Chapter 22
Use of Remote Sensing and GIS for Land Degradation Assessment of Qarun Lake Coastal Area, El-Fayoum, Egypt

M.M. Kotb, R.R. Ali and M.A. El Semary

Abstract El-Fayoum Oasis is a depression or basin in the western desert that is adjacent to the Nile, Egypt. It locates about 130 km southwest of Cairo. Qarun Lake is the only natural contemporary lake in Middle Egypt. The lake is saline with an elevation about 44 m below sea level. It receives drainage water from El-Fayoum Depression but has no surface outflow. Wadi El-Rayan Lakes have been receiving drainage water since April 1973. El-Fayoum is now an intensively agricultural region supported by abundant freshwater from the Nile River via the Bahr Yusef Canal. The main objective of this study is to use Landsat multitemporal images to detect and monitor the changes of Qarun Lake coastal area. To fulfill this objective, Landsat data (path 177/row 40) are as follows: Landsat MSS 1973, Landsat TM 1988, Landsat ETM + 2003 and Landsat-8 2015, and topographic maps (1992) scale 1:50,000 were used. Geometric correction, Image enhancement, and visual interpretation were carried out on the images and maps. Digital elevation model (DEM) and the vector contour lines of the study area were used. ArcGIS 9.2 software had been applied for mapping environmental changes around Qarun Lake in the investigated area. ENVI 4.2 software was also used to produce the physiographic map of the study area. The obtained results from the digitized topographic map (1942) showed that the surface area of Qarun Lake was about 21 km^2. From that time, the surface area of the Lake was more or less stable and it was in a balance with land use in El-Fayoum Depression base on the interpretation of the remotely sensed data. In 1973 the surface area of Qarun Lake reached the maximum (240 km^2) due to receiving the excessive drainage water from El-Fayoum Depression. The surface area of Qarun Lake decreased to about 230 km^2 by 1988. Since that time until 2013 the surface area of the lake was almost stable.

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Introduction

El-Fayoum Oasis locates in the Western Desert of Egypt, about 130 km southwest of Cairo between latitudes 29° 02' and 29° 35' N and longitudes 30° 23' and 31° 05' E (Fig. 22.1). Emanuele et al. (2010) stated that the Oasis occupies a depressed area, surrounded by hills in the South and by a 300 m escarpment in the North: the elevation ranges from 40–45 m below the sea level.

The total rainfall in El-Fayoum Depression does not exceed 7.2 mm/year. The mean minimum and maximum temperatures are about 14.5 °C and 31.0 °C, respectively. The annual mean temperature is 22 °C. The evaporation rates range from 3.06 to 10.26 mm/day, with an annual mean of about 6.75 mm/day, (CLAC 2004). According to the aridity index classes (Hulme and Marche 1990), the climatic condition of El-Fayoum Depression was classified as arid climate.

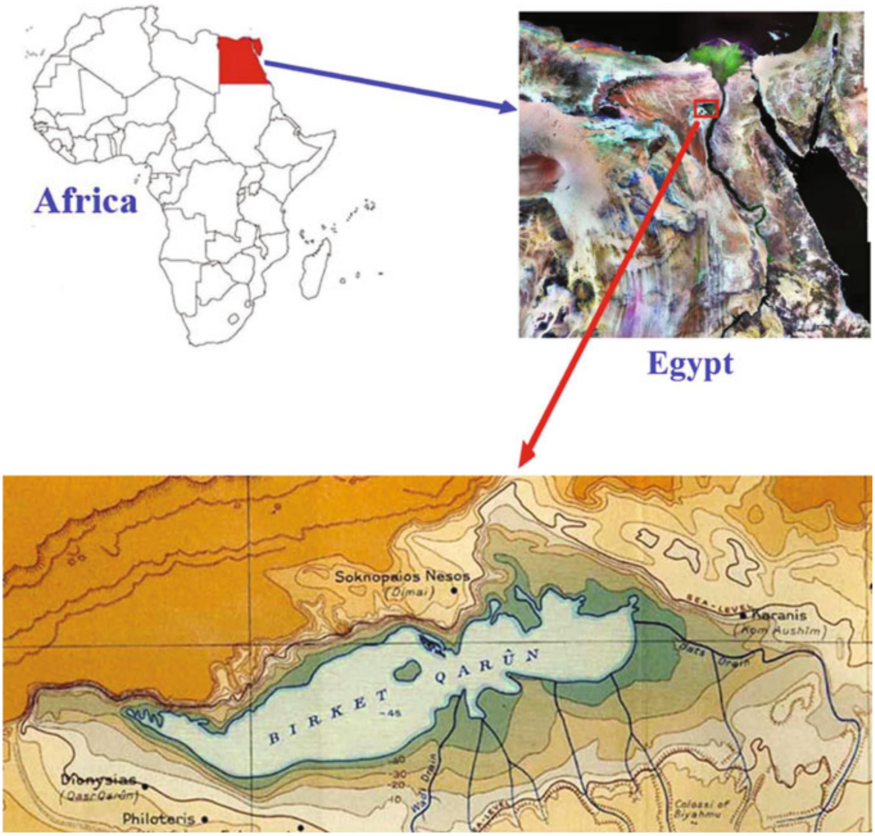

Fig. 22.1 Location of the study area

The relative humidity values vary between 42.6 and 67.4%, the lowest value (42.6%) is recorded in May, while the highest one (67.4%) is recorded in December.

The annual mean of wind speed is 4.46 knots. The Khamaseen wind blows over the area during the period of February–June interval, from the western direction across the Western desert. It is usually warm strong and loaded with sand particles and dust.

The soil temperature regime is Thermic Erian (1982) mentioned that the area is prevailed mainly by Torric moisture regime. He added that the Aquic or Peraquic moisture regimes can be expected in the margins of lakes, river banks, and soils of shallow water table. Moreover, Abdel All (1990) classified the soil moisture regime of El–Fayoum Depression as Torric and Ustic in addition to Aquic in the margin areas subjected to Qarun Lake and the soils of high water table.

Geological Aspect

El-Fayoum Depression has an erosional origin, closely controlled by tectonics and it dates back to no more than the Upper Oligocene or later, Issawi et al. (2001). Said (1962); Tamer (1968); Khalil (1970); Khater (1973); Hanna and Labib (1977); and Shendi (1984) point out that the Fayoum formations recognized into three groups of sediments of distinctly different origins: Nile River sediments, desertic sediments, and lacustrine deposits.

Soil Aspect

Landforms

Abd El–All (1984) and Shendi (1984) identified the main landforms in El-Fayoum Depression as: (a) Nile alluvial (lake terraces, basins, gullies, channels and low parts). (b) Interference zone (lake terraces, basins, gullies, channel high and low parts). (c) Desertic formations (high parts, low parts, plateau, escarpments, slopes, ridges, dry valley, summits, isolated hillocks, rocky table land, sandy areas peneplain, and marches). While, Abo El–Enean (1985) stated that the main landforms in El-Fayoum are; Fans, recent lake terraces, older lake terraces, depression ridges, Fayoum plain, Graham basin old wadies.

Landscape

Ali (2005) and Ali and Abdel Kawy (2013) showed that the soils of El-Fayoum Depression were belonged three landscape units; i.e., alluvial plain (12.22%), fluvio-lacustrine plain (34.20%) and lacustrine plain (53.58%). He stated that the main land forms were terraces, while the overflow and decantation basins represent the rest of the area.

Soil Mineralogy

Various authors; Basta, et al. (1969), Khalil (1970), Labib (1970), Abdel Aal et al. (1976), Hanna and Labib (1977), Kassem and Elwan (1980), Wahab et al. (1988) and Shendi (1990) studied soil mineralogy of El-Fayoum Depression, their observations can be concluded as; the light minerals of sand fraction are mainly composed of quartz in the forms of subangular to subrounded grains, associated with minor amounts of feldspars (microcline, orthoclase and Plagioclase) and micas. The heavy minerals are mainly consisted of iron oxides, amphiboles, pyroxenes and epidotes. The clay fraction of the Nile deposits of El–Fayoum Depression are mainly composed of kaolinite, montmorillonite and illite in the coarse clay (1–2 μ), whereas the fine clay (<0.2 μ), is dominated by montmorillonite group. Smectites (dioctahedral iron rich types) are the dominant clay minerals in the different clay fraction of El–Fayoum sediments except for the coarse clay of the aqueous desertic deposits where kaolinite takes place. Illite, attapulgite, chlorite, quartz, interstratified of illite–montmorillonite, illite–chlorite and montinorillonite–chlorite were also found in both clay fraction.

Soil Classification

Wahab et al. (1988), Harun (2004) and Abd-Elmabod (2014) classified the soils of El-Fayoum Depression according to the soil taxonomy system of the USDA into three orders; Vertisols, Entisols and Aridisols. These soils belong the following subgroups: Vertic Torrifluvents, Typic Haplocalcids, Typic Torrifluvents, Typic Haplogypsids, Typic Haplosalids, Typic Torripsamments.

Land Capability and Productivity

According to ASRT (1991) The El-Fayoum Depression is classified into five grades according to their production capacity. The first and second grades do not exceed 20.2% of the total cultivated area, whereas about 70.2% are accommodating the third and fourth classes.

Hydrology and Drainage

An agricultural drainage system network was established in El-Fayoum Depression as an effort to decrease the accumulation of excess drainage water in Qarun Lake and to protect the nearby agricultural land from inundation (Anon 2003). Qarun Lake receives only the discharge water from the irrigation network; even if some authors such as Hussein et al. (2008) mentioned that it may discharge water speculate a small groundwater flux. Qarun Lake is considered one of the most important ancient natural lakes. It is the remaining part of the ancient Moeris Lake. It comprises 1155 km^2. It is 5 m depth in east, 13 m in west. You can practice water sports, fishing, and bird watching. The best period for fishing is from July to September (ICFG 2016).

Problems of Pollution

Hussein et al. (2008) concluded that Qarun Lake was suffering from various pollution types due to the industrial and agricultural waste disposal as well as domestic waste, which affect the fish and animal life in the lake with the great dangerous impact on the human health.

Under the same condition in another oasis in Egypt (Siwa Oasis) Kotb et al. (2015) pointed out that some environmental hazardous were occurred due to the improper management of groundwater resources. Additionally, the same authors found an increase in the surface area of the water bodies against arable lands.

Due to receiving more water for irrigation for the new reclaimed areas, El-Fayoum Depression has unique geographical satiation, due to this satiation of the depression, the mismanagement of irrigation water and insufficient drainage system, and environmental problems which lead to an increase in the surface area of Qarun Lake were observed. These led to some environmental problems such as increase of soil salinity and waterlogged areas due to the increase of the groundwater table of the areas adjacent to the Qarun Lake.

The present study aims to monitoring and assessment of changing on the surface area of Qarun Lake and its effect on the adjacent areas, using Landsat multitemporal images.

Materials and Methods

Topographic maps of 1942 at scale 1:100,000 and 1992 at scale 1:50,000 of El-Fayoum were used as a basic data (Fig. 22.2). Four Landsat images (path 177/row 40) acquired in 1973, 1988, 2003, and 2015 (Landsat MSS 1973, Landsat TM 1988, Landsat ETM + 2003, and Landsat-8 2015) were used to detect and monitor water bodies over the Qarun Lake (Fig. 22.3). Table (22.1) illustrates the specifications of the used satellite data.

Geometric Correction

In this study, geometric correction was carried out using a total of 48 ground control points from topographic maps to geocode the image of 1992. Then, this image was used to register all the other images. The RMSE between different images was less than 0.4 pixel which is acceptable. ENVI 4.7 software was used for this function.

Image Enhancement and Visual Interpretation

The goal of image enhancement is to improve the visual interpretability of an image by increasing the apparent distinction between the features. The process of visually interpreting digitally enhanced imagery attempts to optimize the complementary abilities of the human mind and the computer (Lillesand and Kiefer 1994). Contrast stretching was applied on all images and the False Color Composites (FCC) were

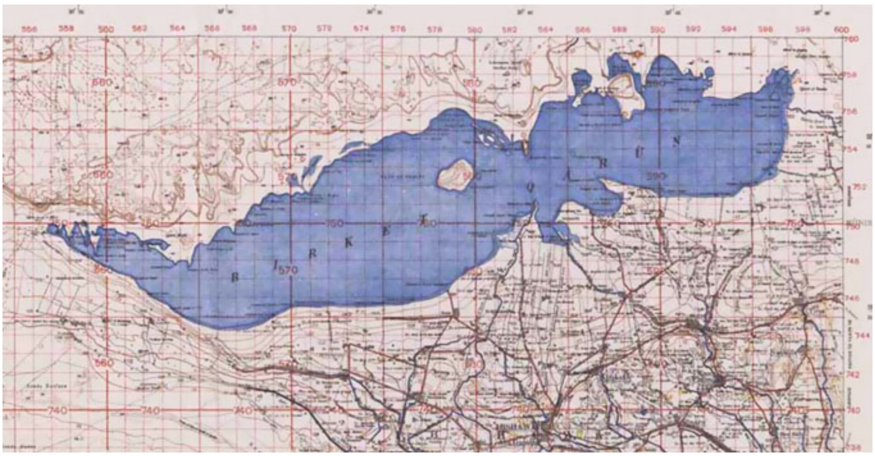

Fig. 22.2 A topographic map (1942) of El-Fayoum Depression at scale 1:100,000

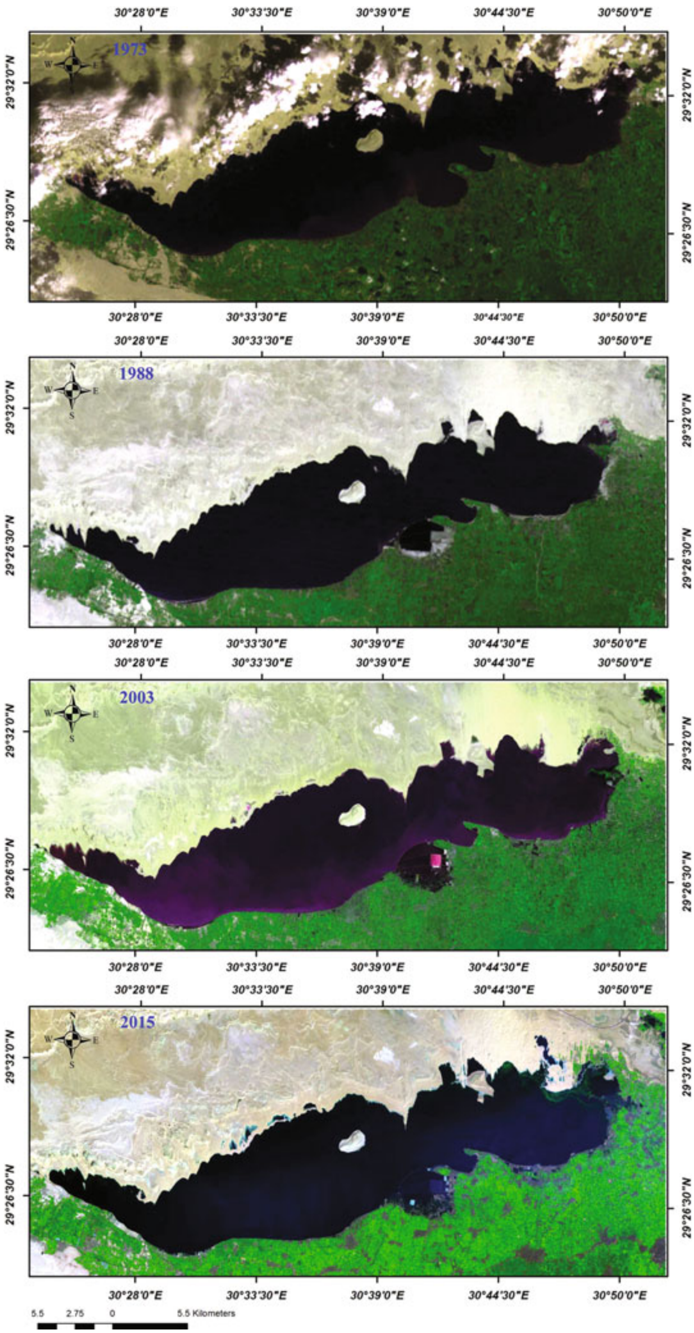

Fig. 22.3 Multitemporal satellite images of Qarun Lake from 1973 to 2015

Table 22.1 Specification of Landsat MSS, TM, ETM+ and Landsat-8

Band	Spatial resolution (m)				Spectral resolution (μm)			
	Landsat MSS	Landsat TM	Landsat ETM+	Landsat-8	Landsat MSS	Landsat TM	Landsat ETM+	Landsat-8
1	60	30	30	30	0.52–0.60	0.45–0.52	0.45–0.52	0.43–0.45
2	60	30	30	30	0.63–0.69	0.52–0.60	0.53–0.61	0.450–0.51
3	60	30	30	30	0.76–0.90	0.63–0.69	0.63–0.69	0.53–0.59
4	60	30	30	30	2.08–2.35	0.76–0.90	0.78–0.90	0.64–0.67
5	–	30	30	30	–	1.55–1.75	1.55–1.75	0.85–0.88
6	–	120	60	30	–	10.4–12.5	10.4–12.5	1.57–1.65
7	–	30	30	30	–	2.08–2.35	2.09–2.35	2.11–2.29
8	–	–	30	15	–	–	0.52–0.90	0.50–0.68
9	–	–	–	30	–	–	–	1.36–1.38
10	–	–	–	100	–	–	–	10.6–11.19
11	–	–	–	100	–	–	–	11.5–12.51

Where: Visible and near infrared (NIR) Bands are 1 to 4; Middle IR bands are 5 and 7
Thermal IR band is 6 and Panchromatic band **is 8**

produced. These FCC are visually interpreted using on-screen digitizing in order to delineate land cover classes that could be easily interpreted such as urban and water.

Regardless of the technique used, the success of change detection from imagery will depend on both the nature of the change involved and the success of the image preprocessing and classification procedures (Milne 1988). In the case of the chosen study area, field observation and measurements have showed that the change in land cover between the four dates was both marked and abrupt. Images were calibrated to radiance using the inputs of image type, acquisition date and time. The images were stretched (normalized) using linear 2%, smoothly filtered, and their histograms were matched. Consequently, the atmospheric correction is carried out using ENVI 4.7 software. The images were classified using supervised classification method and maximum likelihood algorithm, and then the post-classification change detection technique was applied. This technique requires the comparison of independently produced classified images. It is the most effective technique, because of the used images are atmospherically corrected, separately classified, and stretched to avoid the differences that related to atmosphere and sensors type between dates.

Landform Mapping, Soil Survey, and Soil Analysis

Digital elevation model (DEM) of the study area has been generated from the elevation points (recorded during the field survey by GPS), and the vector contour lines; digitized from the topographic map of the year 1992 (scale 1:50,000); ArcGIS 9.2 software was used for this function.

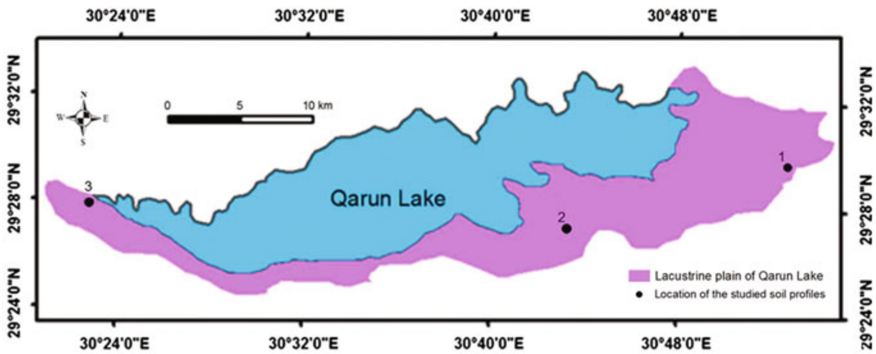

Fig. 22.4 Location of the studied soil profiles

Landsat-8 image of the year (2015) and digital elevation model (DEM) was used in ENVI 4.2 software to produce the physiographic map of the study area, following the methodology described by Dobos et al. (2002). First, the surface elevation, slope, and landform configuration were extracted from DEM, then the land use/land and cover and soil pattern were extracted from Landsat-8 image by using ENVI 4.7 software. Consequently, the data extracted from satellite images generate a preliminary geomorphologic map. Accordingly, field survey is carried out throughout the investigated area in order to gain an appreciation on soil patterns, landforms, and the landscape characteristics. Then the obtained data from land survey and laboratory analyses were linked with their relevant landform units using ArcGIS 9.2 software.

Morphological description of three soil profiles representing the different physiographic units (Fig. 22.4) were carried out according to the field book for describing and sampling soils (FAO, 2006).

Representative of seven disturbed soil samples have been collected from the studied soil profiles according to the morphological variations and were used for laboratory analyses. The laboratory analyses were carried out using the soil survey laboratory methods manual (USDA 2004).

The soils were classified to the subgreat group level on the basis of the key to soil taxonomy (USDA 2010).

Results and Discussion

Digital Elevation Model (DEM)

Digital Elevation Model (DEM) has been obtained from the elevation points and topographic map of the year 1992 (Fig. 22.5). Qarun Lake appears as a depression compared to upland surrounding areas, where the highest closed areas is about 50 m above sea level and suddenly decrease to about 45 m below sea level.

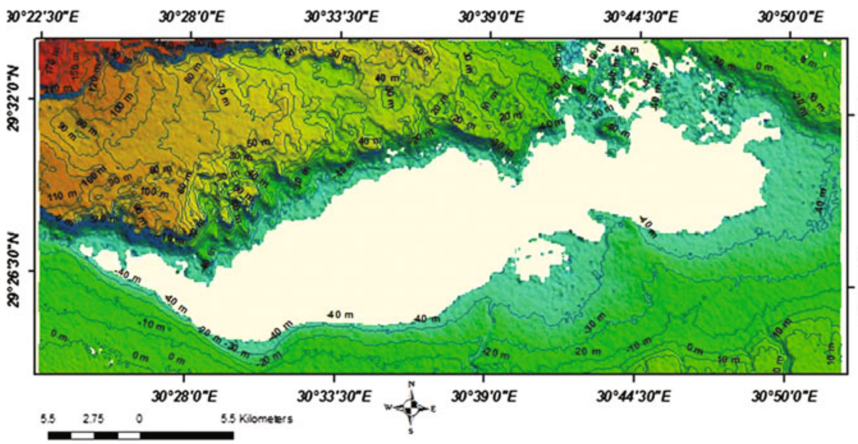

Fig. 22.5 The Digital Elevation Model (DEM) of Qarun Lake

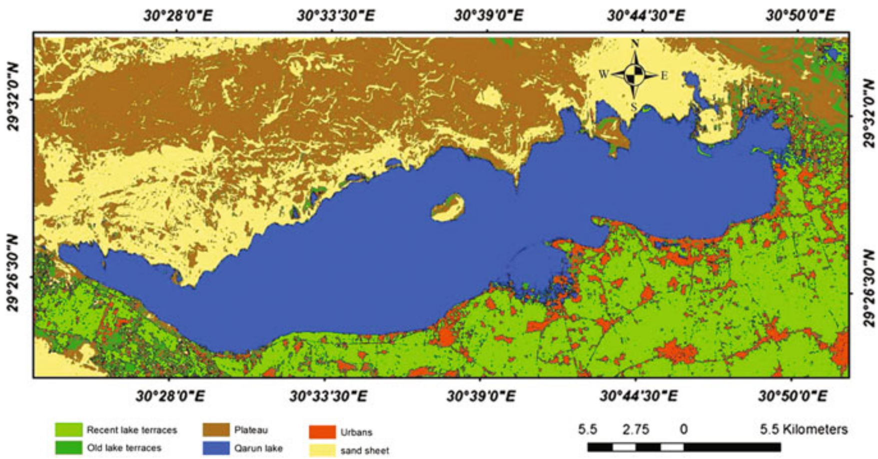

Fig. 22.6 Landforms of areas adjacent to Qarun Lake

Landforms and Soils

Based on the field survey data, Landsat ETM + (2015) images and digital elevation model (DEM), the landforms in the study area were defined according to Dobos et al. (2002), as shown in Figs. 22.6, 22.7 and Table 22.2.

The lacustrine plain is the main landscape in the southern part of Qarun Lake; it includes lacustrine terraces of various elevations. It covers an area of about 194 km^2 (i.e., 19,420 hectare), including soils of relatively high terraces (7413 hectare), soils of the moderately high terraces (4436 hectare), and soils of the relatively low terraces (7571 hectare). These are represented by soil profiles 1, 2 and 3,

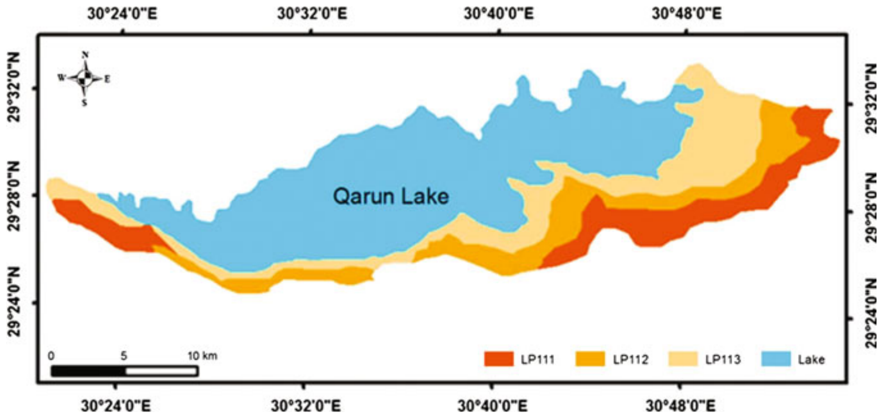

Fig. 22.7 Landforms and soils of south Qarun Lake

Table 22.2 Legend of landforms and soils map of south Qarun Lake

Landscape	Lithology/Origin	Relief/Molding	Land form	Area (km^2)	Taxonomic unit	Map unit
Lacustrine terraces						
Lacustrine	Lacustrine	Flat to	Relatively high	74.13	Typic Haplosalids	LP111
Plain	deposits	almost flat	Moderately high	44.36	Vertic Torrifluvents	LP112
			Relatively low	75.71	Typic Haplosalids	LP113

respectively and are classified to the subgreat group level as Typic Haplosalids (representing 100% of the lacustrine plain). The correlation between physiography and soils indicates that the mapping unit in this landscape is consociation at this survey level. The soil depth, salinity, ESP, and $CaCO_3$ of this landscape ranges from (50 to 90 cm), (11.35 to 36.22 dS/m), (9.14 to 17.26%) and (5.60 to 28.91%), respectively (Tables 22.3, 22.4).

A comparison between the changes of surface areas of Qarun Lake was assessed. This estimation was done from 1942 based on the calculations of a digitized topographic map (1942) at scale 1:100,000; satellite image interpretations from 1973 to 2015, as indicated on different satellite image (Landsat, MSS 1973 and TM 1988, Landsat ETM + 2003 and Landsat-8, 2015), Figs. 22.8 and 22.9.

The obtained results showed the surface area of the lake was about 22 km^2. From that time the surface area of Qarun Lake was more or less stable and it was in a balance with land use in El-Fayoum Depression. But by the end of 1960s, after the High Dam has been established, the Nile water be controlled; a big amount of fresh water became available for agriculture. The Egyptian Government at that time

Table 22.3 Some chemical and physical analysis of the studied soil

Mapping unit	Profile no.	Depth cm	pH 1:2.5	EC dS/m	CEC meq/100 g soil	ESP %	O.M %	$CaCO_3$ %
LP111	1	0–25	8.20	11.35	35.22	13.44	1.81	22.61
		25–60	**8.10**	**31.54**	**37.55**	**9.14**	**1.04**	**21.58**
		60–90	**7.95**	**16.33**	**46.39**	**9.63**	**0.41**	**28.91**
LP111	**2**	**0–35**	**8.31**	**16.52**	**34.50**	**9.55**	**1.80**	**5.60**
		35–65	**8.42**	**36.22**	**39.75**	**14.73**	**0.55**	**9.84**
LP111	**3**	**0–25**	**8.25**	**12.50**	**35.40**	**17.26**	**1.55**	**21.66**
		25–50	**8.34**	**32.44**	**39.18**	**12.40**	**0.64**	**14.80**

Table 22.4 Some chemical and physical analysis of the studied soil

Mapping unit	Profile no.	Particle size distribution %				
		C. sand	F. sand	Silt	Clay	Texture
LP111	1	5.60	41.3	18.3	34.8	SCL
		3.70	20.4	26.5	49.4	C
		12.6	36.7	16.2	34.5	SCL
LP111	**2**	**3.9**	**22.5**	**26.4**	**47.2**	**C**
		2.8	**20.6**	**15.2**	**61.4**	**C**
LP111	**3**	**6.9**	**22.3**	**24.6**	**46.2**	**C**
		3.2	**21.6**	**31.6**	**43.6**	**C**

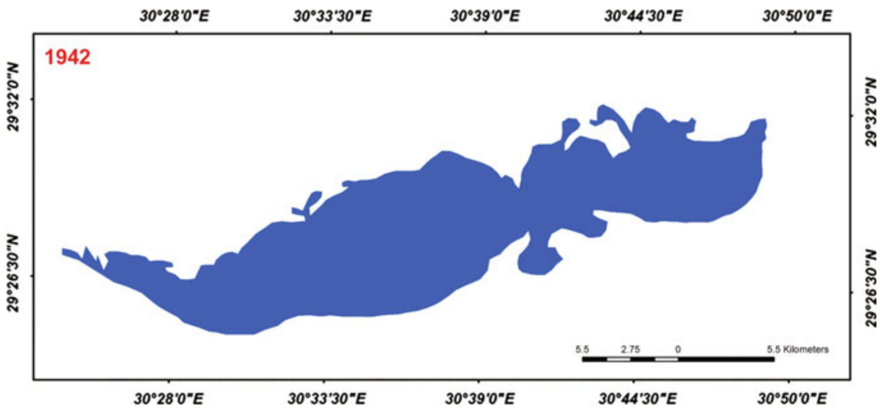

Fig. 22.8 Multitemporal satellite images and mapping of water bodies of Qarun Lake study area from 1973 to 2015

planned to increase the agricultural land in all the country. El-Fayoum Depression was one of those extension areas.

A sudden increase of the surface area of Qarun Lake was happened due to the increase of using water for irrigation in El-Fayoum Depression just after the High

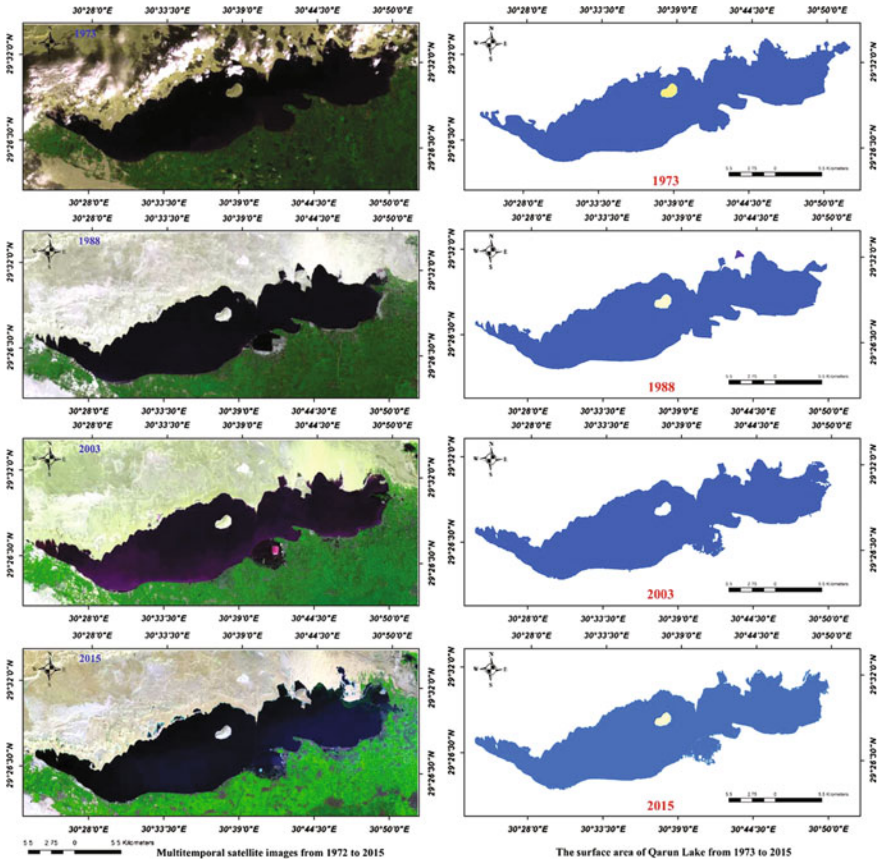

Fig. 22.9 Multitemporal satellite images and mapping of water bodies of Qarun Lake study area from 1973 to 2015

Dam had been constructed at Aswan south of Egypt. This was one of the negative effects of the mismanagement after the establishment of the High Dam in Aswan, Egypt. In 1973 the surface area of Qarun Lake reached its maximum area (240 km^2) due to receiving all excessive drainage water of El-Fayoum Depression.

The government of Egypt at that time decided to convey a part of the excessive drainage water of El-Fayoum Depression to a new depression southwest El-Fayoum, which is called (El-Rayan Depression) that started to receive some drainage water in 1973. Accordingly, the surface area of Qarun Lake decreased to about 230 km^2 by the year 1988 and from that time until 2015 its surface area was almost stable (Table 22.5). These changes in the environmental conditions due to the human impact through mismanagement of water resources of the study area are shown in Fig. 22.9.

Table 22.5 Area of different lakes from 1984 to 2013 in Qarun Lake, (km^2)

Year	Total area km^2	Island km^2	Surface area of Qarun Lake km^2
1973	241.91	2.28	239.63
1988	231.76	2.39	229.37
2003	248.76	2.38	246.38
2015	247.59	2.20	245.39

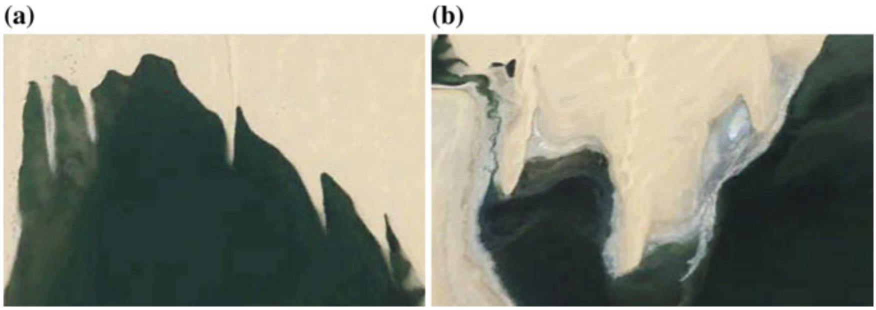

Fig. 22.10 The effect of sand dune on Qarun Lake A & B are some parts affected by sand dune encroachment

During the period from 1988 to 2003, the increase of human activities in different sectors in particular the agricultural proposes in the both horizontal and vertical extension caused changes in the hydrological conditions in the study area. In spite of El-Rayan Depression started receiving some drainage water by the year 1973 the surface area of Qarun Lake increased from 230 km^2 in the year 1988 to 246 km^2 in the year 2003. Within the period from 2003 to 2015 the surface area of Qarun Lake was almost stable as the assigned value for 2015 is 245 km^2. This could be explained by somehow happened in the water budget of El-Fayoum area and/or by increase of the amount of drainage water be conveyed to El-Rayan Depression.

The Effect of Sand Dune on Qarun Lake

As the topographic satiation of El-Fayoum Depression there are some sand dunes and accumulation of sand areas move from north and northwest direction facing Qarun Lake (Fig. 22.10). The effect of these types of accumulation sands encroach water on the lake and pushing the water of the lake to south direction. So, with same amount of water volume, the coming sand from north push the water body southward to cover low areas mainly the agricultural lands and these have somehow a role to degrade the arable lands by rising ground water table salinization and waterlogged areas.

The Negative Impact of Qarun Lake

The effect of Qarun Lake on the surrounding areas is recognized especially in south and southeast parts during the last 50 years. This is due to two factors; the first one is the receiving drainage water. The second factor is the effect of sand movement, somehow by pushing the water southward direction due to the accumulation of sands from the north and/or northwest direction. This causing some environmental problems such as increasing ground water table, salinization and waterlogged areas. This has negative socioeconomical effects on the life of the native people. Most of those people depending mainly on the agricultural sector. With increasing land degradation rates of the areas adjacent to Qarun Lake and lowering of agricultural productivity, the poverty increases which rise more social problems. In the same trend, according to Abd-Elmabod et al. (2010 and 2012) the adjacent soil type to Quarn Lake (Typic Haplosalids) it was more degraded than the other soil types of El-Fayoum Depression as a result of high salinity due to the negative effect groundwater level.

By the same way, Kotb et al. (2015) applied the remote sensing and GIS techniques for monitoring of the water bodies and their effect on the land resources in Siwa Oasis, Egypt. They found a huge fluctuation on the surface areas of the water bodies of the main lakes in Siwa. This effect led to increase on the ground water table, salinization, and waterlogged areas. They mentioned that in some very severely affected areas, the people had left their villages and transferred to other places.

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