Full Length Article

Land use assessment of barren areas in Damietta Governorate, Egypt using remote sensing

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ABSTRACT

Damietta occupies an area of about 910 km^2 north of the Nile Delta and hosts about 1.3 million persons living within four administrative centers. The region comprises agricultural lands, water bodies, urban area and barren lands. Agriculture is the most land use while there is a significant development of barren lands, which occur at the north and east of Damietta. The present study aims to evaluate and assess the suitability of using barren lands in Damietta for the different uses. Satellite images have been utilized in order to make an accurate inventory of barren lands. The physico-chemical characteristics and soil rating were carried out to evaluate soil quality. Results showed that soils of Damietta belong to *Entisols* (recent soils) and there are five classes of soil quality, ranging from excellent to very poor. It was found that barren lands at the north of Damietta have poor potentiality for agriculture. They could be utilized for other land use, such as residential, industrial or for touristic activities. While those occur east of Damietta could be utilized for aquaculture or as bioremediation facilities for biological treatment of agricultural wastewaters.

1. Introduction

Damietta Governorate occurs at the tip of the Nile Delta along the western fringes of the Lake Manzala (Fig. 1). The capital of the Government is Damietta City, which was one of the ancient cities of Egypt and it was the Egyptian gate along the Mediterranean Sea before the construction of Alexandria about 300 years BC. Today, Damietta is one of the most important industrial centers of Egypt and its importance has increased as a new container platforms harbor along the Mediterranean Sea was constructed in 1980s. Damietta Governorate consists of four administrative centers, Kafr Saad, Faraskour, El-Zarka and Damietta center. Population of Damietta is about 1.3 million during the last formal census with most population lives in Damietta City. Agricultural land
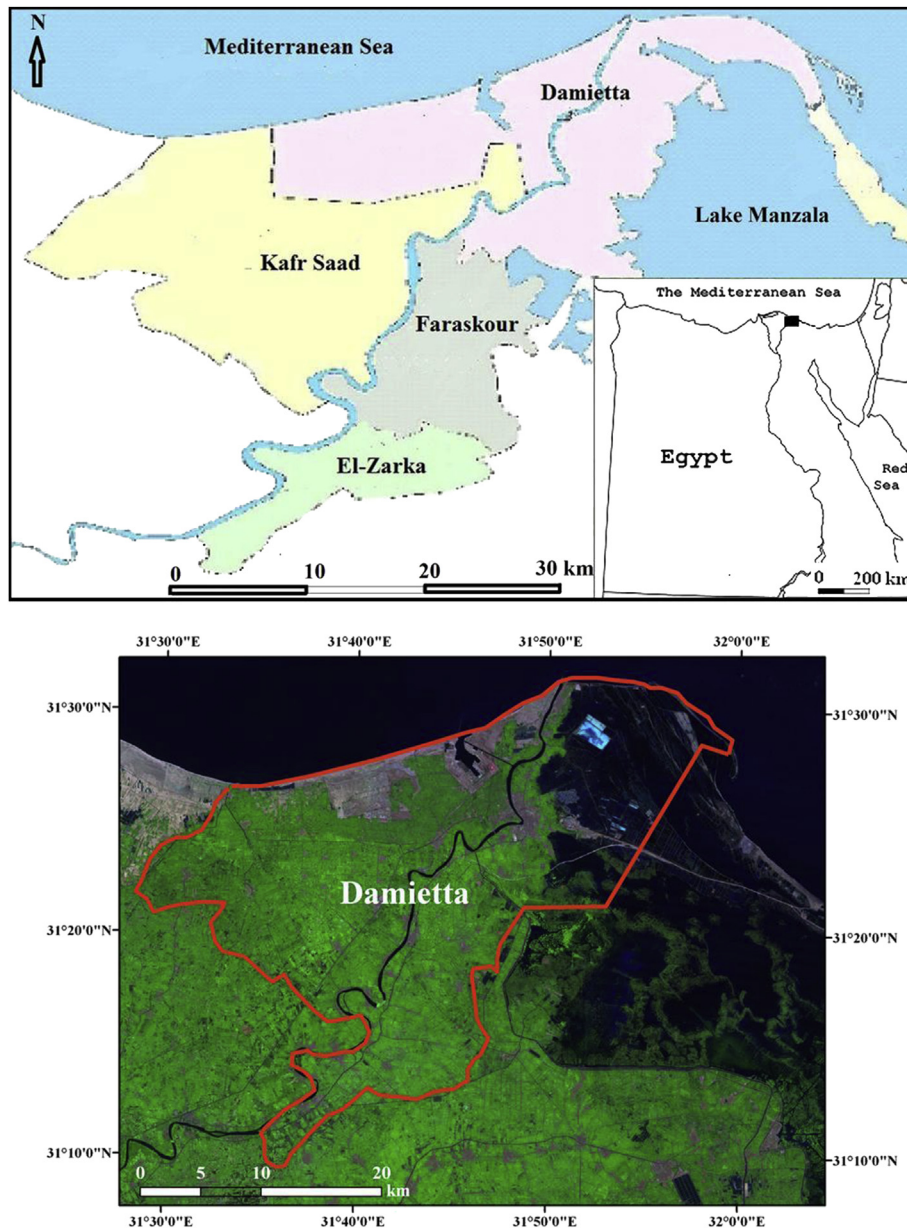

Fig. 1 – Location map and a satellite image of Damietta.

constitutes the majority of Damietta area. There are other lands that are barren mainly at the north and east of the Governorate. The northern barren lands represent the coastal sandy strip bordering the Mediterranean Sea and covered by sand dunes [1] while the eastern strip constitutes the western fringes of the Lake Maznala. According to the Central Laboratory of Agricultural Climate (www.clac.edu.eg) of the Ministry of Agriculture, climate of Damietta is generally Mediterranean, where dry summer predominates with mild dry winter. Annual winter temperatures fall to 13 °C in January and rise to 26 °C in August with a mean annual temperature of 20 °C. Precipitation (P) is generally low and does not exceed 125 mm/y. Due to its occurrence close to the Mediterranean Sea, the humidity is generally high with maximum value during summer months (up to 76%). Evapotranspiration (ET) is

much greater than precipitation rates. Maximum ET occurs in June (198 mm) with a total annual ET of 1374. Wind is generally bimodal. Most of incoming winds blow from the northwest direction in summer, spring and autumn and the other wind direction is from the southwest during winter. According to the UNESCO classification of arid lands [2], Damietta occurs within the arid zone, where its aridity index (the annual P/annual ET) is 0.07.

Soils generally have distinctive characteristics from one to another. The soil classification deals with the systematic categorization of soils based on distinguishing their own characteristics. A comprehensive soil classification system provides a hierarchical grouping of natural soil bodies. The soil classification system now widely used worldwide is the American Soil Classification System developed by the United

States Department of Agriculture (USDA) and published as the *Soil Taxonomy* [3]. This system is designed to classify all the world's soils because expanding soil survey programs entailed more precise definitions of soil properties than with previous soil classification systems. In addition, land assessment has attained the concern of soil scientists throughout the world. The Storie Index (SI) [4] is one of the accepted and widely known soil rating systems. It is a quantitative index, where, percentage values are assigned to the characteristics of the soil itself, including the soil profile (Factor A); the texture of the surface soil (Factor B); the slope (Factor C); and the conditions of the soil, for example, soil salinity (Factor X). A score rating from 0 to 100% is determined for each factor, and the scores are then multiplied together as:

$$SI = [(Factor\ A/100) \times (Factor\ B/100) \times (Factor\ C/100) \times (Factor\ X/100)] \times 100$$

Awareness of the land use and land cover is an important process for many planning and management activities and is considered an essential element for modeling and understanding the earth as a system [5]. Land cover maps are presently being developed from local to national to global scales. The use of satellite data and aerial photographs has been an accepted practice to map land use. The term land cover relates to the type of feature present on the surface of the earth. Lakes, rivers, deserts, and forests are all examples of land cover types. On the other hand, the term land use relates to the human activity or economic function associated with a specific piece of land [6]. Remote sensing is one of the burgeoning and indispensable tools for assessment the best use of land in the natural/human ecosystems. NASA began a successful program for monitoring earth's resources from space in July 1972. All satellites in the series carried the Landsat designation [5]. Eight generations of satellites have been launched into space since 1972. The latest one is the Landsat-8 or the Operational Land Imager (OLI) which was launched in 2013. It has 12 bands in the visible and infrared bands and has 30 m spatial resolution. Features in satellite images can be identified using visual or automated methods. The most common approach is the automated image classification, in which a computer algorithm groups pixels in the image into classes that the analyst defines. There are many studies on the land use and land cover mapping close to the study area. Most of these studies operated satellite images in order to highlight temporal changes [7–10]. The main objectives of the present study are to highlight the spatial distribution of barren lands in Damietta; to determine the soil quality at such barren lands; and to rate their suitability for different land use.

2. Materials and methods

2.1. Satellite data

In this study, an image was acquired from the most recent Landsat-8 satellite (OLI) in August, 3rd 2013, the time which is synchronous with the field visits and sampling. The image

(path 176 and row 38) covers an area of 185 × 185 km and includes the northern part of the Nile Delta. In addition to the OLI image, a digital elevation model (DEM) was acquired from the Shuttle Radar Topography Mission (SRTM), which is an active sensor that radiates electromagnetic energy in the microwave portion of the spectrum and is used to estimate the absolute elevation of the earth's surface. This DEM (path 176 and row 38) has a spatial resolution of 90 m. It was acquired in February 2000 by the Space shuttle *Endeavor* during its mission to scan the earth's topography.

2.2. Field investigation and soil sampling

Many field trips were performed in order to recognize the different land cover units at the study area in summer 2013. During field visits, sheets of satellite data were printed and were used to recognize different land cover units. Soil samples were acquired from natural soil bodies to avoid any disturbance or contamination to the soil from surrounding environment. Soil samples were collected from: 1 – *Agricultural land*; 2 – *non-vegetated land*; 3 – *sabkhas*; and 4 – *Lake Manzala shores*. A total of 20 soil samples were collected, including: 17 surface samples (at 10 cm) and three subsurface samples (at 100 cm) (Fig. 2). A hand-held portable GPS unit was used to determine the accurate position for each sampling station.

2.3. Image processing

Image processing was carried out using ERDAS Imagine software. An unsupervised classification was performed using the iterative self organizing data analysis (ISODATA) algorithms. It uses cluster analysis techniques to create a user-defined number of clusters or classes in an image that must later be labeled to create a land cover map [11]. The ISODATA algorithms were applied for clustering the image into 50 different classes. A careful recoding of each class was done and these fifty classes were reduced to four land cover units according to the USGS Land Use/Cover Scheme [6]: *water*, *urban*, *agricultural* and *barren lands*. Finally, a majority filter of 3x3 was applied to remove odd and random pixels and to enhance the appearance of the classification process. Finally, the DEM of the region was classified using ArcGIS software to generate five vertical elevation classes: <0, 0–1, 1–2, 2–3, and more than 3 m. An elevation map was then produced.

2.4. Soil analysis

In the field, some parameters were extracted directly, such as the soil structure, soil depth, drainage efficiency and occurrence of gravel and hard strata, The collected samples were dried in the air and the dry color was determined using the Munsell Soil Color Charts. The samples were passed through a mesh (#20) to remove gravel particles. The soil texture, was determined using the standard hydrometer methods [12] and the relative percent of sand, silt and clay as well as the soil texture were determined. Calcium carbonate content was determined by acid/base titration methods [13]. Saturation percentage was calculated from the amount of water required for soil saturation. A soil extract (1 W:1 V) was prepared and in the filtrate, the pH and the total salinity expressed as electric
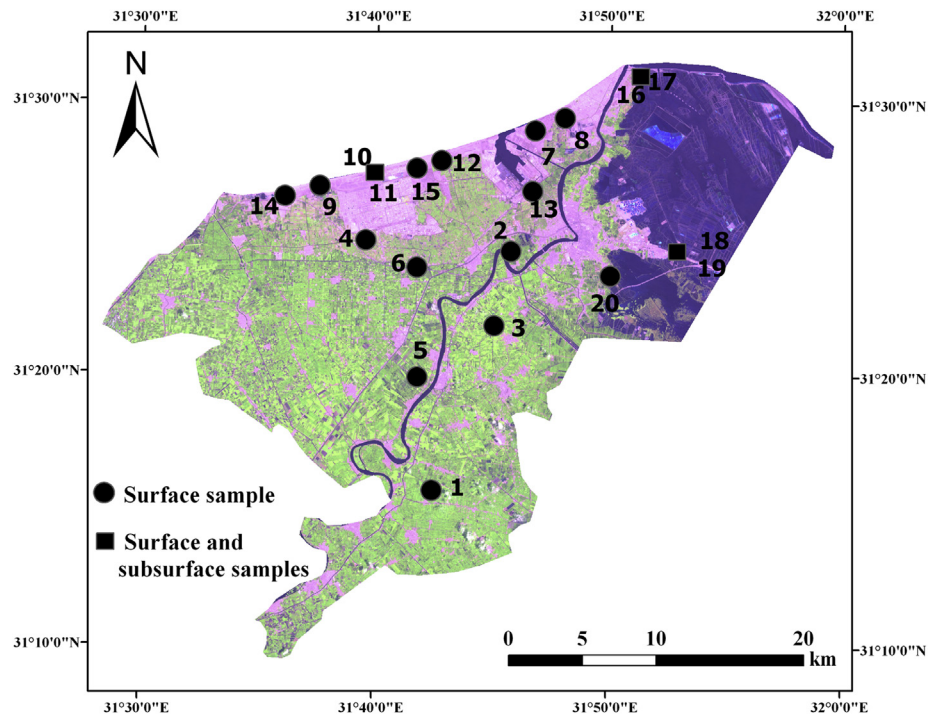
Fig. 2 – Location map of Damietta showing the sampling points. Circles show the locations of surface samples and the squares show the location of the profiles.

conductivity of each soil sample was measured and expressed in dS/m. The nutrients (potassium, phosphorous and nitrogen) were determined in each dry sample. Available potassium in the soil was determined by the flame photometer method [14]. Available phosphorous in the soil was determined by the spectrophotometer method [15]. The total nitrogen of the soil was determined by the Kjeldahl digestion method [14].
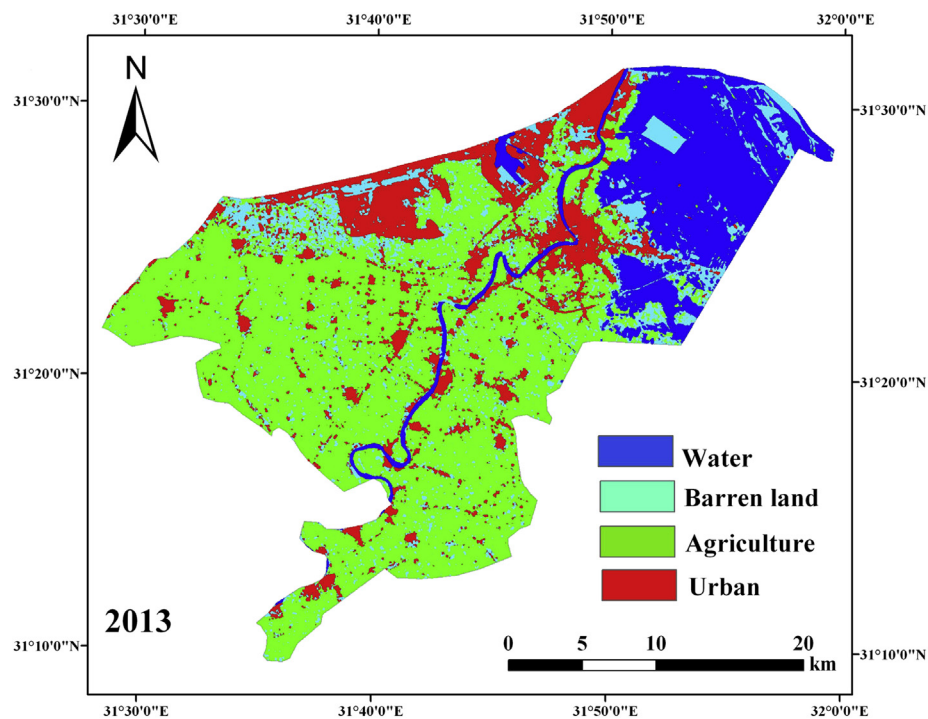

Fig. 3 – The land use/cover map of Damietta Governorate as obtained from the Landsat-8 OLI image classification.

2.5. Soil formation, classification and rating

Factors of soil formation at Damietta region (parent materials, climate, topography, biota and time) [16] were examined in order to highlight the maturity of the soils in the region. Parent materials were identified using the soil characteristics and the Field Book for Describing and Sampling Soils [17]. The climate was studied in terms of the temperature, precipitation, and evapotranspiration. Topography was obtained from digital elevation models. Biota and time information were extracted from previous literature. The formal soil classification of Damietta was applied using the American System of Soil Classification [3]. The point of strength in this system is that it apply a full taxonomy to the soil based not only on the geomorphology, but also upon the pedon characteristics, chemical and physical characteristics as well as the climatic characteristics of the region. In this study, the soil was classified to the Subgroup level in the classification hierarchy. Soil rating was determined using the soul rating index of Storie [4], which contains four factors: the soil profile (Factor A); the texture (Factor B); the slope (Factor C); and the salinity of the soil (Factor X). Each of these factors was assigned the appropriate percentage ranging from 0 to 100% depending on the characteristics of this factor. The Storie's Index was then determined by multiplying the four factors and the result was rated as one of the following classes: *Excellent (100%–80%), Good (79%–60%), Fair (59%–40%), Poor (39%–20%), Very poor (20%–10%)* and *Nonagricultural (less than 10%)*.

3. Results and discussion

3.1. Land cover classification

The use of satellite data to map land use/cover has been an acceptable practice since the launch of the first earth resources satellites in early 1970s. The synoptic view of the land, the regional coverage, the digital format, and the non-visible spectral information provided in satellite images are important advantages that make remote sensing superior to other traditional methods of land use/cover mapping. The land use/cover map of Damietta produced from the Landsat-8 OLI image of 2013 (Figs. 3 and 4) reveals that there are four land use/cover units: agricultural, urban, water and barren lands. The total area of Damietta is 910 km^2. Agricultural land
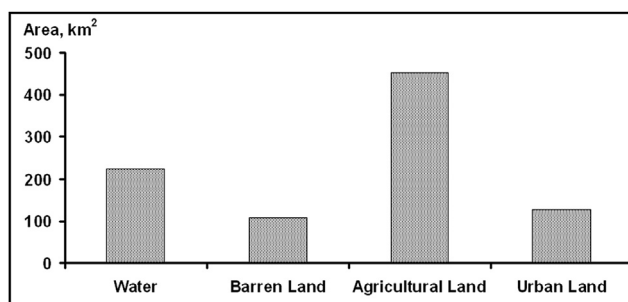

Fig. 4 – The extent of the individual land use/cover units of Damietta.

accounts for about 452 km^2 (49%). It occupies the southern, western and most of the eastern sides of Damietta. During the field visits (August 2013), most crops cultivated are rice, maize, and vegetables. Water is the second abundant land cover of Damietta. It comprises 223 km^2 (25%) and includes the Lake Manzala, the Nile and the Damietta harbor. Urban land approaches 128 km^2 (14%) while barren lands occupy 107 km^2 (12%) of Damietta.

The accuracy of the land cover map is relatively high. The overall accuracy of the classification approaches 97%. The overall Kappa is also high (0.94). At the class level, maximum producer accuracy is determined for urban land (100%), whereas minimum accuracy is for water (75%). Maximum user accuracy is observed for water (100%) and the minimum is for urban land (88%). The individual Kappa statistics is maximum for water (1.0) and minimum for barren land (0.88) (Table 1).

3.2. Soil characteristics

Soil color. The collected soil samples (Table 2) show small variations within their colors. All the soil samples fall within the Hue page 10 YR. Clayey soils are darker and have a general Value/Chroma reading of 4/1. The soils turn to lighter color along the coastal area as the grain size moves toward coarser sediments mainly of the sand size. Value/Chroma readings of sandy soils range from 4/2 to 6/3 values.

Soil texture. The fluvial soils of the Nile have generally clayey textures. These soils are the typical deltaic sediments predominating the entire Nile Delta, which are the real agricultural land of the country. On the other hand, the coastal strip of Damietta is covered by sediments of sand size. The course sediments along the coast differ in the origin from those of the deltaic sediments.

Electric conductivity. Agricultural lands have the lowest EC (1.13 dS/m) with a mean value of 3.38 dS/m. This lower salinity is attributed to the origin of these soils from the Nile sediments and the quality of irrigation water. Other bare soils have a mean EC value of 139 dS/m and soils along the lake Manzala shores have a mean salinity value of 227 dS/m.

Soil pH. The soil reactivity in terms of the hydrogen ion concentration falls within the neutral/alkaline range. The majority of soil sediments have a pH around 8.0 and only one sample (sample #15) has a greater pH than 8.5 and falls within the alkaline range.

Saturation Percent. The saturation means that all the pore spaces within the soils are completely filled with water. It is correlated directly with the soil texture, where clayey soils of agricultural land have saturation percent of 79%. Soils of bare

Table 1 – Classification accuracy of the land use/cover map of Damietta.			
Land use/cover	Kappa	Accuracy producer	Accuracy user
Water	1.00	75.00	100.00
Barren land	0.88	90.00	90.00
Agricultural land	0.92	94.00	94.00
Urban land	0.86	100.00	88.00
Overall	0.94	97.00	

Sample	Description	Color	Sand	Silt	Clay	Texture	Sat.	CaCO$_3$	pH	EC	K	P	N
			%	%	%		%	%		dS/m		mg/kg	
1	Agricultural land	10 YR 4/1	24	44	32	Clay loam	85	1.26	7.93	1.13	493	8	1800
2	Agricultural land	10 YR 4/1	28	19	53	Clay	90	1.16	7.9	2.67	1080	16	1650
3	Agricultural land	10 YR 4/1	20	32	48	Clay	100	0.87	8.06	2.60	635	10	1350
4	Agricultural land	10 YR 4/2	92	6	2	Sand	40	1.06	8.19	7.13	155	22	535
Mean			41	25	34	Clay loam	79	1.08	8.02	3.38	591	14	1334
5	Bare land	10 YR 4/1	12	34	54	Clay	120	2.91	8.11	15.02	702	7	1390
6	Bare land	10 YR 4/1	14	24	62	Clay	105	1.94	7.96	10.55	817	3	1481
7	Bare land	10 YR 4/2	92	5	3	Sand	34	2.91	8.07	142	62	0	924
8	Bare land	10 YR 4/2	91	6	3	Sand	35	2.01	8.11	166	53	0	800
9	Bare land	10 YR 4/2	92	7	1	Sand	37	2.69	8.09	225	52	0	845
10	Bare land	10 YR 4/3	90	7	3	Sand	38	0.67	7.95	164	68	0	822
11	Bare land*	10 YR 6/3	90	8	2	Sand	34	1.57	8.08	205	53	0	907
12	Bare land	10 YR 6/3	93	6	1	Sand	37	0.34	7.89	168	61	0	858
13	Bare land	10 YR 4/2	92	7	1	Sand	37	2.35	8.13	158	45	0	788
Mean			74	12	14	Sandy loam	53	1.93	8.04	139	216	1.1	979
14	Sabkha	10 YR 4/2	80	13	7	Loam sand	38	1.65	7.1	567	1368	16	116
15	Sabkha	10 YR 4/2	92	7	1	Sand	39	1.16	8.85	158	977	30	52
16	Sabkha	10 YR 4/2	92	7	1	Sand	37	0.26	8.05	246	706	0	61
17	Sabkha*	10 YR 4/2	90	9	1	Sand	38	0.17	7.95	214	857	0	19
Mean			88	9	3	Sand	38	0.81	7.99	296	977	11	62
18	Lake shore	10 YR 3/2	48	32	20	Loam	84	4.46	8.05	237	4114	27	1850
19	Lake shore*	10 YR 3/2	56	28	16	Loam sand	80	3.88	8.19	283	4356	21	1862
20	Lake shore	10 YR 4/2	75	14	11	Sand loam	55	0.67	8.09	162	959	6	175
Mean			60	25	15	Loamy sand	73	3.0	8.11	227	3143	18	1296

Table 2 – Soil physical and chemical properties of the samples. Sat. means the saturation %.

lands with sandy texture have saturation percent of 53% and the sabkha soils have a value of 38%. The soils of the Lake Manzala have a saturation percent of 73%.

Calcium Carbonates. Soils of the study area are generally non-calcareous. The least calcium carbonate was observed within the bare Sabkha soils that have a mean value of 0.81. The highest carbonate content was in Lake Manzala shore sediments (3%) due to the presence of remnants of marine fauna skeletons and shells. Agricultural land soils range from 0.87 to 1.26%, with a mean value of 1.08%.

Available Potassium. Potassium is a minor cation that presents in the soil and coincides with the total salinity of the soil. The most available K$^+$ is observed in the Lake Manzala shore soils (3143 mg/kg), which are mainly of marine origin. The lowest available K$^+$ is observed at the bare soils (216 mg/kg). Agricultural lands have available K$^+$ of 155 mg/kg in the sandy textured soil and rises to 1080 mg/kg in the clayey textured soils. Fertilization is the primary source of K$^+$ in these soils.

Available Phosphorous. Soil phosphorous is another nutrient that affects the fertility of the soil. The highest available phosphorous was observed in the soils of the Lake Manzala shores with a mean value of 18 mg/kg. This high availability of phosphorous may be attributed to the use of fish fodders rich in this element. Available phosphorous of agricultural land accounts for 14 mg/kg, which may be attributed to the use of fertilizers.

Total Nitrogen. Nitrogen may enter the soil through rainfall, plant residues, nitrogen fixation, animal manures and fertilizers. Agricultural land has the most mean total nitrogen content (1334 mg/kg) due to fertilizers application. Soils in the shores of Lake Manzala have the second abounded in nitrogen (1296 mg/kg).

3.3. Soil formation

Soil analysis in terms of texture, color and chemical characteristics reveals different origins of parent materials. Dark clayey soils are those formed from the Nile flooding, which are the typical deltaic sediments of the River Nile. The majority of Damietta is covered by this kind of soils and are herein referred to as the *alluvial stream deposits*. These soils are deep, fertile, non-saline and under cultivation all the year round. Mineralogical studies of these alluvial soils indicate that they are rich in *monmorillonite*, *illite* and *kaolinite* from the basaltic rocks weathering in the Upper Nile countries [18]. The lighter color (gray) sandy soils occur along the northern section of Damietta bordering the Mediterranean Sea coast and are covered by sand mounds and sand sheets. Sands along this sector were transported and deposited by the action of wind [1]. The continuous action of wind leads to the formation of a sandy belt along the northern part of the entire Nile Delta coast. Soils along this part are consequently of *aeolian* parent material. Soils along the shores of the Lake Manzala are under the influence of marine agents, where they were formed from the coastal processes in terms of erosion and accretion. Hence, they have sandy loam texture and are of *marine sediments* parent materials.

The climate–soil relationship can be seen by comparing the world soil map with maps of soil moisture and temperature. These two climatic parameters are the most controlling factors of soil properties and consequently soil development. Precipitation at Damietta is low (100 mm/y) and the amount of rainfall is not enough to have significant impacts in the soil development in terms of pedogenic processes. In addition, annual temperatures are high (20 °C) and can accelerate decomposition of the soil organic matter, if presents.

Moreover, the amount of evapotranspiration is high (1374 mm/y) and can accelerate salt accumulation in the soil profile.

The topography is the third influencing factor of soil formation. Generally soils at flat topography have much opportunity to develop more than soils formed along sloping terrains and mountainous ranges [16]. The alluvial soils of the River Nile are generally deep due to the gentle topographic nature of the River Nile and its flood plain. Fig. 5 reveals that regional topography of Damietta is very gentle. This is manifested by the deep profile of the fluvial soil as well as the soils formed along the coastal area. Although the topography of the region could help develop a deep soil profile, the maturity of this profile requires integration and suitability of the other factors.

Organisms or biotic factors are mostly contingent to plant action in the soil profile. Regions under grasses are influenced by the plant residues and their effects on the maturity of the soil profile. However, in arid climate, where vegetation is scarce and soils are exposed to wind action, biotic factors do not have significant impact upon soil formation [19]. With the exception of the agricultural lands, which are under the cultivation management practices, the bare soils of the governorate are generally poor in natural vegetation. The only vegetation cover is represented by *halophytic* vegetation. Plant species occurring at the region are *Arthrocnemum macrostachyum* and *Atriplex portulacoides* [20].

The time is the last factor that control soil formation; simply soils require suitable time to form. The broader concept of time is that it is more concerned with the development and maturity of the soil profile. The age of the soil in Damietta as well as the soils of the Nile Delta is the same age of the River Nile itself. The absolute age of sediments along the coastal area at Gamasa (west of Damietta) was reported to range from 2548 to 3280 years [8]. This age combined with climatic conditions is not enough to form matured soil profiles within the study area and thus the soils are considered young.

3.4. Soil classification

The soil temperature regime, which is determined by adding 1 to the mean annual air temperature of the region [21] is 21.2 °C for Damietta, which means that the regime is *thermic*. When the soil is dry in all parts for more than half of the cumulative days per year, the soil moisture regime is then termed *aridic*, the case that occurs along the soils of Damietta. As the soil is mostly either cultivated, an *Anthropic* Epipedon characterize this soil, while bare lands have an *Ochric* Epipedon (light surface). Diagnostic subsurface horizons, which are the most controlling factors for soil classification are absent. Field observations and soil profiles have shown that no indication of aridic accumulations of salts, such as gypsic, calcic, salic horizons occur within the soil profile. Although the soil profile is deep, the soils have one or two horizons. Cultivated soils, which are under plowing activities, have an "A_p" surface horizon and another "A2" subsurface horizon. Soils of the bare coastal area have an *Ochric* horizon referred to "A" and have another "A2" horizon formed by the episodes of sedimentation in previous times. The shorelines of the Manzala Lake have only one shallow "A" horizon.

Although the climatic conditions along the study area favor the formation of the *Aridisols*, the lack of diagnostic subsurface horizons due to the absence of diagnostic Endopedons and relatively young age of the soil lead to have a soil order of *Entisols* (recent soils). *Entisols* include a wide range of suborders depending on the nature and characteristics of the soils. *Entisols* of Damietta are suggested to have three suborders, according to their abundance (Fig. 6): 1 — *fluvents*,
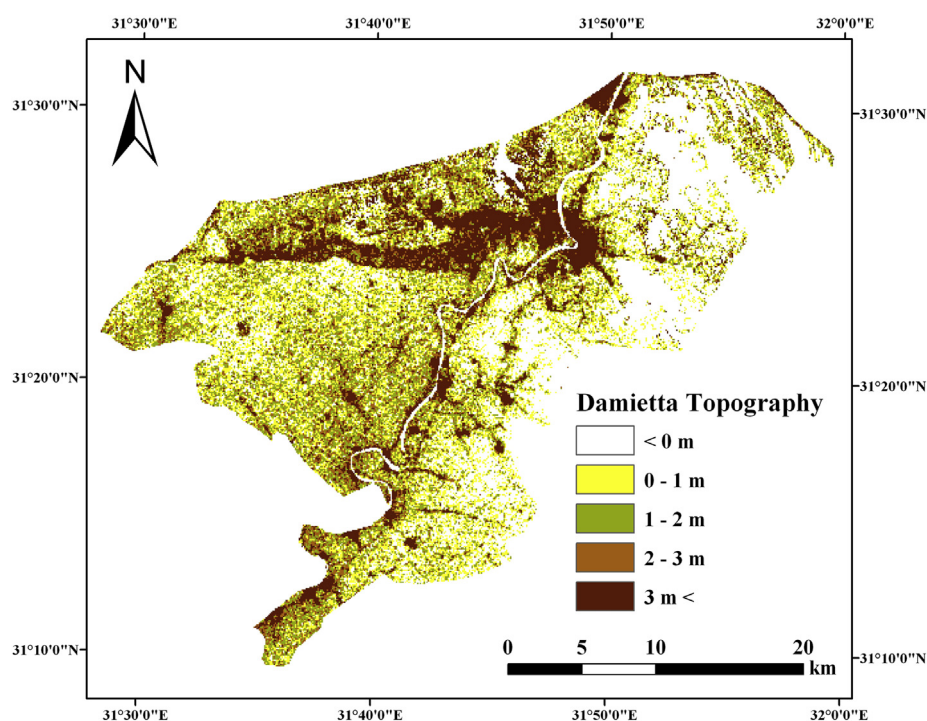

Fig. 5 — Regional topography of Damietta as revealed by digital elevation modes.

which represents the heavy clayey dark soils formed from the River Nile and are under cultivation. 2 — *psamments*, which occurs along the northern coastal plain of Damietta and have coarse texture soils (at least loamy sand). 3 — *Aquents*, which occurs along the fringes of the Lake Manzala and constitutes a narrow belt encompassing the lake shores. For the *fluvents*, there are two most probable Great Groups: *fluvents* soils that have xeric moisture regime and *fluvents* soils that have *aridic* moisture regime. As the moisture regime of the soil is *aridic* (torric), then the Great Group of the *fluvents* is the *torrifluvents*. In a same manner the Great Group of the *psamments* is the *torripsaments*. For the *aquents*, the most suitable Great Group is the *psamaquents* as the soil texture is mostly loamy sand. The fourth level in the soil classification incorporates the presence of specific character in the soil profile. As the soil profile is generally homogeneous, all the three soil Great Groups are described as "typical". Then the three subgroups of the soils are: 1 — *Typic torrifluvents*; 2 — *Typic torripsamments* and 3 — *Typic psamaquents*.

3.5. Soil rating

The Storie's index is a quantitative ranking system for soil suitability. The four factors applied to this index are given in Table 3. Factor (A), which describes the physical profile in terms of its formation and depth. This factor takes scores of 100 and 60% in the studied soils, as they are formed along flood plains or from aeolian/coastal processes. Soils having 100% are deep, whereas those having 60% are shallow. Factor B describes the texture of the soil in each site, where fine texture soils have a higher score than coarser soils. Factor C describes the slope of land in each site, where all the sites take the score of 100 because soils are flat. Factor X describes the

conditions of the soil in terms of the degree of soil salinity. Three classes of salinity could be identified in the soils under considerations: low salinity soils of the cultivated fine soils (100%); moderate soil salinity in the reclaimed cultivated land and in the clayey bare soils (90%); and high soil salinity in the sabkhas and lake shore soils (30%). Multiplying these four factors yields the Storie's Index, which produced five classes of soil suitability: 1 — Excellent soils; those represents agricultural lands of the fine texture (sample 1). 2 — Good soils; those include agricultural lands of the coarser texture (samples 2, 3, 5 and 6). 3 — Fair soils; those have a sandy texture (sample 4). 4 — Poor soils; those include bare soils which have a finer texture (sample 14). 5 — Very poor soils; those comprise all the other bare soils (samples 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20). The most obvious results of these classification systems indicate that bare lands of Damietta Governorates are not suitable for agricultural purposes. They could be used for other land use activity.

3.6. Suitable uses of bare land

Depending on the results obtained from the soil analysis, rating, and land cover mapping, barren lands (12% of Damietta) occur mostly at the coastal strip along the Mediterranean Sea coast and rarely along the shores of the Lake Manzala, do not have a potential for agriculture. The primary reason is that these lands have extremely high salinity. The sources of salinity of salts can include: flooding of seawater during winter surges and the high groundwater table. For coastal bare lands along the Mediterranean Sea, salt crusts have been observed with their white-color. Other coastal bare lands include sand flats covered by little dunes and ripple marks, particularly along the coast. The sands of these flats
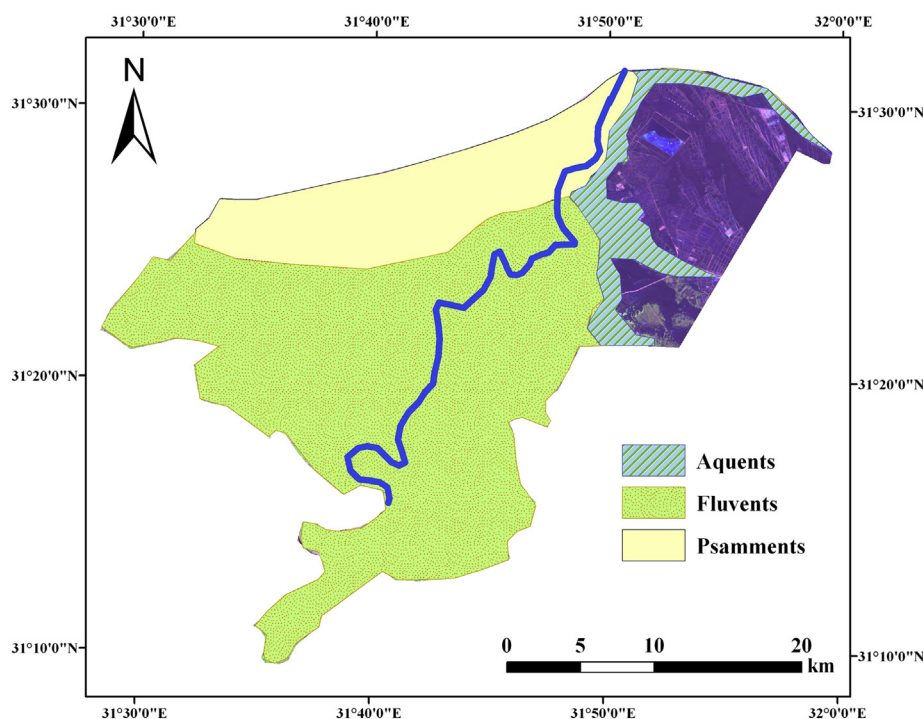

Fig. 6 — Soil classification of Damietta Governorate.

Table 3 – Storie Index Soil Rating of the study area.				
S.	Factor A	Factor B	Factor C	Factor X	Soil Rating
	Physical profile	Texture	Slope	Soil condition	
1	100	90	100	100	90% – Excellent
2	100	70	100	100	70% – Good
3	100	70	100	100	70% – Good
4	100	60	100	90	54% – Fair
5	100	70	100	90	63% – Good
6	100	70	100	90	63% – Good
7	100	60	100	30	18% – Very poor
8	100	60	100	30	18% – Very poor
9	100	60	100	30	18% – Very poor
10	100	60	100	30	18% – Very poor
11	100	60	100	30	18% – Very poor
12	100	60	100	30	18% – Very poor
13	100	60	100	30	18% – Very poor
14	100	80	100	30	24% – Poor
15	100	60	100	30	18% – Very poor
16	100	60	100	30	18% – Very poor
17	100	60	100	30	18% – Very poor
18	60	60	100	30	11% – Very poor
19	60	80	100	30	14% – Very poor
20	60	95	100	30	17% – Very poor

Grade 1 Excellent (80–100%).
Grade 2 Good (60–79%).
Grade 3 Fair (40–59%).
Grade 4 Poor (20–39%).
Grade 5 Very poor (10–19%).
Grade 6 Non-agricultural (Less than 10%).

have been inherited originally from the beach, therefore they add salinity to the receiving areas.

The suitable use of these bare lands could include urban, industrial, commercial and touristic use. One of the industrial activity that is proposed by this study is to establish plants of table-salt extraction, particularly along the north tip of Damietta promontory. DEM could be used to locate low-lands that receive water naturally from the sea. Coastal resorts and villages could be established along the coastal bare land from north of New Damietta City until the western border of the Governorate. This sandy strip has a lower salinity and, hence, could be used for urbanization. Bare lands bordering the Lake Manzala could be used for extending current aquaculture activities. Soils are rich in nutrients and could be used efficiently for fish production. In addition, bioremediation basins could be constructed for biological treatment of agricultural wastes. Domestic wastewater could be diverted after a primary treatment. There, swamp vegetation should be grown in these basins to reduce nutrient levels. It is not recommended to convert these areas for agricultural purposes due to the high salinity of the soil, otherwise expensive and careful management are needed.

4.   Conclusions

Damietta Governorate occupies an area of about 910 km^2 with barren lands occupying 12%. Soils are generally either: agricultural non-saline of alluvial origin or barren saline of aeolian or marine origins. Soils have a *thermic* temperature regime and an *aridic* moisture regime. They are generally deep, however,

pedogenic and soil genesis processes are not observed and no diagnostic epipedon or endopedons have been recognized. Soil classification reveals the presence of one soil order; *Entisols*, with three sub orders: *fluvents*, *psamments* and *aquents*. Five classes of Soil Storie's Index are identified: 1 – Excellent, 2 – Good, 3 – Fair soils, 4 – poor, and 5 – Very poor. Bare soils are not recommended for agricultural purposes. They could be utilized for residential, commercial, industrial, touristic, aquaculture or biological treatment of wastewater. Remote sensing technology is proved to be an effective tool for mapping and classification of land use/cover.

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