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CONTENTS

Geomatics and smart tools in Digital Land Resources Mapping and Sustainability of Coastal Agriculture, Egypt

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Abstract. The northwestern coast of Egypt is characterized by an international interest due to its history and magnificent environment. The area was known as being the bread basket during the Greek and Roman periods. Recently, drastic changes in land use resulting in destructing many of water harvesting tools, thus diminution of the agriculture importance. Restoration of the area and planning self-sufficient communities needs to develop a sustainable land resources database for these regions. Multi concept of remote sensing and the Geographic Information System (GIS) permit to store, merge, and manipulate the huge amounts of thematic maps and attribute data. Sentinel satellite image 2018 scenes, covering the study area at the Egyptian northwestern coast, were acquired. ENVI software was used for image processing. A number of 53 topographic maps at scale 1:50000 were used to input GIS thematic layers relevant to land resources, using Arc_GIS 10.2 system. Field investigation was carried out to represent different soil units and collect ground control points. Chemical and physical soil properties were determined to assist soil classification. Soil map was produced including dominant geographic units and soil association. MicroLEIS system was employed to define soil suitability classes to olives, peach, wheat, beans, and sunflower crops. An intelligent module will be added to analyze the digital maps, interact the given data with learning tool (layer) to provide the decision makers with suggested solution not only information. The results showed that the soils are generally characterized by the presence of Calcic, Petrogypsic and Salic horizons. The limiting factors found in the piedmont and coastal plains are salinity, soil depth and texture. These factors decrease the suitability classes to be between S2 and S5.It can be concluded that the digital mapping of land resources using Geographic Information System (GIS) and satellite data preserve in the investment spent in soil and other thematic mapping.

Keywords: Soils, Space data, GIS, Digital soil mapping, Egypt, IoT.

1. Introduction

With the great explosion in computation and information technology come vast amounts of data and tools in all fields of endeavor. Soil science is no exception, with the ongoing creation of regional, national, continental and worldwide databases. The challenge of understanding these large stores of data has led to the development of new tools in the field of statistics and spawned new areas such as data mining and machine learning [9] In addition to this, in soil science, the increasing power of tools such as geographic information systems (GIS), GPS, remote and proximal sensors and data sources such as those provided by digital elevation models (DEMs) are suggesting new ways forward. Fortuitously, this comes at a time when there is a global clamor for soil data and information for environmental monitoring and modelling. Consequently, worldwide, organizations are investigating the possibility of applying the new spanners and screwdrivers of information technology and science to the old engine of soil survey. The principal manifestation is soil resource assessment using geographic information systems (GIS), i.e., the production corresponding to national to global, catchment to landscape and local extents. In the language of digital soil maps, different from that of, scale is a difficult concept, and is better replaced by resolution and spacing [2].

The northwestern coast represents a promising region for extensive development both for local and expected new inhabitants. The concern of coastal resources has increasingly risen during the last two decades mainly because of the great pressure of human actions (urban expansion, industry, tourism, infrastructure, aquaculture, fisheries ports and marinas, energy production and transportation) but also due to the ineffective information, policies, planning and management tools for controlling or regulating human actions and natural processes (natural risks or hazards) in such sensitive environments as that of coastal zones.

The study area dominates the northwestern coast of Egypt between Burg El Arab and El Sallum (Fig. 1). It is bounded by latitudes 30o 30′ N and 31o 45′ N and longitudes 25o 00′ E and 29o 30′ E. The distance from Alexandria to the extreme east of the study area is about 390 km, while extending for some 600 km to the extreme west.

The cultivable soils in the northwestern coast are originated from transferred sedimentary rocky material. The sediments have been transported by water to alluvial fans and flood plains. Soils were formed also by Aeolian sediments in some locations. The subsoil layers are formed locally from the marine limestone. The soil depth varies according to its location, found shallow in the sloping and plateau landscape, and deep in the coastal plain and alluvial fans. The occurrence of calcium carbonates ranges from 30 to 70% and may reach 99% in the calcareous sands [8].

The area from the coast to the Libyan plateau includes calcareous formation belong to the Pliocene and Pleistocene covered with recent sediments. The existence of parallel ridges along the coast characterizes the area. The ridges are absent in some locations, and consist of calcareous sedimentary material differ in their coherence. The Libyan plateau occupies huge area and extends southwards [3].

The area includes a narrow coastal plain, followed at the south by a sand dune area. Southwards of the dunes, the plain rises gradually till the altitude of the plateau this reaches 50 to 150 meters above sea level. The coastal plain stretches in east-west direction, bounded by the sea to the north and the pediment plain to the south. Its width varies, controlled by the geologic formations from some meters to about 10 km. This plain mainly consists of alluvial fans, descending from the plateau, wad's extensions, rocky plains sabkhas, sand sheets and sand dunes. The pediment plain is clear between Ras El-Hekma to Ras Alam El-Room. It is a low lying plain where rain water, descending from the plateau is collected. This area has a considerable potentiality for agriculture expansion. The plateau is rocky, covered mostly by a thin depth of soil. It plays an important role in distributing winter rainfall [6].

Most of the cultivable soils in the northwestern coast are alluvium. The sediments have been transported by water to alluvial fans and flood plains. However, Aeolian sediments in some locations are being cultivated. The subsoil layers are formed locally from the marine limestone. The soil depth varies according to its location, found shallow in the sloping and plateau landscape, and deep in the coastal plain and alluvial fans [11].

According to Egyptian Meteorological Authority [5], the average annual rainfall ranges between 156 – 180 mm. and the mean minimum and maximum annual temperatures are 16.4 and 23.0 C° respectively. The evaporation rates are coinciding with temperatures where the lowest evaporation rate (6.9 mm/day) was recorded in January while the highest value (8.8 mm/day) was recorded in September.

This study aims to use the remote sensing data and Geographic Information system to produce the land resources digital maps of the Northwestern Coast of Egypt, which can be used as a base for land use planning and sustainable development.

2. Geomatics and smart city

From the perspective of geomatics, a smart city is the full integration of a digital city, the Internet of Things and cloud computing technology. A digital city provides a 3D geospatial framework for cities, while the Internet of Things embedded in the ubiquitous sensor network realizes the real-time sensing, measuring, and data transmitting of still or moving objects. Cloud computing, performing like a human brain, is responsible for massive and complex calculations, data mining, and analysis; and it then helps in the automatic discovery of patterns, rules, and knowledge and provides remote monitoring, control, and feedback to the real world for intelligent city management and public services.

Most of the current smart city efforts are focused on how to build a complete Internet of Things, including men, machines, and city infrastructure through a variety of wireless sensor networks, as well as how to accomplish real-time analysis and control by super-computers on cloud computing platforms.

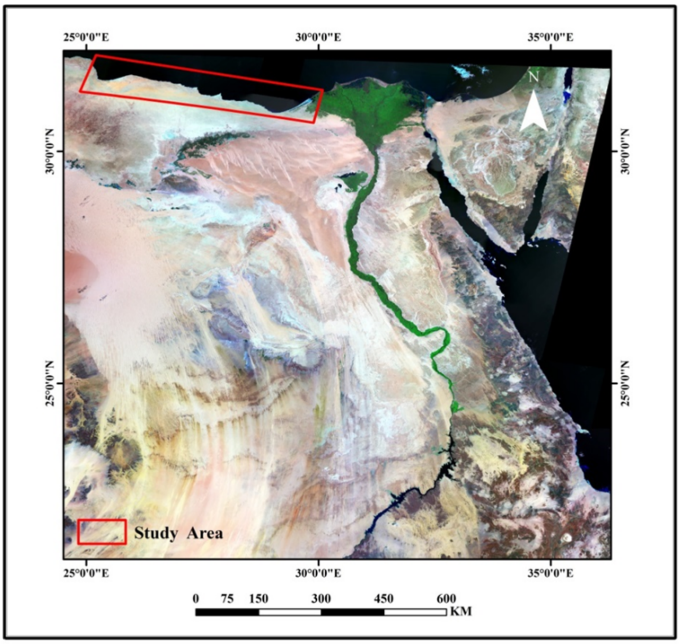

Fig. 1. Location map of study area

2.1. Concept of digital earth

From a geomatics point of view, the supporting techniques of a digital city consist of the following:

1) Space, air, and land-based sensor webs for geospatial data acquisition and updating plus modern communication devices;

2) Building extraction and 3D/4D modeling;

3) Multiresolution, multiscale, and multidimensional visualizations of geospatial data;

4) Distributed spatial data archiving and management for federal databases with interoperability;

5) Spatial data analysis and mining techniques; and

6) Global navigation satellite system (GNSS) and location-based service techniques.

Although these technologies are becoming mature and stable, the future generation of digital cities still requires the complete cooperation of various governments and institutions, the standardization of data and products, and the interoperability of nonprofit organizations and cooperation. The ultimate goal of a digital city, with the help of all the above technologies, is to provide the "right data" to the right person at a right time and a right place (10).

3. Materials and methods

This study is based on the multi concept of remote sensing data and techniques, thus, materials and methods of different sources are used as the following:

- Sentinel satellite image 2018 was used to obtain the space images mosaic of the studied area (Fig. 2).

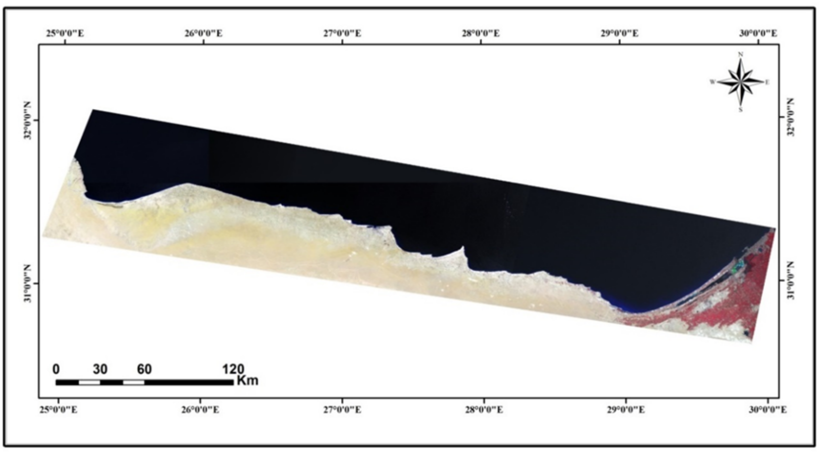

Fig. 2. Sentinel satellite image 2018 of the whole area.

- A number of thematic maps were obtained from different sources. (eg. 53 Topographic maps of Military survey authority (MSA) at scale 1: 50000). Other maps were extracted from different sources and were input as separate layers. These thematic layers includes water bodies, altitude points, contour lines, roads, railways, tracks, pipelines, telephone lines network and mine fields distribution.
- Field missions were carried out with the purpose of collecting ground truth information concerning landscape, soil and vegetation. A number of 149 observation

sites were comprehensively field studied, where different environmental parameters were described according to [7]. Representative soil and water samples were also collected manual from different horizons for laboratory analysis using the soil survey laboratory methods [12].

- Digital Elevation Model (DEM) of the study area has been obtained from the SRTM images (Fig. 3).
- Rectification of studied scenes, (ETM 2001) was performed using sufficient number of GCP's, which are distributed randomly all over the images. The root mean square (RMS) error was found to be 0.74, the process was applied first on the ETM of 1990 and hence, image to image registration was accomplished.
- Arc\Info 7.2 software was used to create GIS coverage's from the CAD file of thematic layers. The same system was used for map features coding, editing, building topology, creating feature attribute tables FAT, edge matching and map projection. Generating check plots, compared with source maps, was fulfilled for quality assurance. This helped in detecting and editing digitizing mistakes. Join item function was used to link the tabular attributes with the spatial features.
- Arc View 3.2 software was used in data analysis, the first step in analysis began with locating the field observation sites on the thematic layers with their attributes (i.e. soils and landscape properties). Using the 3D module of Arc View the interpolation of the spatial distribution of the land use classes was performed. Spatial analyst of Arc View was used to classify the soil parameter ranges on the map and deduct the relation between the soil conditions and the land features. Also, the 3D analyst was used for generating digital Elevation Model (DEM) from the contour lines and spot heights. The DEM creation depends on the nearest neighboring function. Statistical parameters and presentations were used to find out the relation between ground truth and image classification.
- Arc- GIS 9.0 software was used for this function. Sentinel 2018 images and Digital Elevation Model (DEM) were grouped and processed in ERDAS Imagine 8.7 software to define the different landforms of the studied area [4] and [13].

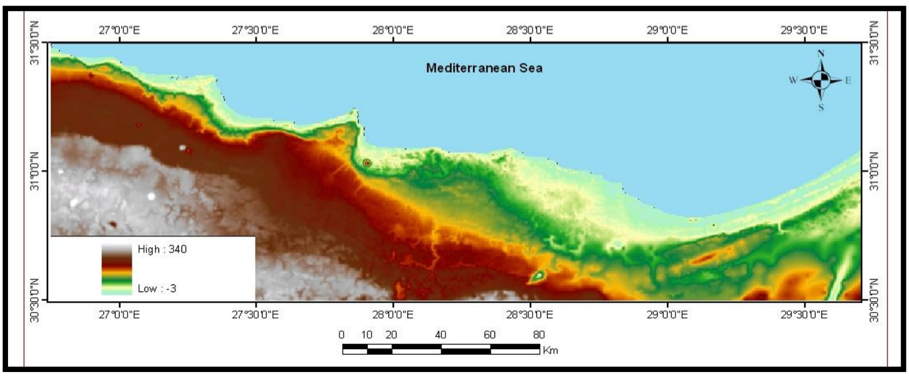

Fig. 3. Digital elevation model of the studied area.

4. Results and discussion

4.1. Producing base layers

The planed schedule was completely fulfilled for this task, as it includes digitizing of 53 topographic map sheets. The maps performed to be available in the digital format; however, their preparation as GIS ready maps has been completed. The mosaic of database layers is represented in Fig.4 – Fig.10.

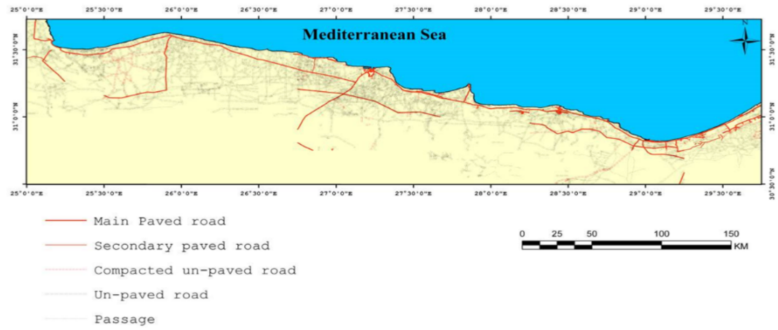

Fig. 4. Roads networks in the Northwestern Coast.

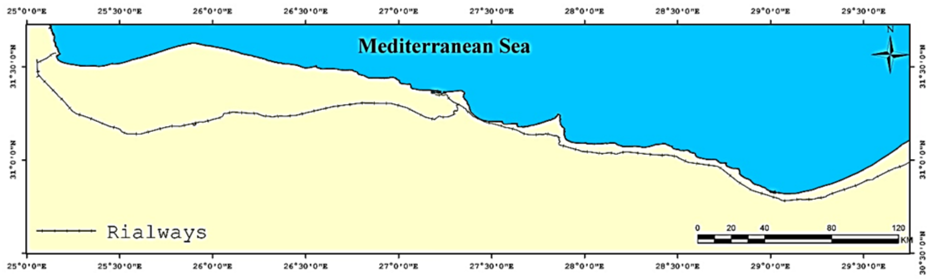

Fig. 5. Railways networks in the Northwestern Coast.

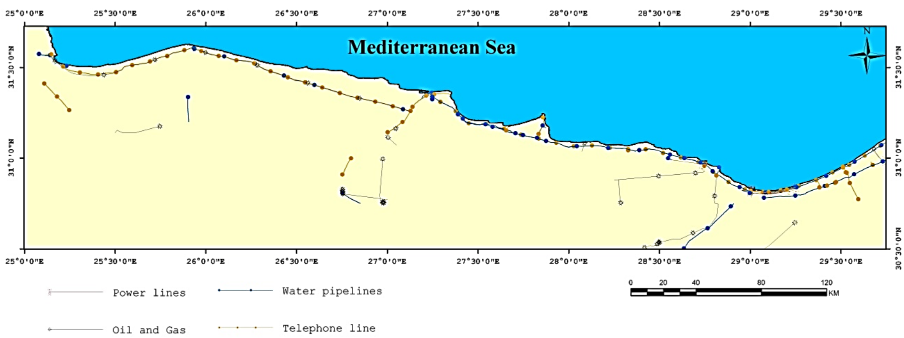

Fig. 6. Utilities layer in the Northwestern Coast.

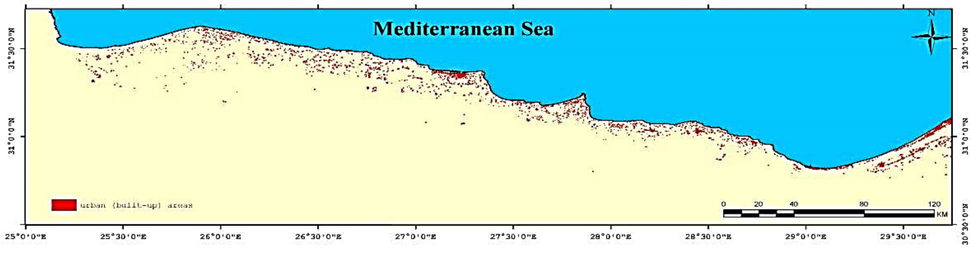

Fig. 7. Urban areas in the Northwestern Coast.

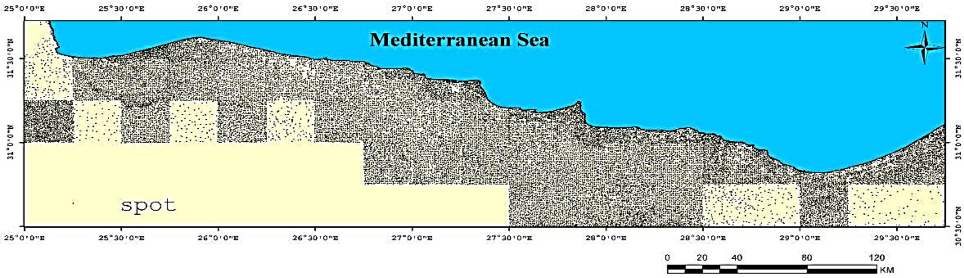

Fig. 8. Spot heights layer in the Northwestern Coast

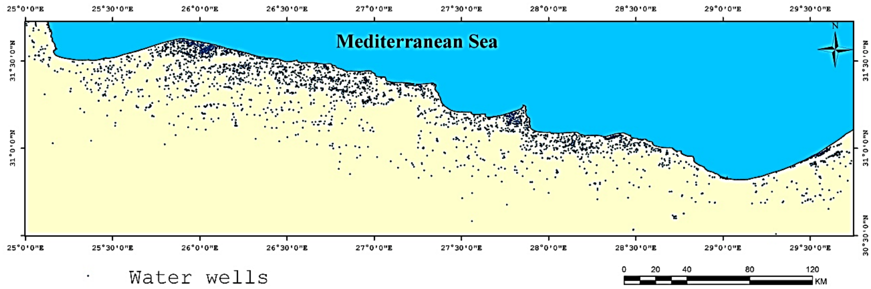

Fig. 9. Wells distribution layer in the Northwestern Coast

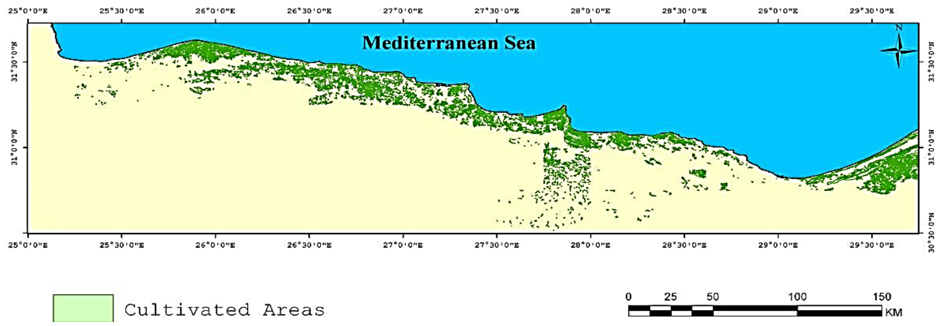

Fig. 10. Cultivated areas in the Northwestern Coast

4.1.1. Defined the physiographic units of the studied area

Physiography is assumed to be one of the driving soils forming factors and soil mapping criteria, concepts provided by this discipline can conveniently be used for soil data structuring. The combination of the geomorphic approach as a hierarchic classification system of geoforms using the existing body of knowledge in geomorphology, with the satellite data and field observations improved the results and allow us to use the computer-assistance procedures.

The delineation of the physiographic units from the satellite data needs a high spatial resolution image; therefore, the spatial resolution of the used Sentinel 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 band data or single band [10]. In this study merged data were performed using multi-spectral bands (20 m) as a low spatial resolution with band 8 of Sentinel satellite image as a high spatial resolution (10 m) resulting in multi-spectral data with high spatial resolution. The enhanced image was draped over the Digital Elevation Model (DEM) of the area to delineate the physiographic map. The physical and chemical analyses of the studied soils were linked to the attribute table of the mapping units.

The physiographic description of the investigated observation sites shows that the relief in the study area ranges between almost flat to slope, while the lithology varies from marine deposits in the coastal plain to Aeolian deposits in plateaus landscape and colluvium in the basins, terraces and slope ones. The dominant land cover is sandy sheets in the coastal plain. Scattered areas are cultivated with fig and olive trees in both coastal plain and plateau. Gravel surface and low dense shrubs exhibit the plateau, while highly dens shrubs exist in the basins. Boulders and stony fragments often exist in the gently sloping areas. The altitudes in the coastal plain ranges between 12 and 19 meters a.s.l., while in the plateau ranges between 92 and 185 meters a.s.l. Fig. 11 represents the different physiographic units in the studied area; the obtained data reveal that the area includes three main landscape units as the following**.**

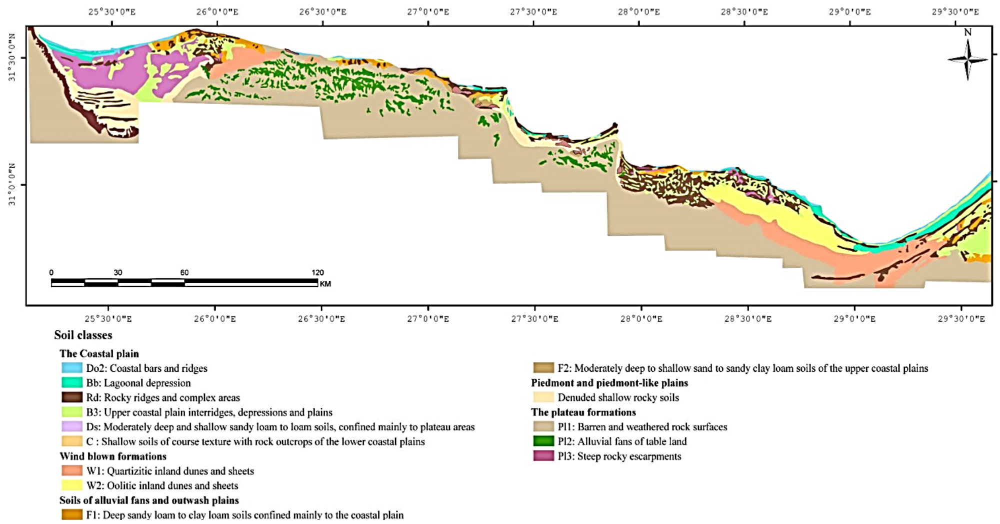

Fig. 11. The main physiographic units in the Northwestern Coast

4.1.2. Coastal plain

This type of landscape is found near to the coast of the Mediterranean Sea and includes different types of land forms such as sand sheets, terraces, vales and basins. It is characterized by the low elevation as the elevation differ from zero to 20 m a.s.l. the elevation increases generally in the southern parts of the coastal plain. This type of landscape contains sand and colluvial deposits with almost flat to gently undulating relief type.

4.1.3. Piedmont

This type is located between the plateau and the coastal plain and has an elevation range between 20 to 65 m a.s.l. The main land forms in this type of landscape are terraces, basins and sand sheets of gently sloping to undulating relief type.

4.1.4. Plateau

The plateaus are found in the south of the study area and have an elevation ranging from 65 up to 275 m a.s.l. and characterized by the limestone deposits as desert pavement and rock outcrops. It was possible to confirm that the rocky surfaces exhibit the plateau landscape. It was found that the surface relief of the plateau type differs from almost flat to undulating relief.

The detailed description of the landscape, relief, lithology, land forms and laboratory analyses are attached to the attribute table of the physiographic digital units (Fig. 12). The cultivations in the investigated area are wheat, barley, fig and olive trees as rain fed cultivation. The cultivated lands are found in the coastal plain and large parts of the piedmont because of the relatively high number of annual rains and the absence of rock outcrops. The cultivation activity is found in the vales, basin, terraces and sand sheet area. The grazing activity is found in different areas depending on the density of the natural vegetation.

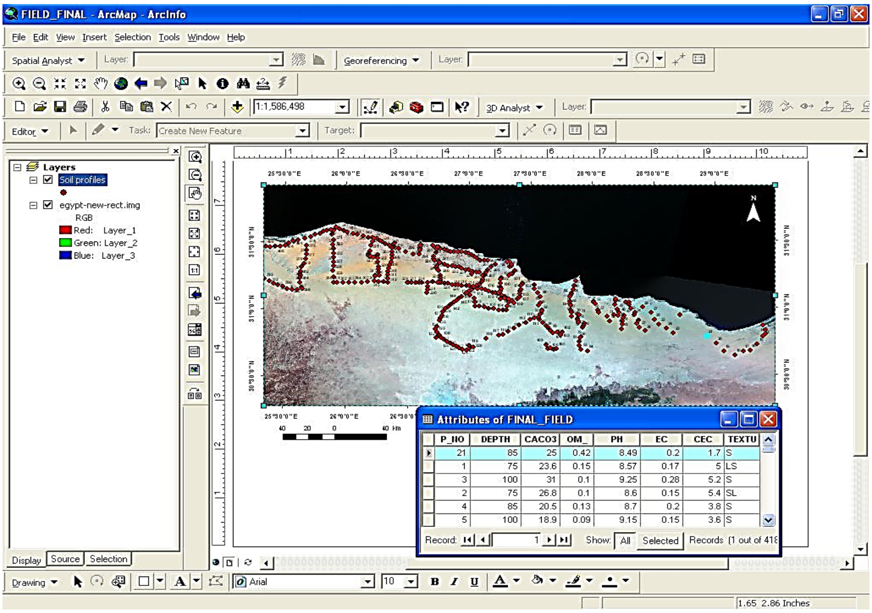

Fig. 12. The geographical distribution of the representative soils profiles with attributed data.

4.1.5. Compilation of digital soil map

The northwestern coastal region attracted the attention of several investigators and with the advantages of satellite images of the earth, reviewing of the previous work was necessary. In view of available resolution (30m) and on regional scale, the soil maps produced formerly were modified as shown in Fig. 13 [6, 7 and 8].

Since 1960, several colleagues in the Desert Institute studied separate parts. Most of their studies were accomplished by aerial photo interpretation. The modern technique at that time provided an adequate and excellent tool as base maps and for interpretation. The soil maps presented were highly predictable and credible.

The soils of the region in general are highly calcareous as the dominant rock is limestone. However; existence of sandstones and shales is reported. The following origins of these soils were identified.

1. Marine origin for the oolite sands of the ridges and dunes either consolidated or loose.
2. Alluvial and /or fluvio-marine origins, for the soils of the coastal plains, alluvial fans and depressions

3. Lacustrine origin for the sediments of lagoons and the deep lagoonal deposits
4. Aeolian origin for the sand dunes, hummocks and sheets of some tracts along the region.

The soils of the studied region are classified according to the Soil Taxonomy, Table 1 and Fig. 13 show the geographical distribution of soil units in the Northwestern coastal region. Both Arididsols and Entisols soil orders are found covering 42.1 and 57.9% of the mapped soils respectively. The Calcids sub-order is mostly clustered in areas of Burg El-Arab, Marsa Matrouh and Sidi Barani exihibiting 14.45% of the area. The Salids sub-order exist around both Matiout and Salum lagoons representing an 6.11% of soils The Gypsids sub-order soils is restricted in the area between El-Hammam and Sedi Heneish covering 21.54 % of the maped soils. The Entisols soil order includes the sub-orders Orthents and Psamments representing 33.99 and 23.91% of the mapped soils respectively. It can be noticed that the area from Burg El-Arab to Matrouh is characterized by variability of soil units (e.g. Torripsamments, Torriorthents), while the area from Matrouh to El-Saloum is occupied by the Torriorthents great group soils.

Table 1. Areas of sub-great groups, in the Northwestern coast of Egypt

Order	Sub-Order	Type (Great group)	Area (Km2)	%
Aridisols	*Calcids*	*Haplocalcids*	542.17	14.45
	Salids	*Haplosalids*	229.4	6.11
	Gypsids	*Petrogypsids*	808.45	21.54
Entisols	*Orthents*	*Torriorthents*	1275.57	33.99
	Psamments	*Torripsamments*	897.14	23.91
Total area			3752.73	100.00

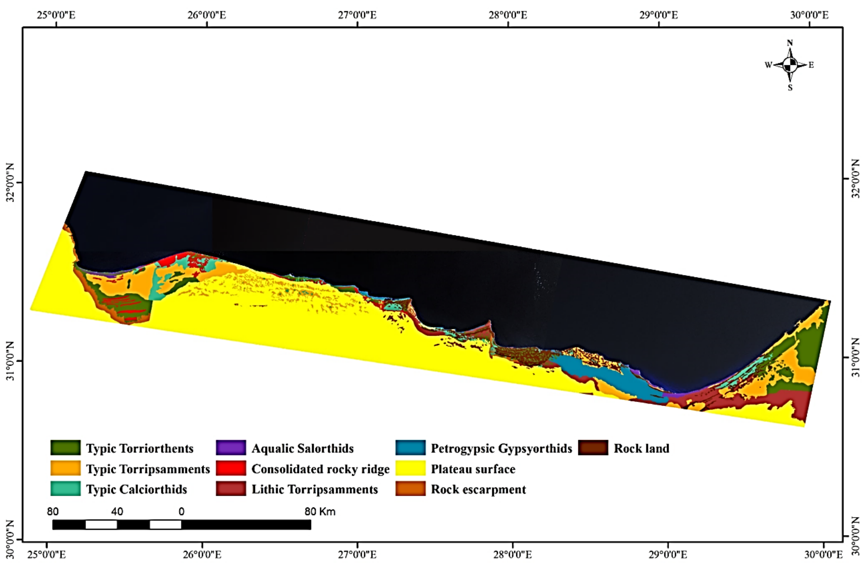

Fig. 13. Soil map of the North Western Coast region.

4.1.6. Application of the digital soil map in crop suitability classification:

Land capability and suitability for some crops (i.e. wheat, melon, sunflower, olive, peach and alfalfa) was determined using MicroLeis software [1]. The obtained data were linked to the attribute tables of the established database for defining the land suitability, Arc-GIS spatial analyst was used perform this task.

The soil characteristics such as soil depth, texture, calcium carbonate content, salinity, natural drainage and development of the soil profile were used in this system to determine the suitability class. Results of this determination are demonstrated in table (2). The suitability of 67 soil profiles representing the different soil types in the studied area was carried out; the results indicate that the olive, peach, wheat, melon and sunflower are the most suitable crops in the study area. Fig trees and barley are already found in the area with a good productivity. The soils in the area were classified to five groups (S2, S3, S4, S5 and N) according to their suitability classes and limiting factors. The map shows that the southern part of the study area is non suitable (N) for cultivation due to its very shallow depth and very high content of calcium carbonates as well as the domination of rock outcrops. The soils of piedmont and coastal plain have a good potentiality for cultivating by the selected crops, as they are classified S2 to S5. These classified soils are characterized by the following:

- Useful depth: 25 to 100 cm
- Soil texture: sandy to sandy clay loam
- Salinity: 0.25 to 31.5 dS/m
- $CaCO_3$: 10 to 57.1%
- Natural drainage: poor to excessively
- Stoniness: 0.2 to 25%
- Development of the soil profiles: incipient

The limiting factors in the soils of the piedmont and coastal plain are salinity, soil depth and texture. These factors decrease the suitability class to S2, S3, and S4 and sometimes to S5. The classes of S2, S3 are found mainly in the coastal plain where the classes of S4, S5 are exhibited in the soils of the piedmont.

In general, the investigated area could be cultivated by wheat, olive and peach with a suitability class (S2), however melon, sunflower and citrus with suitability classes S3, S4 and S5.

The barren lands are covered with gravels, stones, boulders and few patches of natural vegetation (small shrubs). These patterns of land cover are found mainly in the plateaus and the high parts of the piedmont.

Table 2. Limitation factors and land suitability classes of the studied soil profiles

Profile no.	Limiting factors	Suitable crops	Class
1	Useful depth, Texture, Drainage	Wheat	**3, 4**
2	Useful depth, Texture, Salinity	Wheat	**3, 4**
3	Texture, Carbonate %	Olive, Peach,	**2**
4	Useful depth, Texture, Drainage	Non	**5**
5	Useful depth, Drainage	Wheat	**3, 4**
6	Useful depth, Texture	Olive, Wheat, Melon, Peach	**2, 3**
7	Texture	Olive, Wheat, Melon, Peach	**2, 3**
8	Useful depth, Texture	Non	**5**
9	Useful depth, Texture, Drainage	Non	**5**
10	Useful depth	Wheat	**3, 4**
11	Texture	Olive, Peach, Alfalfa, Melon, Wheat	**2, 3**
12	Useful depth	Wheat	**3, 4**
13	Texture, Carbonate %	Olive, Peach, Wheat, Melon	**2, 3**
14	Texture, Carbonate %	Olive, Peach, Wheat, Melon	**2, 3**
15	Texture	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**2**

16	Non	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**2**
17	Carbonate %	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**2, 3**
18	Useful depth, Texture, Carbonate%	Olive, Peach, Wheat, Melon	**3**
19	Texture	Olive, Peach	**4**
20	Salinity, Useful depth, Drainage	Non	**5**
21	Texture, Salinity	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**3**
22	Non	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**2**
23	Texture	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**2, 3**
24	Texture	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**2, 3**
25	Non	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**2**
26	Texture	Olive, Peach	**3**
27	Carbonate %	Olive, Peach, Wheat, Melon,	**2, 3**
28	Non	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**2**
29	Non	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**2**
30	Texture, Carbonate %	Olive, Peach, Wheat, Melon	**2, 3**
31	Texture	Olive, Peach	**3**
32	Useful depth, Texture, Carbonate%	Olive, Peach, Wheat, Melon	**3, 4**
33	Carbonate %	Olive, Peach, Wheat, Melon,	**2**
34	Texture, Carbonate %	Olive, Peach, Wheat, Melon	**3, 4**
35	Useful depth, Texture, Salinity	Non	**5**
36	Useful depth	Olive, Peach, Wheat, Melon	**2, 3**
37	Texture	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**2, 3**
38	Texture, Carbonate %	Olive, Peach, Wheat, Melon	**2, 3**
39	Useful depth, Drainage, Carbonate%	Non	**5**
40	Useful depth, Carbonate%, Salinity	Wheat, Melon, Sunflower	**2, 3**
41	Texture	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**2, 3**
42	Useful depth, Carbonate%, Salinity	Wheat, Melon, Sunflower	**2, 3**
43	Texture	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**2, 3**
44	Useful depth, Texture, Drainage	Non	**5**
45	Useful depth, Carbonate%, Salinity	Wheat, Melon, Sunflower	**2, 3**
46	Useful depth, Texture, Drainage	Non	**5**
47	Useful depth, Texture, Drainage	Non	**5**
48	Useful depth	Wheat	**3**
49	Useful depth, Drainage	Non	**5**
50	Useful depth, Texture, Drainage	Non	**5**
51	Texture	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**2, 3**
52	Texture, Salinity	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**2, 3**
53	Texture	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**2, 3**
54	Useful depth, Texture, Carbonate%	Wheat, Melon, Sunflower	**2, 3**
55	Useful depth, Drainage	Non	**5**
56	Useful depth, Drainage	Non	**5**
57	Useful depth, Drainage	Non	**5**
58	Useful depth	Non	**5**
59	Carbonate%	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**2, 3**
60	Carbonate%	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**3, 4**
61	Carbonate%	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**3, 4**
62	Useful depth	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**3, 4**
63	Useful depth	Olive, Peach, Wheat, Melon, Alfalfa, Sunflower	**3, 4**
64	Useful depth, Drainage	Non	**5**
65	Useful depth, Drainage	Non	**5**
66	Useful depth, Drainage	Non	**5**
67	Carbonate%	Olive, Peach, Wheat and Melon	**3, 4**

5. Conclusion

It can be concluded that the digital mapping of land resources encouraged by the progress of Geographic Information System (GIS) and data provided by satellite images. Such approach may preserve in the investment spent in soil and other thematic mapping, as the digital maps are more granted compared with analogue ones. Updating and manipulating the digital thematic maps are accessible and economically effective. Usage of the digital maps and their attribute tables assist the decision support systems and may result in obtaining maps required for controlling sustainable development projects. The digital format of the soil map facilitate the linkage with the different software, this allow the integration of data for defining the optimum land uses of the studied region. The obtained results from the established database recommend that the soils of alluvial fans and watershed basins are most suiable for olives, peach, wheat, beans, and sunflower cultivation.

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Aims and Objectives

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