Using Satellite Data and GIS for Establishing a Soil Database: A Case Study Middle Egypt

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Abstract: The study area is located in the western side of the Nile River in Beni Suef Governorate, middle Egypt; which forms the most promising areas for horizontal agricultural expansion in Egypt. Nowadays most of these areas are already under cultivation or urban extension. But the horizontal expansion in these areas should be based on integrated scientific studies of their natural resources and their capability. The aim of this study is to setup a soil database as a local condition from the obtained data using remote sensing data and GIS techniques. To fulfill this purpose, fourteen soil profiles had been selected and morphologically investigated in the felid, represented soil samples had selected and analyzed in the laboratory. The studied soils were classified using the USDA (2010) into; Petrogypsic Gypsiorthids, Typic Quartizipsamments, Typic Torrifluvents, Typic Torriorthents and Vertic Torrifluvents. The study produced a soil database in layers of information such layers could be presented as hard copies. The current study deals with remote sensing and spatial analyses techniques to establish a soil database for some soils in Al-Fashn area, Beni Suef Governorate, Egypt. The land surveying data, Digital Elevation Model (DEM) and satellite image were used in a Geographic Information System (GIS) to delineate the landforms of the area. The attribute data of $CaCO_3$ content, soil depth, salinity, alkalinity, cation exchange capacity and soil pH were linked with the landform units of the area. The thematic layers of the attribute data were created in Arc-GIS 9.2 software using the spatial analyses function. The obtained thematic layers in the database will be of great help and basic sources for the planners and decision makers in sustainable planning. These information are important for the end user; farmers, integrators, local authorities and decision makers. [Nature and Science 2010;8(8):116-124]. (ISSN: 1545-0740).

Keywords: Soil properties, soil database, Beni Suef Governorate, western Nile River, Egypt.

1. Introduction

The western desertic fringe of the Nile Valley forms the most promising areas for horizontal agricultural expansion in Egypt.

According to Abu El-Izz (2000) and Said (2006) the flood plain area in the western side of the Nile River is much wider than these in the eastern side, and ending at the Western Desert in the west. The alluvial land consists of black-brown Nile mud, which has accumulated to a considerable in consequence of the river having for thousands of years annually are flowed its banks and deposited suspended matter on its flood plains. The flood plain in the studied area consists of relatively high parts, moderately high parts, and relatively low parts. The flood plain width in the investigated area ranges between 7.2 and 12.5 km. Its surface composed of bar rocky plateau and high-lying stony and sand plains, but few distinct drainage lines, and even from these drainage channels extended for a short distance and consequently do not reach the Nile Valley. They mentioned that the Western Desert is one of the most arid regions in the world.

According to Abu El-Izz (2000) the studied area is built of the sediments of recent alluvium, Pleistocene, and Pliocene periods. Recent Alluvium in the Nile Valley (largely cultivated) is thick deposits of the late Paleolithic age occur along the sides of the Nile valley up to heights diminishing north words. These silts, which are not entirely confined to the Nile Valley but extend in some places for considerable distances into the desert. The gravels and sands of Pleistocene to Recent Age are to be bordering the edge of the cultivated lands in many parts of the Nile Valley, where are series of terraces at various heights above the valley-flood western Desert.

Roberts (1982) mentioned that the soils on the Western Desert related to kinds of parent materials, indicated that the hot dry climate was the main soil forming factor that is responsible for the characteristics that distinguish the red desert soils from other soil groups. The hot climate has oxidized sufficient amounts of iron from iron-bearing minerals to give a pinkish or red colour. The climate, specially the low precipitation, is responsible for thin horizons which are the main characteristic of desert soils. He also noticed that in the Western Desert of Egypt the precipitation is low that only weakly developed red desert soils occur and the soil profiles are much thinner than the typical Red Desert soils. The parent materials play a role in their formation and weathering under the present climatic conditions. The drainage and hydrology of the area are closely related to the general slope of the geological formations. Both have played an important role on soil formation either through its influence on removal of salts or by contributing to salinization of the soil. He also concluded that the relief and erosion played an important role on the soil formation in the Western Desert, where, their soils are weakly developed having a higher chroma and a very thin A horizon than typical Red Desert soils.

Abu El-Enain (1981) concluded that the texture of the soils of the flood plain is sandy clay loam to clay, while the soils of the wind- blown deposits are stratified in their texture as sandy to loamy sands, and the soils of desertic the deposits is sandy. He classified those soils as Torrifluvents, Torrerts, Torripsamments and Salorthids, respectively.

According to El-Hamdy (1982), Abd El-Hady (1995) and Elwan (2008) the texture of the Nile alluvial is clayey to sandy clay loam, the total soluble salts are low, the $CaCO_3$ content less than 4%, the organic matter content ranges between 0.03 and 3.00% and the pH values are 7.3-8.1. He added that, the soils of the alluvial wind blown deposits are stratified in the texture sandy in the parts close to the desert fringes and other parts are different in layers with the texture sandy to silty sand and sandy gravel. The total soluble salts ranges between 5.7 and 15.3 dS/m for the soils of the desert fringes and decreases to 0.86-2.25 dS/m for the soils of the flood plain. The organic matter content ranges between 0.17 and 1.89 %. The pH values ranges between 7.6 and 8.0. The $CaCO_3$ content ranges between 5.10 and 13.56. He also added that, the soils of the desertic deposits are sandy gravel. The total soluble salts ranges between 15.90 and 19.10 dS/m. The $CaCO_3$ content ranges between 1.58 and 7.94%. The organic matter content is very low and less than 0.53 %. The pH values range between 7.6 and 7.8. The same author added that the soils of the bonded channels and the old river courses are clayey to clay loam, and sandy to sandy gravel in desertic parts. The total soluble salts are low near the Nile River and increases towards the desert. The $CaCO_3$ content ranges between 0.57 and 18.30. The organic matter content ranges between 0.17 and 2.75%. Those soils as Typic Torrifluvents, Typic Paleargids, Vertic Torrifluvents, Typic Torrerts, Typic Torripsamments, Typic Torriorthents, Typic Salorthids and Typic Calciorthids.

ISRIC, World Soil Information who had been largely responsible for the development of regional Soil and Terrain Databases (Sombroek, 1984).

Version 2.0 of the WISE (World Inventory of Soil Emission) database, comprising 9607 profiles, has been used to derive topsoil and subsoil parameters using uniform taxonomy-based pedotransfer (taxotransfer) rules (Batjes et al, 1997 and Batjes, 2002). Similarly, soil parameter estimates for all secondary SOTER databases (SOTWIS) were derived using consistent procedures as detailed in Van Engelen et al. (2005) and Batjes et al. (2007).

FAO and the International Institute for Applied Systems Analysis (IIASA) took the initiative of combining the recently collected vast volumes of regional and national updates of soil information with the information already contained within the 1:5,000,000 scale FAO-UNESCO Digital Soil Map of the World, into a new comprehensive Harmonized World Soil Database, HWSD (2008).

The main objective of this study is to establish a soil database using remote sensing data and GIS techniques for agriculture applications.

2 - Materials and Methods

The studied area is located in the western part of the Nile Valley Delta in the waste desert in Egypt, and extended from longitudes 30° 40` and 31° 0` E and latitudes 28° 45` and 28° 55` N (Figure, 1).

Digital Elevation Model (DEM) of the area under investigation has been generated from the Shuttle Radar Topographic Mission (SRTM) image (Figure 2). ARC-GIS 9.0 software was used for this function Landsat ETM + image, (path 176 row 40) taken during the year 2003 (Figure 3) and Digital Elevation Model were grouped and processed in ERDAS Imagine 8.7 software to extract the different land forms of the investigated area (Dobos et al., 2002; Zink and Valenzuala, 1990). The extracted data generate a preliminary geomorphologic map which was checked and completed through field observation.

Fourteen soil profiles were taken to represent different mapping units. The morphological description of these profiles was carried out according to the guidelines edited by FAO (2006). Representative disturbed soil samples have been collected and analyzed according to the soil survey laboratory methods manual (USDA, 2004). The American soil taxonomy (USDA, 2010) was used to classify the different soils of the investigated area to the sub great group level. Then the correlation between the physiographic and taxonomic units, were designed, after El-Bersen and Catalan (1987).

The obtained data were imported in a GIS database; the digital geomorphologic map was used as base map in the established database (Fig. 4). The spatial analyses function in ArcGIS 9.0 was used to create the thematic layers of $CaCO_3$ content, cation exchange capacity, soil depth, salinity (EC), alkalinity (ESP) and soil pH.

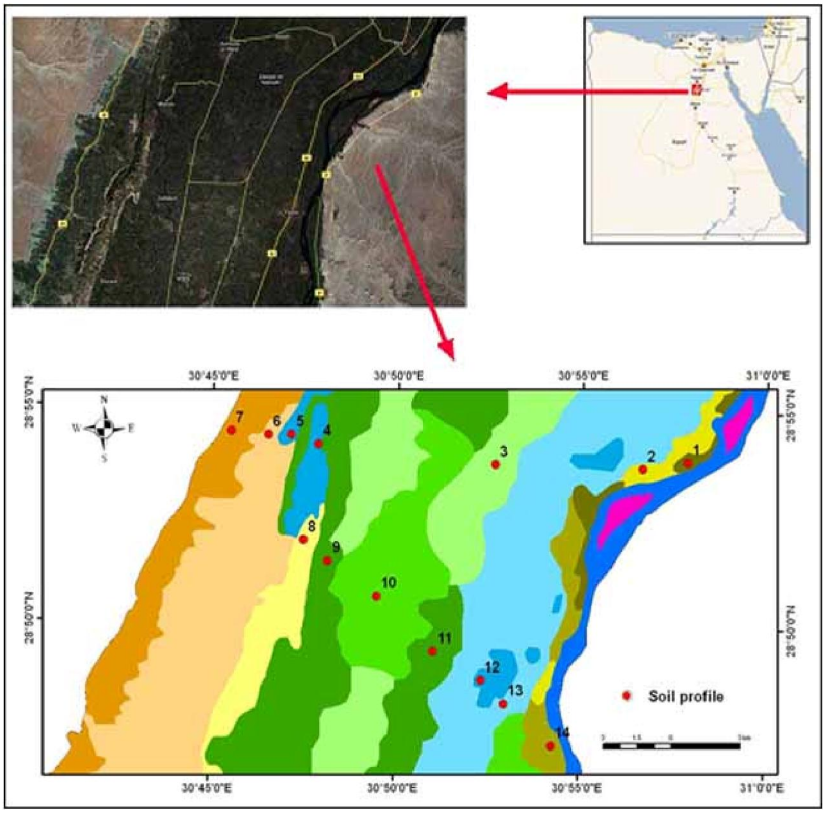

Fig. (1): Location of the study area and the soil profiles.

3. Result and Discussion

Base map

The landforms of the studied area were delineated by using the digital elevation model, Landsat ETM$^+$ and ground truth data. The produced map, representing the landforms of the studied area, was imported in a Geo-database and considered as a base map (Fig. 2). The obtained data indicate that the area is dominated by the landforms of undulating sand sheet, high elevated sand sheet, low elevated sand sheet, high terraces, moderately high terraces, low terraces, overflow basin, decantation basin, high levees, moderately high levees and low levees. Every unit will be discussed based on the data in Tables (1, 2 & 3) and Fig. (2), as the following;

1- Undulating sand sheet:

This unit covers an area of about 27.77 km^2 is about 8.00% of the total of the study area and is represented by soil profile No. 7. It is characterized by; undulating surface. The soil depth is about 110 cm. Sandy textured soil. The natural drainage is well. The $CaCO_3$ content is about 2.65% in the whole profile. The organic mater content is about 0.84%. The pH values are about 8.15. The soil salinity is low where EC values are about 1.89 dS/m. The soil is low alkaline where ESP values are about 19.80. The CEC values are about 10.38 meq/100 g. soil.

2- High elevated sand sheet:

This unit covers an area of about 57.39 km^2 is about 16.54% of the total of the study area and is represented by soil profile No. 6. It is characterized by; undulating surface. The soil depth is about 130 cm. Sandy textured soil. The natural drainage is well. The $CaCO_3$ content is about 3.45%. The organic mater content is about 0.96%. The pH values are about 7.73. The soil salinity is moderately saline where EC values is about 6.28 dS/m. the soil is slightly alkaline where ESP values are about 11.47. The CEC values are about 15.54 meq/100 g. soil.

3- Low elevated sand sheet:

This unit covers an area of about 14.77 km^2 is about 4.26% of the total of the study area and is represented by soil profile No. 8. It is characterized by; low undulating surface. The soil depth is about

130 cm. Sandy textured soil. The natural drainage is well. The $CaCO_3$ content is about 3.62%. The organic mater content is about 0.96%. The pH values are about 7.80. The soil salinity is high where EC values is about 9.81 dS/m. the soil is low alkaline where ESP values is about 15.63. The CEC values are about 6.12 meq/100 g. soil.

4- High terraces:

This unit covers an area of about 61.72 km^2 is about 17.78% of the total of the study area and is represented by soil profiles Nos. 9 and 11. It is characterized by; almost flat surface. The soil depth is about 130 cm. Clay loam textured soil. The natural drainage is moderately. The $CaCO_3$ content ranges between 2.48 and 2.97%. The organic mater content rages between 0.64 and 0.94%. The pH values range between 7.93 and 8.13. The soil salinity is low where EC values range between 2.23 and 4.18 dS/m. the soil is low alkaline where ESP values range between 12.39 and 20.60. The CEC values range between 8.40 and 47.90 meq/100 g. soil.

5- Moderately high terraces:

This unit covers an area of about 36.41 km^2 is about 10.49% of the total of the study area and is represented by soil profile No. 10. It is characterized by; almost flat surface. The soil depth is about 120 cm. Sandy clay loam textured soil. The natural drainage is moderately. The $CaCO_3$ content is about 3.35%. The organic mater content is about 2.02% this is due to the cultivated processes. The pH values are about 6.70. The soil salinity is low where EC values is about 3.34 dS/m. the soil is low alkaline where ESP values is about 13.54. The CEC values 38.18 meq/100 g. soil.

6- Low terraces:

This unit covers an area of about 46.48 km^2 is about 13.39% of the total of the study area and is represented by soil profile No. 3. It is characterized by; almost flat surface. The soil depth is about 100 cm. Clay loam textured soil. The natural drainage is moderately. The $CaCO_3$ content is about 2.70%. The organic mater content is about 1.72%. The pH values are about 8.17. The soil salinity is low where EC values is about 3.50 dS/m. the soil is low alkaline where ESP values is about 16.48. The CEC values are about 40.85 meq/100 g. soil.

7- Overflow basin:

This unit covers an area of about 67.58 km^2 is about 19.47% of the total of the study area and is represented by soil profile No. 13. It is characterized by; almost flat surface. The soil depth is about 120 cm. Loamy textured soil. The natural drainage is moderately. The $CaCO_3$ content is about 2.67%. The organic mater content is about 0.76%. The pH values are about 8.13. The soil salinity is low where EC values is about 10.70 dS/m. the soil is low alkaline where ESP values is about 19.22. The CEC values are about 42.51 meq/100 g. soil.

8- Decantation basin:

This unit covers an area of about 15.18 km^2 is about 4.37% of the total of the study area and is represented by soil profiles Nos. 4, 5, 12. It is characterized by; almost flat surface. The soil depth range between 60 and 110 cm. Clay loam textured soil. The natural drainage is moderately. The $CaCO_3$ content ranges between 1.33 and 10.55%. The organic mater content rages between 0.76 and 1.28%. The pH values range between 7.77 and 8.13. The soil salinity is low where EC values range between 6.93 and 10.70 dS/m. the soil is low alkaline where ESP values range between 9.57 and 19.22. The CEC values range between 12.90 and 49.69 meq/100 g. soil.

9- High levees:

This unit covers an area of about 4.73 km^2 is about 1.36% of the total of the study area and is represented by soil profile No. 1. It is characterized by; almost flat surface. The soil depth is about 90 cm. Sandy clay loam textured soil. The natural drainage is moderately. The $CaCO_3$ content is about 2.27%. The organic mater content is about 0.25%. The pH values are about 7.70. The soil salinity is low where EC values is about 2.50 dS/m. the soil is low alkaline where ESP values is about14.37. The CEC values are about 32.40 meq/100 g. soil.

10- Moderately high levees:

This unit covers an area of about 9.30 km^2 is about 2.68% of the total of the study area and is represented by soil profile No. 14. It is characterized by; almost flat surface. The soil depth is about 120 cm. Sandy clay loam textured soil. The natural drainage is moderately. The $CaCO_3$ content is about 1.96%. The organic mater content is about 0.71%. The pH values are about 8.10. The soil salinity is low where EC values is about 5.80 dS/m. the soil is low alkaline where ESP values is about 12.37. The CEC values are about 33.97 meq/100 g. soil.

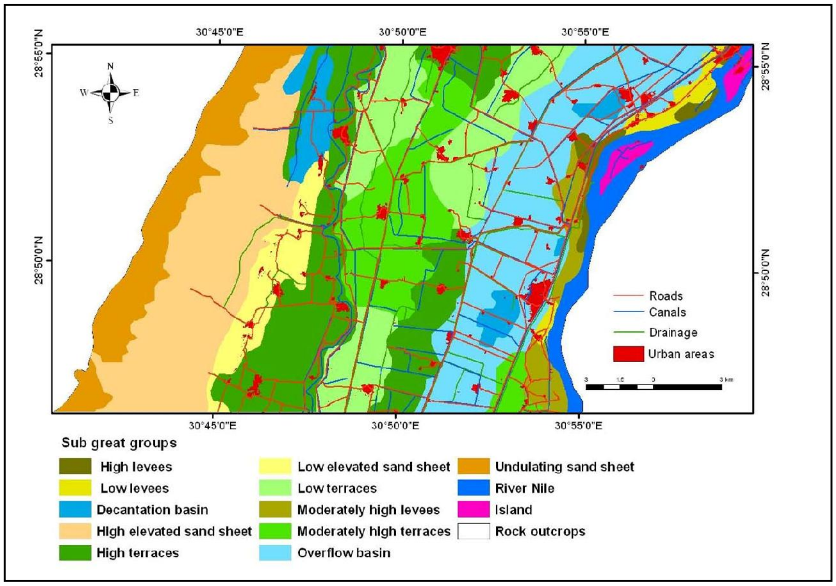

Fig. (2): Physiographic map of the study area.

Table (1): The land form units and their areas of the study area.

Profile	Landforms	Area (%)	Area (km^2)
7	Undulating sand sheet	8.00	27.77
6	High elevated sand sheet	16.54	57.39
8	Low elevated sand sheet	4.26	14.77
9, 11	High terraces	17.78	61.72
10	Moderately high terraces	10.49	36.41
3	Low terraces	13.39	46.48
13	Overflow basin	19.47	67.58
4, 5, 12	Decantation basin	4.37	15.18
1	High levees	1.36	4.73
14	Moderately high levees	2.68	9.30
2	Low levees	1.65	5.71
	TOTAL	100.00	347.04

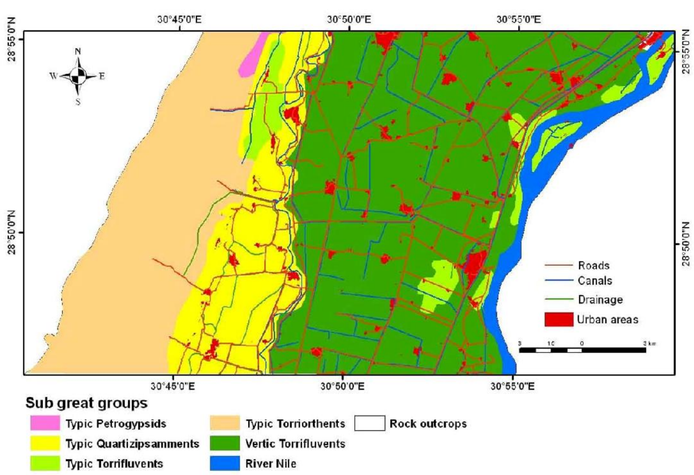

Fig. (3): Soil map of the study area.

11- Low levees:

This unit covers an area of about 5.71 km^2 is about 1.65% of the total of the study area and is represented by soil profile No. 2. It is characterized by; almost flat surface. The soil depth is about 110 cm. Clay loam textured soil. The natural drainage is moderately. The $CaCO_3$ content is about 2.54%. The organic mater content is about 1.21%. The pH values are about 8.07. The soil salinity is low where EC values is about 4.50 dS/m. the soil is low alkaline where ESP values is about 12.67. The CEC values are about 50.19 meq/100 g. soil.

Regarding to the urban areas, it is noticed that the flood plain is highly affected by urban encroachment than the other landscapes. This can be explained by the availability of infrastructure and administrative services.

Soil Taxonomy:

Based on the Egyptian Meteorological Authority (1996) data and Soil Taxonomy System (USDA, 2010), the soil temperature regime of the studied area were defined as Thermic and soil moisture regime as Torric.

According to the analytical data and filed observations the studied soils could be classified using the USDA (2010) as following: 1)- Petrogypsic Gypsiorthids which represented by the soil profile No. 5. 2)- Typic Quartizipsamments which represented by the soil profiles Nos. 8 & 9. 3)- Typic Torrifluvents which represented by the soil profiles Nos. 1, 4 & 12. 4)- Typic Torriorthents which represented by the soil profiles Nos. 6 & 7. 5)- Vertic Torrifluvents which represented by the soil profiles Nos. 2, 3, 10, 11, 13 & 14, (Fig. 3).

Soil Database

The obtained information such as the analytical data (Tables 2 & 3) and filed observations are fed in the Arc- GIS 9.2 software. The example of view and tabulated data are shown in Figs (4, 5).

The attribute data of, CaCO3 content, soil depth, salinity, alkalinity, cation exchange capacity and soil pH (Table 1) were compiled into the units of the digital geomorphologic map in the Arc-GIS program. The incorporated attributes were used to obtain the thematic layers of spatial distribution of the above mentioned characteristics as shown in figure (5). The produced layers include information on the rating value, capability sub class, and distribution for each soil characteristics.

These results are of great importance as they show the distribution of the constraints of productivity all over the region. This is particularly important when planning for optimal land uses, also it benefits the existing land users in determining the most appropriate management practices.

The digital database allows policy makers, planners and experts to overcome some of the shortfalls of data availability. It also facilitates the incorporation of the obtained data on an internal and external network, this can realize by a systematic manner of the digital mapping. The integration of the obtained data from different resources can be achieved to fulfill the sustainable development requirements.

The database also include a remote sensing data which have a high correlation with the main soil surface properties, (Ben-Dor, 2002 and McBratney et al., 2003) and this allow when the updating of the digital database must be applied.

The spatial analysis tool, in the Arc-GIS software alows to produce a set of thematic layers and the montriong of the urban expansion through the mutlitemporal images represent a great importance in land use planning.

Land evaluation, degradation, and sustainability assessments can easely carried out through the integration between the multithematic maps of soil properties, climatic, topographic and socio-economic data.

4. Conclusion

The use of spatial analyses allows producing multi thematic layers of land characteristics, which offer a great source of data for the land use planners. 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. The result of analysis and interpretation of the satellite images; it is recognized the following eleven physiographic units; Undulating sand sheet, High elevated sand sheet, Low elevated sand sheet, High terraces, Moderately high terraces, Low terraces, Overflow basin, Decantation basin, High levees, Moderately high levees, Low levees. The obtained thematic layers in the database will be of great help and basic sources for the planners and decision makers in sustainable planning.

Table (2): Some chemical analyses of the representative soil profiles.

Taxonomic unit	profile	Depth in cm	pH 1:2.5	EC dS/m	$CaCO_3$ %	OM %	ESP	CEC meq/100 g. soil	Soluble cations meq/L				Soluble anions meq/L		
									Na^+	K^+	Ca^{++}	Mg^{++}	HCO_3^- CO_3^{--}	Cl^-	SO_4^{--}
Typic Torrifluvents	1	0-20	7.74	1.54	2.1	0.43	14.2	30.5	5.5	0.2	1.3	2.7	1.7	7.8	0.2
		20-50	7.75	2.33	3.4	0.22	14.6	31.5	18.7	0.4	5.9	4.3	1.9	21.4	6.0
		50-90	7.62	3.62	1.3	0.10	14.3	35.2	6.9	0.3	2.1	1.3	2.6	4.9	3.1
Vertic Torrifluvents	2	0-30	8.60	2.51	2.93	2.11	13.91	53.31	14.99	0.31	5.16	6.47	4.65	12.27	10.01
		30-65	7.8	4.33	2.17	0.83	11.17	51.96	26.98	1.8	4.28	13.47	4.45	19.60	22.48
		65-110	7.8	6.66	2.51	0.68	12.93	45.31	55.27	0.48	4.98	10.14	5.02	37.07	28.78
Vertic Torrifluvents	3	0-25	7.9	2.1	2.8	2.11	17.33	40.11	11.63	0.28	7.34	2.25	2.73	13.61	5.16
		25-50	8.3	3.5	3.2	1.74	16.22	40.13	10.36	0.24	4.51	9.52	3.08	10.11	11.44
		50-100	8.3	4.9	2.1	1.32	15.88	42.32	11.64	0.23	7.53	11.31	3.30	8.25	19.14
Typic Torrifuvents	4	0-25	8.1	4.62	2.51	0.99	19.31	46.32	32.73	0.58	7.02	8.30	4.79	24.88	18.96
		25-55	8.0	8.12	2.63	0.91	14.25	44.88	66.88	0.46	5.77	10.69	6.84	45.27	3169
		55-80	8.1	12.37	2.41	0.71	14.50	41.31	113.54	1.81	6.19	17.29	8.77	88.90	41.16
		80-110	8.3	17.69	3.11	0.43	28.81	37.51	22.38	2.76	15.79	53.09	10.58	181.53	101.91
Typic Petrogypsids	5	0-20	7.73	5.62	8.6	0.84	12.5	14.5	10.4	2.5	34.5	2.6	2.9	9.6	37.8
		20-60	7.65	8.24	12.5	0.91	11.6	11.3	15.2	2.6	26.1	5.6	2.6	9.8	36.6
Typic Torriorthents	6	0-25	7.6	3.65	2.53	1.38	9.24	18.5	31.34	0.49	3.44	7.56	8.15	18.17	16.51
		25-60	7.8	5.41	4.66	1.12	11.52	15.77	47.38	0.66	4.05	6.30	7.42	32.06	18.91
		60-130	7.8	9.77	3.15	0.38	13.64	12.36	85.22	1.12	7.71	15.43	6.82	61.12	41.54
Typic Torriorthents	7	0-15	8.20	3.10	4.10	1.80	22.30	8.50	13.10	1.40	9.00	7.50	1.90	18.00	10.90
		15-40	8.10	2.00	3.10	1.10	21.50	19.50	8.00	1.50	6.00	4.50	2.40	12.30	5.30
		40-65	8.10	1.60	1.70	0.32	18.00	7.20	6.60	1.40	4.70	3.30	2.30	8.00	5.70
		65-110	8.20	0.85	1.70	0.12	17.40	6.30	3.30	0.80	2.50	2.20	1.50	5.10	1.90
Typic Quartizipsamments	8	0-30	7.8	8.61	5.12	1.56	12.2	8.57	69.40	0.81	8.24	19.18	3.76	59.73	34.18
		30-70	7.8	7.32	3.21	0.74	19.8	6.41	54.94	0.59	9.77	21.93	4.08	55.66	27.49
		70-130	7.8	13.51	2.53	0.57	14.9	3.38	109.77	2.19	10.35	20.26	6.22	95.72	40.63
Typic Quartizipsamments	9	0-20	8.20	3.10	4.10	1.10	22.30	8.50	13.10	1.40	9.00	7.50	1.90	18.00	10.90
		20-60	8.10	2.00	3.10	0.51	21.50	9.50	8.00	1.50	6.00	4.50	2.40	12.30	5.30
		60-130	8.10	1.60	1.70	0.31	18.00	7.20	6.60	1.40	4.70	3.30	2.30	8.00	5.70
Vertic Torrifluvents	10	0-15	7.8	2.47	2.85	1.16	7.77	49.31	18.25	0.17	7.68	3.35	1.40	16.74	11.31
		15-45	8.1	1.88	2.63	0.81	14.83	31.57	11.34	0.15	5.33	3.72	1.62	14.38	4.54
		45-85	2.8	3.31	2.93	0.61	18.92	33.71	20.18	0.15	9.44	4.59	1.83	19.72	13.81
		85-120	8.1	5.68	4.97	5.51	12.65	38.13	41.58	0.31	12.51	5.53	2.12	35.16	22.65
Vertic Torrifluvents	11	0-25	7.7	3.73	3.11	1.71	9.18	48.35	28.92	1.35	7.51	6.28	5.05	33.25	7.76
		25-50	7.8	1.98	2.36	0.93	9.35	50.81	16.57	0.58	3.15	2.79	2.79	13.34	6.96
		50-80	8.1	4.21	1.78	0.72	14.72	52.13	32.06	0.69	7.21	5.14	5.93	30.75	8.42
		80-120	8.1	6.81	2.68	0.39	16.31	40.30	63.22	1.04	12.31	9.38	7.87	64.23	13.85
Typic Torrifluvents	12	0-20	7.7	11.7	2.2	1.23	8.31	48.11	50.33	0.81	26.68	16.16	4.68	57.66	30.95
		20-55	7.7	8.7	1.1	1.67	9.22	48.83	40.99	0.73	23.12	21.20	3.18	51.16	31.70
		55-110	7.9	5.1	0.7	0.94	11.17	52.13	30.66	0.51	14.64	12.01	3.64	39.61	14.57
Vertic Torrifluvents	13	0-15	8.1	4.62	2.51	0.99	19.31	46.32	32.73	0.58	7.02	8.30	4.79	24.88	18.96
		15-40	8.0	8.12	2.63	0.91	14.25	44.88	66.88	0.46	5.77	10.69	6.84	45.27	3169
		40-75	8.1	12.37	2.41	0.71	14.50	41.31	113.54	1.81	6.19	17.29	8.77	88.90	41.16
		75-120	8.3	17.69	3.11	0.43	28.81	37.51	22.38	2.76	15.79	53.09	10.58	181.53	101.91
Vertic Torrifluvents	14	0-25	8.00	4.50	2.53	1.12	11.70	33.50	21.00	1.40	17.60	6.90	4.50	23.00	18.90
		25-65	8.10	5.80	1.82	0.64	9.80	39.70	29.00	2.50	23.30	8.70	4.50	30.00	29.50
		65-120	8.20	7.10	1.54	0.36	15.60	28.70	38.00	2.70	26.80	10.90	3.50	34.50	31.10

Table (3): Mean soil characteristics

no	depth	pH	EC	$CaCO_3$	OM	ESP	CEC
1	90.00	7.70	2.50	2.27	0.25	14.37	32.40
2	110.00	8.07	4.50	2.54	1.21	12.67	50.19
3	100.00	8.17	3.50	2.70	1.72	16.48	40.85
4	110.00	8.13	10.70	2.67	0.76	19.22	42.51
5	60.00	7.69	6.93	10.55	0.88	12.05	12.90
6	130.00	7.73	6.28	3.45	0.96	11.47	15.54
7	110.00	8.15	1.89	2.65	0.84	19.80	10.38
8	130.00	7.80	9.81	3.62	0.96	15.63	6.12
9	130.00	8.13	2.23	2.97	0.64	20.60	8.40
10	120.00	6.70	3.34	3.35	2.02	13.54	38.18
11	120.00	7.93	4.18	2.48	0.94	12.39	47.90
12	110.00	7.77	8.50	1.33	1.28	9.57	49.69
13	120.00	8.13	10.70	2.67	0.76	19.22	42.51
14	120.00	8.10	5.80	1.96	0.71	12.37	33.97

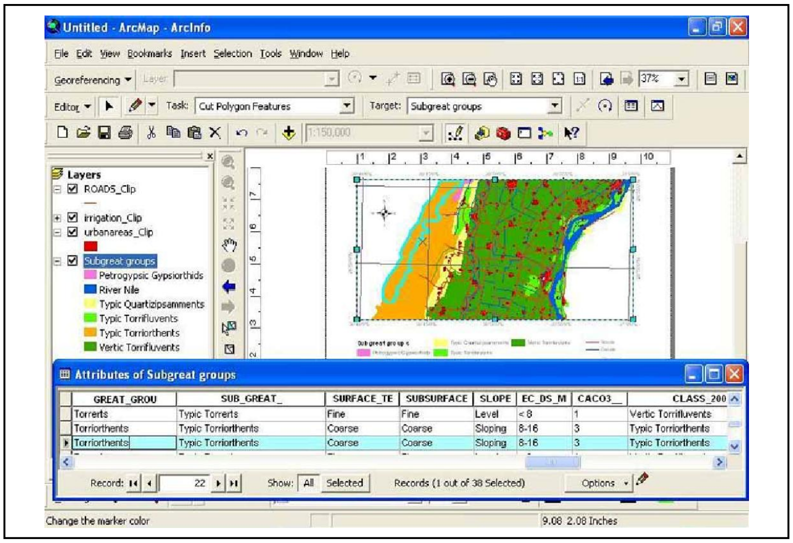

Fig. (4): Soil database as showing from windows of ArcMap Program of the study area.

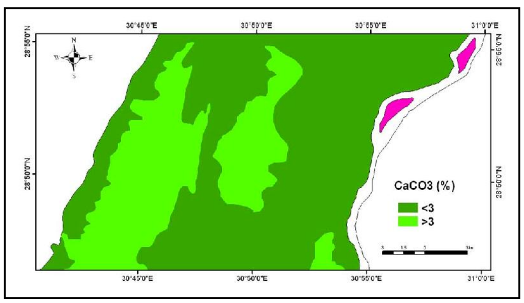

Fig. (5a): The layer of $CaCO_3$ content.

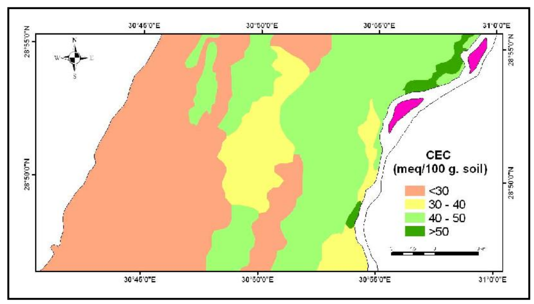

Fig. (5b): The layer of CEC.

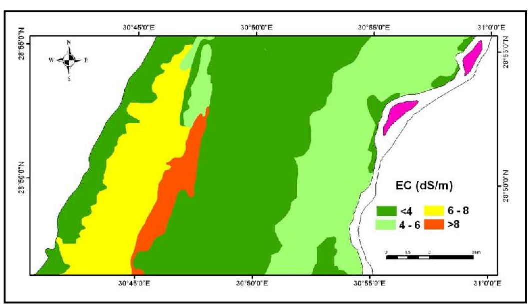

Fig. (5c): The layer of EC.

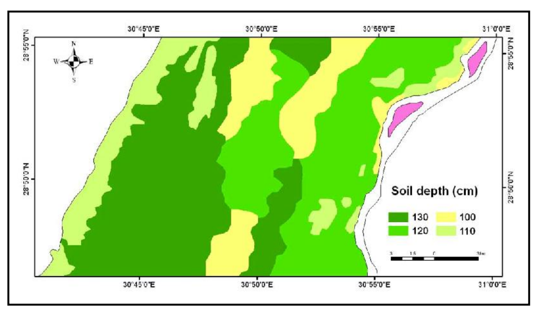

Fig. (5d): The layer of soil depth.

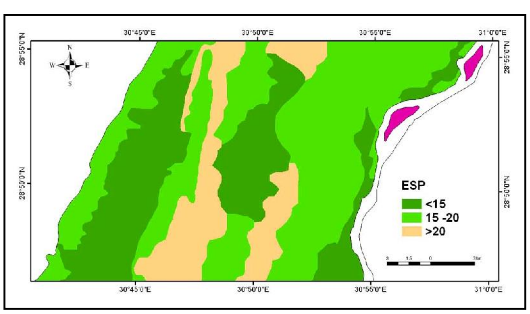

Fig. (5e): The layer of ESP.

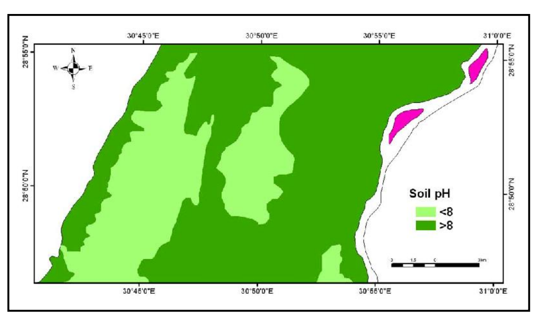

Fig. (5f): The layer of soil pH.

Fig. (5): The thematic layers of the soil database as extracted from ArcMap Program of the study area.

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