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Application of remote sensing and geographic information data in developing soil classificatoin maps of some soils in nile-delta

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ABSTRACT

Development of soil maps in Egypt is a necessity nowadays to provide valuable information required by resource managers and decision makers. This work aimed to apply remote sensing and geographic information data in producing more reliable and accurate soil maps for the studied area in Nile-Delta, Egypt. Studied area is classified into three physiographic units (front shore of coastal plain, back shore of low-laying stretches, and old deltaic plain). Eighteen georeferenced soil profiles representing physiographic units and soils in the studied area were dug and fully described in the field. Soil samples were also collected from soil layers of each soil profile and were analyzed in the laboratory for their physical and chemical properties. Geodatabase in combination with field-work and laboratory data were used to identifying nine soil map units (SMUs) in the studied area. These SMUs were classified according to the United States soil classification system as follow:

SMU1: Clayey, Smectitic, Superactive, Mesic, Aquic Xerofluvents
SMU2: Sandy, Mesic, Aquic Quartizipsamments
SMU3: Clayey, Smectitic, Superactive, Mesic, Typic Haploxererts
SMU4: Sandy, Mesic, Typic Torripsamments
SMU5: Clayey, Smectitic, Superactive, Mesic, Vertic Fluvaquents
SMU6: Clayey, Smectitic, Superactive, Mesic, Vertic Xerofluvents
SMU7: Clayey, Smectitic, Superactive, Mesic, Vertic Xerofluvents
SMU8: Sandy, Mesic, Xeric Torripsamments
SMU9: Clayey over sandy, Smectitic, Superactive, Mesic, Typic Haploxererts

INTRODUCTION

Soil resource inventories of promising areas for agricultural production have much interest of both pedologists and decision makers in Egypt and worldwide. Traditionally soil maps have been developed as paper-map representations of classified soils from aerial photographic interpretation and intensive fieldwork. These soil survey maps were time intensive to compile and publish (Elnaggar, 2007). Accordingly, much of the world remains unmapped at a scale that could be of use to society at local level. Furthermore, these maps are little use when soil or land use change has occurred.

Geographic Units:

Hussien (1999) and Essa (2007) identified three geomorphic units in the studied area, which are:

1. Front shore of coastal plain, which includes the sandy beach, sandy bar, lagoonal depression. The marine deposits of front shore plain are transported based on the grain size and the statistical analyses of these deposits.

2. Back shore of low-lying stretches, includes the sandy sheets, swamps and sand dunes that take different stages of development and different forms (i.e., longitudinal barchanoidal, transversal dunes and their complexes patterns). The aeolian and marine deposits of the back shore plain-based upon the grain size analysis and the statistical measures are deposits are transported and deposited under wind-marine action, but the wind is the predominant agent.
3. Old deltaic plains, which vary in age from Pleistocene to recent ages and from a series of terraces of different heights above the valley floor.

Geographic Information System (GIS) is a powerful set tools for collecting storing, retrieving as well, transformation and displaying spatial data from the real world for a particular set of purposes (Burrough, 1986). Until recently, all spatial data were stored and presented to the user in a classified form on paper maps.

Remote sensing (RS) is defined for our purposes, as the measurement for object properties of earth's surface using data acquired from aircraft and satellites. It is therefore an attempt to measure something at a distance, rather than in situ. Since we are not in direct contact with the object of interest, we must rely on propagated signals of some sort, for example optical, acoustical, or microwave (Robert, 2007).

Soil Mapping illustrated that digital soil mapping is now moving inexorably from the research phase to the effective production of soil maps, it is destined to play a great role in the development of current and future soil spatial information systems (Lagacherie et al, 2007). The way digital soil mapping will be integrated into current soil inventory and soil data acquisition programs has thus to be carefully addressed to ensure an effective benefit to the users. It seems obvious that no single and ideal way can be proposed because the current state of soil data is strongly influenced by the pedological, historical and economic particularities of each region of the world.

Natural Vegetation of east Nile-Delta was classified according to Bayoumi (1971) and Essa(2007) as *a)* In the fluvio-marine plains, the natural vegetation growing on these soils are reed swamps represented by *Typha aitstralis* and *Phragmites communes,* whereas the sedge-medow vegetation are represented by the *Juncus acutus community* and the salt marches vegetation are represented by *Artheocnemon glaucum, Salicornia Fraticosa, Halocnemon strobilaceum, Suada sp., Tamarix sp.* and *Haifa grassland (Desmostachya bipinnata)*. b) In sandy plains, the plant communities of this ecosystem are either salt tolerant or sandy loving species, *viz. Zygophyllum album. Anabasis orticulata* and *Bassia muricate.* A few individual plants of *Artimisia monosperma* and *Phoenix dactylifera* are also found***.*** **P**lant species growing on sand dune habitats are *Alhagi maurarum, Nitraria retusa, Desmastachya bipennate, Echinops. Spinossimns* and *Tamarix sp.*

MATERIALS AND METHODS

Studied area is located in the Northern part of Nile-Delta in Dakahlia Governorate between 31° 15´ to 31° 30´ E 31° 15´ to 31° 30´ N (total area about 659 km^2). Landsat ETM+ path 178 row 39 acquired in November, 11, 2000 (downloaded in March, 15, 2008 from http://glcfapp.umiacs. umd.edu: 8080/esdi/index.jsp) was subsetted to cover the studied area. False color composite (FCC, RGB 432) of the Landsat was used to identify physiographic units, land covers, land uses, and soil characteristics of the studied area. Studied area comprises of sand dunes, sabkha deposits, and Nile deposits according to the Egyptian Geologic Survey (1981). Surface elevation ranged between 0 and 5 m above the sea level. Area is almost leveled (slope varies from 0 to 2%). Soil temperature regime of the studied area could be defined as Thermic and soil moisture regime as Xeric , Torric and aquic according to water table..

Mini pits and eighteen georeferenced soil profiles were dug to represent physiographic units and soils in the studied area. The spatial distribution of soil profiles is overlaid on the Landsat image as represented in Figure 2.

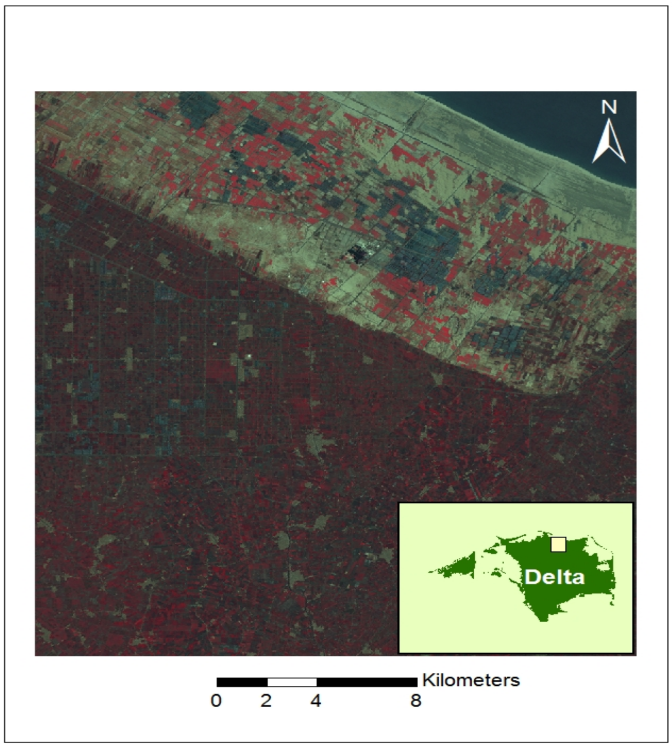

Fig 1: Insight map of the studied area

These profiles were fully described in the field according to the Soil Survey Staff (2002). Soil samples were also collected from each soil profile using a 20 cm depth interval to the ground water depth, where soils are poorly developed and no obvious diagnostic horizons were observed. Soil samples were finely grounded, crushed to pass through 2 mm sieve, and stored for analysis. Soil physical and chemical analyses were done according to the soil survey laboratory methods (USDA, 2004).

On the basis of the topographic nature (Military survey maps) (1: 50000) namely, sheets of Elgarida eighteen soil profiles were selected from these regions representing the different soils, (Fig. 2).

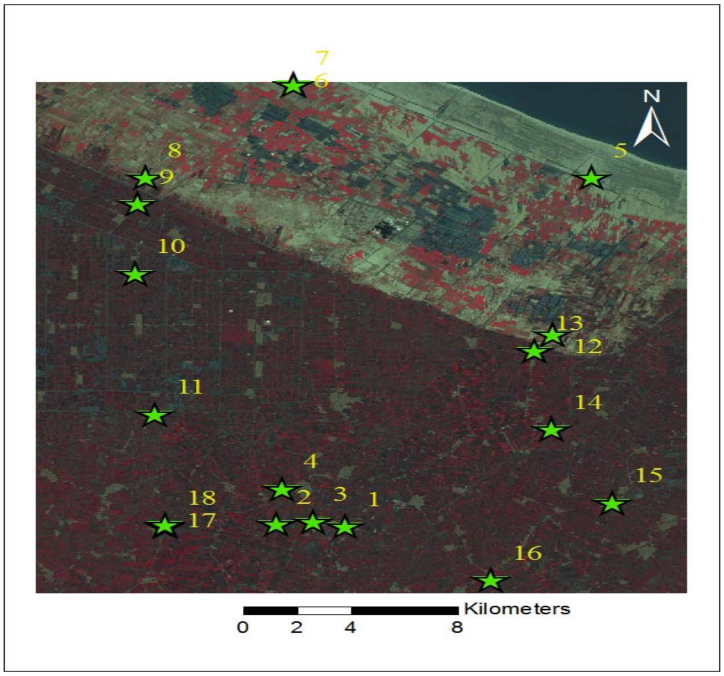

Fig. 2: Spatial distribution of soil profiles in the studied area overlaid on the Landsat image.

The digitized contour lines and spot heights were exported to Arc View software 9.0 as vector format, and the contour gridder extension was utilized to generate the Digital Elevation Model (DEM).

Landsat ETM+ images(7, 4, 2 bands acquired in 2002) and Digital Elevation Model (DEM) was used in ERDAS Imagine 8.4 software to produce the physiographic map of the studied area (Dobos *et al.*, 2002).

RESULTS AND DISCUSSION

Nine soil map units (SMUs) were recognized in the studied area (Figure 3) according to United States soil classification system (Soil Survey Staff, 2006). The following are the characteristics of these SMUs and their taxonomy (data are represented in tables 2 and 3):

SMU1: Soils in this map unit are represented by profile No 10. Land surface is approximately leveled. Soils are moderately well drained, deep, and clayey covered by sandy clay loam. Soils in this map unit are non-saline. EC values ranged between 0.35 to 1.01 dSm^{-1}, and increased with depth. Soils vary from slightly alkaline to alkaline (pH from 7.6 to 8.2); pH values were also increased with depth. Soils are non-calcareous (total carbonate content ranged between 1.69 and 1.37%) and have no pattern with depth. Soil organic matter was low (0.05 to 1.36%), the highest value was obtained in surface layer, whereas the lowest value was in lowest layer.

According to Soil Survey Staff (2006), this map unit could be classified as: *clayey, Smectitic, Superactive, Mesic, Aquic Xerofluvents*. It covers about 19645 Feddan (about 12.51% of the total area).

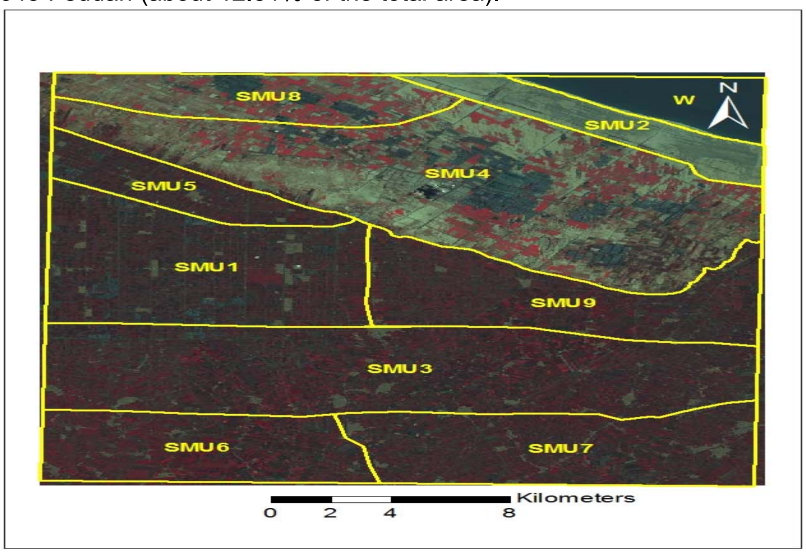

Fig. 3: Developed map of Soil map units (SMUs) in the studied area.

SMU2: Soils in this map unit are represented by profile No 5. Land surface is nearly leveled. Soils are moderately drained, deep, with a sandy texture. This map unit is slightly saline in the surface layer (EC 3.57 dSm^{-1}) and in the deepest layer (EC 4.97 dSm^{-1}), non-saline in the middle layer (EC 1.57 to 1.62 dSm^{-1}), soil pH from 7.8 to 8.0, non-calcareous (total carbonate content between 0.16 to 0.27%) and have no pattern with depth and have low organic matter content (0.00 in the lowest layer to 0.22% in the upper layer). According to Soil Survey Staff (2006), this map unit could be classified as

Sandy, Mesic, Aquic Quartizipsamments and this map unit covered 6052.3 Feddan (about 3.86% of the total area).

Table 2: Particle size distribution, soil texture, $CaCo_3$ content, organic matter (OM), electric conductivity (EC) in soil past extract and pH in soil suspension (1:2.5) of the studied soils.

Profile No.	SMU	Depth (cm)	Particle size distribution				Texture	$CaCO_3$ (%)	OM (%)	EC (dSm^{-1})	pH
			Fine sand (%)	Coarse sand (%)	Silt (%)	Clay (%)					
1	7	0-20	37.41	8.16	13.61	40.82	Sandy clay	1.81	1.47	0.34	7.6
		20-40	29.48	2.14	34.19	34.19	Clay loam	1.84	1.63	0.28	7.6
		40-60	23.15	4.94	53.93	17.98	Silt loam	1.61	0.42	0.32	7.8
		60-80	29.00	1.73	60.61	8.66	Silt loam	2.62	0.28	0.38	8.0
		80-100	49.08	1.84	41.72	7.36	Loam	1.49	0.08	0.38	8.0
2	6	0-20	29.66	2.54	33.90	33.90	Clay loam	2.37	0.29	0.33	7.6
		20-40	30.35	1.28	17.09	51.28	Clay	2.17	0.23	0.28	7.6
		40-60	27.87	0.22	17.98	53.93	Clay	2.48	0.17	0.27	7.8
		60-80	15.68	0.70	27.87	55.75	Clay	2.36	0.54	0.37	7.8
		80-100	6.91	0.99	52.63	39.47	Silty clay loam	1.59	0.12	0.38	7.8
3	7	0-20	18.19	2.27	34.09	45.45	Clay	4.05	0.80	0.31	7.9
		20-40	13.99	2.10	27.97	55.94	Clay	3.73	0.69	0.28	8.0
		40-60	7.14	0.42	42.02	50.42	Silty clay	2.71	0.41	0.92	8.0
		60-80	9.39	2.21	44.20	44.20	Silty clay	2.40	0.12	0.95	8.2
		80-100	9.62	0.64	25.64	64.10	Clay	0.94	0.41	0.92	8.2
4	3	0-20	16.80	3.20	56.00	24.00	Silt loam	1.69	1.86	0.75	7.6
		20-40	16.26	2.44	32.52	48.78	Clay	1.40	1.08	0.26	7.6
		40-60	15.28	2.07	33.06	49.59	Clay	1.07	0.66	0.44	7.8
		60-80	15.46	2.06	20.62	61.86	Clay	0.98	0.49	0.62	8.0
		80-100	20.00	3.80	38.10	38.10	Clay loam	1.84	0.20	0.76	8.2
5	2	0-20	25.20	74.80	0.00	0.00	sandy	0.22	0.22	3.57	7.8
		20-40	11.61	88.39	0.00	0.00	sandy	0.16	0.08	1.75	7.8
		40-60	13.53	86.47	0.00	0.00	sandy	0.19	0.00	2.68	8.0
		60-80	13.85	86.15	0.00	0.00	sandy	0.27	0.00	4.97	7.8
6	8	0-20	6.37	93.63	0.00	0.00	sandy	0.41	0.43	0.77	8.0
		20-40	4.09	95.91	0.00	0.00	sandy	0.46	0.18	0.82	8.0
		40-60	4.27	95.73	0.00	0.00	sandy	0.18	0.05	1.38	8.0
		60-80	7.36	92.64	0.00	0.00	sandy	0.18	0.05	2.77	8.2
		80-100	4.08	95.92	0.00	0.00	sandy	0.14	1.12	3.38	8.3
7	8	0-20	5.95	94.05	0.00	0.00	sandy	0.43	0.34	0.86	7.8
		20-40	11.24	88.76	0.00	0.00	sandy	0.48	0.19	1.08	7.8
		40-60	14.81	85.19	0.00	0.00	sandy	0.11	0.06	1.09	7.8
		60-80	8.26	91.74	0.00	0.00	sandy	0.11	0.00	1.45	7.9
		80-100	3.55	96.45	0.00	0.00	sandy	0.14	0.00	1.69	7.9
8	4	0-20	24.26	69.68	2.02	4.04	sandy	0.23	0.79	0.29	7.9
		20-40	23.93	76.07	0.00	0.00	sandy	0.18	0.16	0.23	7.8
		40-60	24.02	75.98	0.00	0.00	sandy	0.06	0.00	0.34	8.0
		60-80	20.93	79.07	0.00	0.00	sandy	0.06	0.00	0.33	8.2
9	5	0-20	50.74	1.30	4.36	43.60	Sandy clay	1.84	0.32	3.15	7.8
		20-40	43.50	0.72	4.46	51.32	clay	1.91	0.18	4.94	7.8
		40-60	51.61	0.65	4.34	43.40	Sandy clay	1.20	0.00	5.23	7.8
		60-80	46.17	0.38	4.45	49.00	Sandy clay	1.08	0.00	10.05	7.6

Table 2: (Cont.)

Profile No.	SMU	Depth cm	Particle size distribution				Texture	$CaCO_3$ %	O.M %	EC (dSm^{-1})	pH
			Fine sand %	Coarse sand %	Silt %	Clay %					
10	1	0-20	55.81	0.85	10.83	32.51	Sandy clay loam	1.36	1.36	0.53	7.6
		20-40	34.09	0.65	17.40	47.86	clay	1.05	0.48	0.65	7.8
		40-60	36.65	0.27	10.87	52.21	clay	1.37	0.39	0.89	8.1
		60-80	36.53	0.10	13.11	50.26	Clay	0.74	0.06	0.96	8.2
		80-100	36.19	0.86	15.19	47.76	Clay	0.69	0.05	1.01	8.2
11	3	0-20	53.54	0.49	6.56	39.41	Sandy clay	1.76	1.53	0.41	7.8
		20-40	45.26	0.48	8.68	45.58	Sandy clay	0.39	0.76	0.76	7.8
		40-60	65.44	26.28	4.14	4.14	Loamy sand	2.91	0.09	0.52	8.4
		60-80	80.88	2.40	6.27	10.45	Loamy sand	1.07	0.08	0.80	8.0
12	4	0-20	19.67	72.19	0.00	8.14	Sand	0.33	0.68	1.22	7.6
		20-40	11.36	88.64	0.00	0.00	Sand	0.19	0.00	0.28	7.9
		40-60	17.32	82.68	0.00	0.00	Sand	0.25	0.00	0.31	7.9
13	9	0-20	32.07	40.59	0.00	27.34	Sandy clay loam	1.64	1.78	0.64	7.9
		20-40	29.88	36.51	8.40	25.21	Sandy clay loam	1.42	1.06	0.60	7.7
		40-60	18.98	64.65	4.09	12.28	Loamy sand	0.61	0.38	0.45	8.2
		60-80	10.38	73.28	4.08	12.26	Loamy sand	1.16	0.17	0.38	8.2
14	3	0-20	27.37	2.59	31.63	38.41	Clay loam	1.46	1.42	0.39	7.6
		20-40	31.83	2.19	19.79	46.19	Clay	1.84	0.52	0.40	7.7
		40-60	19.65	25.01	13.28	42.06	Clay	1.91	0.11	0.46	7.8
		60-80	31.48	0.81	21.84	45.87	Clay	1.20	0.09	0.45	8.0
15	7	0-20	39.29	2.11	34.73	23.87	Loam	1.59	1.98	0.27	7.6
		20-40	49.08	1.24	19.44	30.24	Sandy clay loam	1.33	1.17	0.38	7.9
		40-60	37.98	1.51	25.93	34.58	Clay loam	0.19	0.46	0.44	8.0
		60-80	41.32	0.27	32.45	25.96	Loam	1.14	0.18	0.45	8.0
16	7	0-20	38.47	2.03	24.24	35.26	Clay loam	1.48	1.05	1.73	7.4
		20-40	38.97	1.59	28.62	30.82	Clay loam	1.25	0.36	0.23	7.6
		40-60	31.91	1.55	33.27	33.27	Clay loam	1.58	0.08	0.27	7.6
		60-80	51.84	0.66	12.34	35.16	Sandy clay	1.26	0.05	0.30	7.6
17	6	0-20	40.70	1.44	21.43	36.43	Clay loam	1.96	0.38	1.06	8.0
		20-40	52.52	5.04	14.85	27.59	Sandy clay loam	1.43	0.11	1.52	8.1
		40-60	34.09	0.27	30.63	35.01	Clay loam	1.36	0.05	0.53	7.8
		60-80	48.10	51.90	0.00	0.00	Sand	1.11	0.05	0.57	7.8
18	6	0-20	26.69	1.25	34.94	37.12	Clay loam	1.93	0.78	1.32	7.8
		20-40	33.89	0.27	28.53	37.31	Clay loam	1.51	0.16	1.44	7.8
		40-60	27.78	0.16	34.94	37.12	Clay loam	1.18	0.09	1.37	7.9
		60-80	29.90	0.43	37.01	32.66	Clay loam	1.18	0.07	1.16	7.9

SMU3: Soils in this map unit are represented by profile numbers 4, 11, and 14. Land surface is nearly leveled. Soil are moderately well drained, deep, clayey covered by silt loam in profile No 4 and clay loam in profile 14, whereas loamy sand covered by sandy clay in profile No. 11. Soils in this SMU are non-saline (EC values ranged between 0.26 and 0.80 dSm^{-1}). Soils vary from slightly alkaline to moderately alkaline (pH ranged between 7.6 and 8.2). Soil are non-calcareous (total carbonate content varied from 0.39 to 2.91%), no distribution pattern was observed with depth. Soils are poor in OM (Values vary from 0.08 to 1.86%); OM content is decreased with depth.

According to Soil Survey Staff (2006), this map unit could be classified as: *Clayey, Smectitic, Superactive, Mesic, Vertic Xerofluvents*. This map unit covers 31807 Feddan (about 20.26% of the total area).

3

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SMU4: Soils in this map unit are represented by profile numbers 8 and 12. Land surface is flat. Soils are moderately well drained, deep, with a sandy texture. Soils are non-saline (EC ranged between 0.23 and 1.22 dSm^{-1}). Soils vary from slightly alkaline to moderately alkaline (pH values ranged between 7.6 to 8.2). non-calcareous (total carbonate content between 0.06 to 1.11%), calcium carbonate distribution has no pattern with depth, organic matter content decrease with depth and the highest value was in the upper layer of the both profile 0.79% in profile No 8 and 0.68 in profile No 12. According to Soil Survey Staff (2006), this map unit could be classified as: *Sandy, Mesic, Typic Torripsamments*. It covers about 37476 Feddan (about 23.87 % of the total area).

SMU5: Soils in this map unit are represented by profile No 9.Land surface is almost flat, nearly leveled. Soil is moderately drained, deep, sandy clay. This map unit is non-saline in the surface layer the EC value was 3.15 dSm^{-1} and increased with depth to be saline in the lowest layer EC values 10.05 dSm^{-1}, slightly alkaline pH from 7.6 to 7.8, non-calcareous (total carbonate content between 1.08 to 1.91%), calcium carbonate distribution has no pattern with depth, organic matter content decrease with depth and the highest value was in the surface layer 0.32% (0-20cm) tables. According to Soil Survey Staff (2006), this map unit could be classified as: *Clayey, Smectitic, Superactive, Mesic, Vertic Fluqaquents*. This SMU covers about 6081.4 Feddan (about 3.87% of the total area).

SMU6: Soils in this map unit are represented by profile No 2, 17 and 18. Land surface is almost flat, nearly leveled. Soil is moderately well drained, deep; clay loam to clay with exception layer (60-80) in profile 17 was sandy. This map unit is non-saline EC value ranged between 0.27 dSm^{-1} in profile 2 (40-60 cm) and 1.52 dSm^{-1}. in profile 17 (20-40 cm), slightly alkaline to alkaline pH from 7.6 to 8.1. non-calcareous (total carbonate content between 1.11 to 2.48%), calcium carbonate distribution has no pattern with depth, low organic matter content ranged between 0.05 to 0.78% . According to Soil Survey Staff (2006), this map unit could be classified as: *Clayey, Smectitic, Superactive, Mesic, Aquic Torrifluvents*. It covers about 11728 Feddan (about 7.47% of the total area).

SMU7: Soils in this map unit are represented by profile No 1, 3, 15 and 16. Land surface is almost flat, nearly leveled. Soil is moderately well drained, deep, loam to clay. This map unit is non-saline EC value ranged between 0.23-1.73 dSm^{-1} in profile 16 (20-40 cm) and (0-20 cm) respectively, slightly alkaline to moderately alkaline pH from 7.6 to 8.2, non-calcareous (total carbonate content between 0.19 to 4.05%), calcium carbonate distribution has no pattern with depth, low organic matter content ranged between 0.05 to 1.63% as well as decreased with depth. According to Soil Survey Staff (2006), this map unit could be classified as: *Clayey, Smectitic, Superactive, Mesic, Typic Haploxererts*. This map unit covers 15484 Feddan (about 9.86 % of the total area).

SMU8: Soils in this map unit are represented by profile No 6 and 7. Land surface is almost flat, nearly leveled. Soil is moderately well drained, deep, with sandy texture. This map unit is non-saline EC value ranged between 0.77-3.38 dSm^{-1} in profile 6 (0-20 cm) and (80-100 cm) respectively and was increased with depth, alkaline to moderately alkaline pH from 7.8 to 8.3, non-calcareous (total carbonate content between 0.11 to 0.48%), calcium carbonate distribution has no pattern with depth, low organic matter content ranged between 0.06 to 1.12%. According to Soil Survey Staff (2006), this map unit could be classified as: *Sandy, Mesic, Xeric Torripsamments*. This SMU covers about 8956 Feddan (about 5.71% of the total area).

SMU9: Soils in this map unit are represented by profile No 13. Land surface is almost flat, nearly leveled. Soil is moderately well drained, deep, sandy clay loam over loamy sand. This map unit is non-saline EC value ranged between 0.38 dSm^{-1} (60-80 cm) to 0.64 dSm^{-1} (0-20 cm), slightly alkaline to moderately alkaline pH from 7.7 to 8.2, non-calcareous (total carbonate content between 0.61 to 1.64%), calcium carbonate distribution has no pattern with depth, low organic matter content ranged between 0.05 to 1.78% the highest value was reached in the surface layer (0-20 cm). According to Soil Survey Staff (2006), this map unit could be classified as: *Clayey, Clayey over sandy, Smectitic, Superactive, Mesic, Vertic Xerofluvents*. It covers 14557 Feddan (about 9.27% of the total area).

Conclusion:

It can be concluded that soils in the studied area are poorly developed according to soil pedology, where no obvious diagnostic horizons were observed. Accordingly, soil orders in the studied area were Entisols and Verisols. Soil texture varied significantly from sandy to clayey. Electrical conductivity (EC) values varied from 0.23 to 10.05 dSm^{-1}, higher values are generally observed in the surface soil layers. Soils varied from slightly alkaline to highly alkaline (pH values ranged between 7.4 and 8.4). Soils are generally poor in organic matter (0.00 to 1.98 %), and decreased with soil depth. Soils in the studied area are non-calcareous (0.06 to 4.05 %).

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تطبيق بيانات الإستشعار عن بعد ونظم المعلومات الجغرافية في تطوير خرائط تقسيم الأراضي لبعض الأراضي في دلتا النيل – مصر.

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يعتبر تطوير خرائط تقسيم الأراضي في مصر من الضرورات القصوي اللازمة لتوفير معلومات أرضية مفيدة لمستخدمي الأراضي ومتخذي القرارات. تهدف هذه الدراسة إلي تطبيق بيانات الإستشعار عن بعد والمعلومات الجغرافية في إنتاج خرائط أرضية على درجة عالية من الدقة والمصداقية لمنطقة الدراسة في دلتا النيل بمصر. تقسم منطقة الدراسة إلي ثلاث وحدات فيزيوجرافية وهي السهل الشاطئ الأمامي والخلفي والدلتا القديمة.تم تحديد ١٨ قطاعا أرضيا تمثل الوحدات الفيزيوجرافية المختلفة للأراضي في منطقة الدراسة وتم توصيفها بالحقل. كما تم تجميع عينات تربة من الطبقات المختلفة لكل قطاع وقد أجريت التحليلات المعملية للتعرف على خواصها الطبيعية والكيميائية. وقد أستخدمت قواعد البيانات الجغرافية بالإضافة للدراسات الحقلية والتحليلات المعملية لتحديد ٩ وحدات أرضية في منطقة الدراسة. وقسمت هذه الوحدات الأرضية وفقا لنظام التقسيم الأمريكي للأراضى كالتالى:

SMU1: Clayey, Smectitic, Superactive, Mesic, Aquic Xerofluvents
SMU2: Sandy, Mesic, Aquic Quartizipsamments
SMU3: Clayey, Smectitic, Superactive, Mesic, Typic Haploxererts
SMU4: Sandy, Mesic, Typic Torripsamments
SMU5: Clayey, Smectitic, Superactive, Mesic, Vertic Fluvaquents
SMU6: Clayey, Smectitic, Superactive, Mesic, Vertic Xerofluvents
SMU7: Clayey, Smectitic, Superactive, Mesic, Vertic Xerofluvents
SMU8: Sandy, Mesic, Xeric Torripsamments
SMU9: Clayey over sandy, Smectitic, Superactive, Mesic, Typic Haploxererts

قام بتحكيم البحث

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Table 3: Morphological description of the studied soil profiles.

Profile No.	Latitude	Longitude	Depth cm	SMU	Texture	Color		Structure	Consistence				Effervescence
						Dry	Moist		Dry	Wet	Moist St	Moist Pl	
1	31.2819	31.3703	0-20	7	Sandy clay	10YR 3/3	10YR 2/2	SB	EH	SR	VS	VP	NEF
			20-80		Silt loam	10 YR3/3	10YR 2/2	MA	VH	EF	VS	VP	NEF
2	31.2828	31.3431	0-15	6	Clay loam	10YR 4/3	10YR 3/2	MA	VH	EF	VS	VP	NEF
			15-30		Clay	10YR 4/3	10YR 3/2	MA	EH	SR	VS	VP	NEF
			30-50		Clay	10YR 3/3	10YR 2/2	MA	EH	SR	VS	VP	NEF
			>50		Silty clay loam	10 YR4/3	10YR 2/2	MA	VH	EF	VS	VP	NEF
3	31.2842	31.3575	0-15	7	Clay	10YR 3/3	10YR 2/2	SB	EH	SR	VS	VP	NEF
			15-90		Silty clay	10YR 3/3	10YR 2/2	SB	EH	SR	VS	VP	NEF
4	31.3003	31.3453	0-20	3	Silt loam	10YR 4/2	10YR 2/2	SB	EH	SR	VS	VP	NEF
			20-41		Clay	10YR 4/2	10YR 2/2	SB	EH	SR	VS	VP	NEF
			41-64		Clay	10YR 4/3	10YR 3/2	SB	EH	SR	VS	VP	NEF
			64-100		Clay loam	10YR 4/3	10YR 3/2	SB	VH	EF	VS	VP	NEF
5	31.4556	31.4636	0-7	2	sandy	10YR7/3	2.5Y 5/2	SG	Lo	Lo	NS	NP	NEF
			7-35		sandy	10YR 8/3	10YR 7/2	SG	Lo	Lo	NS	NP	NEF
			35-65		sandy	10YR 8/3	10YR 7/3	SG	Lo	Lo	NS	NP	NEF
6	31.5002	31.3460	0-35	8	sandy	10 YR7/4	10YR7/2	SG	Lo	Lo	NS	NP	NEF
			35-60		sandy	10 YR7/6	10YR 7/4	SG	Lo	Lo	NS	NP	NEF
			60-82		sandy	10 YR7/4	2.5YR 4/0	SG	Lo	Lo	NS	NP	NEF
			>82		sandy	2.5YR 3/0	10 YR7/2	SG	Lo	Lo	NS	NP	NEF
7	31.4999	31.3462	0-35	8	sandy	10 YR7/4	10YR 5/2	SG	Lo	Lo	NS	NP	NEF
			35-60		sandy	10 YR7/4	10YR 6/6	SG	Lo	Lo	NS	NP	NEF
			60-82		sandy	10 YR6/4	10YR 6/6	SG	Lo	Lo	NS	NP	NEF
			>82		sandy	10 YR6/4	2.5Y 8/2	SG	Lo	Lo	NS	NP	NEF
8	31.4534	31.2893	0-40	4	sandy	10 YR5/4	10YR 5/3	SG	Lo	Lo	NS	NP	NEF
			40-60		sandy	10 YR7/6	10YR 7/4	SG	Lo	Lo	NS	NP	NEF
			60-115		sandy	10 YR7/3	10Y 5/4	SG	Lo	Lo	NS	NP	NEF
9	31.4403	31.2863	0-15	5	Sandy clay	10 YR5/2	10YR 3/3	MA	EH	SR	VS	VP	NEF
			15-60		clay	10 YR5/2	10YR 3/2	MA	EH	SR	VS	VP	NEF
			>60		Sandy clay	2.5 Y 4/2	2.5Y 3/0	VMA	EH	SR	VS	VP	NEF

Lo= Loss, SG= Single Grain, NS= Non Sticky, NP= Non Plastic, NEF= Non effervescence, MA= Massive, VMA= very Massive, EH= Extremely Hard, SR= Slightly Rigid

Table 3: (Cont.)

	Latitude	Longitude	Depth cm	SMU	Texture	Color		Structure	Consistence				Effervescence
						Dry	Moist		Dry	Wet	Moist		
											St	Pl	
10	31.4059	31.2859	0-30	1	Sandy clay loam	10 YR 5/1	10YR 3/2	SB	VH	EF	VS	VP	NEF
			30-80		clay	7.5 YR5/2	7.5YR 3/2	SB	EH	SR	VS	VP	NEF
			>80		clay	2.5YR 4/0	10YR 5/2	MA	EH	SR	VS	VP	NEF
11	31.3365	31.2949	0-20	3	Sandy clay	5YR 4/2	5YR 2.5/2	SB	VH	EF	VS	VP	NEF
			20-41		Sandy clay	10 YR5/2	10YR 3/2	SB	VH	EF	VS	VP	NEF
			41-64		Loamy sand	10YR 5/4	10YR 5/3	MA	VH	EF	VS	VP	NEF
			64-100		Loamy sand	10 YR5/4	10YR 3/3	MA	VH	EF	VS	VP	NEF
12	31.377	31.449	0-20	4	Sand	10 YR 4/3	10YR 3/2	SG	LO	LO	NS	NP	NEF
			20-63		Sand	10YR 7/4	10YR 6/4	SG	LO	LO	NS	NP	NEF
13	31.3699	31.4424	0-16	9	Sandy clay loam	10YR 3/3	10YR 3/1	SB	VH	EF	VS	VP	NEF
			16-46		Sandy clay loam	10 YR3/3	10YR 3/2	MA	VH	EF	VS	VP	NEF
			46-66		Loamy sand	10 YR5/3	10YR 4/3	SG	SH	VFI	SS	SP	NEF
			>66		Loamy sand	10 YR5/3	10YR 4/2	SG	SH	VFI	SS	SP	NEF
14	31.3309	31.4500	0-24	3	Clay loam	10YR 4/2	10YR 3/2	SB	VH	EF	VS	VP	NEF
			24-50		Clay	10 YR4/2	10YR 3/2	MA	EH	SR	VS	VP	NEF
			50-85		Clay	10 YR4/3	10YR 3/3	MA	EH	SR	VS	VP	NEF
15	31.2949	31.4743	0-15	7	Loam	10YR 4/2	10YR 3/2	MA	HA	VFI	VS	VP	NEF
			15-90		Sandy clay loam	10 YR4/3	10YR 3/2	MA	VH	EF	VS	VP	NEF
16	31.2561	31.4274	0-15	7	Clay loam	10YR 3/3	10YR 2/2	SB	VH	EF	VS	VP	NEF
			15-38		Clay loam	10 YR4/2	10YR 3/2	MA	VH	EF	VS	VP	NEF
			38-75		Clay loam	10 YR4/2	10YR 3/2	SB	VH	EF	VS	VP	NEF
			>75		Sandy clay	10 YR4/2	10YR 3/2	MA	EH	SR	VS	VP	NEF
17	31.2811	31.3000	0-15	6	Clay loam	10YR 4/2	10YR 3/2	SB	VH	EF	VS	VP	NEF
			15-30		Sandy clay loam	10 YR4/3	10YR 3/3	MA	VH	EF	VS	VP	NEF
			30-50		Clay loam	2.5 YR4/4	10YR 5/2	MA	VH	EF	VS	VP	NEF
			>50		Sand	10 YR5/4	10YR 5/3	SG	LO	LO	NS	NP	NEF
18	31.2817	31.3000	0-2	6	Clay loam	10YR 5/2	10YR 4/2	SB	VH	EF	VS	VP	NEF
			20-80		Clay loam	7.5 YR5/2	7.5YR 3/2	MA	VH	EF	VS	VP	NEF

VH= Very Hard, EH= Extremely Hard, EF= Extremely Firm, Lo= Loss, SG= Single Grain, NS= Non Sticky, NP= Non Plastic, NEF= Non effervescence, SB= Sub-angular blocky, VFI= Very Firm, SR Slightly Rigid