



LAND AND WATER RESOURCES ASSESSMENT FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT IN EL-KHARGA OASES BY USING REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM

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Received: Jan. 8, 2019

Accepted: Mar. 8, 2020

ABSTRACT: El-Kharga Oases, New Valley governorate, Egypt was selected as a study area. It is located between latitudes 25°15' and 26°05' N. and longitudes 30°05' and 30°45' E., having an area of 18813.8 km². The aim of this investigation is to study the characteristics of soils and groundwater in this area for evaluating their capability and suitability for growing main crops using RS and GIS. The obtained geomorphic map showed that, the area comprises three distinct geomorphic units namely, high land (28.8%), plateau (39.3%) and depression floor (31.9%). The depression floor of various origin and almost flat areas is the main landforms and suitable units for developmental plans. The soils were classified up to sub great group level on the basis of Soil Survey Staff (2014). Land evaluation was conducted using a model depend on the bases of Sys & Verheye index and land suitability for irrigated agriculture. Accordingly, the current capability of the studied soils was classified as: fair (III) for about 45% from the studied area, poor IV (about 50%) and very poor N for the remaining area. By executing a suitable improvement practices, these classes could be developed to the following three potential capability classes; good (II), fair (III) and poor (IV). Also, soil suitability for growing specific field, vegetable and fruit crops were evaluated in the studied geomorphic units. The quality evaluation of ground water resources showed that, the pH values ranged from ultra-acid (3.47 north El-Kharga) to slightly alkaline (7.83 in Max Qibly). The salinity of ground water changed from 0.48 to 119 dS m⁻¹ indicating non-saline to very extremely saline, TDS values varied from 307.2 to 71424 ppm (fresh, brackish, to extremely saline water). Total hardness varied from soft to very hard.

Key words: Geomorphic Units, Remote Sensing (RS), GIS, Soil Taxonomy, Land Evaluation.

INTRODUCTION

Egypt population is \square 102 million, which however, settles on just 6.6% of the Egyptian territory along the flood plain and Nile Delta and the River Nile. The over increase of population has inspired both government and individuals for lateral spread towards the desert land. One of the main targeted areas for lateral expansion are in the Western Desert but at specific localities such as Oases.

The Western Desert of Egypt covers approximately 650.000 km², which are

more than two thirds of the total area of Egypt. The significant areas in the Western Desert are Siwa, Bahariya, Farafra, Dakhla and Kharga Oases. El-Kharga Oases is one of the suggested areas for the horizontal expansion in the Western Desert which has high store of artesian water from multi layers of Nubian sandstone Aquifer System. It is bounded by the Eocene₂ limestone plateau from the east and north, where steep cliffs form a sharp boundary to the depression floor. El- Kharga Oases area is located between latitudes 25° 15' and

26° 05' North and Longitudes 30° 05' and 30° 45' East. (Fig.1). It is bordered on the north and east by a steep disjointed scarp 200 m high. On the west it opens on to the Dakhla Depression. The Southern boundary is not clear cut, as the depression floor blends gradually into the terrain to the south. Elevation on the floor of the depression range from near 0 (a. s. l.) to 120 m (a. s. l.). The surface elevation rises gently from the depression to the west up to over 400 m. (a. s. l.).

El-Kharga Oases is characterized by a tropical arid climate. The maximum day time temperature fluctuates within a wide range, reaching up to 42 C° in summer months, meanwhile in winter, the minimum temperatures may drop as low as zero at night. The annual mean value of relative humidity is about 33.5%. Generally, the atmospheric precipitation extremely scarce and insignificant (□ 3.0 mm/year). Wind speed tends to be low in August. It increases progressively in November to January reaches a peak from March to May causing dust storms famously known as "El-Khamasin" (CLAC, 2016).

Lithological soil origins of El-Kharga Oases have been studied by Hermina (1990), Said (2000) and Shawna *et al* (2016). These authors revealed that, El-Kharga Oases are occupied by different type of rock varying between Quaternary to Cretaceous areas. It owes its origin to the exposure by erosion of the Nubian sediments which consist of alternation of clays, shales, sands and sandstones. The overlying Cretaceous and Eocene formation which consist essentially of limestone form the plateau which border the Oases from North and East (Fig 2).

The landscape features of El- Kharga Oases were also studied by El – Shazly (1976), Hargha (1976), DRI (1983), ASRT (1989) and UNDP/ UNECO (2001) using a technique of photo- interpretation and

remote sensing, the authors reported that, the Oases consist of three geomorphic units, namely, the elevated plateau, the foothill slopes and the Kharga Oases depression. The latter includes hills, ridges, lacustrine deposits, local marches, crescent sand dunes and sand sheets.

Hydrologically, the only source of water for irrigation and other purposes is the ground water. According to El-Shazly (1976), Ezz El- Deen (1996) and the Egyptian Geological Survey (1999) reported that, the hydrogeology of the Nubian aquifer in El- Kharga Oases is a succession overlain by variegated shale bed (Cap rock) and underlain by the basement complex. The whole thickness of deep aquifer varies from about 230 m in the south to more than 750m in the north. The depth of shallow aquifer in El-Kharga Oases varies from 35 m below ground surface at the south to 16 m at north, so the piezometric water level varies from 72 to 26 m. from the south to the north. This indicates that, the general trend of ground water movement tend to be from the south to the north. However, the productive layers in the past were generally exploited under artesian flowing condition. At present, pumping is necessary where all wells have stopped flowing due to over pumping and the consequent formation of regional cones of depression.

Zhongxin *et al.*, (2004) reported that, remote sensing (RS) is defined as the acquisition of information about an object without being in physical contact with it. Remote sensing techniques have been utilized in soil science for many years as a tool for soil surveyors that reduce the time and expense of sampling. Some soil properties can also be delimited from Satellite images using the band combinations and computational indices depending on the

particular reflectance of each soil category (Sharma et al., 2006).

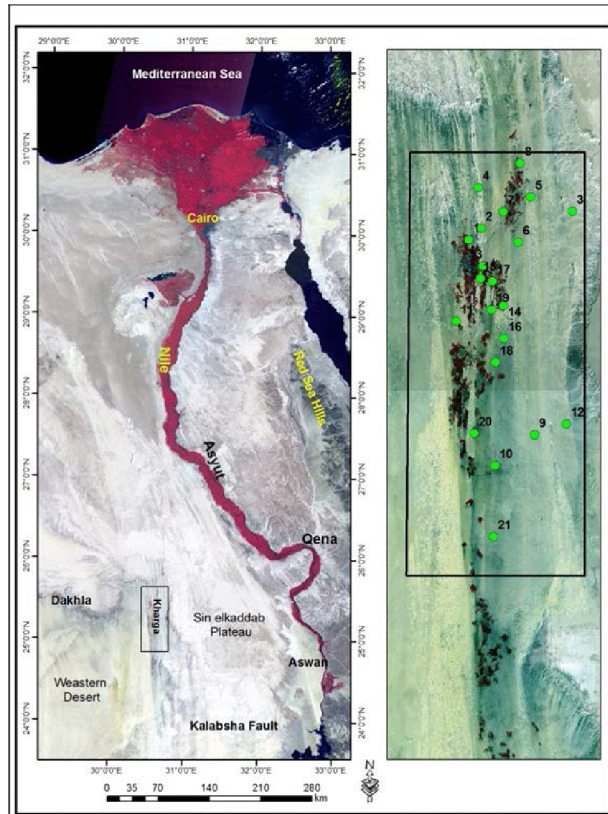


Fig. (1): Location of the study area.

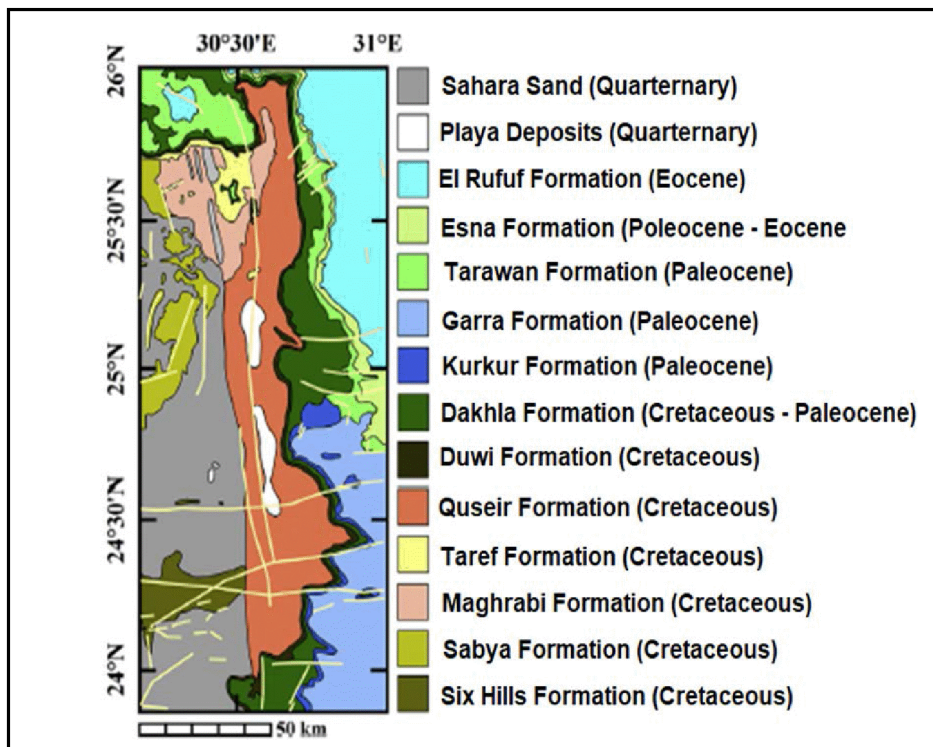


Fig. (2): Geological formation of El Kharga Oasis (after Hermina, 1990).

On the other hand, geographic information system (GIS) is considered as an organized collection of computer hardware, software, spatial and non-spatial data that can help users for the efficient capture, storage update, manipulation analysis and management of all geographically referenced information. RS in combination with GIS techniques proved to be effective in sustainability and planning studies (Rajitha *et al.*, 2006).

One of the ways to provide food is to increase production in area and to use the land with respect to its potentiality in an appropriate way. Land quality has been defined as "The condition and capacity of land", including its soil, climate, topography and biological properties for purpose of production, conservation and environmental management" (Pieri *et al.*, 1995). Today advanced computer programs including two of data gathering systems, (GIS) and (RS) as well as assessment models contribute to the speed and efficiency of the overall planning process and allow access to large amounts of information quickly. Especially during the last decade, GIS and RS have received much attention in application related to resources at a large spatial scale (Green 1995) and (Hinton 1996).

The aims of this study is to identify the geomorphic units of El- Kharga oases area in the Western Desert using remote sensing and GIS techniques and evaluation the land and water resources for a sustainable agricultural development. The land suitability for a specific field, vegetable and fruit crops are also evaluated.

MATERIALS AND METHODS

Two Landsat 8 OLI satellite images with spatial resolutions of 30.6 m. acquired in year 2015 for El- Kharga Oases (Path 176 - row 42) and (path 176 - row 43) were used for this research. The digital image processing was executed using ENVI 5.1 software (ITT, 2009). Image was stretched using linear 2 %, smoothly filtered and their histograms were matched according to Lillesand and Kiefer (1997).

Image was atmospherically corrected using FLASH module (ITT, 2009). The different landforms were initially determined and delineated from the satellite image. Digital Elevation Model (DEM) were produced from the shuttle radar topography mission (NCSA, 2005) and the available contour map (Figs 3 and 4) following the methodology developed by Dobas *et al.*, (2002) and Kalogirow (2002). GIS works were performed to produce base, geomorphic units, soil taxonomy, capability and suitability maps of the studied area using Arc GIS 10.2 software (ESRI, 2014).

Field work

The preliminary geomorphic map was refined during the ground truth to the emphasis the boundaries between the geomorphic units. Twenty-one soil profiles (Fig. 5) were chosen representing the main geomorphic unit (Depression Floor) of the study area. Also, 120 mini pits were located to represent the different geomorphic units. Soil profiles were dug to 150 cm. or to the lithic or water table level which is first contact. These profiles were described according to the Soil Science Division Staff (2017) and presented in Table (1). The profile sites and water samples are detected in the field by means of the Garmin 12 XL GPS Garmin Co. (1997). Sixty one soil

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samples and ten water samples were collected. The soil samples were air dried, crushed, sieved and used for physical and chemical analyses.

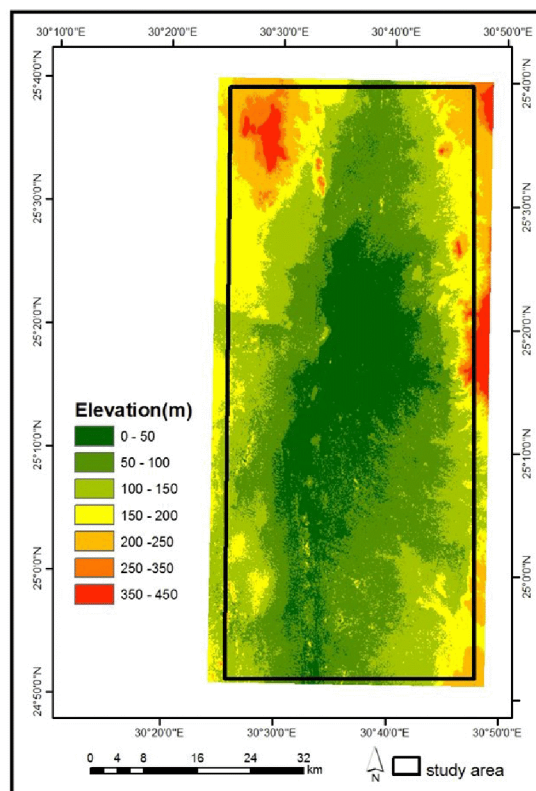
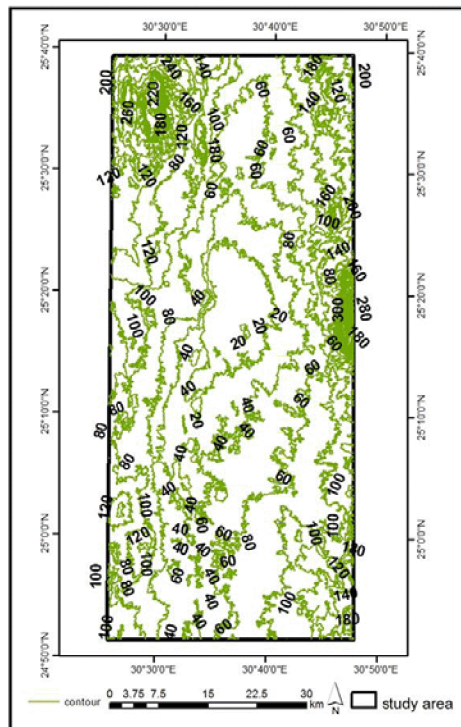


Fig. (4): Digital Elevation Model (DEM) of the studied area

Table 1 (1

Table 1(2

Table 1(3)

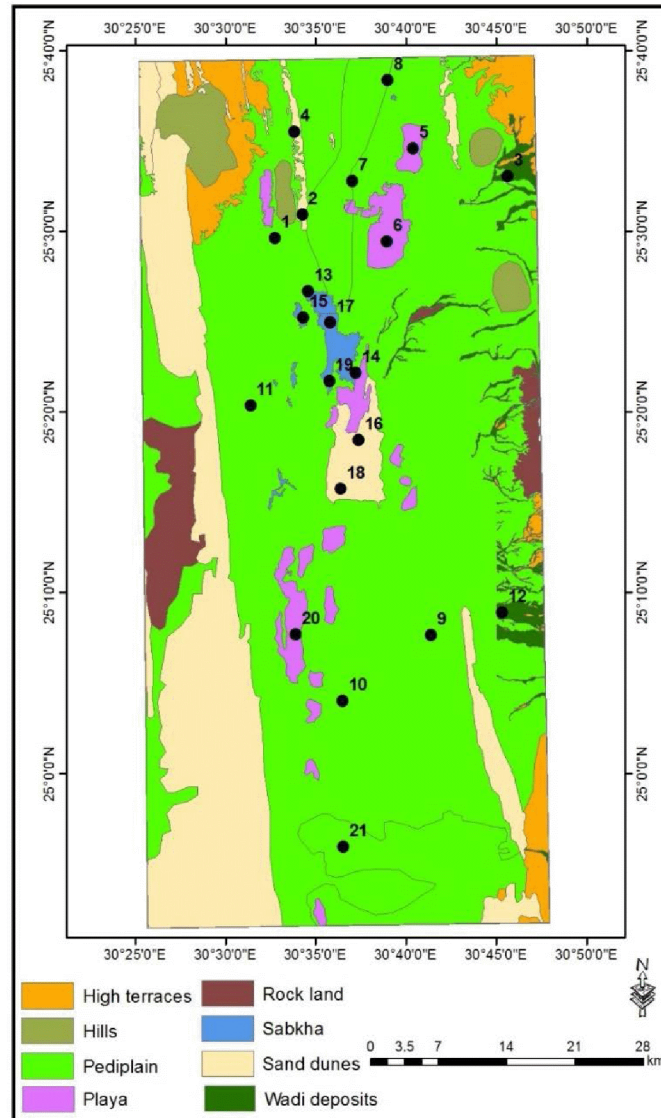


Fig. (5): Geomorphic map and Location of soil profiles

Laboratory analysis

Soil physical analysis

- Soil color in both wet and dry conditions was determined using Munsell Soil Color Charts (2010).
- Particle size distribution was determined according to Klute (1986) using hexa-metaphosphate as a dispersing agent.

Soil chemical analysis

The following analyses were carried out according to the methods outlined in Burt (2004): calcium carbonate, gypsum, organic matter, Electrical conductivity (ECe), Soil reaction (pH) in the soil paste, cation exchange capacity (CEC), and exchangeable sodium percentage (ESP).

Ten irrigation water samples were collected from some wells and filtered with Whatman paper filter. Water reaction (pH), ECe, total dissolved solids (TDS),

soluble cations and anions, Sodium adsorption ratio (SAR), Residual sodium carbonate (RSC) and some trace elements (B, Fe, Mn, Zn and Cu) were determined for these water samples using the methods described in Burt (2004). Suitability of water for irrigation was determined according to limitation outlined by FAO (1985).

The investigated soils were classified up to sub great group level based on the available climatic data, soil morphology, physical and chemical properties according to Soil Survey Staff (2014).

Soil limitations as well as land capability evaluation was obtained by using the parametric systems based on the basis of Sys and Verheye (1978) and Sys *et al.*, (1991). Also, evaluation of land suitability for growing specific field, vegetables, and fruit crops was done according to Sys *et al.*, (1991) and Sys *et al.*, (1993) by matching the land characteristics with crop requirements.

RESULTS AND DISCUSSION

Geomorphology of El-Kharga Oases

The geomorphic units distinguished in the studied area as a result of the satellite images interpretation and field observations are shown in Fig. (3) and Table (2). They can be broadly grouped in the following three major geomorphic units.

1. High Land including four sub units landforms namely; rocky land; foot hills, low slope and mountain.
2. Plateau including; gravelly plain, low cover with sand sheet plain, almost flat plain and undulating plain.
3. Depression Floor having nine sub unit landforms: Pediplain, Wadi Deposits, Playa, Sabkha, Decantation Basin, Agriculture areas, Sand Sheets, Sand Dunes and Nabkes Dunes.

The Depression Floor landform unit shows the most suitable unit for developmental agricultural plans. The morphological, physical and chemical characteristics for the soil profiles representing the soils of the sub units of this landform are presented Tables (1 and 3) and could be summarized as follows.

1- Soils of Pedi plain (DF111)

This sub unit occupies the most of El-Kharga Oases area and extends from north to southward as well. It is forming a narrow belt between the "rock exposure" unit in the east and undulating sand dunes in the west, covering approximate area of 862.8 km² (207072 feddans). The surfaces are almost flat and locally covered by desert pavement. These soils are very deep. Their representative profiles are 1, 7,8,9,10,11 and 21. Soil dry colour varies between weak red (2.5 YR 5/2) and very pale brown (10 YR 7/3). While the moist colour ranges from weak red (2.5 yr4/2) to pale brown (10 YR 6/3). Soil texture varies from sand to clay with gravel content ranges from 1% to >30% by volume. Soil consistence coincides well with soil texture and ranged from non-sticky, to very sticky and non-plastic to very plastic.

Data in Table (3) reveal that, the soil reaction ranged from neutral to strongly alkaline as revealed by pH values that ranged from 6.71 to 8.83. The soil salinity values indicate that these soils are non to very extremely saline as indicating from E_c values that varied from 1.42 to 123.1 dsm⁻¹. Organic matter content is generally very low, ranges from 0.02 to 0.87% owing to the prevalence of arid condition, which facilitate the decomposition of the organic matter. CaCO₃ content varied from 0.04 to 18.06% with an irregular distribution pattern with soil profile depths. Gypsum

content ranged from 0.01 to 2.68%. The cation exchange capacity (CEC) ranged from 0.32 to 39.59 Cmole kg⁻¹ reflects differences in clay and silt content among the soil profile and their layers. Exchangeable sodium percentage (ESP) values varied from 0.24% to 91.16%.

Table 2

Table 3 (1

Table 3(2)

Table 3(3)

2- Soils of sand dunes (DF311)

This sub unit occupies a rather less extended small patches within the northern and middle parts of El-Kharga Oases. Also, it dominates in the western sides of El-Kharga Oases and extends from south to north, covering approximate area of 2414.7 km² (579528 feddans) and representing by profiles 2, 4, 16 and 18. Its surfaces are undulating which are mostly covered by aeolian deposits of the Great Sand Sea. The majority of this sub unit have a moderately deep to very deep sandy soils with very few fine gravels content ranging from 1 to 7% by volume. Soil dry and moist colour varies from reddish yellow (7.5 YR 7/6) to brownish yellow (10 YR 6/6). Soil texture class is sand or loamy sand throughout the entire profile depths, except for the surface layers of profiles 4 and 6 where the texture class is sandy loam with single grain structure throughout the entire profile depths. Soil consistence varied from non-sticky to slightly sticky and non-plastic to slightly plastic, (Table, 1).

The analytical data in Table (3) reveal that, soil reaction is slightly alkaline to strongly alkaline with pH values ranged between 7.73 to 8.7. The soils of this geomorphic unit are non to strongly saline where ECe values ranged from 1.22 to 20.0 dSm-1. Organic matter content is very low not exceeds 0.9 %. The soils are non-calcareous to slightly calcareous having a total carbonate content range from 0.08 to 6.3%. Gypsum content is very low and varied from 0.01 to 1.8%. Cation exchange capacity varied in narrow limit between 0.26 and 7.95

Cmole kg-1, while ESP values ranged from 3.89 to 23.82%.

3- Soils of wadi deposits (DF121)

Wadi deposits sub geomorphic unit is located in the North and South borders with almost flat surface covering approximate area of 402.8 km² (96672 feddans). It is represented by profiles 3 and 12. This sub geomorphic unit was probably deposited with the drainage from the Eastern plateaus throughout the different rock structures. The soil relief is almost flat with moderately deep soil profile. Soil dry colour varied from light brown (7.5 YR 4/6) to pale brown (10 YR 6/3), while moist colour ranged between dark brown (7.5 YR 3/4) and brown (10 YR 5/3). Soil texture varied from sandy loam to clay with very few fine gravels. The soil structure is undeveloped where weak sub angular blocky structure. Soils have a consistence varied from slightly sticky to very sticky and slightly plastic to very plastic.

The data in Table (3) showed that, pH values ranged from 7.22 to 8.18 indicating neutral to moderately alkaline soil reaction. ECe values ranged from slightly to very extremely saline as revealed by ECe values that varied from 6.22 to 115.5 dSm-1. Organic matter content is very low not exceeds 0.48%. CaCO₃ content varied from 9.24 to 24.84%. Gypsum content is very low and varied from 0.06 to 1.23%. The Cation exchange capacity (CEC) ranged from 5.82 to 25.20 Cmole kg-1 and ESP varied from 0.01 to 29.94 %.

4- Soils of playa (DF131)

This sub unit is delineated along the north and south western part of El-Kharga Oases covering approximate area of 481. Km² (116064 feddans) and representing by profiles 5 ,6 and 20. The morphological description (Table 1) reveal that, the soil relief is almost flat

with deep soil profile (>150 m). Soils of playa has dry colours ranged from reddish yellow (7.5 YR 6/6) to yellow (10 YR 7/6). The moist colours vary from reddish yellow (7.5 YR 6/6) to grey (10 YR 6/1). Soil texture varied from sand to clay with gravel content less than 25% by volume. These soils were structure less (single grains) and massive. The consistence was non sticky to very sticky and non-plastic to very plastic.

Data in Table (3) reveal that, soil reaction in generally neutral to moderately alkaline having pH values ranged from 7.02 and 8.4. The studied soils are characterized by very slightly saline to very extremely saline, where the E_c values ranged between 3.87 and 1120 dS m⁻¹. Organic matter content in generally very low not exceeds 0.43 %. The total carbonate content was very low due to the sandstone origin. Gypsum content is very low and varied from 0.01 to 1.04%. The CEC values showed a relative increase in the deepest layers of soil profiles due to the relatively high clay content. It varied from 0.064 to 32.06 Cmole kg⁻¹, while ESP values ranged between 5.25 to 60.48 %.

5- Soils of Sabkha (DF141)

This sub geomorphic unit located in the middle of El-Kharga Oases with an area of about 20 km² (4800 feddans). The

soils of this sub unit are represented by profiles 13, 14, 15, 17 and 19. Topographically, the landscape is almost flat with moderately deep to deep soil profiles. Soil dry colour varied from reddish grey (5 YR 5/2) to very pale brown (10 YR 8/2). Moist colour ranged between dark reddish grey (5 YR 4/2) and light grey (10 YR 7/2). Soil texture class varied from sand to clay with single grain and massive structure respectively. Soil consistence ranged from non-sticky to very sticky and non-plastic to very plastic. Table (3) reveals that, these soils are slightly acid to moderately alkaline where pH values varied from 6.35 to 8.1. E_c values varied between 2.64 and 125.9 dSm⁻¹ indicating very slightly saline to very extremely saline soil. Organic matter content was very low and ranged from 0.03 to 1.15 %.

Calcium carbonate content was very low and varied in narrow limit from 0.14 to 6.12%, Gypsum content varied from 0.10 to 8.42%. Cation exchange capacity ranged from 0.26 to 37.36 Cmole kg⁻¹. ESP values varied from 0.61 -60.70 %.

The spatial distribution pattern of soil salinity and calcium carbonate content in the studied area of El- Kharga Oases are shown in Figs. (6) and (7).

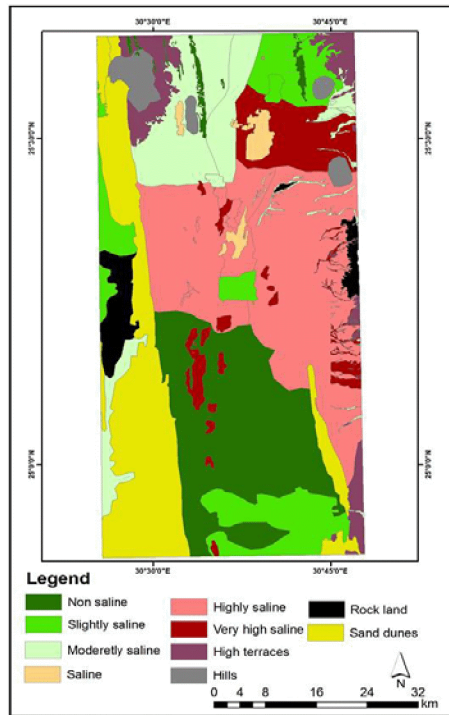


Fig (6): Spatial distribution of salinity status in the studied area

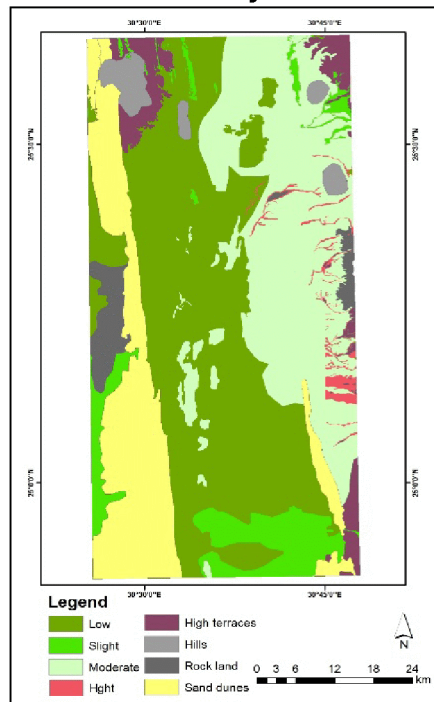


Fig (7): Spatial distribution of calcareous features in the studied area

Soil classification:

Classification for the studied soils (Table, 4 and Fig. 8) of El-Kharga Oases represented by different soil profiles based on the morphological, physical

and chemical characteristics was done according to Soil Survey Staff (1999 and 2014).

Accordingly, the studied soils could be classified up to sub great group levels

into three orders, namely, Vertisols, Aridisols and Entisols as presented in Table (4) and Fig (8).

Land Evaluation

The parametric land evaluation system, undertaken by Sys and Verheye (1978) and Sys *et al.*, (1991) is applied to identifying the soil limitations and their intensities as well as the land capability classes in the to the current and potential status.

Current land Capability:

The capability indexes (Ci) for the studied soil profiles are presented in Table (5) and Fig (9). The results reveal that, the studied soil profiles are placed between the fair soils (III) and very poor soil (N).

1- Soils of grade III (fair soils): These soils are found in Pediplain unit which represented by profiles 1,8,10 and 11

and in Sand Dunes (profiles 2,4,16, and 18) as well as in Sabkha (profiles 14 and 19). The soils of this grade are affected by moderate to severe intensity of soil texture and salinity and alkalinity and slightly to moderately intensity of CaCO₃ and gypsum contents, this grade representing 45% of the studied area.

2. Soils of grade IV (poor soils): The soils of this grade are found in Pediplain (profiles 7,9 and 21), playa (profiles 5,6 and 20), Wadi deposits (profiles 3 and 12) and Sabkha (profiles 13 and 17). Their Ci values varied from 21.9 to 39.7% This grade is representing 50% of the studied area. The soils of this grade are suffering from some soil limitations i.e. soil texture, CaCO₃, gypsum contents as well as salinity and alkalinity with different intensity degrees.

Table (4): Soil classification categories of the studied profiles.

Order	Sub order	Great group	Sub group	Prof. No.
Vertisols	Torrerts	Haplotorrerts	Chromic Haplotorrerts	1
Aridisols	Salids	Haplosalids	Typic Haplosalids	6
				7
				14
				17
19				
			Gypsic Haplosalids	15
			Calcic Haplosalids	9
				12
				20
			Typic Haplocalsids	8
Entisols	Fluvents	Torri-Fluvents	Typic- Torrfluvents	5
	Orthents	Torri-orthents	Typic-Torriorthents	11
			Typic- Torriorthents	3
	Psamments	Torri-psamments	Typic- Torripsamments	16,18
		Quartzi-psamments	Typic Quartzipsamments	10
			2,4,13	

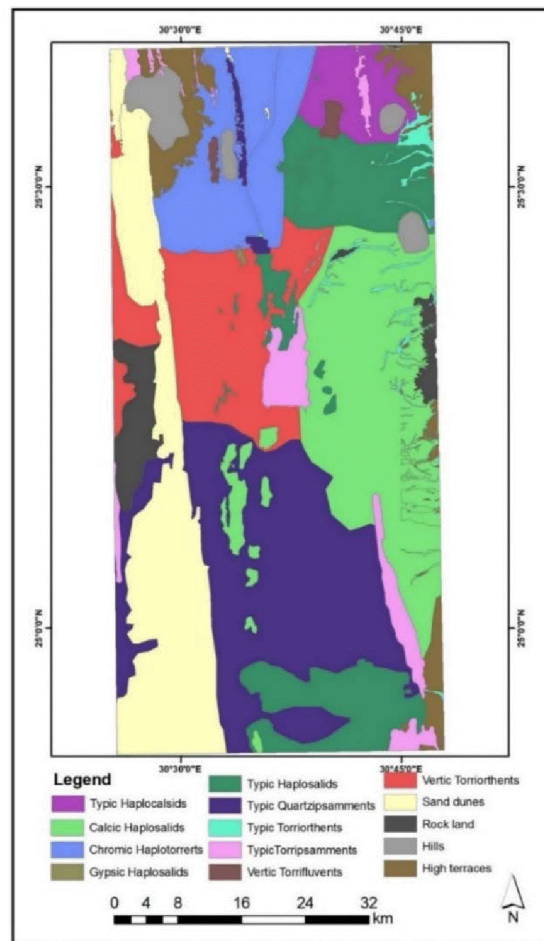


Fig (8): Soil classification of the studied area

Table (5): Current and potential land Capability classes for the studied soil

Prof. No.	Topography (t)		Wetness (w)		Rating of Soil Physical Characteristics					Salinity/Alkalinity		Current Capability		Potential Capability	
	CS	PS	CS	PS	Depth	Texture		Li me	Gyp sum	CS	PS	Ci	Class	Ci	Class
						CS	PS								
1	95	100	100	100	100	85	90	90	90	85	100	55.6	S3	72.9	S2
2	90	100	100	100	100	50	70	100	90	100	100	40.5	S3	63.0	S2
3	100	100	100	100	60	65	80	90	90	85	100	26.9	S4	38.9	S4
4	100	100	100	100	100	50	70	100	90	100	100	45.0	S3	63.0	S2
5	100	100	100	100	100	50	70	90	90	98	100	39.7	S4	56.7	S3
6	100	100	100	100	100	50	70	100	90	80	100	36.0	S4	63.0	S2
7	100	100	100	100	100	60	80	90	90	45	80	21.9	S4	51.8	S3
8	90	100	100	100	100	60	80	100	90	90	100	43.7	S3	72.0	S2
9	100	100	100	100	100	65	80	90	90	75	100	39.5	S4	64.8	S2
10	100	100	100	100	100	50	70	90	90	100	100	40.5	S3	56.7	S3

Fig. (9): Current Soil capability of the studied area for irrigated agriculture.

3- Soils of grade N (very poor soils): The soils of this grade are mainly found in Sabkha unit (profile 15). These soils are affected by moderate to severe limitations. The dominant limitations are soil texture, soil profile depth and salinity and alkalinity. This grade of soils is representing 5% of the studied area.

Potential land Capability:

For raising the potential land capability of El-Kharga soils, soil improvement practices should be carried out such as land levelling and removing the excess of soluble salts through applying the leaching requirements under an efficient drainage ditches for soils suffering from salinity. Such management practices will be corrected the rating suitability class for

studied soils, and potential land capability becomes as follows.

1- Soils of grade II (good soils): The Ci values of this grade varied from 63 to 72.9% and found in Pediplain soils (profiles 2,8,9, 11 and 21), Sand dunes (profiles Nos. 2,4,16 and 18), Playa (profiles 6 and 20) and Sabkha (profiles 14,17 and 19). The soils of grade II are representing 65% of the studied area (Table, 5 and Fig 10).

2- Soils of grade III (fair soils): The Si values of this grade ranged from 48.6 to 56.7% and found in Pedi plain (profiles 7 and 10), playa (profile 5), wadi deposits (profile 12), and sabkha (profile 13). Soils of this grade (III) are representing 25% of the studied area.

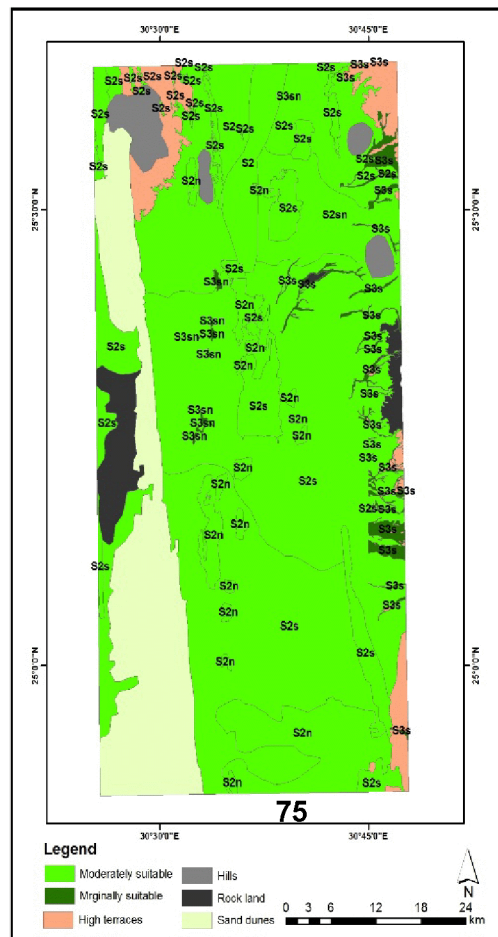


Fig. (10): Potential Soil capability of the studied area for irrigated agriculture.

3- Soils of grade IV (poor soils): The soils of this grade have Si values less than 38.9% and found in Wadi deposits (profile 3) and Sabkha (profile 15). The soils of this grade are representing 10% of the studied area.

Land suitability for specific crops

Current and potential soil suitability for cultivation of specific main crops are assessed in the studied areas of El-Kharga Oases according to Sys *et al.*, (1993) The results are shown in Table (6).

1- Current land suitability:

Most of the studied soils (70.60%) are not suitable for cultivation of studied crops in the current situation. Only 29.4% of these soils are marginally suitable for these crops as follows:

Table (6): Current and potential Suitability classes of the studied soil profiles for specific crops.

Crops	Current suitability					Potential suitability				
	Pediplain	Sandunes	Palaya	W.deposits	Sabakhas	Pediplain	Sandunes	Palaya	W.deposits	Sabakhas
Alfalfa	S3	S3	N1	N1	S3	S2	S2	S2	S3	S2
Barley	N1	N1	N1	S3	S3	S2	S2	S2	S2	S2
Peans	N1	N2	N2	N2	N2	S3	S3	S3	N1	S3
Cowpea	N1	N1	N1	N1	N1	S2	S2	S2	S3	S2
Pea	N1	N1	N1	N1	N1	S2	S2	S2	S3	S2
Sunflower	N1	N1	N1	N2	N1	S3	S2	S2	N1	S2
Wheat	N1	N1	N1	S3	S3	S2	S2	S2	S2	S2
Maize	N1	N1	N1	N1	S3	S2	S2	S2	S3	S2

- Soils of Pedi plain for alfalfa, green pepper, olives and mango.
- Soils of sand dunes for onion, cabbage, green pepper, citrus, olives and mango.
- Soils of playa for olives and mango.
- Soils of wadi deposits for barley, wheat, guava, and olives.
- Soils of sabkha for alfalfa, barley, wheat, guava, and olives.

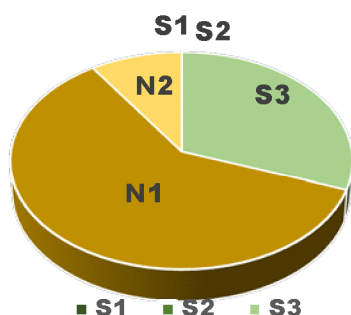
2- Potential land suitability:

Only 1.18 % of the studied area could be considered as highly suitable for olives in the soils of playa. Also, 64.7% of the studied area could be developed to moderately suitable (S2) for cultivation of the studied crops as follows:

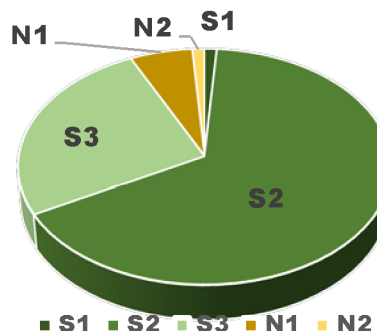
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Tomato	N1	N1	N1	N2	N1	S2	S2	S3	N1	S3
Potato	N1	N1	N1	N1	S3	S2	S2	S3	S3	S2
Onion	N1	S3	N1	N1	N1	S2	S2	S3	S3	S3
Cabbage	S3	S3	N1	N1	S3	S2	S2	S2	S3	S2
Green Pepper	S3	S3	N1	N1	N1	S2	S2	S2	N1	S3
Citrus	N1	S3	N1	N2	N1	S3	S2	S3	N2	S3
Guava	N1	N1	N1	S3	S3	S2	S2	S2	S2	S2
Olives	S3	S3	S3	S3	S3	S2	S2	S1	S2	S2
Mango	S3	S3	S3	N2	N1	S2	S2	S2	N1	S3

S			N		S			N	
S1	S2	S3	N1	N2	S1	S2	S3	N1	N2
0.00	0.00	30.59	60.00	9.41	1.18	65.88	25.88	5.88	1.18
30.59			69.41		92.94			7.06	
100.00					100.00				



Different classes of the current land suitability for crops



Different classes of the potential land suitability for crops

- Soils of Pedi plain for alfalfa, barley, cowpea, pea, wheat, maize, tomato, potato, onion, cabbage, green pepper, guava, olives and mango.
- Soils of Sand dunes for alfalfa, barley, cow pea, sunflower, wheat, maize tomato, potato, onion, cabbage, green pepper, citrus, guava, olives and mango.
- Soils of Playa for alfalfa, barley, cowpea, pea, sunflower, wheat, maize, cabbage, green pepper, guava, and mango.
- Soils of Wadi deposits for barley, guava and olives.
- Soils of Sabkha for guava and olives.

Moreover, about 25.9% from the studied area could be considered as marginally suitable (S3) for crops as follow:

- Soils of Pedi plain for beans, sun flower, and citrus.
- Soils of sand dunes for beans.
- Soils of playa for beans, tomato, potato, onion and citrus.
- Soils of wadi deposits for alfalfa, cowpea, pea, maize onion and cabbage. Soils of sabkha for beans, tomato, onion, green pepper, citrus and mango. Finally, some soils of Wadi deposits (8.25%) are not suitable (N2) for beans, sunflower, wheat, tomato, green pepper, citrus and mango.

Quality of groundwater

Irrigation water in the study area is mainly ground water. To study the quality of this water. Ten ground water samples were collected from wells found in this area. The samples were chemically analysed and the results were presented in Table (7). Data in Table (7) revealed the following features:

Water reaction (pH): The reaction of water samples ranged from ultra-acid (pH 3.47) in the north of El-Kharga to slightly alkaline (pH 7.83) in Max Qibly.

Water salinity (EC): The water salinity of the study area ranged from non-saline (0.48 dSm⁻¹) in the east of El-Kharga to extremely saline (119 dsm⁻¹) in south Bolaqe. Mandel and Shifitan (1981), found that, the water samples of El-Monira, Rakoda village, Edan village and East el-Kharga are fresh water. While the samples were fresh to brackish in the north of El Kharga, Paris, and El-Torfiya village and brackish in Ezbit Mostafa , south Bolaqe and Max Qibly.

Total dissolved solids (TDS): According to the classification of Hem (1985), the ground water of investigated area (based on their TDS) varied from fresh in El-Monira, Rakda village, Eden village and East El-kharga, fresh to

Table (7): Chemical analysis of ground water samples in the studied area.

<i>properties</i>	East El Kharga	Eden village	Rakda villige	El Tarfiya	Max Qibly	Paris	South Bolaqe	North El Kharga	El Monira	.Ez Mostafa
PH	6.52	6.96	7.38	7.26	7.83	5.98	6.66	3.42	7.05	7.1
EC dS/m	0.48	0.54	0.84	3.13	302.6	3.32	119	4.1	0.57	111.4
TDS ppm	307.2	345.6	537.6	2003.2	65664	2124.8	7616	2624	364.8	71424
Anions (meq/l)										
CO3=	--	--	--	--	0.1	--	--	--	--	--
HCO3-	3	2.4	3	9.4	13	1	3.8	0	2.8	1
Cl ⁻	2	2	4	13	2270	15	3330	10	4	1580

slightly saline (brackish) in the north of El-Kharga, Paris and El-Torfiya village. It is extremely saline in Ez. Mostafa, South Bolaqe and Max Qibly.

Soluble cations in the studied groundwater samples follow three orders. The first order Ca⁺⁺ > Na⁺ > Mg⁺⁺ > K⁺. The second order Mg⁺⁺ > Na⁺ > Ca⁺⁺ > K⁺. The third order Na⁺ > Ca⁺⁺ > Mg⁺⁺ > K⁺. The anionic composition of the studied groundwater samples follow the order Cl⁻ > So₄⁼ > HCO₃⁻ except for the groundwater samples of Ez. Mostafa, North El-kharga, South Bolaqe and Paris where the anionic follow the order So₄⁼ > Cl⁻ > HCO₃⁻. The concentration of the major cations and anions are lower than the maximum stander and limits of the World Health Organization “WHO” (1984) except for the samples of Ez. Mostafa, South Bolaqe and Max Qibly.

Sodium Adsorption Ratio (SAR): Data in Table (7) showed that, most of the studied ground water samples have SAR value <10 and could be characterized as excellent suitable water for irrigation except the ground water samples of Ez Mostafa, North El-kharga and Max Qibly that have SAR values >10.

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SO4=	0.04	0.76	0.55	10.17	592.9	24.89	333.46	44.2	1	2880.02
Cations (meq/l)										
Ca++	1.78	2.33	3.33	7.22	66.67	13.89	113.33	22.22	2.78	61.11
Mg++	0.9	0.35	0.88	5.93	1380.73	11.37	850.87	14.62	1.96	1633.6
Na+	1.34	1.25	1.81	18.08	1171.99	12.78	1321.56	14.65	2.09	2618.2
K+	1.02	1.23	1.53	1.34	56.55	2.81	158.15	2.71	0.97	151.12
SAR	1.16	1.06	1.25	7.05	43.37	3.6	91.28	3.41	1.36	89.94
RSC	0.32	-0.28	-1.21	-3.75	-1434	-24.26	-415.42	36.84	-1.94	-1690.7
*t.w.c	C2-S1	C2-S1	C2-S1	C4-S1	C4-S1	C4-S1	C4-S1	C4-S1	C4-S1	C4-S4
Trace elements (ppm)										
B	--	--	--	0.28	4.2	--	2.94	0.37	--	3.67
Fe	2.84	3	4.52	2.5	2.15	2.32	3.21	2.85	5	4.87
Mn	2.41	2.45	4.11	2.41	2	2.98	2.98	2.57	4.41	4.75
Zn	0.3	0.24	0.49	0.21	0.35	0.45	0.55	0.39	0.47	0.58
Cu	0.97	1	0.75	1.02	0.4	1.2	1	0.8	0.31	0.65
Hardness	2.68	2.68	4.21	13.15	1447.4	25.26	964.2	36.84	4.74	1994.7

Residual sodium carbonate (RSC): Data in Table (7) indicated that, the calculate RSC values for all the studied groundwater samples has < 1.25 meq/l RSC (Class 1) which is good quality and suitable for using in irrigation for all types of soils.

Richards, (1954) divided the water quality into classes C1, C2, C3, and C4 according to its salinity and into S1, S2, S43 and S4, according to its SAR. The studied ground water samples of the Rakoda village, Eden village and East El-Kharga lies in the field of C2-S1. This indicates that, these waters are good and suitability for irrigation purposes under normal condition. Groundwater samples of El-Monira, North El-Kharga, South Bolage, Paris, Max Qibly and El-Tarfiya are belong to class (C4-S1) which characterized by very high salinity hazards and low sodium water. while groundwater sample of Ez. Mostafa is belonging to class (C4-S4) having very highly saline and very high SAR. These two classes of water are not suitable for

irrigation under ordinary conditions. It may be used under special circumstances, such as, the soil must be permeable, drainage must be adequate, irrigation must be applied in excess to provide considerable leaching and selection of high salt tolerant crops.

Trace elements: Date in Table (7) showed that, the values of trace elements in the studied groundwater samples varied from 0.28 to 4.62; 2.15 to 5.0 ; 2.0 to 4.75; 0.21 to 0.58 and 0.4 to 1.2 meq/l for B, Fe, Mn, Zn and Cu respectively. The relatively high content of B, Cu and Mn is related to the geological nature of the study area which enriched by these elements in their sedimentary secession (CONOCO, 1987).

Hardness (TH): Hardness of water is a property allocable to dissolved Ca++ and Mg++ in water. The total hardness is related to the total quantities of Ca++ and Mg++ in water, while permanent hardness is due to the quantities of Ca++ and Mg++ that are still soluble in water after

removing temporary hardness by boiling the water. Based on the amount of dissolved Ca⁺⁺ and Mg⁺⁺ in ground water, its hardness can be divided into five categories starting from very soft whose Ca⁺⁺ and Mg⁺⁺ constituents are not more than 1.5 meq/l, and ending with very hard that contain more than 9 meq/l. According to the studied ground water samples range between soft to very hard where total hardness values ranged between 2.68 and 1694.7 meq/l.

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تقييم الموارد الأرضية والمائية للتنمية الزراعية المستدامة في الواحات الخارجة باستخدام نظم المعلومات الجغرافية وتقنيات الاستشعار عن بعد

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المُلخَص العَرَبِي

تبذل الدولة جهود كبيرة لإدخال مساحات جديدة من الأراضي الصحراوية في مشاريع التنمية الزراعية لمواجهة الزيادة السكانية والمطرودة بهدف توفير الغذاء وتعتبر الواحات الخارجة بمحافظة الوادي الجديد من المناطق الواعدة حيث تقع ما بين خطي عرض $15^{\circ} 25'$ و $05^{\circ} 26'$ شمال وخطي طول $05^{\circ} 30'$ ، $45^{\circ} 30'$

شرقاً بمساحة قدرها 18813.8 كم² . ويهدف هذا البحث إلى دراسة الخواص الطبيعية والكيميائية لأراضي الواحات الخارجة وتقدير القدرة الإنتاجية لها وصلاحية التربة لزراعة المحاصيل المختلفة، وذلك باستخدام الإستشعار عن بعد ونظم المعلومات الجغرافية.

حيث استخدمت صور القمر الصناعي لاندسات (سنيتال OLI 8) والنظام الرقمي ثلاثي الأبعاد لتحديد الوحدات الجيومورفولوجية بواسطة برنامج ENVI 5.1 وقد إتضح أن الواحات الخارجة تتكون من ثلاث وحدات أساسية وهي الأراضي المرتفعة تمثل (28.8 %) والهضاب تمثل (39.3 %) والأراضي المنخفضة تمثل (31.9 %) وتعتبر الأراضي المنخفضة من المناطق المناسبة للتنمية الزراعية والتي تختلف في أصلها وإرتفاعها. وقد تم إستخدام نظام التقسيم الأمريكي (USDA, 2014) لتقسيم أراضي الواحات الخارجة حتى مستوى العائلات.

وقد أجرى تقييم لأراضي منطقة الدراسة باستخدام نظام دليل الصلاحية للزراعة المروية والمقترح بواسطة (Sys & Verheye, 1978) و (Sys et al (1991) وقد وجد أن أراضي منطقة الدراسة تقع تحت درجات الصلاحية الحالية التالية: أراضي هامشية الصلاحية (III) وتمثل نسبة 45 % من مساحة منطقة الدراسة، هذه الأراضي تأثرت بمحددات التربة التالية: القوام وكربونات الكالسيوم والجبس والملوحة والقوية كمحددات للتربة ودرجات شدة من متوسطة إلى شديدة، وبلي هذه الدرجة من القدرة الإنتاجية الأراضي الفقيرة (IV) والتي تتأثر بعدد من محدات التربة ودرجات شدة مختلفة لكل من قوام التربة وكربونات الكالسيوم والجبس والملوحة والقوية وتمثل هذه الدرجة حوالي 50% من مساحة قطعة الدراسة.

وأخيراً الأراضي الغير صالحة (N) والتي تمثل حوالي 5% من مساحة منطقة الدراسة ومحددات التربة بها لكل من القوام وعمق قطاع التربة والملوحة والقوية ذات تأثير من متوسط إلى شديد ويمكن أن ترتفع درجة القدرة الإنتاجية لهذه الأراضي عن طريق عمليات تحسين التربة فيمكن أن تصبح درجات الصلاحية الكامنة (المستقبلية) لهذه الأراضي هي: جيدة (II) وهامشية (III) وفقيرة (IV).

كما تم تقييم أراضي منطقة الدراسة من حيث ملائمتها لزراعة المحاصيل المختلفة وذلك لتحديد درجة الصلاحية لكل محصول سواء بالنسبة إلى صفات التربة الحالية والمستقبلية بعد إجراء التحسين الملائم حيث قدمت هذه الموائمات بين هذه المحاصيل المختارة في أراضي الواحات الخارجة في صورة جداول لتكون دليلاً للإستخدام الأمثل لأراضي منطقة الدراسة.

وتقييم جودة المياه الجوفية في الواحات الخارجة من خلال التحليلات الكيميائية المختلفة تشير النتائج إلى أن قيم pH تراوحت ما بين 3.47 (بئر شمال الخارجة) إلى 7.83 (بئر الماكس قبلي) من حمضي شديد إلى قلوي خفيف. تتغير ملوحة المياه الجوفية من عديم الملوحة إلى عالية الملوحة جداً (0.48 - 119 ديسيمنز/متر) والأملاح الكلية الذائبة (TDS) من عديم إلى مائل للملوحة وعالية الملوحة حيث تراوحت قيم TDS ما بين 307.2 إلى 71424 جزء في المليون، وتراوحت نوعية المياه من عسر جداً إلى مياه يسره (TH) من إلى 2.68 إلى 1694.7 ملليكامفئ / لتر) الكاتيونات والأنيونات الذائبة ذات تركيز منخفض عن الحد المسموح به بواسطة منظمة الصحة العالمية 1984 فيما عدا المياه الجوفية لآبار عربة مصطفي وجنوب بولاق

والماكس القبلي. وتبين نتائج أذ SAR وأذ RSC إلى جودة المياه للري حيث وجد أن المياه الجوفية لأبار قرى راقوده، عدن، شرق الخارجة تقع في (C2-S1) (مياه جيدة).
أما عينات المياه الجوفية لأبار قرى المنيرة وشمال الخارجة وجنوب بولاق وباريس والماكس قبلي والطرفاية تقع في (C4-S1) (عالية الملوحة جداً - منخفضة القلوية) أما عينات المياه الجوفية لأبار عزبة مصطفى فتقع في المجال (C4-S4) (عالية الملوحة جداً - عالية القلوية جداً).

السادة المحكمين

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Table (1). Morphological Description of the studied soil profiles.

Geomorphic units	Profile No.	Depth (cm)	Soil colour		Soil texture*	Gravels %	Soil structure	Consistence	Effervescence*	Boundary	Soil classification***
			Dry	Moist							
Pediplain	1	0-30	10YR	6/2	10YR	5/2	w.c.s.ang	fr. v.st. v.pl.	w	c.s	FDDE
		30-75	10YR	5/4	10YR	4/4	mod.c.ang bl	fi.v.st v.pl.	w	c.s	
		75-150	10YR	5/3	10YR	4/3	mod.med.ang bl	v.fi.v.st v.pl.	w	--	
	7	0-25	7.5YR	6/6	7.5YR	5/6	st.less	fr.sl.st.sl pl.	w	c.w	GDAG
		25-75	10YR	5/2	10YR	4/2	st.less	fr.sl.st.sl pl.	w	c.w	
		75-150	10YR	7/3	10YR	6/3	sn.g	lo.n.st. n.pl.	w	--	
	8	0-35	7.5YR	6/6	7.5YR	5/6	sn.g	lo .n.st. n.pl.	mo.	c.s	GFBU
		35-85	7.5YR	6/6	7.5YR	5/6	sn.g	lo .n.st. n.pl.	mo.	c.s	
		85-150	10YR	5/4	10YR	4/4	mod.med.ang.bl.	fi. v.st. v.pl.	St.	--	
	9	0-30	10YR	4/6	10YR	3/6	ma.	fr. st. pl.	St.	c.s	GBBE
		30-80	10YR	5/4	10YR	4/4	ma.	fr. st. pl.	mo.	c.s	
		80-150	10YR	5/4	10YR	4/4	ma.	sl.h. st. pl.	mo.	--	
	10	0-30	7.5YR	7/4	7.5YR	6/4	ma.	fr .st. pl.	w	c.w	LCBH
		30-75	10YR	7/3	10YR	6/3	sn.g.	lo .n.st. n.pl.	w	c.w	
		75-150	7.5YR	7/6	7.5YR	6/6	sn.g.	lo. st. pl.	w	--	
	11	0-30	10YR	5/6	10YR	4/6	sn.g	lo. n.st. n.pl.	mo.	c.w	LECF
		30-80	10YR	6/6	10YR	5/6	ma.	h. st. pl.	w	c.w	
		80-150	10YR	6/3	10YR	5/3	ma.	h. st. pl.	w	--	
21	0-20	7.5YR	5/3	7.5YR	4/3	ma.	fr. st pl	w	c.s	GBBF	
	20-60	7.5YR	4/3	7.5YR	3/3	st.less	v.fr.sl.st.sl pl	w	c.s		
	60-150	2.5YR	5/2	2.5YR	4/2	w.c.ang.bl	v.fi.v.st v.pl	w	c.s		
		10YR	5/2	10YR	4/2	mod..med.ang.bl	v.fi.v.st v.pl	w	--		

Table (1): Cont.

Geomorphic units	Profile No.	Depth (cm)	Soil colour				Soil Texture*	Gravels %	Soil structure	Consistence	Efficiency*	Boundary	Soil classification***
Sand Duns	2	0-35	10YR	6/4	10YR	5/4	S	5	sn.g.	lo .n.st. n.pl.	w	c.s	LCCM
		35-80	10YR	5/6	10YR	5/4	S	1	sn.g.	lo. n.st. n.pl.	w	c.w	
		80-120	10YR	6/3	10YR	5/4	S	5	sn.g.	lo. n.st. n.pl.	w	c.w	
		120-150	10YR	6/6	10YR	5/6	S	1	sn.g.	lo. n.st. n.pl.	w	--	
	4	0-25	7.5YR	7/6	7.5YR	6/6	SL	1	sn.g.	so. n.st. n.pl.	w	c.s	LCCM
		25-50	7.5YR	7/6	7.5YR	6/6	S	3	sn.g.	lo. n.st. n.pl.	mo.	--	
	16	0-30	10YR	7/6	10YR	5/6	SL	7	ma.	so.sl.st.sl.pl	w	c.s	LCBH
		30-120	10YR	6/6	10YR	5/6	LS	1	sn.g.	lo. n.st. n.pl.	w	--	
18	0-50	10YR	5/4	10YR	4/4	LS	1	sn.g.	lo. n.st. n.pl.	w	c.s	LCBH	
	50-150	10YR	5/6	10YR	4/6	LS	1	sn.g..	lo. n.st. n.pl.	w	--		
3	0-25	7.5YR	4/6	7.5YR	3/4	C	2	gr.	fi. sl.st sl.pl	mo.	c.s	LECN	
	25-50	7.5YR	5/4	7.5YR	4/4	SL	1	st.less	fr.sl.st sl.pl	mo.	--		
12	0-20	10YR	5/4	10YR	4/4	SC	-	w.c.sub ang.bl.	fr. v.st. v.pl	st.	C.s	GBBE	
	20-50	10YR	6/3	10YR	5/3	C	-		fi. v.st. v.pl	st.	--		
5	0-30	10YR	7/6	10YR	6/6	S	20	sn.g.	lo. n.st. n.pl.	w	c.s	LDEB	
	30-75	7.5YR	6/6	7.5YR	6/6	S	15	sn.g.	lo. n.st. n.pl.	w	c.s		
	75-150	10YR	6/3	10YR	5/3	S	10	ma.	lo. n.st. n.pl.	w	--		
6	0-20	10YR	5/2	10YR	4/2	SC	25	sn.g.	fr. n.st. n.pl.	mo.	c.s	GBBF	
	20-80	10YR	7/2	10YR	6/1	S	5	sn.g.	lo. n.st. n.pl.	w	c.w		
	80-150	10YR	5/2	10YR	4/2	S	1	sn.g.	lo. n.st. n.pl.	w	--		
20	0-35	10YR	5/4	10YR	4/4	C	-	ma.	h.st pl.	st.	c.s	GBBE	
	35-75	10YR	5/4	10YR	4/4	C	-	w.c.ang.bl	v.fi. v.st v.pl	mo.	c.s		
	75-150	10YR	6/6	10YR	5/6	C	-	mod.med.ang.bl	v.h.v.st v.pl	w	--		

Table (1): Cont.

Geomorphic units	Profile No.	Depth (cm)	Soil colour		Soil Texture*	Gravel %	Soil structure	Consistence	Effervescence**	Boundary	Soil classification***
			Dry	Moist							
Sabkha	13	0-20	7.5YR 8/1	7/1	S	1	sn.g	lo. n.st n.pl	w	c.w	LCCM
		20-40	10YR 8/2	7/2	S	15	sn.g	lo. n.st n.pl	w	c.w	
		40-80	10YR 6/3	5/3	S	2	sn.g	lo. n.st n.pl	w	c.w	
		80-150	10YR 5/4	4/4	S	3	sn.g	lo. n.st n.pl	w	--	
Sabkha	14	0-20	10YR 6/3	5/3	L	1	ma.	fr..st .pl	w	c.s	GBBF
		20-75	10YR 7/3	6/3	SCI	1	ma.	sl.h. sl.st sl.pl	w	c.s	
		75-150	10YR 7/4	6/4	SCI	1	ma.	sl.h. sl.st sl.pl	w	--	
Sabkha	15	0-15	7.5YR 7/6	6/6	SL	1	st.less	so.sl.st.sl pl	mo.	c.s	GBBD
		15-50	10YR 5/4	4/4	LS	2	sn.g	lo. n.st. n.pl.	mo.	--	
		0-30	5YR 5/4	4/4	Ls	25	St.less	lo. n.st n.pl	mo.	c.s	
Sabkha	17	30-80	10YR 5/3	4/3	C	-	w.c.ang. bl	fi. v.st v.pl	w	c.s	GBBF
		80-130	5YR 5/2	4/2	C	-	w.medang. bl	v.fi. v.st v.pl	w	c.s	
		130-150	5YR 5/3	4/3	C	-	mod..med.ang. bl	v.fr. v.st v.pl	w	--	
Sabkha	19	0-30	10YR 4/3	3/3	Cl	-	gr.	h.st. pl.	w	c.s	GBBF
		30-75	7.5YR 3/3	2.5/3	C	-	w.c.ang. bl.	fi.v. st v.pl	w	c.s	
		75-150	10YR 3/3	2.5/3	Cl	-	w.med.ang. bl.	fi.st. pl.	w	--	

*Text: v.f.c= very fine clay _ f.c= fine clay - C= clayey - SC= Sandy Clay - SCL= Sandy Clay Loam - Cl= Clay loam - SL=Sandy Loam - LS= Loamy Sand. Consistence: (dry)- lo=loss so=soft h=hard v.h.=very hard sl.h= slightly hard - (moist)- lo=loss fr=friable v.fr= very friable fi=firm v. fi.= very firm - fr= friable fi= firm st= sticky pl= plastic - (wet)- n.st=non sticky n.pl.=non plastic st=sticky pl=plastic v.st=very sticky - v.pl.= very plastic - sl.st.=slightly sticky sl.pl=slightly plastic. Structure: ma= massive - w.c.s.ang.b.=weak coarse sub angular blocky - w.med. ang. bl= weak medium angular blocky - mod.c.ang bl= moderate coarse angular blocky - mod.med.ang.b.=moderate medium angular blocky - mod. med. s. ang.b.= moderate medium sub angular blocky - sn. g= single grain.

**Effervescence: w= weak - mod= moderate - st= strong. Boundary: c.s= clear smooth, d.s= diffuse smooth- d.w= diffuse wavy, c.w= clear wavy

***According to Soil Survey Staff (2014)

FDDE=Chromic Haplotorrerts

GBBD= Gypsic Haplosalids

GBBF= Typic Haplosalids

LECF=Vertic Tottiortherents

LCBH=Typic Torripsammments

LDEL=Typic Torrifluvents

LECN= Typic Torriortherents

LDEB= vertic Torrifluvents

GDAG=Typic Petrogypsic

Table (2): Geomorphic legend of EI- Kharga Oases.

Geomorphic unit	Relief	Lithology/Origin	Geomorphic sub units	Mapping unit	Area (Km2)	%
High land (HL)	Hilly (HL1)	*Shale, silt stone and lime stone (HL11)	*Rocky land (HL111)	(HL111)	1766.8	9.4
			*Foot Hills (HL112)	(HL112)	1937.4	10.4
			*Low slope (HL113)	(HL113)	158.5	8.2
Plateau (PL)	A.Flat (PL1)	*Red granite (HL12) *Lime stone with shale and marl (PL11) *Lime stone cover with Aeolian deposites * Limestone cover with alluvial deposites (PL11)	*Mountain (HL121)	(HL121)	148.3	0.8
			*Gravelly plain (PL111)	(PL111)	382.5	2.0
			*low cover with sand sheet (PL112)	(PL112)	734.9	3.9
			*Almost flat plain (PL113)	(PL113)	1495.2	7.9
			*Undulating plain (PL211)	(PL211)	4804.9	25.5
Depression Floor (DF)	A.Flat (DF1)	*limestone (DF11) *limestone mixed with sand ston (DF12) *saline material mixed with alluvial deposites (D13) *saline materials mixed with alluvial deposites and sandstone (DF14) *Alluvial deposites (DF15) *Alluvial deposites mixed with silt....(DF16)	*Pediplain (DF111)	DF (111)	862.8	4.6
			*Wadi deposites (DF121)	DF (121)	402.8	2.1
			*Playa (DF131)	DF (131)	483.6	2.6
			*Sabkha (DF141)	DF (141)	20.0	0.1
			*Dcanton basin (DF151)	DF (151)	756.7	4.0
			*Agriculture area (DF161)	DF (161)	318.0	1.7
	Flat (DF2)	*Aeolian deposites (DF21)	*Sand sheet(DF211)	DF (211)	625.7	3.4
			*Sand dunes (DF311) *Nabkes (DF 312)	DF (311)	2414.7	12.8
				DF (312)	111.5	0.6
				Total	18813.8	100%

Table (3): Particle Size Distribution, Texture class, OM%, CaCO₃, Gypsum Contents , CEC and ESP of the studied Soil Profiles.

Geomorphologic sub units	Prof. No.	Depth (cm)	pH (soil paste)	EC dS/m	Particle size distribution%				Text. class	OM %	CaCO ₃ %	Gyp. %	CEC Cmol/kg	ESP %
					C.S	F. S	Silt	Clay						
Pediplain	1	0-40	7.67	8.75	3.78	13.59	5.13	77.50	C	0.42	0.84	0.06	39.59	8.42
		40-70	7.53	12.32	14.67	11.55	3.53	70.25	C	0.87	0.83	0.01	36.86	10.91
		70-150	7.66	8.65	15.87	14.88	7.50	61.75	C	0.35	0.42	0.40	31.57	11.38
	7	0-20	7.33	123.10	66.99	10.36	13.90	8.75	SL	0.40	0.08	0.38	5.17	91.46
		20-25	8.07	24.30	73.23	8.52	5.02	14.23	SL	0.18	0.42	0.16	7.47	41.64
		25-150	8.17	6.54	96.85	1.90	0.80	0.45	S	0.06	0.08	0.07	0.34	12.49
	8	0-25	8.35	3.31	83.60	10.24	2.41	3.75	S	0.07	5.04	0.06	2.02	11.79
		25-75	8.12	6.26	74.10	11.50	1.65	12.75	LS	0.12	7.40	0.06	6.62	11.13
		75-150	8.11	5.45	13.14	19.23	21.75	52.50	C	0.12	18.06	2.68	26.49	0.24
	9	0-30	7.52	39.30	21.64	23.43	22.93	32.00	SCL	0.39	17.64	0.15	16.78	22.50
		30-90	7.73	15.45	69.48	11.00	6.50	22.25	SCL	0.11	8.40	0.06	11.35	19.43
		90-150	7.63	16.54	39.06	18.61	10.50	32.00	SCL	0.14	14.30	0.02	16.28	20.16
10	0-30	8.17	2.61	92.92	5.64	3.00	4.50	SCL	0.03	0.08	0.05	2.31	7.57	
	30-75	8.20	1.42	93.11	5.65	0.54	0.75	S	0.02	0.04	0.05	0.42	3.97	
	75-150	7.95	2.10	96.23	2.58	1.00	0.19	S	0.01	0.08	0.04	0.32	4.75	
11	0-30	8.83	23.50	81.49	10.40	6.00	2.11	S	0.03	5.46	0.27	1.12	17.09	
	30-80	8.15	13.52	39.88	8.22	13.12	38.78	SC	0.01	4.20	0.42	19.41	19.54	
	80-150	7.96	18.85	40.72	7.28	10.00	42.00	SC	0.04	0.42	1.02	21.08	18.61	
21	0-20	7.30	83.50	19.85	30.06	13.34	36.75	SC	0.39	0.69	0.02	19.15	48.06	
	20-60	7.08	45.50	39.08	33.20	9.72	18.00	SL	0.35	0.43	0.32	9.70	35.73	
	60-90	6.71	41.00	5.71	10.50	20.29	63.50	C	0.32	1.38	0.22	32.39	24.41	
		90-150	6.88	22.60	7.13	13.77	69.25	C	0.31	1.43	1.12	39.59	32.36	

Table (3): Cont.

Geomorphologic sub units	Prof. No.	Depth (cm)	pH (soil paste)	EC dS/m	Particle size distribution%				Text. class	OM %	CaCO3 %	Gyp. %	CEC Cmol/kg	ESP %	
					C.S	F. S	Silt	Clay							
Sand Duns	2	0-35	7.55	7.25	85.39	2.34	6.00	6.27	S	0.64	1.01	1.06	4.42	9.57	
		35-80	8.02	2.58	93.10	4.28	2.30	0.32	S	0.05	5.04	0.06	0.26	4.04	
	4	80-120	7.53	6.30	86.86	10.46	2.10	0.58	S	0.15	0.17	0.08	0.59	8.45	
		120-150	7.76	3.20	85.46	8.82	3.71	2.01	S	0.15	0.08	0.01	1.31	5.61	
	16	0-30	8.22	1.82	94.28	3.03	1.00	0.69	S	0.09	4.17	0.09	0.53	4.16	
		30-120	8.11	2.05	91.48	5.36	2.05	1.11	S	0.07	6.30	0.12	0.70	3.89	
	18	0-30	8.60	18.33	8.50	71.20	6.00	14.30	SL	0.40	3.50	1.20	7.95	18.59	
		30-120	8.40	20.00	66.10	17.70	7.20	10.00	LS	0.10	0.18	0.60	5.20	19.02	
	Wadi deposits	3	0-50	8.70	7.62	9.20	73.20	7.10	10.50	LS	0.30	5.20	1.80	5.85	23.82
			50-150	8.66	6.55	47.10	37.50	6.60	8.80	LS	0.90	2.50	1.50	6.20	19.44
		12	0-25	8.10	15.31	74.21	6.38	8.21	11.20	SL	0.11	10.50	0.08	5.82	15.65
			25-50	8.09	6.22	61.98	11.99	9.47	16.58	SL	0.07	9.24	0.06	8.42	9.96
5		0-25	7.22	115.50	25.67	20.95	13.63	39.75	SC	0.48	16.56	1.23	20.83	0.01	
		25-50	8.18	48.60	19.38	19.78	11.84	49.00	C	0.35	24.84	1.00	25.20	29.94	
Playa	6	0-30	7.82	6.00	97.62	2.18	1.31	3.25	S	0.06	0.08	0.12	1.74	5.95	
		30-70	8.01	4.41	91.86	6.50	0.64	1.00	S	0.07	0.08	0.11	0.64	5.25	
	20	70-150	7.50	10.03	13.65	36.59	10.41	39.35	SC	0.25	0.42	0.18	20.18	12.26	
		0-20	8.40	16.04	77.63	15.81	1.81	4.75	S	0.14	6.30	0.01	2.66	37.10	
	20	20-80	8.06	3.87	96.32	1.83	0.90	0.95	S	0.09	0.08	0.05	0.66	6.58	
		80-150	7.56	24.00	4.94	15.65	16.41	63.00	C	0.28	0.21	0.37	32.06	60.48	

Table (3): Cont.

Geomorpho- phic sub units	Prof. No.	Depth (cm)	pH (soil paste)	EC dS/m	Particle size distribution%				Text. class	OM %	CaCO3 %	Gyp. %	CEC Cmol/kg	ESP %
					C.S	F. S	Silt	Clay						
Wadi deposits	13	0-20	8.10	2.64	97.89	1.64	0.23	0.24	S	0.07	0.35	0.10	0.26	0.61
		20-50	7.47	6.97	97.06	1.63	1.01	0.30	S	0.09	0.35	0.16	0.33	10.94
		50-80	6.88	13.40	97.41	1.35	0.78	0.46	S	0.03	0.69	0.11	0.29	11.45
		80-150	7.02	12.40	95.69	3.03	1.01	0.27	S	0.09	0.48	0.16	0.32	14.84
	14	0-20	7.45	35.20	33.52	3.03	41.70	21.75	L	0.18	0.17	0.97	11.24	16.42
		20-60	7.74	29.20	26.23	31.78	16.24	25.75	SCL	0.13	0.43	3.92	13.23	20.75
		60-150	7.54	13.01	18.40	44.03	16.32	21.25	SCL	0.07	0.43	0.40	10.76	9.35
		0-15	6.55	125.90	69.30	51.01	9.58	16.11	SL	0.08	6.12	6.11	8.22	-0.23
	15	15-40	7.40	96.80	76.77	5.01	10.22	8.00	LS	0.48	6.12	2.74	4.96	43.33
		0-30	7.62	38.70	78.10	5.69	5.71	10.50	LS	0.19	5.15	1.21	5.63	30.96
		30-80	7.90	25.20	3.76	12.11	29.88	54.25	f.C	0.60	1.72	0.57	28.32	37.96
		80-130	7.63	23.60	2.76	7.75	15.49	74.00	v.f.C	0.18	0.86	0.31	37.36	26.36
17	130-150	7.48	25.20	0.27	8.20	20.53	71.00	v.f.C	0.30	0.43	0.16	36.10	29.90	
	0-30	6.35	86.00	27.14	13.23	32.38	27.25	CL	1.15	0.34	8.42	15.93	-0.76	
	30-75	6.46	89.50	12.50	18.49	23.76	54.25	C	0.77	0.21	3.26	28.66	33.63	
	75-150	6.61	104.20	23.12	8.66	31.47	36.75	CL	0.06	0.14	5.17	18.50	60.70	
Sabkha	19													

C. S* = Coarse sand f.s= fine sand Text. Class= Texture classes f.C= fine clay v.f.c= very fine clay C= clay
 S= sand SI= sand loam SC= sand clay SCL= sand clay loam