	0-5	16.20	25.20	23.20	35.40	CL	34.55	14.23	15.50	8.10	1.31	4.58	2.66
		5-30	14.8	25.6	24.4	35.2	CL	39.20	10.56	7.80	8.10	0.41	3.22	2.85
		30-50	11.5	29.1	32.1	27.3	CL	26.75	11.46	11.40	7.90	0.22	3.11	2.95
		50-100	1.40	38.10	33.20	27.30	CL	25.85	12.98	13.50	7.90	0.24	4.15	3.55
F112	4	0-30	15.40	39.60	17.60	27.40	SCL	26.99	10.20	4.50	8.00	1.12	2.53	2.05
		30-50	3.00	59.30	19.50	18.20	SCL	16.88	9.85	5.80	8.10	0.64	1.82	2.65
		50-90	3.20	61.00	18.40	17.40	SL	16.12	10.62	7.10	8.20	0.36	1.54	2.95
F112	6	0-20	16.50	1.00	34.00	48.50	C	47.88	10.03	6.50	8.06	2.01	3.20	2.12
		20-50	6.50	1.00	38.50	54.00	C	53.64	9.55	4.30	8.09	1.32	3.51	3.56
		50-80	7.00	0.32	26.50	66.18	C	65.89	9.32	5.60	7.86	0.89	4.12	3.99
		80-120	24.00	0.62	16.70	58.68	C	57.98	9.20	5.80	8.12	0.51	2.63	3.42
F113	8	0-25	27.70	1.00	23.00	48.30	C	47.82	8.15	3.77	7.92	2.20	1.55	2.30
		25-50	21.00	1.20	22.60	55.20	C	54.25	7.56	3.19	7.85	1.80	2.40	2.56
		50-110	11.22	1.00	43.95	43.83	SiC	42.85	8.65	4.17	7.93	0.90	1.90	2.87
F111	11	0-15	2.50	19.30	18.30	59.90	C	58.88	7.98	5.80	7.80	1.66	3.87	2.99
		15-45	1.90	14.50	23.40	60.20	C	59.78	7.85	3.90	8.00	0.75	2.69	2.75
		45-90	2.80	6.40	27.90	62.90	C	61.56	7.97	3.64	7.90	0.47	4.00	3.02
F121	12	0-15	0.20	34.60	31.30	33.90	CL	32.98	8.12	4.60	7.10	1.45	1.20	2.01
		15-45	0.40	31.10	28.00	40.50	C	39.78	8.65	4.20	7.50	0.28	1.15	2.35
		45-90	1.20	29.60	28.50	40.70	C	39.99	7.02	3.30	7.60	0.29	1.34	2.45
F124	1	0-15	2.30	10.30	15.40	72.00	C	71.98	14.65	34.40	7.90	1.03	8.22	4.56
		15-40	1.90	13.30	17.40	67.40	C	66.25	13.98	31.50	7.90	0.51	7.52	5.75
		40-70	2.90	16.40	22.50	58.20	C	57.95	14.98	38.90	7.90	0.32	9.71	6.95
F123	3	0-30	18.30	28.20	25.20	28.30	CL	27.89	10.25	6.20	8.10	1.52	5.16	4.02
		30-50	2.80	58.40	14.30	24.50	SiCL	23.98	7.89	4.50	8.10	0.58	3.40	4.56
		50-90	1.20	62.10	14.90	21.80	SiCL	20.75	10.75	8.10	8.20	0.43	4.10	4.79
F124	5	0-20	11.00	0.75	24.75	63.50	C	62.45	12.12	12.50	8.31	2.60	6.90	5.20
		20-60	8.50	0.50	26.50	64.50	C	63.76	12.23	15.05	8.53	1.40	5.50	6.20
F123	7	0-20	43.32	1.70	19.50	35.48	CL	34.98	12.65	15.90	7.44	2.10	1.84	2.12
		20-50	39.15	1.00	36.30	23.55	L	22.75	6.78	8.56	7.52	1.80	2.36	2.45
		50-100	41.92	1.00	11.03	46.05	C	45.78	12.30	14.11	7.49	0.70	2.54	2.75
F123	10	0-20	3.00	15.30	20.70	61.00	C	60.78	13.21	20.80	7.00	1.62	8.22	5.30
		20-40	8.50	17.80	19.50	54.20	C	53.55	12.15	15.10	7.50	0.84	6.47	6.71
		40-75	1.50	6.00	27.10	65.40	C	64.95	12.25	15.30	7.50	0.25	7.25	7.02
L116	9	0-25	2.30	10.40	24.40	62.90	C	61.75	14.65	59.50	7.50	2.15	9.14	4.35
		25-50	1.90	13.30	24.40	60.40	C	59.82	14.20	45.40	7.60	1.05	8.18	5.25
M111	13	0-25	23.3	68.23	4.2	4.27	S	3.56	6.78	4.30	8.60	2.61	4.21	1.45
		25-60	25.58	58.42	8.22	7.78	S	5.22	6.22	3.55	8.50	0.60	4.63	2.35
		60-120	24.48	57.52	8.78	9.22	S	5.99	13.85	30.00	7.90	0.35	5.42	3.67
M212	14	0-10	22.41	68.75	4.32	4.52	S	3.52	6.10	3.10	8.20	1.80	6.57	2.02
		10-30	30.44	45.86	14.86	8.84	LS	6.25	6.20	2.00	8.10	1.80	7.81	3.23
		30-40	18.44	72.32	4.56	4.68	S	2.10	7.76	5.60	8.10	0.58	5.62	3.52
		40-120	13.85	82.89	2.05	1.21	S	1.02	12.05	25.85	8.20	0.59	3.95	4.25

Table (3): Correlation scheme between the physiographic and taxonomic units.

Mapping unit	Soil taxonomy				Sum of Profiles
	Aridisols		Entisols		
	Argids	*Salids*	*Torripsamments*	*Torrifluvents*	
F111	--	--	--	2, 11	2
F112	6	--	--	4	2
F113	--	--	--	8	1
F121	--	--	--	12	1
F123	--	--	--	3, 7, 10	3
F124	--	1	--	5	2
L116	--	9	--	--	1
M111	--	--	13	--	1
M212			14		1
Total	**1**	**2**	**2**	**9**	**14**

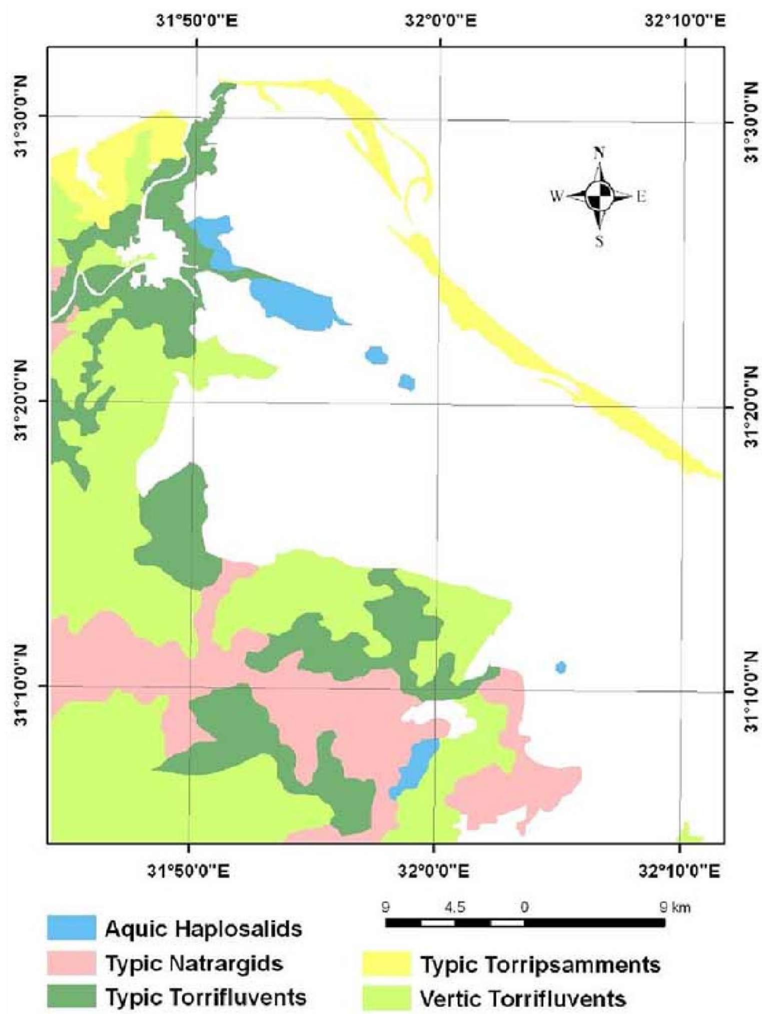

Figure (5): Soil classification of the studied area.

Table (4): Main land characteristics of the studied area

Unit	Profile	Main land characteristics						
		Depth	Drainage	Texture	$CaCO_3$	Ec	CEC	ESP
F111	11	90	Moderate	C	3.52	4.43	53.96	17.47
F112	6	120	Well	C	3.41	5.55	50.17	21.5
F113	8	110	Well	C	1.95	3.71	47.80	15.82
F121	12	90	Moderate	CL	1.23	4.03	42.33	13.03
F123	3	90	Moderate	SiC	4.22	6.26	32.03	20.06
F124	5	60	Imperfect	C	6.20	14.05	51.20	28.51
L116	9	50	Poor	C	8.66	51.56	52.10	40.13
M111	13	120	Well	S	1.50	1.50	14.03	20.03
M212	14	90	Moderate	S	2.65	2.65	10.37	19.80

Table (5): Rank and rating classes of the different soil characteristics.

Rank values	$CaCO_3$ (%)	Soil depth (cm)	Soil texture (class)	EC (dS/m)	ESP (%)	CEC meq/100 g. soil	Drainage (class)
0- 0.01	--	--	--	--	--	--	--
0.01-0.6	> 30	< 60	S	>16	>50	<6	Very poor
0.61-0.7	15-30	60 – 80	SiC, C	8-16	30-50	6-12	Poor
0.71-0.9	8-15	80 - 100	CL, LS	4-8	20-30	12-18	Imperfectly
0.91-0.96	4-8	100 - 150	SL, CL	2-4	10-20	18-24	Moderate
0.97 -1	0-4	>150	L, SiL, SCL	< 2	<10	>24	Well drained

Natrargids sub great groups. The soils of the lacustrine plain were classified as *Typic Haplosalids*, while the marine plain soils were classified as *Typic Torripsamments*, (Figure 5).

Land capability assessment:

This part of study dealt with spatial analyses techniques to evaluate the agricultural land capability in the studied area. The landforms of the studied area were delineated by using the digital elevation model, Landsat ETM+ images and ground truth data of the studied area. The produced map, represents the landforms of the studied area, was imported in a Geo-database and considered as a base map.

The attributed data of $CaCO_3$ content, texture class, soil depth, salinity, alkalinity, CEC and drainage condition (Table, 4) were linked with the units of the digitized geomorphologic map in a Geographic Information System (GIS). The incorporated attributes were used to obtain the thematic layers of spatial distribution of the above mentioned characteristics as shown in figures 6 to 12. The produced layers include information on capability sub class, and spatial distribution for the soil characteristics. The obtained data indicated that the main limiting factors in the studied area were soil depth, drainage conditions, soil salinity, soil texture, $CaCO_3$ content and alkalinity. The limiting factors of $CaCO_3$ content, soil depth, drainage condition, salinity and alkalinity are associated with the lacusrtine plain, while the soil texture and CEC are the main limiting factors in the fluvio-marine plain. The limiting factors of the soil depth, drainage condition and soil salinity are dominating the soils of the flood plain. These results are of great importance as they show the distribution of the constraints of productivity all over the region. The rank and rating classes used to produce the thematic layers are shown in table 5. The thematic layers of the attribute data were matched together to produce the soil capability map of the area (Figure, 13).

The land capability was classified into to five categories according the rating values (ranges from 0 to 1), whereby the soil capability tend to increase when the rating value is closed to 1. It became clear that the high capable soils (class II) represent 10.25 % of the total area; it is associated with the river terraces landforms. The moderate capable soils (class III) dominate the decantation

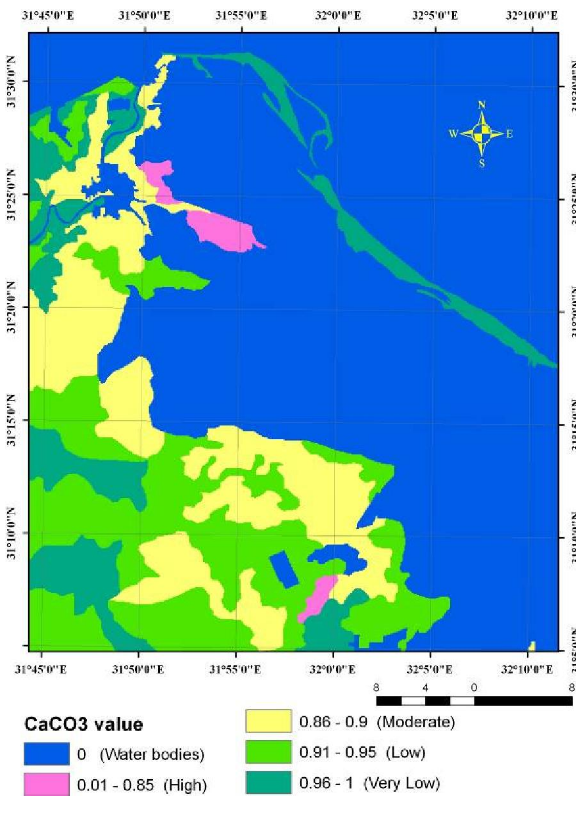

Figure (6) Spatial distribution of $CaCO_3$ content

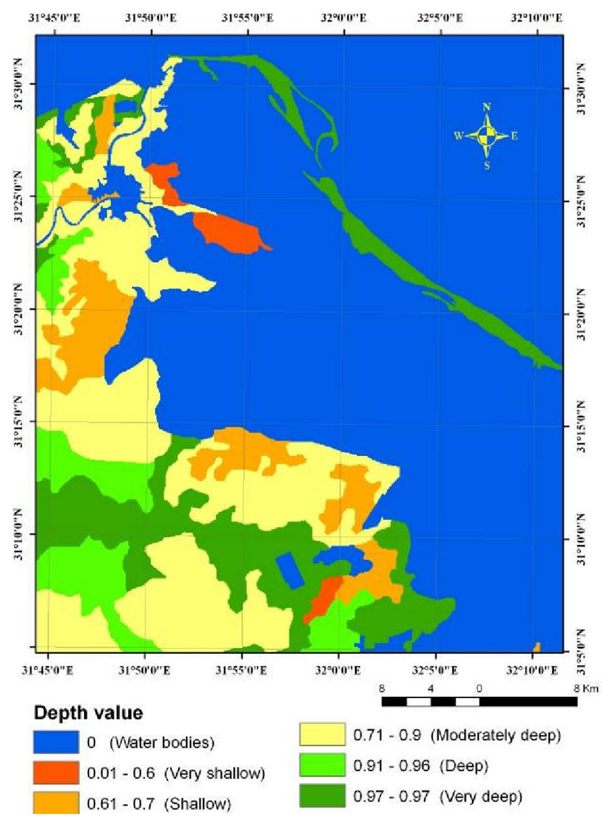

Figure (7) Spatial distribution of soil depth

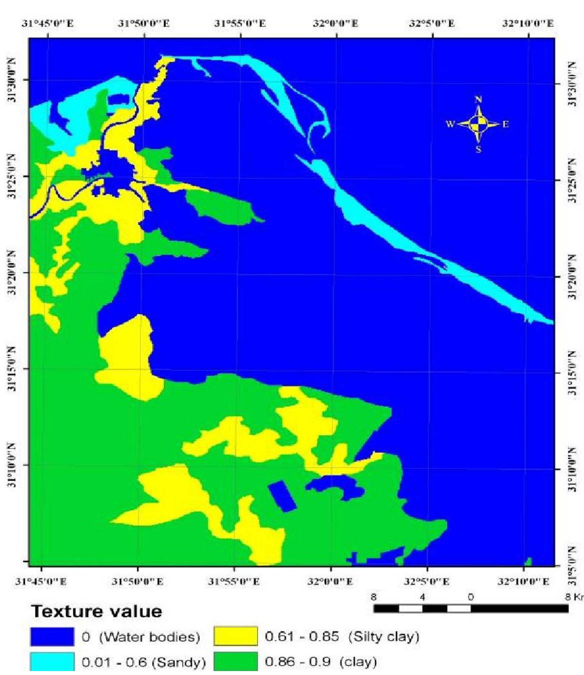

Figure (8) Spatial distribution of soil texture

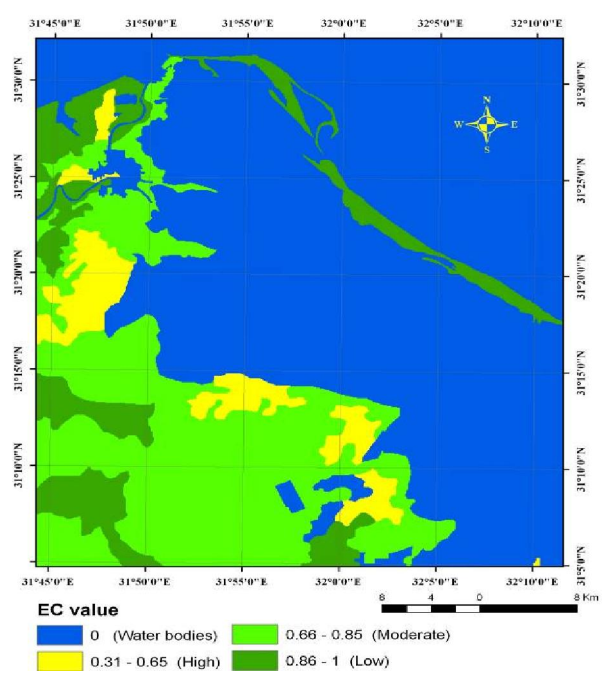

Figure (9) Spatial distribution of soil salinity

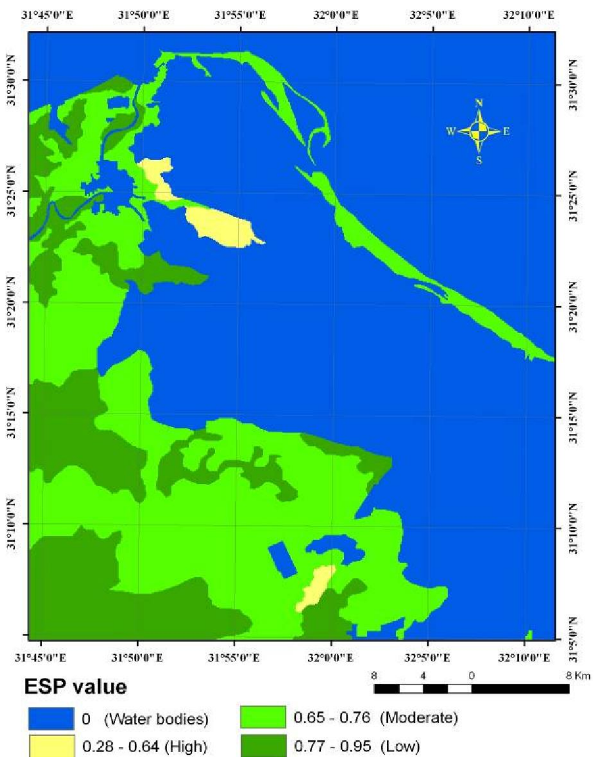

Figure (10) Spatial distribution of soil alkalinity

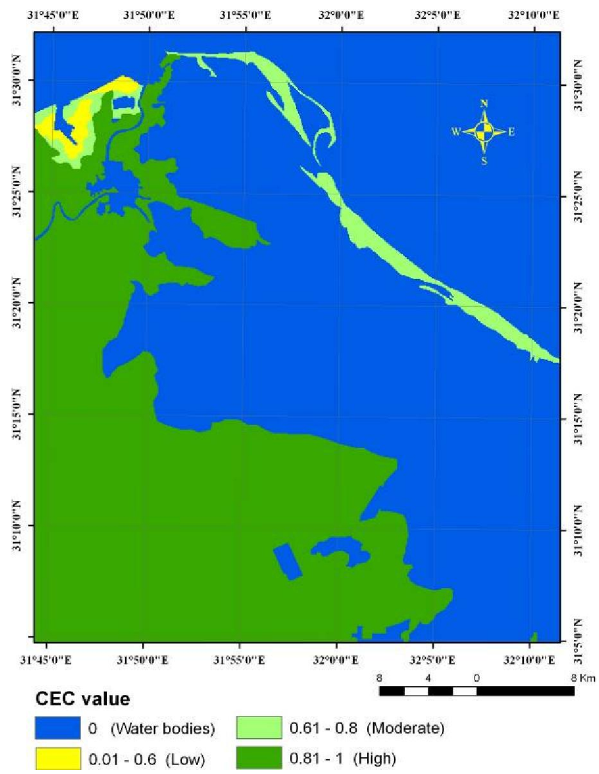

Figure (12) Spatial distribution of CEC

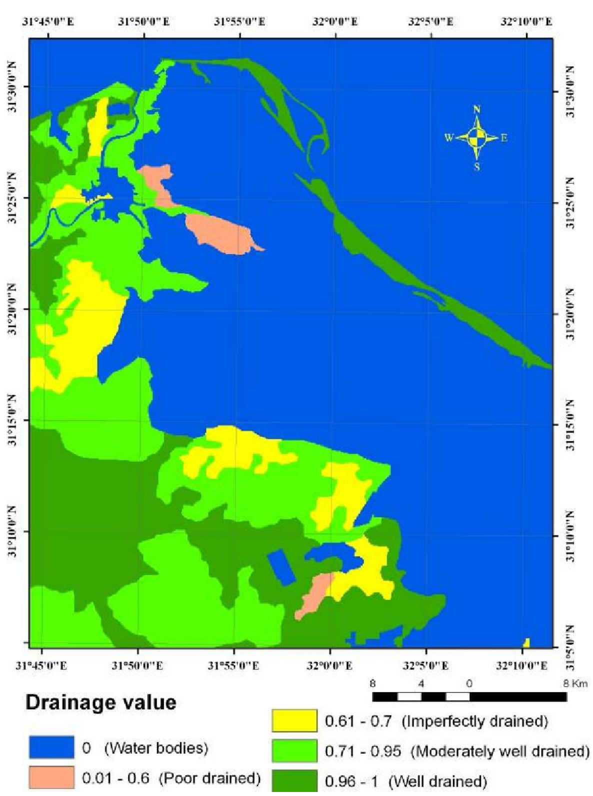

Figure (11) Spatial distribution of drainage condition

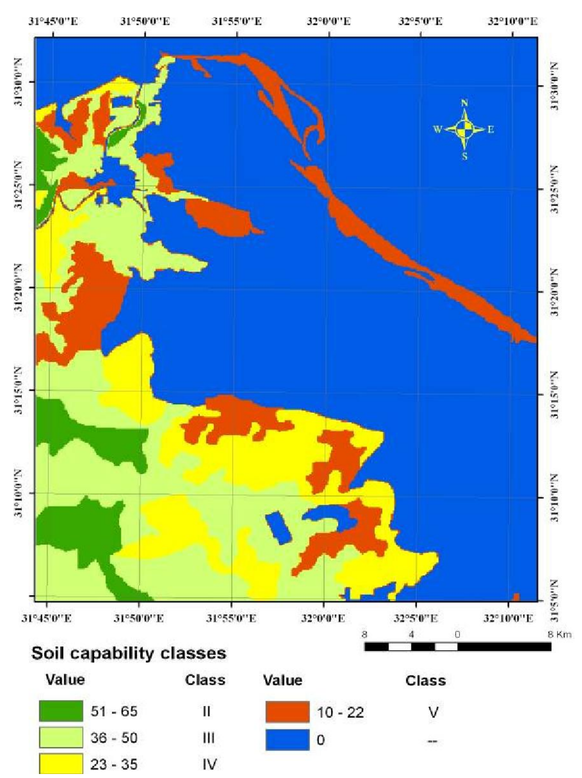

Figure (13) Soil capability Classes of the study area and overflow basins in the flood plain representing 42.74 % of the total area. The low capable soils (class IV) are associated with the landforms adjacent to the El-Manzala Lake, it representing 25.06 % of the area. The soils of the fluvio-marine deposits and decantation basins which were adjacent to the lake have a very low capability class (class V) representing 21.95 % of the total area. The spatial distribution represents the correlation between the soil characteristics and landforms, with more detailed data, that can be used in extrapolation of soil characteristics in the different landforms.

4. Conclusion

This study reaffirms the importance of the Shuttle Radar Topographic Mission (SRTM) and satellite images in defining the main landforms and the soil phases of the area at a regional scale. The integration between remote sensing and land surveying data facilitate the semi-detailed soil mapping. The produced semi-detailed map highlights the relationship between landforms and soil qualities, which can be used in extrapolation of soil characteristics in the different landforms. The use of spatial analyses techniques in evaluating the soil capability, allow producing multi-thematic maps, accordingly suitable suggestions could be attained to understanding how to deal with these soils for sustainable agricultural use. The spatial distribution of limiting factors through the different landforms is particularly important when planning for the optimal land uses, also it benefits the existing land users in determining the most appropriate management practices.

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