

Land Suitability Classification of a Desert Area in Egypt for Some Crops Using Microleis Program

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Abstract: Desert reclamation for agricultural production is one of the priorities to compensate for the loss of agricultural land and to minimize food supply shortage in Egypt. Wadi El-Rayan Depression is one of the reclamation projects the Egyptian government has initiated. Since cultivation started at Wadi El-Rayan Depression, several problems have arisen in the project area including soil salinity, drought, water logging and expansion of the water bodies. This region is a world heritage site and has been selected to be a protected area. Thus, optimum use of the resources in the region needs to be thoroughly evaluated. Based on the interpretation of satellite image with the dominant geomorphic units, 65 soil profiles represented by 138 soil samples were characterized in Wadi El-Rayan Depression. A Web-based program, MicroLEIS, was used to compare the soil characteristics and quality needed for 12 different types of crops. The Web-based soil evaluation system indicated that the soils of the study area are not suitable for the selected crops due to one or more limiting factors. However, there are some exceptional cases where the soils were either suitable or marginally suitable. Unnecessary agricultural expansion may harm or damage the study area. Alternatively, continuing to improve tourism activities is a better land use for natural resource protection and economical development in Wadi El-Rayan Depression.

Key words: Suitability • MicroLEIS • Almagra Model • Wadi • El-Rayan Depression • Egypt

INTRODUCTION

The Wadi El-Rayan Depression was designated as a Protected Area in 1989 by the Egyptian Government to protect the area's biological, geological and cultural resources. The depression covers approximately 1,759 km² and is located in the southwest of El-Fayum Governorate about 135 km from Cairo. A diversity of habitats, each with its own characteristic wildlife and other biological features, comprises the Protected Area. Moreover, this area is distinguished by many beaches and waterfalls. The depression is also home of Egypt's first natural World Heritage Site, Valley of the Whales and is an internationally designated "Important Birds Area" [1].

Historically, Wadi El-Rayan Depression was selected as a solution to cope with the excess drainage waters in the El-Fayum Depression through an 8 km underground drainage system in 1973. The drainage waters accumulated year by year leading to the formation of two large artificial lakes. Recently, the Egyptian Governorate

focused on Wadi El-Rayan as one of the newly reclaimed areas in the desert to increase agricultural production. The Egyptian Governorate had planned to reuse the lake waters to reclaim some areas in Wadi El-Rayan Depression. In 1984, the infrastructure including the construction of roads, irrigation canals and uplifting pumps to reclaim 4800 ha was initiated. Since then, about 769 ha have been reclaimed west of the lower lake. In 1999, people started to settle there and began farming on about 1 ha per family.

Several problems have appeared in the area due to reclamation efforts including high salinity, drought and water logging. Water logging has contributed to extending the water bodies through the study area in addition to its negative effects on plant growth and production. Therefore, it is necessary to evaluate the soils of the project area and the surrounding areas in order to understand which factors negatively affect cultivation and to find alternative promising areas suitable for agriculture or other uses.

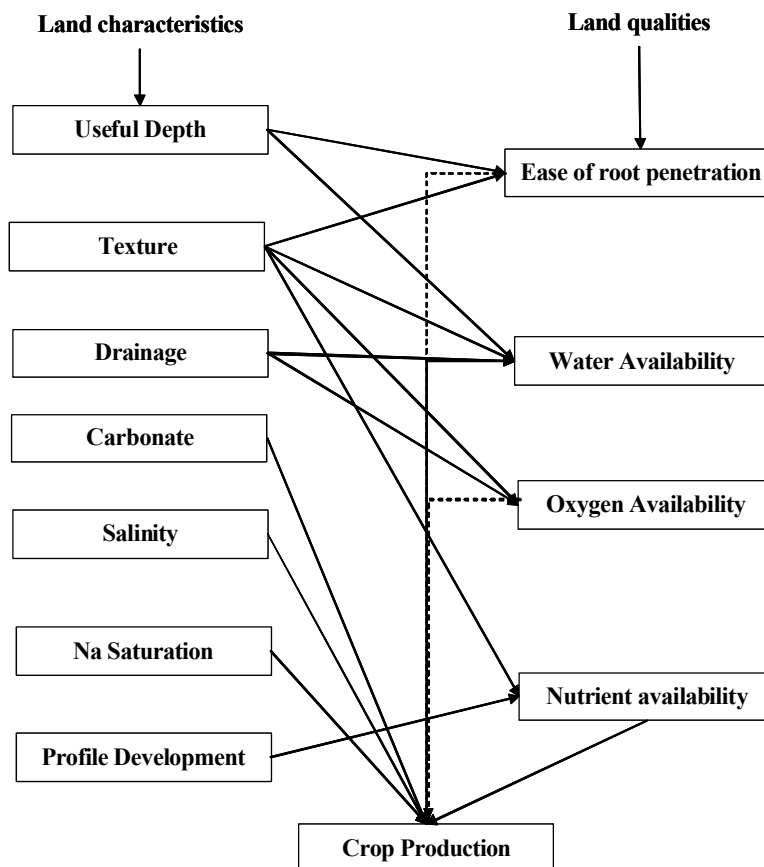


Fig. 1: General scheme of the Almagra model, showing the direct and indirect effects of some soil characteristics and soil qualities

The fundamental principle of land evaluation is to estimate the potential of a land for different productive uses, such as farming, livestock production, or forestry, together with uses that provide services or other benefits, such as water catchment, recreation, tourism and wildlife conservation [2]. Consequently, land evaluation is a tool for strategic land use planning. A specific agricultural use and management system on land that is most suitable according to agro-ecological potentialities and limitations is the best way to achieve sustainability [3].

There are different models for conducting land evaluation in land use planning [4]. However, the Microcomputer Land Evaluation Information System (MicroLEIS) package has been considered a user-friendly agro-ecological decision support system for sustainable land use and management [5]. The MicroLEIS with an Almagra model (Agricultural Soil Suitability) has been used to assess the suitability of different soils [5]. The program works interactively, comparing the values of the characteristics of the land unit with the generalization levels designated for each suitability class for specific

types of annual, semiannual and perennial crops. In addition, the classification is applicable to all arid and semi-arid condition throughout the Mediterranean Region. The soil suitability Almagra model is based on analysis of edaphic factors which affect the productivity of twelve traditional crops: wheat, maize, melon, potato, soybeans, cotton, sunflower, sugar-beet, alfalfa, peach, citrus and olive. The edaphic factors including the effective depth (p), texture (t), drainage (d), carbonate content (c), salinity (s), sodium saturation (a) and degree of profile development (g) are used as diagnostic criteria (Figure 1).

MicroLEIS program has not been used to evaluate the soils of the study area [6] evaluated the soils located on the eastern side of Wadi El-Rayan depending on their own understanding of land evaluation. The revealed data showed that most of the soils were rated as less than 5%, meaning the soils are non-agricultural. The land capability classification [7] used to evaluate some soils of Wadi El-Rayan Depression demonstrated that most of the soils were not suitable for agricultural uses [8].

As for the other desert soils in Egypt, MicroLEIS has been used to determine the main limiting factors that hinder or reduce soil productivity. In Banger El-Soker area, Egypt, this program was used to assess the soil suitability for some specific crops [9]. This study found that the common suitability subclasses were suitable (S2) and moderately suitable (S3) whereas one or more of the soil properties such as texture, profile depth, salinity, alkalinity and soil fertility were the main limiting factors. The MicroLEIS program was used to predict the effect of water table and salinity on the productivity of wheat in the same area [10]. Their results indicated the productivity of wheat decreased with increasing salinity and decreasing water table depth due to the poor management practices in the area.

Darwish *et al.* [11] evaluated the soils of Farafra Oasis as one of the newly reclaimed areas in Egypt using MicroLEIS. Their output data showed that most of the Typic Haplogypsis soil unit was highly suitable for wheat, potato and sunflower, while the rest of the units had low suitability with a dominant soil texture limitation. The soils of Calcic Haplosalids and Gypsic Haplosalids showed moderate suitability with texture and/or drainage limitations. The other units were not suitable due to the limiting factors of salinity, sodium saturation and texture

classes. Wahba *et al.* [12] studied the soils of Sahal Baraka, Farfra Oasis to assess the suitability of soils for olives, peach and sunflower. The results revealed the following order of suitability: olive > peach > sunflower, melon and corn. This sequence reflects the priority of agricultural land utilization. Salem [13] found that the soils of El- Bostan area were highly suitable, moderate suitable and not suitable with respect to soil texture and exchangeable sodium percent (ESP) in most soil profiles.

The objectives of this study are to (1) determine the common land characteristics of the Wadi El-Rayan Depression, (2) assess the main land use limitations in the depression and (3) evaluate the land suitability of the depression for some crops using the MicroLEIS Land Evaluation System.

MATERIALS AND METHODS

The study area, Wadi El-Rayan Depression and its environs, is situated between longitudes 30°14'13'' and 30°32' 28'' E and latitudes 29°00'00'' and 29°27'50'' N (Figure 2). The area is located west of El-Fayum Depression in the western desert and is approximately 135 km west of Cairo.

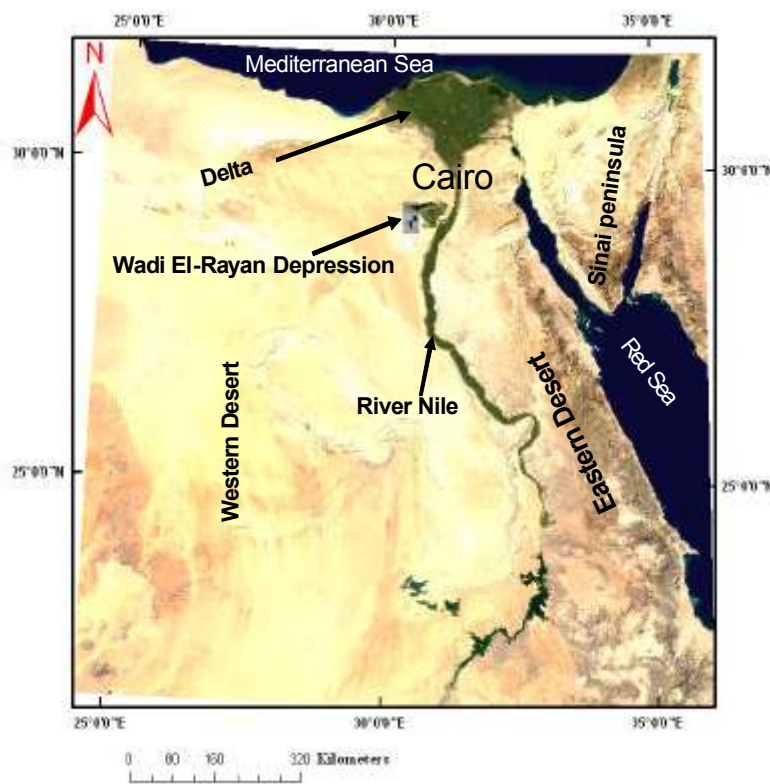


Fig. 2: Location map of the studied area

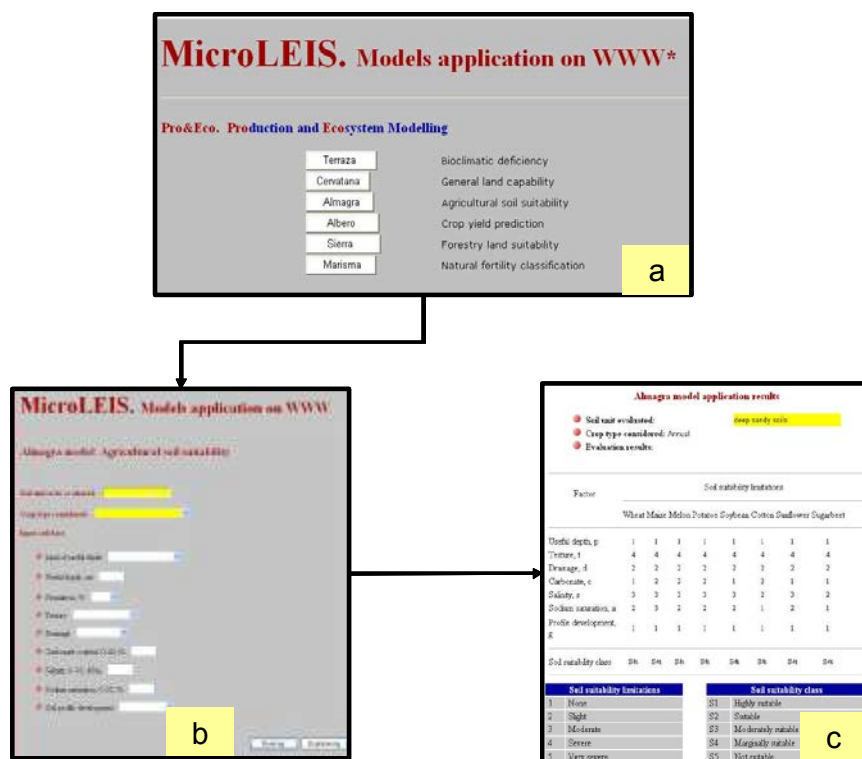


Fig. 3: MicroLEIS program (Almagra model); a) the main interface of MicroLEIS throughout you can pick up the model you need, b) the interface to input your own data, and c) the output data for the selected crops

According to the geological map [14] the study area is essentially of Middle Eocene limestone and lacustrine deposits of Pleistocene. The lacustrine deposits occupy the eastern portion of the study area. The middle Eocene beds, clay, marl and limestone with Numulites are forming the oldest beds found in the area. The climate of the study area is typically arid, where the mean annual temperature, rainfall, evapotranspiration and relative humidity are 22.0°C, 22.0 mm, 210 mm and 51%, respectively.

The dominant landforms were delineated based on Digital elevation model (DEM) and satellite image (Enhanced Thematic Mapped ETM+) obtained from United State Geological Survey site <http://edcns17.cr.usgs.gov/EarthExplorer> (USGS) [15] and geological formations covering the study area. Accordingly, the study area was masked using ArcGIS 9.3 to extract the actual study area by excluding the unrepresentative areas. During the field study, the landforms were checked to define the boundary of each landform. Accordingly the study area (masked map) was used as a base map and was represented by 65 soil profiles. The soil profiles were morphologically described according to FAO [16]; consequently, 138 soil samples were collected and processed for laboratory analyses.

The gravels content was measured by volume according to USDA [17]. The total calcium carbonate was measured by treating the samples with HCl and the evolved CO₂ was measured manometrically, [17]. The exchangeable sodium percent is the relative amount of exchangeable sodium and cation exchangeable capacity. According to Bashour and Sayegh [18], the exchangeable sodium was estimated using Ammonium acetate method. While the cation exchangeable capacity was measure by sodium oxalate method for gypsiferous and calcareous soils. The electrical conductivity (EC) was estimated in the extracted soil paste by Conductimeter, [18]. The organic matter was measured using Walkley-Black Wet method, [18].

The soil texture class was determined using dry sieving method for sandy textured soils (fine fraction less than 5%) according to Piper [19] and by hydrometer method for heavier textured soil (fine fraction more than 5%) according to Gavlak *et al.* [20]. The mean weighted value of each determined soil property (V) that was used to evaluate the soils was calculated based on multiplying the parameter value (Vi) of each horizon by horizon thickness (ti) divided by the total profile depth (T) according to the following equation [21]:

$$v = \left[\frac{\sum_{i=1}^n (v_i \times t_i)}{T} \right]$$

After the final data preparation, the physical and chemical properties were applied to Almagra Model available at <http://www.evenor-tech.com/microlei/microlei.aspx> [22] to run the land suitability evaluation for some selected crops: wheat (W), maize (M), melon (Me) potato (P), soybean (S), cotton (A), sunflower (G) and sugar beat (R) as annuals; alfalfa (Af) as semiannual and peach (Pe), Citrus fruit (C) as well as olive (O) as perennials, (Figure 3). The spatial analysis function in ArcGIS 9.3 was used to create thematic layers of the most constrained factors.

RESULTS AND DISCUSSION

Landforms of the Study Area: The Digital Elevation Model, (Figure 4) was presented in 3D mode and was then overlaid by Landsat ETM+ image, (Figure 5) to produce a 3D image for the study area, (Figure-6). The produced 3D image was consequently used along with the ground truth data to delineate the different landforms of the area under investigation. Therefore, it was masked to get the final representative area by excluding the highland and Qarun Lake (Figure-7). The resulting image shows that the study area is represented by 8 landforms; each landform is represented by several soil profiles, namely: isolated hills, El-Rayan lakes, Quta-Qarun depression, El-Rayan depression, alluvial plain, Aeolian deposits complex rocky and desert pavement plain and El-Rayan karstified plateau. The first and second landforms were not represented by any soil profiles due to the steep slope and rockiness for the first one and the second one is a water-body. So there are not going to be discussed hereafter. The landforms covering the study area are summarized as following:

Quta-qarun Depression: This area occupies approximately 90 km² (Figure 7) and is almost covered by cultivation which is mainly olive trees, scattered palm trees and some field crops such as maize, Egyptian clover and alfalfa. This landform is almost flat, below sea level and covered by fluvial and lacustrine sediments.

El-Rayan Depression: The depression covers an area that is approximately 137 km² (Figure 7) representing the area located around the upper and the lower El-Rayan lakes. This unit is too below sea level and almost covered by dry

and wet sabkhas (i.e. salt flat) with dense halophyte plant species. The sabkhas formation was formed mainly from the water intrusion or seepage from El-Rayan lakes. The surface is almost flat to gently undulating. The west 12 km² of this area is occupied by olive trees and different kinds of field crops. However, most of these plants are unhealthy due to high salinity.

Aeolian Deposits Complex: This unit encompasses approximately 163 km² and is located mainly at the extreme southern part of the study area (Figure 7) with dissected forms existing on the soils of El-Rayan karstified plateau. Three types of land elements represent this landform: sand ripples, sand heaps and sabkhas (sandy hillocks) and longitudinal sand dunes [23]. The longitudinal sand dunes are the most common type and extend parallel to the eastern side of monqar El-Rayan mesa. Generally, the longitudinal sand dunes are organized in NNW to SSE direction which corresponds to the prevailing wind direction.

Alluvial Plain: Two alluvial plains occur in the study area (Figure 7). The larger one covers the northwest portion while the smaller one is located at the southwest portion of the study area and occupies an area about 194 km². This unit is relatively flat and was created by the deposition of the sediments eroded and transported from the adjacent highlands: Qatrani- birket Qarun plateau, Qaret Gehanem plateau and Qaret El-Robban plateau. The sediment eroded, transported, deposited and reshaped by water is typically made up of a variety of materials including fine particles of silt and clay and larger particles of sand and gravel. Approximately 12 km² of this unit is cultivated with the same plants mentioned in the El-Rayan depression.

Rocky and Desert Pavement Plain: The total area of this unit is approximately 177 km² (Figure 7) and the surface cover is dominated by rock outcrops, desert pavement, or a combination of rock outcrops and desert pavement. The underneath rock is hard limestone that was identified during the field study. The desert pavement forms a surface gravel deposit of tightly packed pebbles, layered just one pebble thick and generally devoid of vegetation. Generally, it is formed by gradual removal of the sand, dust and other fine grained materials by wind action that represent the main physical weathering in the study area.

El-ryan Karstified Plateau: The plateau is the largest landform and covers approximately 446 km² (Figure 7). The soft carbonatic rocks form the main lithology of this unit.

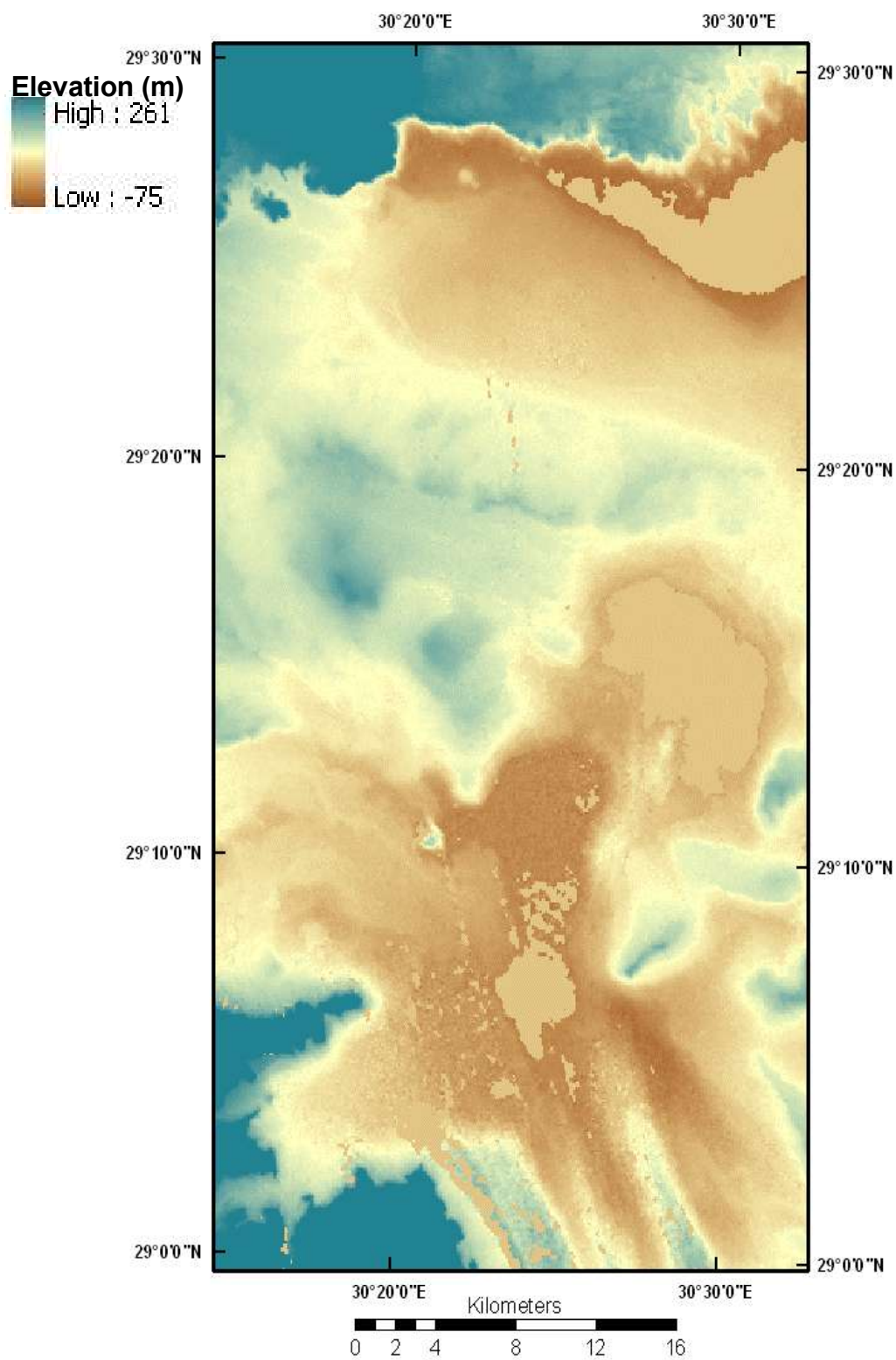


Fig. 4: Digital elevation model (DEM)

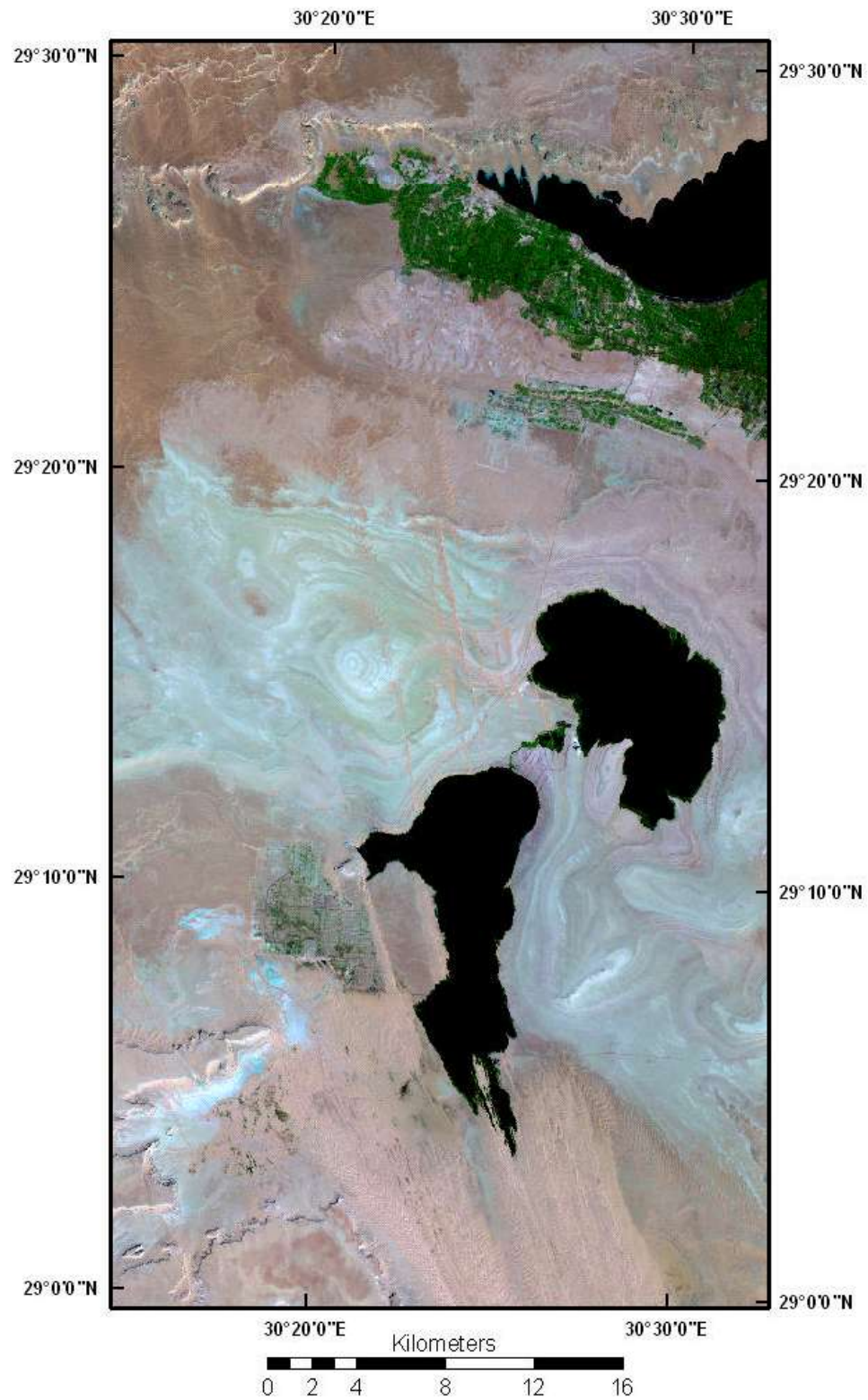


Fig. 5: Landsat image (ETM+ 30x30m); bands 7-4-2

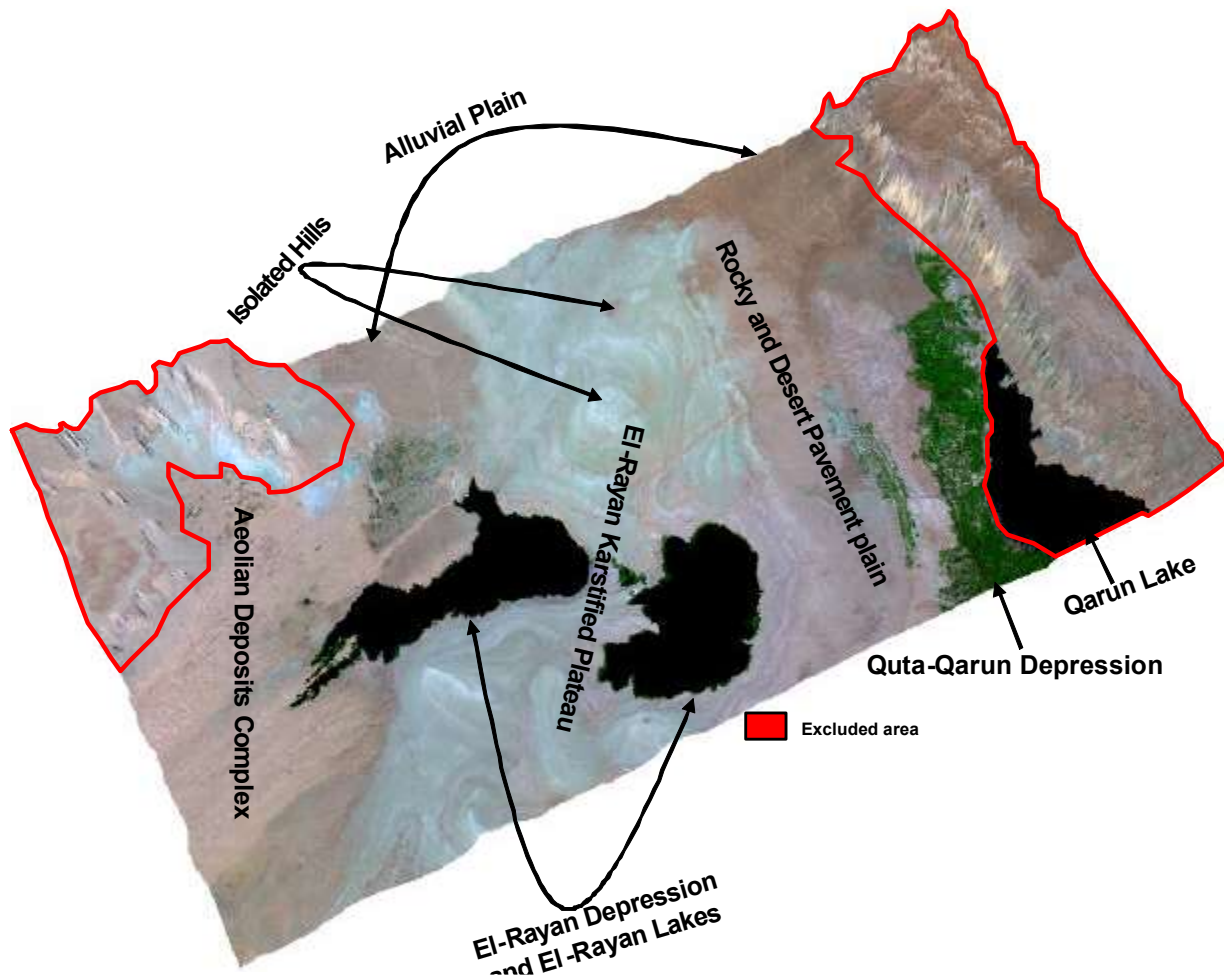


Fig. 6: 3D map of the study area showing the main landforms and the excluded area

They constitute marls, chalks, or soft limestone and are characterized by high porosity and water permeability. The substrata are very friable; therefore they are easily disintegrated by erosion. This plateau is gently undulating to rolling and covered by dense Tertiary limestone deposits [24]. It is characterized many macro-relief landforms such as yardinge, furrows, gullies, very small dissected dry wadi, sinkholes and many karstified features.

Soil Properties and Soil Suitability Classification:

Selected soil physical and chemical properties of the study area are shown in Table 1. The soil profiles vary widely from very shallow (less than 25 cm) to deep (more than 100 cm). Soil depth is well correlated with landform positions. It is very shallow in the highly elevated units such as Rocky and Desert Pavement Plain, El-Rayan Karstified Plateau and some parts of the Alluvial Plain. In contrary, the soils formed on

low elevation or depressions are generally moderately deep to deep as well as for the soils formed on the Aeolian Deposits Complex. The deep soils that are detected in rocky and desert pavement are mainly the result of human activity such as the excavation of the limestone to a depth 50 to 100 cm and refilling with a new soil transported from other parts in the study area. The soil texture of the study area is mainly coarse-texture to moderately coarse-texture with few exceptional cases that are either, medium, moderately fine, or fine texture. The coarse fragments (more than 2 mm) are widely varied throughout the study area from none (< 15%) to very gravelly (from 35 to 60%). It is noted that the coarse fragments originating from the local parent rock disintegration are detected in the soils of Rocky and Desert Pavement plain and El-Rayan Karstified Plateau while coarse fragments existing in the soils of Alluvial Plain are transported from highlands surrounding the study area.

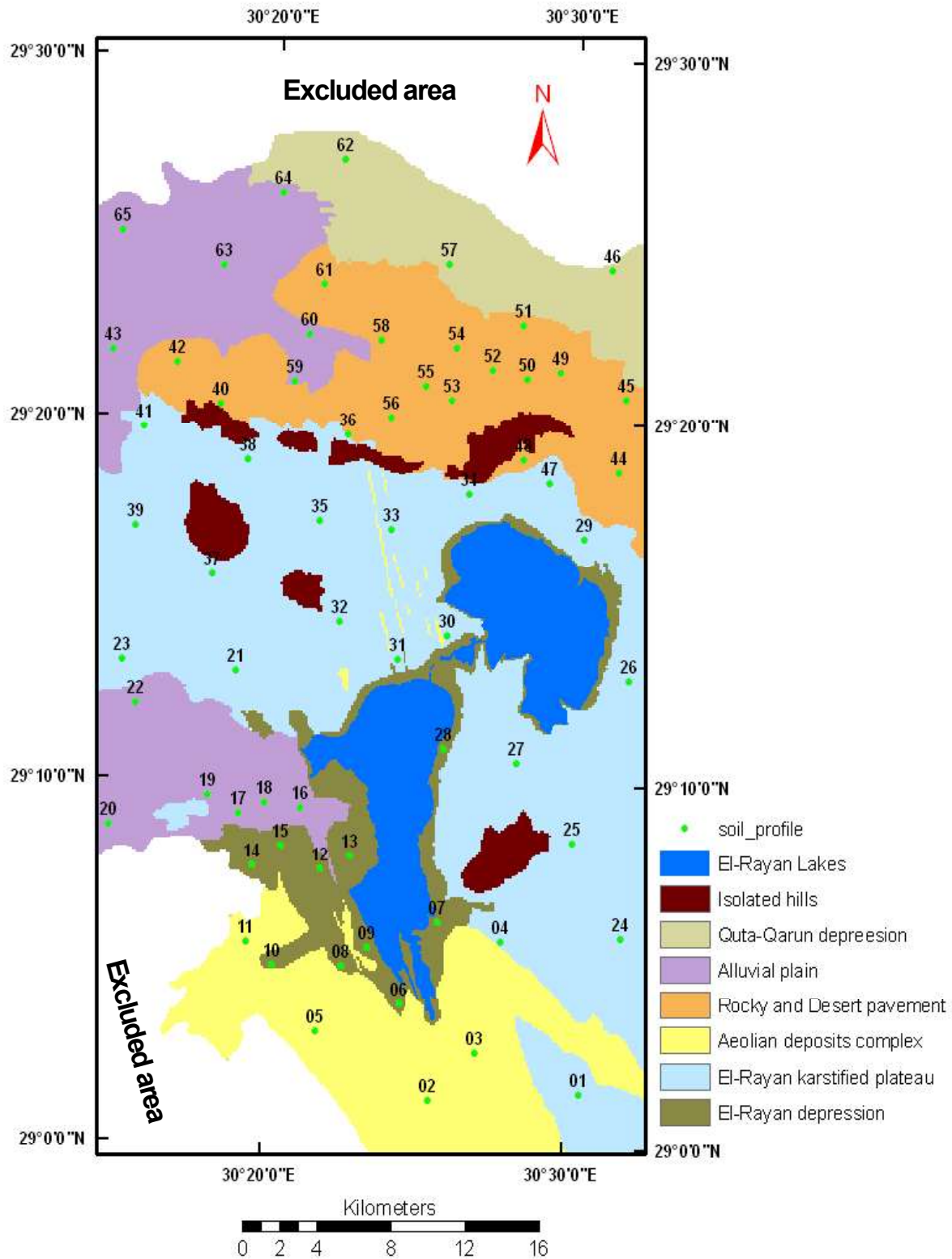


Fig. 7: Landform map of the study area represented by soil profiles

Table 1: Mean weighted values of selected soil properties of dominating landforms in the study area.

Prof. no	Depth (cm)	Gravel content %	Texture class	ESP %	CaCO ₃ %	EC dS/m	O.M %	CEC cmol kg ⁻¹
Quta-Qarun depression								
46	150	0.00	Fine	20.6	14.3	22.4	0.58	35.5
57	130	19.2	Coarse	3.62	28.8	2.71	0.42	8.04
62	120	18.2	Coarse	4.86	20.8	3.75	0.62	5.00
El-Rayan Depression								
6	30	0.86	Coarse	21.7	12.6	27.1	0.34	2.06
8	100	0.00	Coarse	20.7	7.73	45.6	0.14	0.95
9	80	0.00	Coarse	17.8	5.50	36.5	0.30	1.47
10	150	0.00	Fine	38.3	0.36	184	0.92	44.9
12	150	1.35	Coarse	8.63	22.8	8.40	0.14	5.21
13	100	0.66	Coarse	13.4	10.1	15.0	0.13	1.17
14	150	0.00	Coarse	20.6	8.84	59.5	0.15	1.70
15	145	1.92	Coarse	8.05	14.1	4.60	0.07	3.09
Aeolian deposits complex								
2	150	0.00	Coarse	13.1	4.61	27.5	0.10	0.76
3	150	0.00	Coarse	3.37	8.96	4.03	0.07	1.12
5	150	0.00	Coarse	10.8	4.42	27.7	0.14	1.44
11	150	0.00	Coarse	13.5	7.11	28.0	0.06	2.21
Alluvial plain								
16	150	47.7	Coarse	31.5	42.6	76.5	0.46	3.29
17	105	1.22	Moderately fine	26.9	4.97	35.4	0.13	28.2
18	105	16.0	Coarse	11.5	30.8	6.37	0.10	2.00
19	35	33.1	Moderately coarse	26.7	59.4	101	0.35	3.18
20	45	28.9	Medium	12.5	51.2	11.7	0.15	10.6
22	35	10.8	Coarse	25.2	19.1	47.9	0.13	1.37
43	70	17.9	Moderately fine	21.3	35.4	43.6	0.32	16.1
59	45	0.59	Medium	21.6	18.0	59.4	0.20	11.2
60	70	19.4	Coarse	26.1	13.6	52.4	0.14	3.52
63	60	4.51	Moderately coarse	15.4	15.3	20.9	0.15	10.5
64	150	5.33	Moderately coarse	13.6	5.28	9.4	0.04	4.68
65	120	0.53	Coarse	24.6	2.23	41.9	0.13	2.04
Rocky and desert pavement plain								
36	15	29.2	Medium	24.4	56.1	45.5	0.25	6.63
40	20	2.63	Coarse	16.2	11.8	18.2	1.33	12.3
42	45	41.7	Medium	16.2	31.4	18.2	0.33	12.1
45	25	23.47	Moderately coarse	12.0	9.86	15.5	0.27	12.0
48	30	1.69	Moderately coarse	36.2	11.1	85.4	0.52	8.50
49	100	11.7	Coarse	7.85	20.3	1.65	0.15	5.71
50	150	23.0	Coarse	18.9	25.1	43.4	0.06	3.02
52	150	12.0	Moderately coarse	11.9	19.6	43.3	0.83	8.71
53	60	8.84	Moderately coarse	27.1	39.8	59.1	0.14	7.70
54	150	7.49	Coarse	10.1	7.61	3.84	0.10	1.29
55	80	0.48	Moderately fine	6.49	43.0	5.49	0.48	22.7
56	35	23.1	Moderately coarse	20.1	26.6	20.7	0.12	5.94
58	60	1.86	Coarse	21.3	7.63	32.3	0.14	4.30
El-Rayan karstified plateau								
1	45	47.3	Coarse	21.2	45.5	20.1	0.11	1.56
23	20	0.86	Moderately coarse	37.0	64.6	68.6	0.98	9.17
24	20	9.38	Moderately coarse	29.2	46.8	101	0.35	10.5
25	20	16.0	Moderately coarse	33.3	56.1	121	0.32	9.65
27	15	19.2	Moderately coarse	43.6	43.0	117	0.41	7.47
30	25	1.96	Moderately coarse	28.0	32.9	42.4	0.12	6.60
31	15	2.49	Moderately coarse	24.2	43.1	41.0	0.06	6.94
32	15	48.3	Moderately coarse	30.3	64.7	39.2	0.16	8.80
33	25	59.4	Moderately coarse	27.2	52.2	166	0.36	7.87
35	25	59.3	Moderately coarse	27.1	53.6	104	0.25	6.63
37	20	43.6	Moderately coarse	27.4	63.0	46.7	0.19	8.29
38	15	59.5	Moderately coarse	27.6	50.1	101	0.23	7.18
39	10	25.0	Moderately coarse	28.9	59.3	80.6	0.25	7.95
41	10	34.7	Moderately coarse	19.2	69.3	79.5	0.21	7.08

Table 2: The suitability classification codes of 12 different crops generated by MicroLEIS of the study area.

Prof. no	wheat	maize	Melon	Potato	Soybean	cotton	sunflower	Sugar-beet	Alfalfa	Peach	Citrus	Olive
Quta-Qarun depression												
46	S5s	S5sa	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
57	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t	S4t	S3t
62	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t	S4t	S3t
El-Rayan Depression												
6	S5s	S5sa	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
8	S5s	S5sa	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
9	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
10	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa
12	S4td	S4td	S4td	S4td	S4td	S4td	S4td	S4td	S4td	S4s	S4ts	S3ds
13	S5s	S5s	S5s	S5s	S5s	S4ts	S5s	S4ts	S4ts	S5s	S5s	S5s
14	S5s	S5sa	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
15	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3ts	S3ts	S3s
Aeolian deposits complex												
2	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
3	S4td	S4td	S4td	S4td	S4td	S4td	S4td	S4td	S4td	S4tdg	S4tdg	S4tdg
5	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
11	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
Alluvial plain												
16	S5tsa	S5tsa	S5tsa	S5tsa	S5tsa	S5tsa	S5tsa	S5tsa	S5tsa	S5tsa	S5tsa	S5sa
17	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa
18	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t	S4t	S3ts
19	S5tsa	S5tsa	S5pts	S5tsa	S5pts	S5pts	S5pts	S5pts	S5pts	S5psa	S5psa	S5psa
20	S5s	S5s	S5s	S5s	S5s	S4ps	S5s	S4pts	S4pts	S5ps	S5ps	S5ps
22	S5s	S5sa	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
43	S5s	S5sa	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
59	S5s	S5sa	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5ps	S5ps	S5ps
60	S5tsa	S5tsa	S5tsa	S5tsa	S5tsa	S5tsa	S5tsa	S5tsa	S5tsa	S5sa	S5sa	S5sa
63	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
64	S4s	S4s	S4s	S4s	S4s	S4s	S4s	S3ts	S3ts	S5s	S5s	S3s
65	S5s	S5sa	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
Rocky and desert pavement plain												
36	S5ps	S5psa	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps
40	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps	S5pds	S5pds	S5pds
42	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5ps	S5ps	S5ps
45	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps	S5pds	S5pds	S5pds
48	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa
49	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2pta
50	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5s	S5s	S5s
52	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
53	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa
54	S4td	S4td	S4td	S4td	S4td	S4td	S4td	S4td	S4td	S3tdg	S3tdg	S3d
55	S2csa	S2sa	S3s	S2tsa	S2csa	S2t	S2csa	Sc2	S2csa	S3s	S3s	S3s
56	S5s	S5s	S5ps	S5s	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps
58	S5s	S5sa	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
El-Rayan karstified plateau												
1	S5ts	S5tsa	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5pts	S5pts	S5pts
23	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5pds	S5pds	S5dsa
24	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5sa	S5pds	S5pds	S5dsa
25	S5psa	S5psa	S5psa	S5psa	S5psa	S5psa	S5psa	S5psa	S5psa	S5pds	S5pds	S5pds
27	S5psa	S5psa	S5psa	S5psa	S5psa	S5psa	S5psa	S5psa	S5psa	S5pds	S5pds	S5pds
30	S5psa	S5psa	S5psa	S5psa	S5psa	S5psa	S5psa	S5psa	S5psa	S5pds	S5pds	S5pds
31	S5ps	S5psa	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps	S5ps	S5pds	S5pds	S5pds
32	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pds	S5pds	S5pds
33	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pds	S5pds	S5pds
35	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pds	S5pds	S5pds
37	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pds	S5pds	S5pds
38	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pds	S5pds	S5pds
39	S5psa	S5psa	S5psa	S5psa	S5psa	S5psa	S5psa	S5psa	S5psa	S5pds	S5pds	S5pds
41	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pts	S5pds	S5pds	S5pds

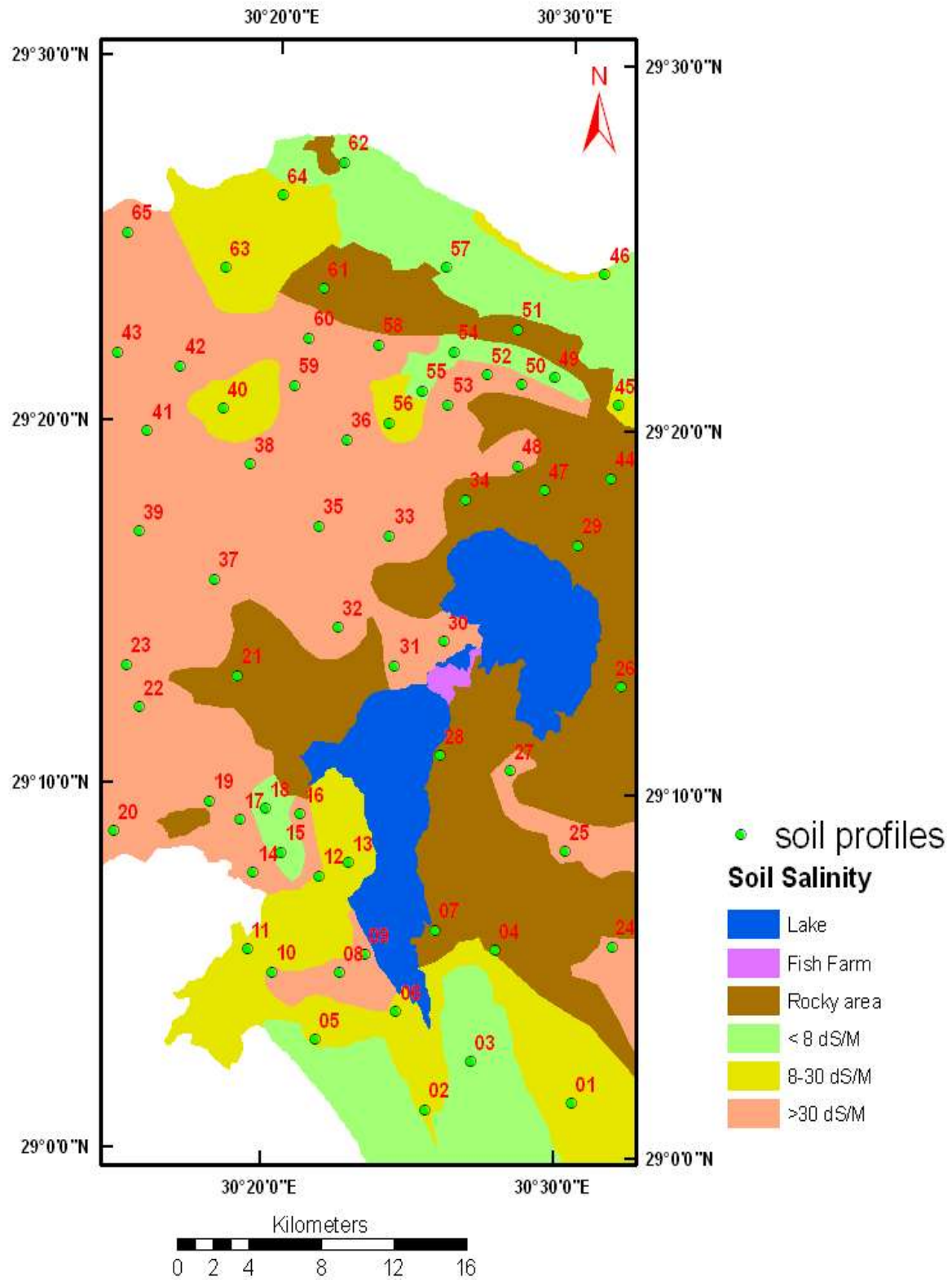


Fig. 8: Spatial variability of soil salinity in the study area showing large area characterized by extremely saline conditions (>30dS/m)

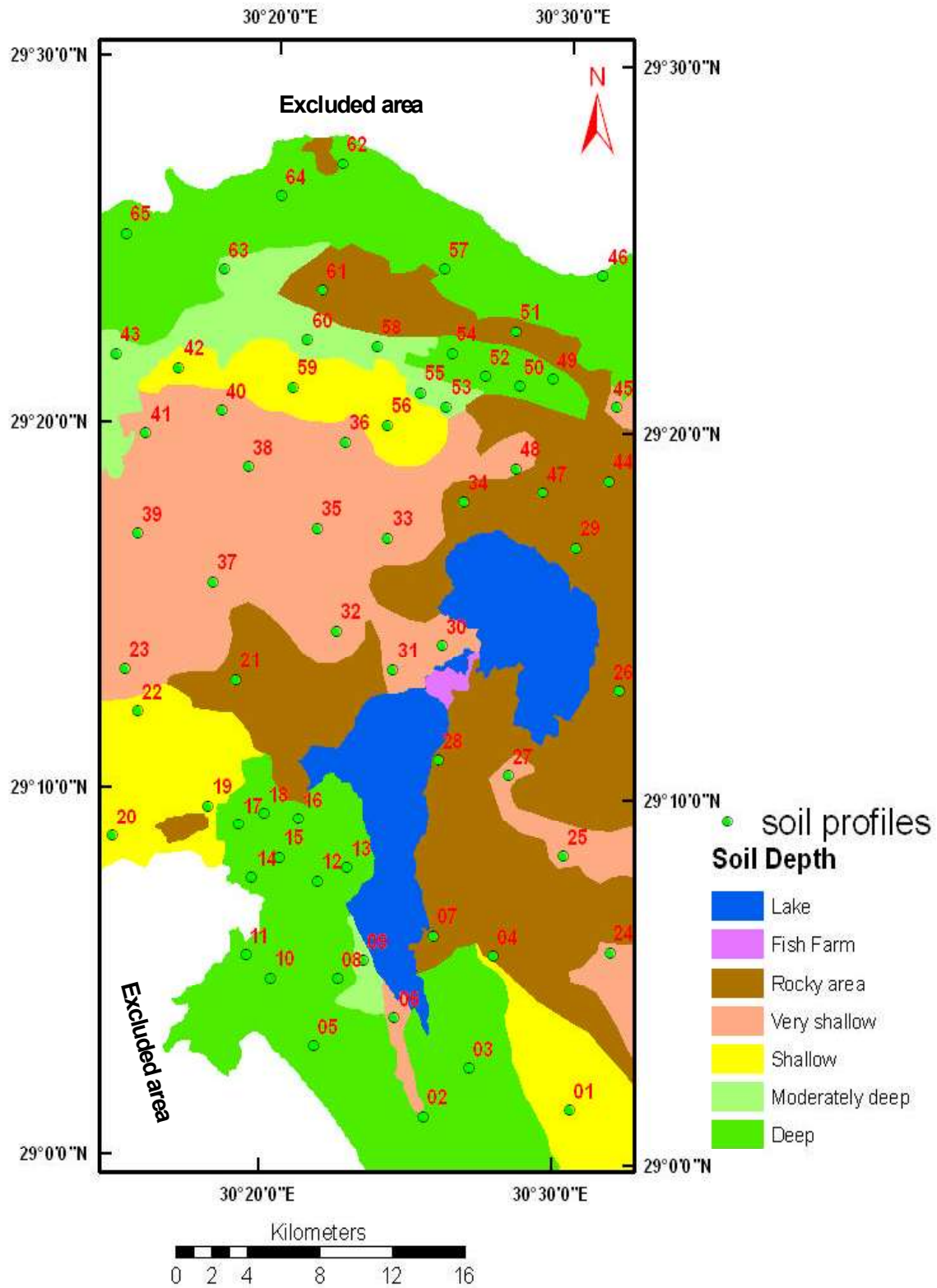


Fig. 9: Spatial variability of soil depth in the study area showing large area characterized by rocky, very shallow and shallow soil profiles

The chemical properties of these soils are influenced by their position on the landscape as a result of the soft and hard limestone parent material. Therefore, they are dominated by high free calcium carbonate ($> 10\%$), with a few exceptions such as slightly or moderately calcareous ($< 10\%$). Depending on the values of salt content and exchangeable sodium percent (ESP), soil in the study area are considered as salt affected: saline non alkaline soils ($EC > 4$ dS/m and $ESP < 15\%$) or saline-alkaline soils ($EC > 4$ dS/m and $ESP > 15\%$) with few small spots of good quality soils which was non saline non alkaline soils ($EC < 4$ dS/m and $ESP < 15\%$). There are two sources of salinity dominating the study area: the geological formation that is mainly composed of shale and limestone with evaporates lamella, the dissolution of limestone and the water intrusion from El-Rayan and Qarun Lakes. Moreover, the soils generally have low organic matter content (less than 1%). In general, the coarse-textured and moderately coarse-textured soils of the study area had low cation exchangeable capacity ($CEC < 10$ cmol kg^{-1}) while the higher CEC was found with medium-texture, moderately fine-texture and fine-texture soils.

The agricultural suitability generated by the computer program (MicroLEIS- Almagra model) is presented in Table 2. It includes the soil suitability classes for the selected crop. The definitions of soil suitability classes, soil factors and limitation are listed as following:

Soil factors		Limitation		Soil suitability classes	
symbol	Definition	symbol	Definition	symbol	Definition
a	Sodium saturation	1	None	S1	Highly suitable
c	Carbonate	2	Slight	S2	Suitable
d	Drainage	3	Moderate	S3	Moderately suitable
p	Profile development	4	Severe	S4	Marginally suitable
g	Useful depth	5	Very severe	S5	Not suitable
s	Salinity				
t	Texture				

However, the overall land suitability classes of the study area do not have significant differences among each other. In general, the soils of the study site are not suitable (S5) for all selected crops with a few exceptional cases which are highlighted in Table-2. The unsuitable classification resulted from the existence of one or more soil limitations such as soil depth, soil texture, drainage condition, carbonate content, salinity, or sodium saturation.

The results of the current study indicated that the most limiting factors was salinity, followed by soil texture, soil depth, sodium saturation, lime content and gravel content. Examples of the spatial variability of soil salinity (Figure 8) and soil depth (Figure 9), demonstrate their

effect on the land use of the study area. The effect of soil depth is very apparent in the soils with very shallow and shallow soil profiles especially for the fruit crops that require soils with deep and very deep profiles. Exception cases highlighted in Table-2 varied from marginally suitable (S4) to suitable (S2) that are scattered throughout the study area.

Salinity and alkalinity are correctable limitations but they are difficult to be accomplished because of the circumstances of the study area. The factors responsible for correcting soil salinity and alkalinity are quite complicated. First, the dominant parent material throughout the study area consists of shale, limestone, evaporates successions that contribute to increase the salt content. The bedrock under the shallow soil profiles hinders the water percolation and results in elevated water table level in the study area. Additionally, water intrusion from Qarun and El-Rayan Lakes contributes to the same problem. The cultivated area in El-Rayan Depression relies on the poor quality water ($EC > 2$ dS/m) of the upper lake for irrigation using surface irrigation instead of a drip irrigation system by the farmers. The surface irrigation has led to an elevated groundwater table due to bedrock or extremely hard layers near the surface. The elevated canal above the adjacent field and because of pervious damage tends to leak water into the soils and contributes to the water table level and causes water-logging.

CONCLUSIONS

The purpose of our study was to determine the soil suitability of Wadi El-Rayan Depression and to identify the factors that hinder the cultivation process. However, during the study using a well-known land evaluation program (MicroLEIS), it was found that the use of the study area for agricultural production was very complicated resulted from one or more of soil use limitations. That is clear where the output of MicroLEIS program showed that the soil grade is mostly S5 (not suitable). Naturally occurring soil salinity combined with salinity induced by human activities is the greatest problem throughout the study area. Theoretically and practically the soil salinity is a correctable limitation, but it is extremely difficult to cure this problem due to the circumstances of the study area. The irrigation system, the water quality, the drainage condition and the topography in addition to the superficial impermeable layers (bedrock or extremely hard layer) are the most responsible factors that impede salinity leaching out of the plant root medium. Besides the salinity,

other profound constrains such as very shallow and shallow soil depths, rocky soils, coarse soil texture and high sodium saturation influence agricultural development in the study area.

Wadi El-Rayan is designated as a World Protected Area (WPA) and contains amazing places for visitors including Wadi El-Hytan, waterfalls, ancient springs, a beautiful landscape, sand dune hills and buttes and some of the old civilization (pharos memorials). Due to the severe limitation and then the difficulty of agricultural development, however, the study area should remain primarily a tourist attraction. In fact, unnecessary agricultural expansion may harm or damage the value of this site. Therefore, it is logical to continue and improve tourism activities instead of shifting to agricultural use in Wadi El-Rayan Depression.

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