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LAND RESOURCES ASSESSMENT OF SIWA OASIS, WESTERN DESERT, EGYPT

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Abstract

The present work was carried out to identify land resources for evaluating the possibilities of improving and extending the cultivated areas within the borders of the oasis itself using remote sensing and GIS capabilities. The investigated area located in the western desert, and bounded by latitudes 29° 05' 00" & 29° 25' 00" N and longitudes 25° 05' 00" & 26° 06' 00" E. Seventeen soil profiles were taken to represent the soils of the area. Morphological description and soil sampling were conducted during the field work. The soil properties including texture, depth, organic matter (O.M), EC, $CaCO_3$, pH, CEC, and ESP have been determined. According to the American soil taxonomy the soils were classified as Typic Torripsamments, Calcic Aquisalids, Typic Haplosalids, Gypsic Haplosalids, Typic Aquisalids, Typic, Lithic and Duric Haplocalcids and Typic Psammaquents. The soil capability classes ranged between class 3 (fair) and 5 (very poor) and the other soil profiles located low than class 5 of land capability. The most suitable crops for the soils of the area are Cotton, Date palm, Olive, Alfalfa, Barley, Wheat, Maize, Faba been, Soya been, Sugar beet, and Citrus. The suitability for Cabbage, Onion, Rice and Banana is ranges between currently non suitable to permanently non suitable.

***Keywords*:** Soil taxonomy, Soil evaluation, Remote sensing, GIS, Siwa Oasis, Egypt.

Introduction

The agricultural sector plays an important and major role in the growth and stability of the global economy, and it is from this concept that the government of Egypt seeks to find a suitable area for agricultural production. Siwa oasis is a natural depression in the western desert south from the Mediterranean coast related to the city of Marsa Matruh. A great efforts and huge investments were adapted for achieving the development of Siwa oasis by national and international agencies and organizations. Siwa oasis is suffering from several problems that hinder the development efforts. The main problem is the enlargement of lakes areas that raises the water table level in addition to sand dunes encroachment in the southern part of the oasis, which comes from the great sand sea. Through proper and suitable management, a considerable area of this oasis could be used. The present work was carried out to identify land resources for evaluating the possibilities of improving and extending the cultivated areas within the borders of the oasis itself. Siwa Oasis is bounded by latitudes 29°05′00″N & 29°25′00″N and longitudes 25°05′00″E & 26°06′ 00″ E (Figure 1). From available climatological data the average rainfall reached about 10 mm/year, with an average below 3 mm / month. The maximum temperature reaches about 38 °C and the minimum is 3.8 °C, relative humidity values ranged between 33.0 and 60.0 %. The annual relative humidity is 45.0 %., wind velocity ranged between 2.39 and 3.79 m/sec and. the annual mean of wind speed is 2.97 m/sec, Evaporation (mm/day) value is 283 mm/day and minimum is 62 mm/day. Based on USDA (2010), the soil moisture regime ranged between Torric and Aquic while the soil temperature regime is Thermic. Parsons (1963) and Said (2000) stated that, the geological history of Siwa is as follows, I) The early geological history of Siwa depression is unknown, II) Below the Miocene and during most Mesozoic the Siwa depression seems to be part of the great basin included the modern Qattara depression, III) during the Eocene, the depression appears to be covered with a shallow sea. Middle Eocene sediments having numulitic, organic and limestone faces are exposed on the southeast of the depression while the upper Eocene sediments are in the form of shale faces. IV) In the Oligocene, fluviatile continental sediments were deposited in Siwa area and V) During the Miocene; the sediments were followed upon Oligocene deposits by the marine transgression in lower Miocene. In this era, Siwa was separated from the sea to the north. According to Parsons (1963) and Abu Al-Izz (2000) Siwa depression is bordered from the north by Miocene limestone plateau (about 200m a.s.l) and from the south by Eocene limestone plateau (about 500m a.s.l). Siwa depression is below the zero contour line, and the lowest part reaches 17m below sea level. Thus the greatest depression (Siwa-Qattara) is different from the other depressions of the western desert, which are all situated above sea level. The depression is bordered from the north by a high wall, rises to about 100m above the depression floor. Many soil studies have been completed on Siwa Oasis (i.e. Saleh 1970, Haraga *et al.*, 1974; Gomaa, 1976; NARSS, 1998 and Thabet, 2013) these studies showed that all soils of Siwa Oasis contain large proportions of sand and very little clay. With fairly high total soluble salts, consisting mainly of particles of sandstone and limestone derived from the floor and walls of the depression or carried in from the plateau by the wind. The textural classes of Siwa oasis are mainly sand, loamy sand, sandy loam, and sand clay loam. According to Fanous (1979) and Sherif (1979), there are native forage such as common sedges mishear grass (*Cladium mariscus* cyperaceae), Camel thorn (*A. maurorum*) (Leguminosae) and matsedge (*Juncus arabicus*) grown in some areas having relatively high water table. Also, native seeding date palms (*Phoenix dectylifera*) are widely spread in Siwa oasis. According to El Hossary (1999 and 2013), Abdulaziz and Faid (2015) and FAO (2016) the groundwater is a very important source of water in the oasis. Siwa is located above two huge reservoirs of groundwater, the only substantial fresh water supply in the region. The upper reservoir is composed of interstitial water confined in the cavities of Miocene limestone. This reservoir extends down to a depth of about 550 m below ground surface. The deep aquifer consists of thick layers of Nubian Sandstone, which belongs to the cretaceous and carboniferous ages. These layers go down to a depth of about 2000 m below ground surface. The origin of the groundwater is the rain, which fell during the more humid ages 30,000-40,000 years ago on the Green Mountains in Libya and slowly percolated downwards to the oasis. The present study aims to achieve the following objectives: Physiographic mapping, soil mapping, capability and suitability mapping of the studied area.

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

Materials and Methods

Band composition was displayed from via Landsat 8 ETM+ image and spatial resolution 30 m) as RGB (7, 4 and 2). The main geomorphologic units have been interpreted, delineated and digitized on screen. Landsat ETM+ image and Digital Elevation Model (DEM) were used in Arc GIS 10.5 (ESRI, 2008) software to produce the physiographic map and other thematic maps. Seventeen soil profiles representative the mapping unit were dug and fifty two samples were collected from deferent layers for lab analysis. Morphological description of soil profiles were done according to FAO (2006). Soil samples were air dried; ground gently; and sieved through 2 mm sieve. Then, physical and chemical analysis were done according to USDA (2004), as particle size distribution, soil reaction (pH), electrical conductivity (Ec ds/m), soluble carbonate and bicarbonate (meq/l), soluble chlorides(meq/l), soluble sulfate (meq/l), soluble calcium and magnesium (meq/l), soluble sodium and potassium (meq/l), Total calcium carbonate ($CaCO_3$%), organic matter (OM %), gypsum content ($CaSO_4$. nH_2O), cation exchange capacity (meq/100g soil), exchangeable sodium percentage (ESP%) and NPK (ppm). Finally, land capability and suitability were calculated by using the Agriculture Land Evaluation System for arid and semi arid regions (ALES-arid).

Results and Discussion

1. Physiographic map of the studied area

Digital Elevation Model (DEM) can be employed to offer varieties of data that can assist in mapping of landforms and soil types. Information derived from a DEM, i.e. surface elevation, slope % and slope direction, could be used with the satellite images to increase their capabilities for soil mapping. The landforms of the studied area were delineated by using the digital elevation model (Figure 2), Landsat ETM+ and ground truth data. The produced map was imported into a Geodatabase. Six physiographic mapping units were found in the studied area as following: Playa soils, Depression soil, Sand sheet soil, Sabkha soil, Hummocks and Footslope soil shown in Figure (3) and Table (1).

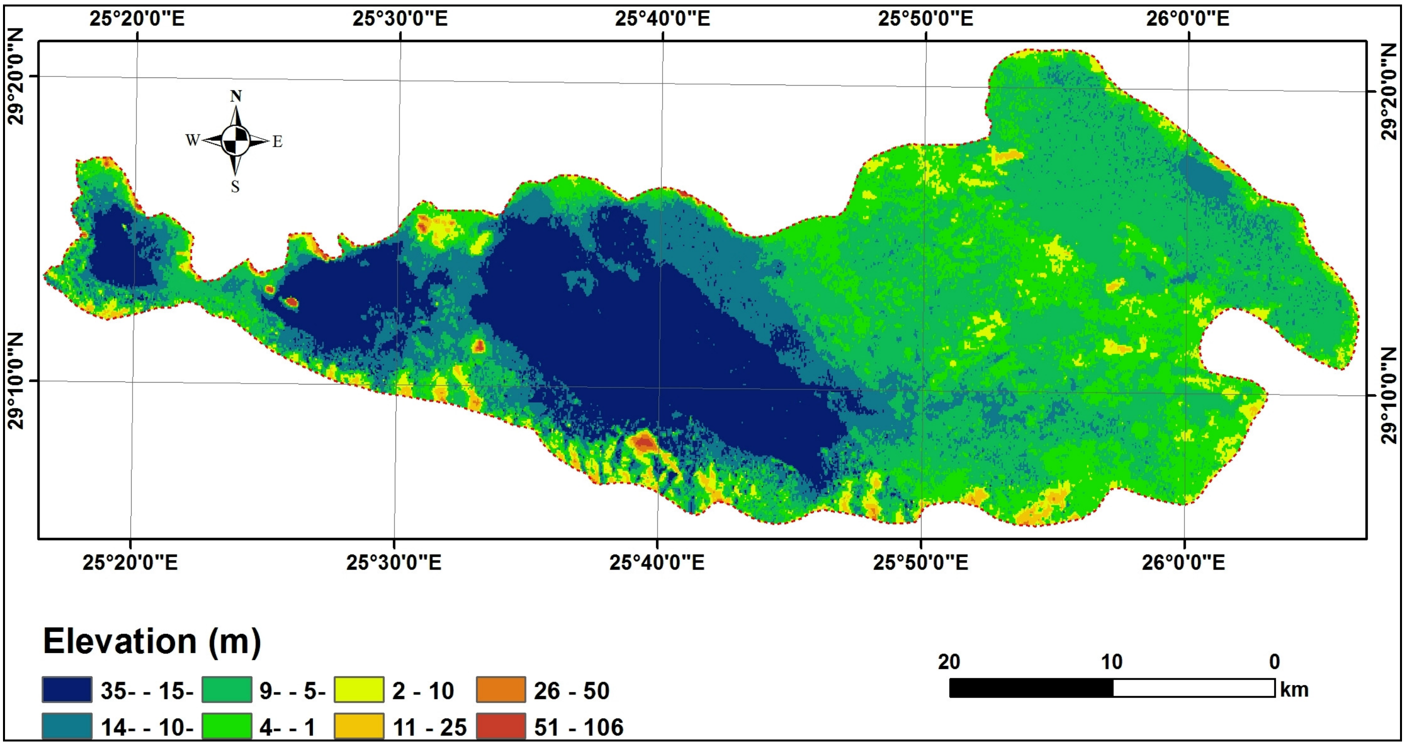

Fig. 2 : Digital Elevation Model (DEM) of the studied area

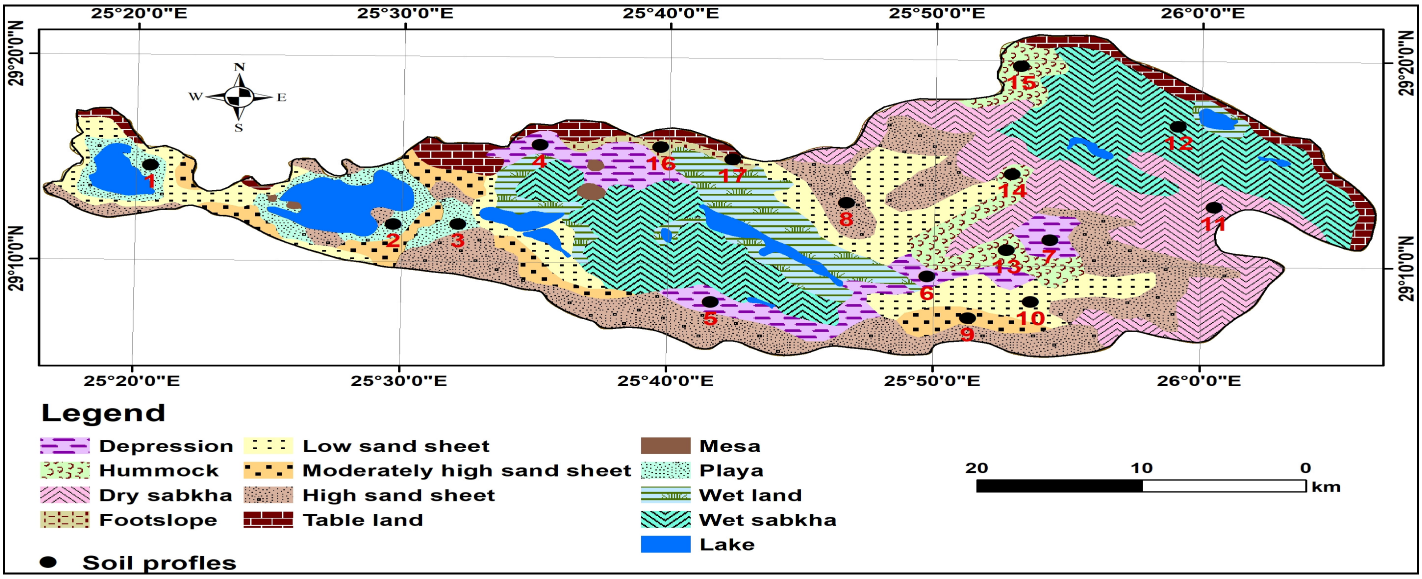

Fig. 3 : Physiographic units and profiles sites

Table 1 : Physiographic mapping Units and areas

Mapping Units and symbol	Area (sq km)	Area (%)
Depression (DS)	78.01	6.40
Hummocks (HS)	56.04	4.60
Dry sabkha (DSS)	164.44	13.49
Footslope (FS)	9.86	0.81
Low sand sheet (LSS)	139.25	11.43
Moderately high sand sheet (MSS)	53.98	4.43
High sand sheet (HSS)	214.04	17.56
Tableland (TLS)	57.35	4.71
Mesa(M)	3.93	0.32
Playa (PS)	42.60	3.50
Wetland (W)	85.18	6.99
Wet sabkha (WSS)	244.87	20.10
Lake (L)	69.02	5.66
Total area	1218.58	100

The soils of different physiographic unite could be detailed as the following:-

1.1. Playa soil (PS)

The soil of playa unit occupied 42.6 Km^2 i.e. 3.5 % of the total area, it represented by soil profiles No. (1, 2 and 3). The landform of soil is almost flat, slope of surface is nearly level and the area is cultivated with orchards. Parent material is alluvium, soil depth ranged between shallow and deep. the soil analysis shown in Tables (2, 3 and 4) indicate that the texture is sandy to sandy loam. Cations exchange capacity values ranged between 2.5 and 18.9, exchangeable sodium percentage values ranged between 6.5 and 14.8 %, soil reaction (pH) values varied from 7.8 and 9.5, electric conductivity (EC) dS/m values ranged between 1.3 and 14.5, calcium carbonate ($CaCO_3$) content varied from 9.1 and 36.1%, gypsum content is low than one, organic matter content (OM) ranged between 0.0 and 2.5, soluble cations (mq/L) are Na^+> Ca^{++}> Mg^{++}> K^+, soluble anions mq/L are Cl^-> SO_4^{--}> HCO_3^-> CO_3. Available macronutrients (NPK ppm) values changed from soil profile to another where K > P > N (ppm) in profiles 1 and 2, while in soil profile 3 are K > N > P (ppm)

Table 2 : Some physical analyses of soil profiles No. **1**, 2 and 3

Profile	Depth cm	Particle Size distribution%				Texture Class	Exch. Na+ mq/100 g	CEC mq/100 g	ESP %
		C. Sand	F. Sand	Silt	Clay				
1	0-20	56.6	8.0	28.6	12.1	Loamy sand	1.0	11.5	8.7
	20-50	70.0	9.0	20.1	5.6	Sand	0.4	4.4	9.1
	50-100	67.0	18.0	16.2	3.5	Loamy sand	0.3	2.5	12.0
	100-130	77.5	12.0	11.3	3.6	Sand	0.4	2.7	14.8
2	0-25	30.1	29.6	21.5	18.8	Sandy loam	1.1	17.9	6.1
	25-60	28.2	28.3	23.9	18.7	Sandy loam	1.2	18.0	6.7
	60-100	15.6	31.4	35.1	19.1	Sandy loam	1.3	18.9	6.9
	100-120	66.6	23.5	9.1	2.8	Loamy sand	0.6	9.0	6.7
3	0-25	63.1	26.5	6.5	4.1	Sand	0.3	4.2	7.1
	25-50	63.3	27.9	4.5	4.2	Sand	0.2	3.1	6.5
	50-75	62.3	28.8	5.6	3.6	Sand	0.2	3.0	6.7

Table 3 : Some chemical analyses of soil profiles No. 1, 2 and 3

Profile No.	Depth	pH	EC dS/m	Soluble cations (mqe/L)				Soluble anions (mq/L)				$CaCO_3$ %	$CaSO_4$ %	OM %
				Na^+	K^+	Ca^{++}	Mg^{++}	Co_3	HCO_3^-	Cl^-	$SO_4^=$			
1	0-20	7.5	9.0	38.8	7.6	30.6	21.4	0	1.4	60.0	37.0	9.1	0.5	2.5
	20-50	8.0	12.6	73.2	10.4	36.0	24.4	0	2.4	89.0	61.6	15.2	0.6	1.2
	50-100	8.0	14.5	89.0	18.0	36.0	25.0	0	2.0	100.0	66.0	21,3	0.7	1.0
	100-130	8.0	11.0	69.7	18.0	25.0	13.3	0	1.7	75.0	49.3	20.4	0.8	0.5
2	0-25	8.0	4.5	26.5	1.5	3.7	6.3	0	4.1	21.0	10.9	10.9	0.7	2.4
	25-60	8.0	2.3	6.5	1.4	1.7	8.4	0	2.8	11.5	26.1	11.8	0.8	1.5
	60-100	8.0	3.4	12.4	1.6	4.9	10.1	0	1.6	24.5	32.7	13.5	0.9	0.9
	100-120	8.0	3.3	11.7	2.0	6.1	9.2	0	2.0	23.5	34.1	36.1	0.7	0.8
3	0-25	7.9	1.5	3.2	0.4	4.5	6.9	0	4.0	9.0	2.0	12.0	0.7	0.1
	25-50	7.8	1.5	5.6	1.4	3.5	4.5	0	4.0	10.5	0.5	13.2	0.5	0.1
	50-75	8.1	1.3	6.6	0.4	3.3	2.7	0	2.4	9.3	1.3	10.1	0.5	0.2

Table 4 : Available macronutrients of soil profiles No. 1, 2 and 3

Profile No.	Depth	Available macronutrients (mg/kg)		
		N	P	K
1	0-20	10.0	20.5	220.0
	20-50	11.1	30.7	236.0
	50-100	10.2	35.1	212.0
	100-130	9.1	30.2	200.0
2	0-25	15.0	18.1	211.0
	25-60	20.1	13.2	205.0
	60-100	9.0	7.3	202.0
	100-120	3.0	6.5	240.0
3	0-25	10.5	20.6	90.0
	25-50	11.3	21.3	99.0
	50-75	12.5	10.5	80.0

Based on the soil profile description, soil database and USDA (2004) the soil could be classified as Typic Torripsamments in soil profiles No. (1 and 2) while in soil profile (3) Typic Psammaquents. From soil analysis capability classes are class 4 (poor) and index 39.03 in soil profile (1) while in soil profile (2) is class 3 (fair) with capability index 45.98 and class 5 (very poor) and index 14.75 in soil profile (3) The improving of capability class in soil profile (2) could be referred to the good management. While the decrease of capability class in soil profile 1 and 3 is could be referred to the poor management. Suitability classes ranged between suitable for Date palm, Tomato, Olive, Cotton, Fig, Sunflower, Sugarbeet, Barley, Wheat, moderately suitable for Sorghum, marginally suitable for Pepper, Water melon, onion, Grape, Pea, currently suitable for Peanut, Citrus, Potato, Soyabean, Maiz, Faba bean, Apple, Pear and permanently suitable for Banana, Cabbag, Rice

1.2. Depression soils

This mapping unit (Depression soil) occupied (78.01 Km^2 and 6.40 %) of the area under investigation and representative by soil profiles (4, 5, 6, and 7). From the soil profile description clear that the land form of soil is almost flat, slope of soils is nearly level, cultivated with orchards (Olive and Palm, trees), Parent material is alluvium, soil depth are deep in soil profiles 4 and 5, while moderately deep in soil profile 6 and shallow in soil profile 7. Drainage class ranged between well in profile 4, 5 and moderately drained in soil profiles 6, 7,

From soil analysis data shown in Tables (5, 6 and 7) the texture class varied from sand to loam, cation exchange capacity (CEC) (mq/ g soil) values varied from 1.1 to 32.3. Exchangeable sodium percentage (ESP) % values varied from 5.3 to76.1 %. The soil reaction (pH) varied from 7.5 to 8.2, Electrical conductivity (EC) dS/m values are high except in soil profile (6) are low. They values are different from layer to another and from 5 to 65 dS/m in soil profile 4, 18.9, 22.0, 17.2 dS/m, Calcium Carbonate content values are ranged between 1.5 and 52.5%. Gypsum content % values are varied between 0.5 to 6.7%. Organic matter content (OM) values are low than one percent and decrease with depth%. Soluble cations (mq/L) are Na^+> Ca^{++}> Mg^{++}> K^+ (mq/L), soluble anions mq/L are Cl^-> SO_4^{--}> HCO_3^-> CO_3 (mq/L). Available macronutrients (NPK) values (ppm) are K> P> N (ppm) in profiles4, 5 and 6 while are K> N> P (ppm) in profile 7.

Table 5 : Some physical analyses of soil profiles No. 4, 5, 6 and 7

Profile No.	Depth cm,	Particle Size distribution				Texture Class	Exch. Na+ mg/100g.	CEC mg//100g soil.	ESP %
		Sand%		Silt & clay					
		C. Sand	F. Sand	Silt	clay				
4	0-30	56.1	4.3	22.3	13.2	Sandy loam	5.8	11.3	51.3
	30-50	55.1	12.6	12.5	19.8	Loamy sand	3.3	15.2	21.7
	50-90	39.2	11.0	30.7	18.2	Loam	5.6	17.5	32.0
	90-180	50.2	11.1	23.2	22.6	Sandy loam	2.5	20.1	12.4
5	0-30	4.2	36.6	60.1	4.1	Silty loam	1.7	32.3	5.3
	30-70	8.2	78.3	10.3	4.2	Sand	7.0	9.2	76.1
	70-120	11.3	39.9	48.2	4.4	Loamy sand	8.3	25.1	33.1
6	0-50	54.0	40.1	4.7	1.1	Sand	0.1	1.2	8.3
	50-100	64.4	30.3	3.9	1.3	Sand	0.1	1.1	9.1
7	0-20	26.6	29.6	25.3	19.3	Sandy loam	6.7	18.5	36.2
	20-50	45.3	24.2	23.4	7.5	Loamy sand	2.1	6.2	33.9
	50-60	54.5	27.3	11.3	6.6	Loamy sand	1.6	6.0	26.7
	60-70	41.0	28.6	13.4	6.8	Loamy sand	1.1	7.0	15.7

Table 6 : Some chemical analyses of soil profiles No. 4, 5, 6 and 7

Profile No.	Depth cm	pH	EC dS/m	Soluble cations (mmole/L)				Soluble anions(mmole/L)				$CaCO_3$ %	$CaSO_4$ %	OM %
				Na^+	K^+	Ca^{++}	Mg^{++}	Co_3	HCO_3^-	Cl^-	$SO4^=$			
4	0-30	7.8	65.0	61.0	40.4	96.3	129.3	0	3.2	704.0	168.8	4.5	2.6	0.6
	30-50	7.9	45.0	317.0	10.2	55.0	83.4	0	2.8	368.0	94.8	3.1	5.8	0.3
	50-90	7.8	5.0	15.7	1.3	15.0	22.0	0	3.2	49.6	1.0	3.3	6.7	0.2
	90-180	8.0	30.0	4.8	0.8	8.9	14.5	0	4.1	13.4	11.6	1.5	5.0	0.2
5	0-30	7.9	18.9	96.8	26.0	51.0	41.0	0	2.5	115.0	97.3	21.2	1.3	0.9
	30-70	8.0	22.0	130.0	28.0	81.0	37.0	0	1.5	200.0	74.5	30.9	1.5	0.5
	70-120	8.0	17.2	110.3	20.0	38.0	26.1	0	1.9	101.2	91.3	52.5	0.9	0.2
6	0-50	8.0	0.8	2.3	0.3	1.1	1.3	0	1.9	2.8	0.3	10.6	0.5	0.3
	50-100	8.1	0.9	1.7	0.3	0.7	3.3	0	2.3	2.6	1.1	13.0	0,6	0.2
7	0-20	8.2	85.0	763.0	34.0	107.4	127.6	0	6.5	831.0	194.5	17.0	0.6	0.7
	20-50	8.0	48.0	429.0	28.8	52.0	61.4	0	5.7	435.0	130.5	18.0	0.5	0.6
	50-60	7.5	26.0	214.0	2.2	38.9	49.7	0	2.8	225.4	76.6	29.0	0.5	0.5
	60-70	8.1	6.5	29.0	5.7	17.4	24.7	0	3.2	58.8	14.8	50.0	0.6	0.7

Table 7 : Available macronutrients of soil profiles No. 4, 5, 6 and 7

Profile No.	Depth	Available macronutrients (mg/kg)		
		N	P	K
4	0-30	12.1	13.5	214.0
	30-50	11.6	15.6	156.0
	50-90	10.9	7.8	110.0
	90-180	11.2	3.5	110.0
5	0-30	9.1	21.1	210.0
	30-70	6.2	25.3	245.0
	70-120	8.1	30.1	135.0
6	0-50	10.2	10.5	200.0
	50-100	14.5	8.8	198.0
7	0-20	20.1	7.6	220.0
	20-50	18.2	3.6	191.0
	50-60	10.0	3.3	130.0
	60-70	1.2	4.2	135.0

The soils were classified as Gypsic Haplosalids, Typic Haplocalcids, Typic Torripsamments, and Typic Aquisalids. The land capability ranged between class 4 (poor) and class 6 (Non-agriculture). Soil capability index ranged between 2.1 and 36.48% the decrease of capability class associated with high ESP and shallow soils.

1.3. Sand sheet soil deposits (SS)

The mapping unit (SS) covered about 407.27 Km^2 i.e. 33.42% of the investigated area this unit was represented by soil profiles 8, 9, 10. The Landform is almost flat, surface slope is nearly level, land use is barren, parent material is Aeolian deposits, soil depth is deep and drainage is well drained. From soil analysis data shown in Tables (8, 9 and

10) the texture class is sand, cation exchange capacity values are low and varied from 1.2 to 2.5, mq/100 g soil. Exchangeable sodium percentage ranged between 7.7 and 21.4 %, the soil reaction (pH) values varied from 7.7, and 8.3 electrical conductivity (EC) dS/m is ranged between 0.7 and 28 dS/m. Calcium Carbonate content values varied from 6.2 % and 15.1%. Gypsum content % is varied from 0.7 to 1.5 %. Organic matter (O.M) % content varied from 0.3 to 1.2 %, Soluble cations (mq/L) values varied from layer to another as $Na^+ > Ca^{++} > Mg^{++} > K^+$ (mq/L), and soluble anions are $Cl^- > SO_4^{--} > HCO_3^- > CO_3^{--}$ (mq/L). Available macronutrient (NPK) (ppm) values are varied as K>P>N.

Table 8 : Some physical analyses of soil profiles No. 8, 9 and 10

Profile No.	Depth cm,	Particle Size distribution				Texture Class	Exch. Na+ mg/100g.	CEC mg//100g soil.	ESP %
		Sand%		Silt & clay					
		C. Sand	F. Sand	Silt	clay				
8	0-30	41.4	54.1	1.9	2.4	Sand	0.2	1.5	13.3
	30-140	40.3	55.4	2.9	2.7	Sand	0.3	1.4	21.4
9	0-40	62.5	30.6	4.7	2.2	Sand	0.1	1.3	7.7
	40-120	71.3	22.8	3.2	2.7	Sand	0.1	1.2	8.3
10	0-25	48.0	41.9	7.6	2.7	Sand	0.3	1.6	18.8
	25-40	47.2	47.4	6.9	3.2	Sand	0.2	2.5	8.0
	40-55	8.9	40.8	7.5	2.8	Sand	0.2	1.8	11.1
	55-75	42.1	48.2	7.3	2.9	Sand	0.2	2.5	8.0

Table 9 : Some chemical analyses of soil profiles No. 8, 9 and10

Profile No.	Depth cm	pH	EC dS/m	Soluble cations (mqe/L)				Soluble anions (mqe/L)				$CaCO_3$ %	$CaSO_4$ %	OM %
				Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^{--}	HCO_3^-	Cl^-	$SO4^=$			
8	0-30	7.9	0.7	2.2	0/7	2.7	1.7	0	1.3	5.6	0.4	13.8	1.4	0.9
	30-140	8.2	0.7	2.7	0.8	3.0	0.9	0	1.6	2.1	3.7	9.4	1.5	0.5
9	0-40	8.0	7.9	50.5	1.5	18.9	24.9	0	3.9	63.9	28.0	6.2	0.6	0.4
	40-120	7.9	28.1	220.8	3.9	50.8	69.9	0	2.3	2.3	340.7	5.9	0.7	0.3
10	0-25	7.7	5.0	8.6	1.0	25.5	16.8	0	6.0	35.8	9.1	10.5	0.7	1.2
	25-40	8.1	4.0	14.9	2.0	12.1	6.2	0	4.0	27.0	4.2	12.0	0.9	0.4
	40-55	8.3	2.6	11.0	1.6	6.0	4.0	0	2.8	18.0	1.8	15.1	1.0	0.3
	55-75	8.2	2.9	10.0	2.0	5.1	7.9	0	3.0	20.0	2.0	12.0	1.0	0.3

Table 10 : Available macronutrients of soil profiles No. 8, 9 and 10

Profile No.	Depth	Available macronutrients (mg/kg)		
		N	P	K
8	0-30	10.1	15.3	130.0
	30-140	3.1	12.4	120.0
9	0-40	3.6	2.1	120.0
	40-120	4.2	2.6	1.3
10	0-25	8.3	7.3	120.0
	25-40	9.1	8.2	111.0
	40-55	5.2	6.5	105.0
	55-75	1.3	5.6	110.0

The soils of this unit were classified as Typic Torripsamments. Land capability ranged between class 4 (poor) and class C5 (very poor) and index differ from 10.3 to 22.46 %, the capability class is low due to absent of management coarse texture.

1.4. Sabkhas soils (SBS)

This mapping unit is covering about 409.31 km^2 i.e. 33.59 % of the total area and represented by profiles No. 11and 12. From the soil analysis shown in Tables (11, 12 and 13) the texture varied from sandy to silty loam, cation exchange capacity varied from 3.0 to 28.2 mq/100 g soil. Exchangeable sodium percentage (ESP) % values are high and varied from 20.0 to 42.9. The soil reaction (pH) values varied from 8.0 to 8.2. Electrical conductivity (EC) dS/m values are different from 12.1 to 85. Calcium carbonate content is varied from 9.6 to 55.0. Gypsum content is varied from 1.0 to 1.6. Organic matter content (OM) % is low and decrease with depth and deferent from0.1 to 0.6 in. Soluble cations values (mq/L) are $Na^+ > Ca^{++} > Mg^{++} > K^+$ (mq/L) while soluble anions (mq/L) values are $Cl^- > SO_4^{--} > HCO_3^- > CO_3^{--} >$ mq/L. Available macronutrients (NPK) (ppm) values are varied from K>P>N and K>N>P.

Table 11 : Some physical analyses of soil profiles No. 11 and 12

Profile No.	Depth cm,	Particle Size distribution				Texture Class	Exch. Na+ mg/100g.	CEC mg/100g soil.	ESP %
		Sand%		Silt & clay					
		C. Sand	F. Sand	Silt	clay				
11	0-25	13.0	20.0	38.0	29.0	Sandy clay loam	12.1	28.2	42.9
	25-50	13.5	7.6	53.0	26.0	Silty loam	10.2	25.3	40.3
	50-70	10.0	10.1	55.0	25.0	Silty loam	7.1	24.6	28.9
12	0-25	46.2	40.3	9.1	5.2	Sand	1.6	4.5	35.6
	25-50	44.0	50.2	3.0	3.5	Sand	0.6	3.0	20.0
	50-80	50.2	36.1	8.2	6.1	Sand	1.5	5.1	29.4

Table 12 : Some chemical analyses of soil profiles No. 11 and 12

Profile No.	Depth cm	pH	EC dS/m	Soluble cations (mqe/L)				Soluble anions (mqe/L)				$CaCO_3$ %	$CaSO_4$ %	OM %
				Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^-	HCO_3^-	Cl^-	$SO4^=$			
11	0-25	8.0	27.8	184.6	19.3	83.4	48.7	0	3.2	236.0	96.8	42.0	1.6	0.6
	25-50	8.0	35.6	259.9	17.7	70.0	88.0	0	3.2	335.0	97.4	55.0	1.0	0.3
	50-70	8.0	12.1	80.7	7.9	29.8	22.0	0	6.2	102.0	32.2	52.0	1.6	0.2
12	0-25	8.2	85.0	522.0	35.2	55.0	79.0	0	2.8	532.0	156.4	9.6	1.2	0.3
	25-50	8.1	38.0	274.8	50.4	66.0	61.0	0	1.6	242.0	208.8	34.0	1.6	0.2
	50-80	8.2	24.6	66.0	65.0	79.0	72.0	0	2.4	141.6	138.0	12.0	1.6	0.1

Table 13 : Available macronutrients of soil profiles No. 11 and 12

Profile No.	Depth	Available macronutrients (mg/kg)		
		N	P	K
11	0-25	9.7	10.2	130.0
	25-50	10.5	8.1	120.0
	50-70	8.9	9.3	105.0
12	0-25	19.7	10.1	130.0
	25-50	15.2	9.2	140.0
	50-80	3.5	6.1	40.0

The soils were classified as Calcic Aquisalids. Land capability class ranged between C4 (poor) and C6 (Non-agriculture) where the index ranged between 5.61 and 24.77, the loe of capability class referred to highly salinity.

1.5. Hummocks soils (HS)

This unit is covering about 56.04 km^2, i.e. 4.60% of the area represented by profiles No. 13, 14 and 15. The data shown in Tables (14, 15 and 16) indicate that the texture is sandy to sandy loam. Cation exchange capacity changed from 1.3 to 12.0 mq/100g soil. Exchangeable sodium percentage (ESP) ranged between 6.3 to 16.7 %. The soil reaction (pH) values varied from 7.2 to 8.3. Electrical conductivity values are varied from 2 to 101 dS/m. Calcium carbonate content varied from 6.7 to 12.5%. Gypsum is less than one percent. Organic matter content values are deferent from 0.1 to 0.7. Soluble cations are $Na^+ > Ca^{++} > Mg^{++} > K^+$ (mq/L) while soluble anions are $Cl^- > SO_4^- > HCO_3^- > CO_3^{--} >$ (mq/L). Available macronutrients are K>N>P.

Table 14 : Some physical analyses of soil profiles No. 13, 14 and 15

Profile	Depth cm	Particle Size distribution				Texture Class	Exch. Na+ mg/100g.	CEC mg/100g.	ESP %
		C. Sand %	F. Sand %	Silt %	clay %				
13	0-30	68.1	20.0	12.2	10.1	Loamy sand	0.6	9.2	6.5
	30-60	34.0	43.0	13.7	8.9	Loamy sand	0.5	8.0	6.3
	60-130	34.1	33.8	20.1	11.5	Sandy loam	0.5	3.0	16.7
14	0-25	25.1	43.9	20.0	11.4	Sandy loam	1.7	10.2	16.7
	25-40	26.5	46.0	8.0	12.1	Loamy sand	1.8	11.3	15.9
	40-80	48.2	30.1	9.0	12.5	Loam	2.0	12.0	16.7
	80-115	47.0	45.2	5.2	2.4	Sandy loam	0.5	3.1	16.1
15	0-25	46.5	30.5	11.2	12.0	Loamy sand	0.7	11.0	6.4
	25-50	48.0	43.1	5.6	3.6	Sand	0.3	2.6	11.5
	50-80	53.0	40.4	4.3	2.6	Sand	0.1	1.3	7.7

Table 15 : Some chemical analyses of soil profiles No. 13, 14 and 15

Profile No.	Depth	pH	EC dS/m	Soluble cations (mqe/L)				Soluble anions (mqe/L)				$CaCO_3$ %	$CaSO_4.H_2O$ %	OM %
				Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^-	HCO_3^-	Cl-	$SO_4^=$			
13	0-30	7,2	2.2	11.9	1.2	2.5	2.0	0	3.5	12.8	1.3	11.5	0.7	0.4
	30-60	7.7	2.4	8.8	1.1	3.6	5.0	0	4.2	8.1	6.2	12.1	0.8	0.3
	60-130	7.7	2.0	12.3	1.3	2.5	1.0	0	3.0	12.2	1.9	12.5	0.9	0.5
14	0-25	8.2	50.0	346.2	21.8	230.0	350.0	0	4.2	698.0	245.8	10.0	0.5	0.7
	25-40	8.1	51.0	247.0	14.6	139.0	209.0	0	2.5	438.0	169.1	7.0	0.5	0.1
	40-80	8.2	101.7	954.0	5.4	113.0	136.0	0	4.8	989.0	214.6	8.0	0.5	0.3
	80-115	8.3	26.4	102.2	67.8	69.8	64.9	0	4.4	149.2	151.2	9.0	0.5	0.1
15	0-25	8.2	3.5	17.2	1.2	8.4	7.2	0	3.3	27.8	2.9	8.1	0.6	0.5
	25-50	8.1	7.0	17.5	1.0	21.5	17.5	0	4.1	56,8	19.5	7.0	0.5	0.4
	50-80	8.1	3.0	2.6	0.9	4.5	2.6	0	2.8	21.5	2.7	6.7	0.5	0.3

Table 16 Available macronutrients of soil profiles No. 13, 14 and 15

Profile No.	Depth	Available macronutrients (mg/kg)		
		N	P	K
13	0-30	10.2	7.2	120.0
	30-60	8.9	6.1	115.0
	60-130	5.7	8.2	120.0
14	0-25	10.3	10.1	125.0
	25-40	11.2	11.2	115.0
	40-80	9.3	9.1	110.0
	80-115	7.1	8.2	100.0
15	0-25	10.5	8.5	120.0
	25-50	6.7	7.6	115.0
	50-80	3.8	6.1	100.0

The soils in this unit were classified as Typic Torripsamments, Typic Haplosalids and Typic Torrents. The land capability ranged between class 4 (poor) and class 6 (Non-agriculture) and final index ranged between 8.83 and 24.2. This refers to non-management practices and high salinity.

1.6. Footslope soil (FS)

This mapping unit is covering about 6.33 km2, 0.52% from the area and represented by soil profiles No. 16 and 17. From the soil profile description the land form is Mountain foot slope, slope of soil are ranged between Gently and nearly level, land use is none, Parent material is Aeolian and Colluvial deposits, drainage class is poorly, the depth of the soil profile is shallow because there is Limestone hard pans in 50 cm other sediments dolomite. From soil analysis shown in Tables (16, 17 and 18) clear that the texture class is sandy. Cation exchange capacity (CEC mq/100 g soil) varied from 2.1 to 3.6. Exchangeable sodium percentage (ESP %) are varied from 4.8 to 13.9. pH values varied from 7.9 to 8.1. Electrical conductivity (EC dS/m) values are different from 3.5 to 28.1. Calcium Carbonate content (CaCO3 %) values are varied from 15.5 to 21.3 %. Gypsum content (%) values are low than one. Organic matter content values are low in both profiles and varied from 0.1 to 0.5. Soluble cations (mq/L) values are deferent as Na^+> Ca^{++}> Mg^{++}> K^+ (mq/L), and soluble anions (mq/L) values are also varied as Cl-> SO_4^{--}> HCO_3^-> CO_3^{--} (mq/L). Available macronutrient are varied as K>N>P.

Table 16 : Some physical analyses of soil profiles No. 16 and 17

Profile No.	Depth cm	Particle Size distribution				Texture Class	Exch. Na+ mg/100g.	CEC mg//100g	ESP %
		Sand%		Silt & clay					
		C. Sand	F. Sand	Silt	clay				
16	0-25	78.0	13.0	5.5	3.5	Sand	0.3	2.9	10.3
	25-50	75.6	14.4	5.3	4.8	Sand	0.3	2.5	12.0
17	0-25	37.7	35.3	12.0	5.0	Sand	0.5	3.6	13.9
	25-50	60.5	23.3	6.3	3.2	Sand	0.1	2.1	4.8

Table 17 : Some chemical analyses of soil profiles No. 16 and 17

Profile No.	Depth cm	pH	EC dS/m	Soluble cations (mqe/L)				Soluble anions (mqe/L)				$CaCO_3$ %	$CaSO_4$ %	OM %
				Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^-	HCO_3^-	Cl^-	$SO4^=$			
16	0-25	8.0	3.5	11.0	1.6	12.3	9.1	0	2.0	21.0	11.0	15.5	0.5	0.5
	25-50	7.9	14.5	89.0	18.0	36.0	25.0	0	2.0	100.0	66.0	21,3	0.7	0.1
17	0-25	8.1	7.9	50.5	1.5	18.9	24.9	0	3.9	63.9	28.0	16.2	0.6	0.4
	25-50	8.0	28.1	220.8	3.9	50.8	69.9	0	2.3	2.3	340.7	15.9	0.7	0.3

Table 18 : Available macronutrients of soil profiles No. 16 and 17

Profile No.	Depth cm	Available macronutrients (mg/kg)		
		N	P	K
16	0-25	10.1	3.3	115.0
	25-50	10.2	5.1	212.0
17	0-25	6.2	2.1	120.0
	25-50	4.2	2.6	10.3

The soils were classified as Lithic and Duric Haplocalcids. Land capability ranged between class 4 (poor) and class 5 (very poor) where the decrement of land capability associated with miss-management, soil depth and coarse texture.

2. Soil map

Figure 4 illustrate the soil classification of the investigated area. It is clear that the sub greatgroups oriented as Typic Torripsamments, Calcic Aquisalids, Typic Haplosalids, Typic Haplocalcids, Gypsic Haplosalids, Typic Aquisalids, Lithic Haplocalcids & Duric Haplocalcids and Typic Psammaquents respectively.

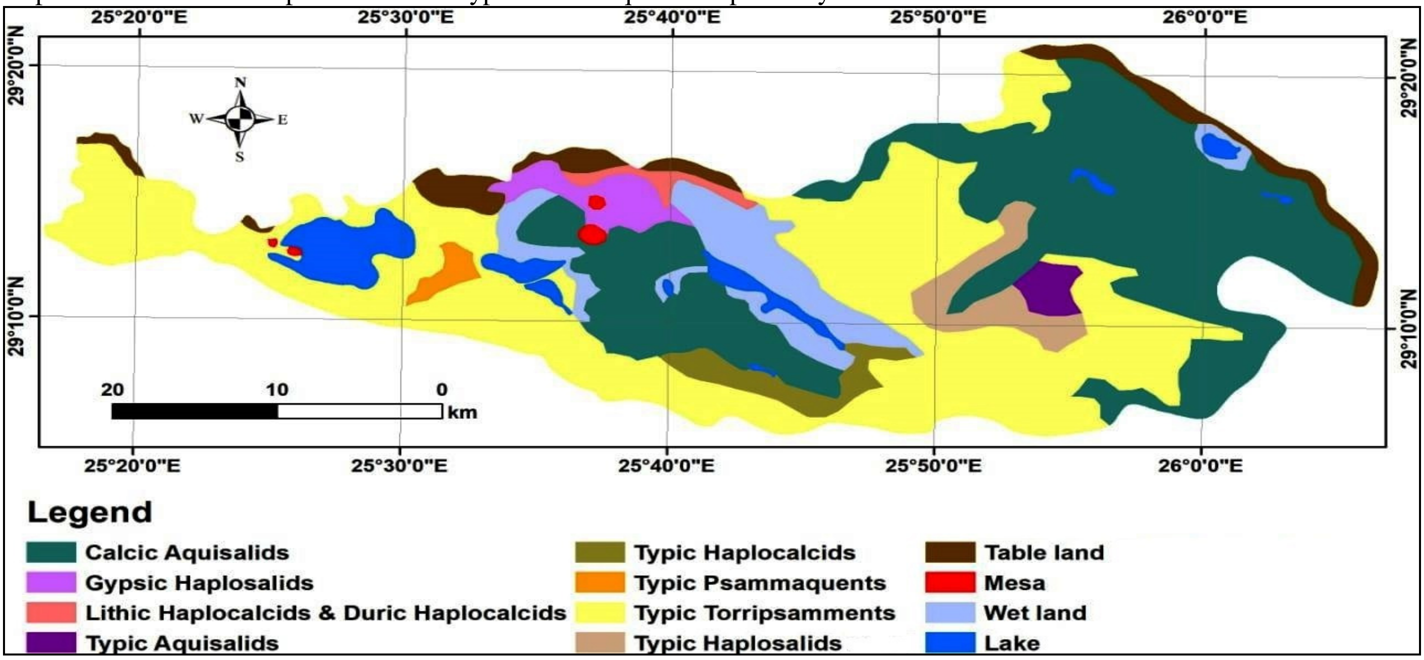

Fig. 4 : Soil map of the studied area

3. Soil Capability

The results showed that the land capability of the studied area ranged between class 3 (fair) and 5 (very poor) and the other soil profiles located low than class 5 of land capability. The highly capability class related to improved the management in soil fertility and soil texture as shown in Table (19) and Figure. (5)

Table 19 : Soil capability classes Siwa Oasis

Capability Class	Capability Index	Area (km^2)	Area (Fed)	Area (%)
Fair	<15	14.36	3424.27	1.18
Poor	15 – 24	228.13	54408.96	18.72
Very poor	24 – 40	736.35	175619.73	60.43
Non	> 40	239.75	57179.43	19.67
Total		**1218.58**	**290632.40**	**100.00**

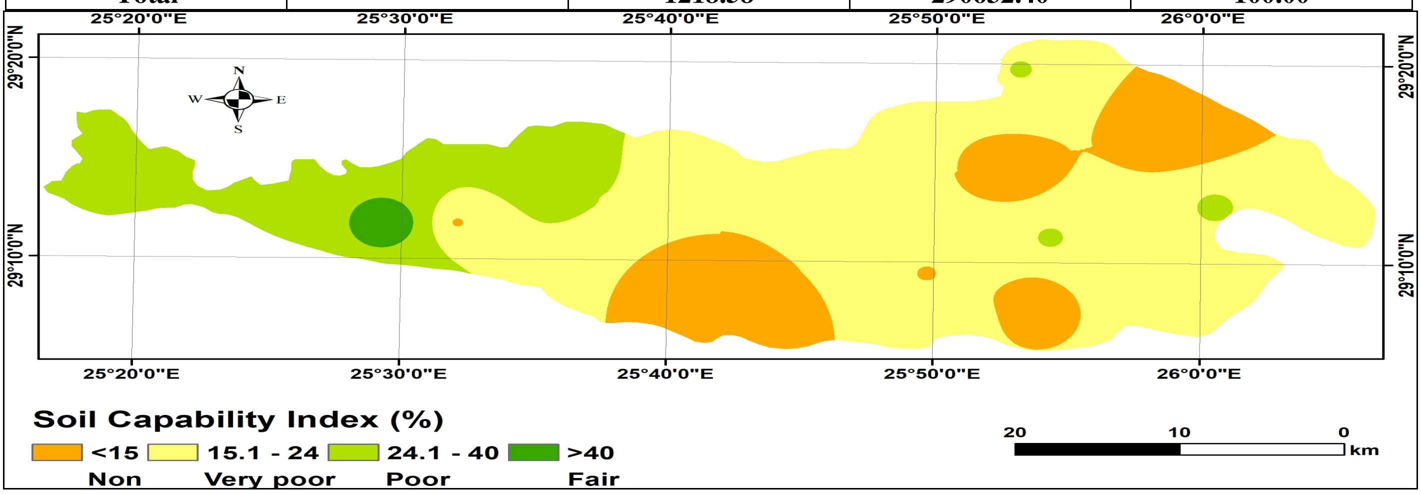

Fig. 5: Soil capability map of the studied area

4. Suitability classes at the studied area:

According to environmental requirements for selected 28 crops (wheat, barley, faba bean, sugar beet, sun flower, rice, maize, soya bean, peanut, cotton, sugar cane) as failed crop, (onion, cabbage, pea, potato, tomato, pepper, watermelon, alfalfa, sorghum) as vegetable and forage crops and (citrus, banana, grape, olive, apple, pear, figs, date palm) as fruit trees. The match between this crop requirements and soil characteristics at the studied area showed that the most suitable crops are cotton, date palm, olive, alfalfa, barley, wheat, maize, faba been, soya been, sugar beet, and citrus. The suitability of cabbage, onion, rice and banana is currently non suitable to permanently non suitable.

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