DELINEATION OF PHYSIOGRAPHIC-SOIL UNITS OF THE NORTH-EAST DESERT OUTSKIRT OF El-FAYOUM DEPRESSION AND ITS SOIL SUITABILITY FOR AGRICULTURAL UTILIZATION PURPOSES BY USING LANDSAT IMAGERY

Tolba S. Abdel Aal and Mohamed S.A. Ewees
Soils and Water Dept., Fac. of Agric., El Fayoum University, Egypt

Abstract

The north-east desert outskirt of El-Fayoum depression, Egypt, *i.e.,* adjacent to both sides of Cairo- El Fayoum desert road, Egypt, is considered a promising area for agricultural utilization as well as a model for representing some landscape features in the Western Desert, Egypt. So, it selected to be identified within the context of soil physiographic units, soil classification, land evaluation for agriculture-irrigated soils and their suitability for specific crops. The physiographic-soil units were identified by applying the guidelines of Landsat data ETM 7 (Enhanced Thematic Mapper 7) and the physiographic approach for the studied area that lies between latitudes 29° 34′ to 29° 45′ North and longitudes 30° 50′ to 31° 00′ East.

The physiographic-soil units, which occupied the studied area, were distinguished into desert sediments that were derived from the local parent rocks, *i.e.,* Piedmont (fan), Alluvial terraces (gently undulating), Depressed plain, Alluvial plain (locally terraced of moderate high terraces and relatively low terraces), Mesa, Hills, Questa, Rock outcrops and Wadies. Thirty-five mini pits were located and studied for setting up the physiographic boundaries and characteristic of soil map legend. Also, the variations of soil characteristics between the main identified physiographic units were represented by eleven soil profiles, which to be full morphologically described.

Soil taxa were surveyed according to the USDA (1975 and 2006), and could be categorized into two orders and nine families, as follows:

i) *Entisols:* include three families of *Typic Torriorthents, fine loamy, mixed, hyperthermic* (*i.e.,* Relatively moderate high hills), *Typic Torriorthents, sandy or clayey, mixed, hyperthermic* (*i.e.,* rock outcrops).

ii) *Aridisols:* include five families of *Typic Haplogypsids, fine loamy, mixed, hyperthermic* (*i.e.,* Gently undulating alluvial terraces), *Typic Calcigypsids, coarse loamy, mixed, hyperthermic* (*i.e.,* Relatively low terraces), *Leptic Haplogypsids, coarse loamy, mixed, hyperthermic* (*i.e.,* relatively low terraces), *Leptic Haplogypsids, sandy, mixed, hyperthermic* (*i.e.,* Wadies), *Leptic Haplogypsids, coarse loamy, mixed, hyperthermic* (*i.e.,* Realively low hills, Questa fronts and moderately high hills), *Leptic Haplogypsids, fine loamy, mixed, hyperthermic* (*i.e.,* Moderately high terraces) and *Gypsic Haplosalids, fine loamy, mixed, hyperthermic* (*i.e.,* Relativel low terraces).

The obtained results showed that the studied essential nutrient contents in the soil, either in total or available form, are markedly varied and depending upon the soil main characteristics. Hence, building simple correlation coefficients and stepwise were distinguished by aiding the program outlined by SPSS (2003) software to assess the different relationships between the studied soil variables and plant nutrient forms as well as to define the contribution percentages of soil constituents with either the studied total nutrient contents or the available fractions.

The soils of the identified physiographic units were evaluated to assess the supreme current and potential suitability for giving the maximum outputs. The current land suitability for agriculture-irrigated soils could be categorized into three suitability classes, *i.e.*, moderately suitable (S2), marginally suitable (S3) and not suitable (N), besides four subclasses (Ns_1s_2, $S3s_1$, $S2s_1$ and S2n) which are suffering from some soil properties {*i.e.,* soil texture (s_1), soil depth (s_2) and salinity/alkalinity (n)} as soil limitations with different intensity degrees (*i.e.,* moderate and severe). By applying the improvement practices for achieving the potential condition, the suitable classes would be become three, besides four subclasses (*i.e.,* S1, $S1s_1$, $S2s_1$ and $S3s_1s_2$). Also, soil suitability for some specific crops of cereal (*i.e.,* wheat, barley and maize), fodder (*i.e.,* alfalfa and sorghum) and vegetable or fruit (*i.e.,* tomato, citrus, mango, olive and palm) were presented for soils developed on the identified physiographic units as land suitability guide tables.

Keywords: El Fayoum Governorate, landsat imagery, soil taxa, land evaluation for agriculture-irrigated soils and for specific use of certain crops.

Introduction

The strategy of El Fayoum Government for the horizontal expansion in agriculture needs more suitable land resources than the currently exists. The north-east desert outskirt of a closed internal drainage Fayoum depression represents one of the main available land resources, due the supplementary irrigation water could be partly balanced by the reuse of drainage water of El Bats drain after mixing with the Nile water from Bahr Wahbey canal. In facts, **Ministry of irrigation (1977)** suggested that a part of the drainage water (about 0.75 x 10^9 m^3/year) could be reused for irrigation purposes to partially satisfy the crops demand to irrigation water. According to the national plan target in Egypt, the official drainage water reuse in all of the country, as targeted by the year 2017 is 8631x10^6 m^3/year **(National Water Resources Plan, 1999)**. Meanwhile, of which 396 x 10^6 m^3/year are targeted for reuse at the year 2007 and up to 2017 for El Fayoum Governorate. Actually, at the Bats mixing station, waters from Bahr Wahbey are mixed with waters from Bats drain to produce the blending water at Bats mixing station. Total salts of waters from Bahr Wahbey, Bats drain and Bats mixing station are 614.4, 1292.8 and 1132.8 mg L^{-1}, respectively **(El Shakweer and Abdel Hafeez, 2008**). Different efforts aimed to introduce more suitable mixed irrigation water for the reclaimed soil types in El Fayoum under the prevailing climatic factors and crop patterns.

The area of Egypt is about one million km^2 (238 million faddans), of which only about 4% is cultivated. Reclamation and utilization of the desert areas of siliceous and calcareous in nature is the only hope for overcome the agriculture needs. Space images proved to be a useful tool of reconnaissance inventories for large area of many types of landscapes. Also, Landsat Imagery has been widely accepted as a basis for soil surveys at small scales **(Myers, 1975)**. Furthermore, its use has been successfully demonstrated in delineating soil associations on the landscape **(Worcester & Moore, 1978 and Westin & Frazee, 1976)**. **Siegal and Abrams (1976)** concluded that Landsat data were useful for mapping major geomorphic units. **Sanchyn and Trench (1978)** determined, however, that for detailed studies of slope stability, Landsat data were only marginally useful.

As for soil fertility aspects, **Abdel Nasser *et al.* (2010)** found that the essential plant nutrient contents of the soil, either in total or available forms, are markedly varied and depending upon the soil genesis status. Consequently, the essential plant nutrient contents in the soil are more related to the inherited main soil characteristics which are exhibited widely variations. Hence, it should be recommended that a geographic database should be building to assess the different relationships between soil variables and plant nutrients as well as whether as the contribution percentages of soil constituents with either total nutrient contents or the available nutrient fractions.

Data of the current study were created to support the local knowledge, specially the best use of land whether be under demand for agriculture use or be planned for later on use at some areas at the northern-east desert outskirt of El Fayoum Governorate. That means the aim of this study is to identify the physiographic features of a unique area in the Western Desert of Egypt by mapping them to be a digital model in a harmony of physiographic units and soil data set, and in turn serving the extrapolation approach when other areas will be under study. Also, it is executed for finding the best adaptation between certain land units with specific crop to give the maximum outputs For this purpose, the harmony of descriptive and processing systems, established by **Sys and Verheve (1978), Sys (1991) and Sys *et al*. (1993)** were considered, being highly required in this study.

Materials and Methods

Image interpretation:

Space images interpretation performed using the physiographic analysis as proposed by **Burnigh (1960) and Gossen (1967)**. Landsat Image composite of Enhanced Thematic Mapper (ETM7) with bands 2, 3 and 4 was used to add an extra landscape assessment to the photo-interpretation map. The image was helpful for getting a collective overall view of the studied area as well as using the spectral signatures of the used bands in detecting the cultivated areas and drainage conditions.

Visual analysis of landsat TM5:

The overall view for delineating the promising areas at the northern-east desert outskirt of El Fayoum Governorate is characterized by the spectral signatures of an Orthorectified Landsat Thematic Mapper (TM 5) Mosaic. It is a composite of the bands 4, 3 and 2. The pixel size is a mixture of 28.5 and 30.0 meters. The composite output was of benefit, especially when focusing on the infrared bands that permit the detection and discrimination of broad combinations of different vegetation cover types and identification of water bodies, active drainage, drainage conditions, cultivated areas, and rock types.

The images of Landsat 5 Thematic Mapper (TM) were used for the detailed physiographic analysis for modeling the study areas. This Landsat 5 was acquired during the year 2005 (path 175 rows 42, resolution 28.5 to 30 m). The Thematic Mapper of this Landsat is operating in eight spectral bands. The images are considered as a source of recent information that can be aimed at transferring the recent or modified infrastructures to the maps during the phase of cartography.

Fieldwork:

The preliminary image-interpretation map was checked in the field to confirm the boundaries of the physiographic units or to revise what were shifted. Soil profiles representing the predominant characteristics of the identified physiographic units of the studied area were taken, however, eleven soil profiles were dug to a depth of 150 cm or lithic contact and their locations are shown in Fig. (1).

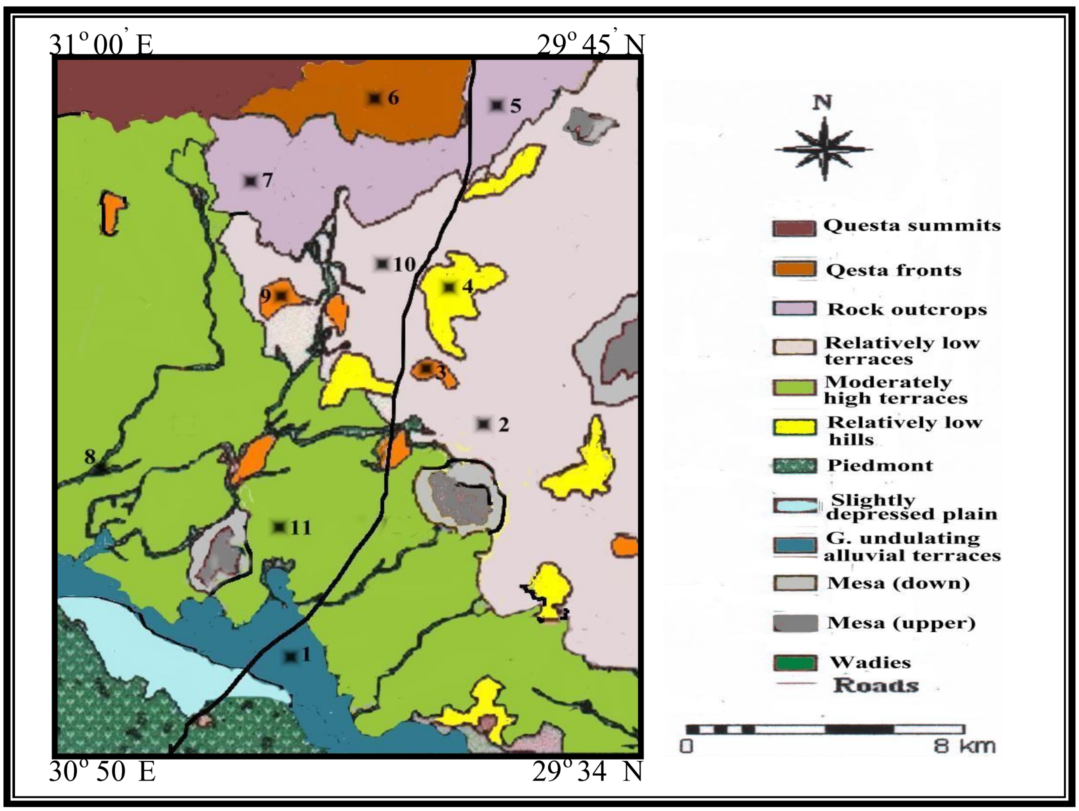

Fig. (1): Physiographic units map and locations of the studied soil profiles.

Soil profiles were described, using the nomenclature of the Soil Survey Division Staff Manual **(USDA, 2003)**. Soil samples were air dried, crushed, with wooden hammer, sieved through a 2 mm sieve to obtain the fine earth used for physical and chemical analysis. The elements of soil color description, *i.e*., the colour name and notations were determined using the **Munsell Soil Colour Chart (1975)**.

Laboratory analyses:

Particle size distribution was determined using the International Pipette method **(Gee and Bauder, 1986)** and sodium hexametaphosphate as dispersing agent **(Baruah and Barthakur, 1997)**. Calcium carbonate content was measured using the Collin's Calcimeter method **(Wright, 1939)**. Gypsum was determined by the acetone method **(Bower and Huss, 1948)**. Saturation soil paste extract, soil pH in the soil water suspension of 1:2.5 and soil organic matter content were determined according to the methods describe by **Jackson (1973)**. Cation exchange capacity and the exchangeable sodium were determined according to the methods describe by **Richards (1954)**.

Total contents of N, P, K, Fe, Mn, Zn and Cu were determined in the digested soil samples **(Hesse, 1971)**. Total contents of N was determined using Kjeldahl method **(Jackson, 1973)**, P **(Houba *et al*., 1995)**, K (Flame Spectro-Photometer), Fe, Mn, Zn and Cu (Atomic Absorption Spectro- Photometer, model GBC 932). Available macronutrients of N, P and K in soil were extracted by 1 % potassium sulphate, 0.5 M sodium bicarbonate and 1 N ammonium acetate, respectively **(Soltanpour and Schwab, 1977)** and their contents in soil were determined according to **Jackson (1973)**. Available micronutrients of Fe, Mn, Zn, and Cu in soil were extracted using DTPA according to **Follet and Lindsay (1971) and Lindsay and Norvell (1978)**. These micronutrients were also determined by using Atomic Absorption Spectro-photometer. The obtained results of the different soil properties and nutrients status were statistically analyzed by using the program outlined by **SPSS (2003)** software to distinguish the possible statistical relationships, *i.e.,* simple correlations and a stepwise regression between both total and available nutrient contents vs the different studied soil characteristics to define the significance of these relationships and the contribution percentages of soil constituents with either the studied total nutrient contents or the available nutrient fractions.

Soil classification and evaluation:

The studied soils were classified according to the guidelines of Soil Taxonomy System **(USDA, 1975)** and its keys **(USDA, 2006)**. Soils under investigation were evaluated using the parametric system undertaken by **Sys and Verheye (1978)**. Land suitability classification for specific crops was done according to **Sys *et al* (1991) and Sys *et al.* (1993)**, by matching the land characteristics with the crop requirements.

Results and discussion

I. A general view on the physiographic-soil units:

Physiographic-soil legend has been set up as shown in Fig. (1), which associated with the morphological description of the representative soil profiles, Table (1). The identified physiographic-soil units were Landsat Imagery delineated in the desert formation, *i.e.*, Piedmont (fan), Alluvial terraces (gently undulating), Depressed plain, Alluvial plain (locally terraced of moderate high terraces and relatively low terraces), Mesa, Hills, Questa, Rock outcrops and Wadies. These desert formations under investigation represent the desert outskirts adjacent to El-Fayoum north-east area, El Fayoum Governorate, Egypt. In general, these virgin desert outskirts have a topography of the landscape is almost flat to gently undulating with level to gently sloping, deflated or denuded surface. The soil surface is therefore covered with drift sand or varnished gravels, or both. The soil texture throughout the entire depth of soil profiles is variable according to the sediment origins*, i.e*., in situ eroded limestone at the north-eastern rim of El Fayoum depression.

A weak evidence of soil development is exhibited in some soils developed on these physiographic units, *i.e.,* secondary formations of gypsum and $CaCO_3$ vary widely from few to many in forms of soft fine crystals, calcic nodules or segregations and concretions. It is noticed that an accumulation of gypsum in some surface or subsoil layers could be mixed or over lined by accumulation zone of salts in the forms of sali-gypsic concretions, as shown in some soil sites of alluvial landscape (Terraces). In general, the occurrence of these secondary formations (*i.e.,* $CaCO_3$, gypsum and salts) within the soil profile layers reflects to great extent, its formation mode under the prevailing environmental conditions.

A brief note about the identified physiographic units, which are occupied the previous desert formations in the studied area, was carried out as follows:

i. Miscelaneoud landtypes:

These structures are divided into two physiographic units, *i.e.,* Questa that represents the remnants of a structural plateau, subjected to severe dissection resulting in a rocky structure. This physiographic unit could divided into two sub-units, *i.e.,* a) *Questa* that includes *Questa summit* (original elevation of the limestone body before the dissection processes) and *Questa fronts* (rocky slopes covered by talus and pediments with a complex pattern of steep and rolling concave convex surfaces) and b) *Rock outcrops* which are found as isolated local structures that are mostly located in the pediplain.

ii) Piedmont:

This unit is a depositional fan in the studied area along the elevated rock structures. It is broad and gently inclined, alluvial landscape slope extending from the base range out into a relatively low basin east and north-eastwards. Soil surface is gullied, gently sloping and well drained. The representative soils are more developed, being with gypsic horizon (By).

iii. Alluvial plain, locally terraced:

The area of this physiographic-soil unit occupied a relatively large area and divided intro tow sub-units, *i.e.,* moderately high terraces and relatively low terraces, and it extends as a parallel zone towards the eastern portion of the investigated area. This unit is characterized by the depositional deposits of weathered limestone. The representative area has been artificially modified in order to change the landscape into depressed terraces. Also, this unit has topographic landscape of almost flat to either slightly or gently undulating.

iv. Relatively developed slightly depressed plain:

The polygons of this unit occupy the north area of the Piedmont as slightly depressed spots, which are most probably representing an old erosional bed of decayed water erosion in the fluvial period. The soils are suffering from salinity condition.

v. Gently undulating alluvial terraces:

This physiographic unit was formed under the prevailing aridic conditions through an action of physical weathering processes on the limestone parent rock. This unit has gently undulating topography to gently sloping, somewhat gravely or stony surfaces and including well drained soils. Its landforms are the remnants of weathered limestone rock, including residual parent material over limestone lithic contact.

vi. Wadies:

The surface of Wadies is almost flat, partly vegetated with very open zerophytic herbaceous as natural vegetation on well drained soils. This physiographic unit is the resultant of dissection action of the surrounding landscape as the interaction of erosional and depositional processes in the fluvial period. They appear as dry Wadies that seasonally receive flush flooding and running from northern-east. The soils of these wadies occur in a complex pattern and dominated by two contrasting particle size classes within the control section, sandy the upper part and loamy sands in the underlying one.

vii. Hills:

The parent material of this physiographic unit is derived from either marine deposits intercalated with marl or shallow marine limestone and shale. This unit randomly isolated structures on the margins of the studied, immediately bordering the southern half area. It is most probably that, these hill deposits are covering an old rock bed that was naturally eroded. This unit is locally occurred as scattered dunes have two elevations, *i.e.,* Relatively low and moderately high hills.

viii. Mesa:

This physiographic unit is found as isolated randomly distributed local structures, that are mostly rock remnant like desert table due to the relatively hardness of the uppermost rock structures underlain ones able to be eroded by wind.

II. Soil morphology:

The representative soil profiles for the identified physiographic units were morphologically described according to the nomenclature of **USDA (2003)** and the **Munsell Colour Chart (1975)**, as shown in Table (1).

Table (1): Morphological features of the studied soil profiles.

Physiographic unit	Profile No.	Slope gradient	Horizon	Depth (cm)	Soil colour	Modified texture class	Soil structure	Soil consistency
Alluvial Terraces	1	Gently undulating	A	0-30	10YR8/4d	SL	Massive	Soft
			By	30-75	10YR7/6d	SCL	Granular	Slightly hard
			C_1	75-100	10YR7/4d	SL	Massive	Slightly hard
			C_2	100-150	10YR7/6d	SCL	Crumb	Slightly hard
Relatively Low Terraces	2	Almost flat	ABy	0-50	10YR7/6d	LS	Massive	Slightly hard
			By	50-90	10YR7/4d	SL	Crumb	Slightly hard
			Bk	90-150	10YR7/4d	SCL	Mmsbk	Hard
Relatively Moderate High Hills	3	Gently undulating	A	0-50	10YR7/4d	SCL	Massive	Slightly hard
			C_1	50-110	10YR8/4d		Mmsbk	Hard
			C_2	110-150	10YR7/4d		Mmsbk	Hard
Moderately Low Hills	4	Undulating	ABy	0-40	10YR7/6d	SL	Massive	Loose
			C_1	40-75	10YR7/6d	SL	Massive	Slightly hard
			C_2	75-150	10YR7/6d	SCL	Mmsbk	Hard
Rock outcrops	5	Very gently sloping	C1	0-15	10YR7/4d	G SL	Massive	Slightly hard
			C2	15-70	10YR7/6d	G LS	Single grain	Loose
			C3	70-110	10YR6/6d	SG LS	Single grain	Slightly hard
Questa fronts	6		ABy	0-35	10YR7/6d	G LS	Single grain	Loose
			C	35-75	10YR8/4d	SG SL	Granular	Slightly firm
Rock outcrops	7	Undulating	A	0-40	10YR7/6d	G SCL	Massive	Very friable
			C	40-90	10YR5/4d	C	Cstsbk	Very hard
Wadies	8	Almost flat	ABy	0-25	10YR7/6d	LS	Single grain	Loose
			By	25-100	10YR6/6d	LS	Crumb	Friable
			C	100-150	10YR7/4m	SL	Massive	Slightly hard
Moderately High Hills	9	Very gently sloping	ABy	0-35	10YR7/6d	SL	Massive	Slightly hard
			By	35-80	10YR7/6d	SL	Massive	Slightly hard
			By	80-150	10YR8/4d	SCL	Mmsbk	Hard
Relatively Low Terraces	10	Gently undulating	A	0-30	10YR7/4d	SCL	Massive	Friable
			By	30-100	10YR8/4d		Mmsbk	Hard
			By	100-150	10YR7/6d		Mmsbk	Hard
Moderately High Terraces	11		ABy	0-25	10YR7/6d	SL	Massive	Friable
			By	25-90	10YR8/4d	SCL	Mmsbk	Hard
			By	90-130	10YR7/6d	SL	Mmsbk	Hard

Soil colour: d=Dry ***Soil texture class:*** *fine earth*: LS=Loamy sand, SL=Sandy loam, SCL=Sandy clay loam and C=Clay *Gravel*: SG=slight gravelly, G=Gravelly.
Soil structure: Mmsbk=Medium moderate subangular blocky, Cstsbk=Coarse strong subangular blocky.

Soil profile, as a soil section controlled by the morphological features of its horizons, is reliable for several modifications through various environmental conditions. Field work shows that the studied soil profiles developed on physiographic-soil units have topographic features characterized by almost flat, gently undulating, undulating and very gently slopping. The effective soil depth was 150 cm, except some areas had moderate depth due to the existence of bedrock at a depth of 90-130 cm such as in cases of Questa fronts, Rock outcrops and moderately high terraces. Exceptional of some areas characterized by a relatively coarse texture grade (loamy sand to sandy loam), *i.e.,* Rock outcrops, Questa fronts and Wadies, in general, the majority of studied soils having a medium texture grade.

The secondary formations of $CaCO_3$, as soft and hard lime nodules or accumulations, are found in subsoil layers of soil profile No. 2 (relatively low terraces), and its content is enough to the requirements of calcic horizon. In addition, some secondary formations of gypsum segregations occurred in most of the studied soil profiles, *i.e.,* 1, 2, 4, 6, 8, 9, 10 and 11, and their contents are enough to the requirements of gypsic horizon. Also, subsoil salty accumulations are characterized the studied soil profile No. 10, which is developed on the physiographic unit of Relatively low alluvial terraces, and their contents are enough to the requirements of salic horizon.

The signs of both the prevailing environmental conditions and soil genesis played an important role for identifying soil structure, which is considered as a function of soil physico-chemical properties, from single grain to massive, moderate granular or crumb, in addition to another type of moderate medium sub-angular blocky to coarse strong sub-angular blocky. The occurrence of the diagnostic horizons of calcic, gypsic and salic horizons could be taken into account to minimize soil development degree. Whereas, the undeveloped conditions of soil profiles in another soil sites are mainly related to the youngest soil materials or undeveloped soil profiles.

II. Physico-chemical properties:

It could be concluded from the obtained data, Table (2), that increasing soil fine particles is coupled with increasing the intensive chemical weathering that were prevailed in the ancient periods for these desert formations.

Table (2): Some main physico-chemical properties of the studied soil profiles.

Profile No.	Soil depth (cm)	Gravel %	Soil depth (cm)	Particle size distribution %				Texture class*	Organic matter %	$CaCO_3$ %	Gypsum %	CEC, (Cmolc kg^{-1})
				Coarse sand	Fine sand	Silt	Clay					
1	0-30	--	0-30	41.75	28.17	6.00	24.08	SL	0.19	3.37	1.09	16.88
	30-75	--	30-75	43.66	21.75	11.22	23.37	SCL	0.15	1.58	7.50	15.53
	75-100	--	75-100	45.95	17.86	22.75	13.44	SL	0.11	1.85	2.37	8.56
	100-150	--	100-150	51.17	14.87	10.65	23.31	SCL	0.09	1.58	1.90	15.50
2	0-50	--	0-50	59.91	17.88	13.98	8.23	LS	0.23	10.34	6.74	5.96
	50-90	--	50-90	53.65	14.37	17.31	14.67	SL	0.14	12.97	6.63	9.18
	90-150	--	90-150	41.99	23.68	11.47	22.86	SCL	0.10	18.55	2.86	15.77
3	0-50	--	0-50	39.88	26.59	12.55	20.98	SCL	0.13	4.85	4.26	14.33
	50-110	--	50-110	45.44	19.99	13.23	21.34		0.08	7.07	3.21	13.51
	110-150	--	110-150	41.91	23.97	11.99	22.13		0.06	7.80	3.48	15.91
4	0-40	--	0-40	44.57	19.68	21.91	13.84	SL	0.15	9.39	7.33	8.76
	40-75	--	40-75	41.88	21.64	19.99	16.49		0.13	6.96	3.53	10.09
	75-150	--	75-150	49.29	15.55	12.98	22.18	SCL	0.11	6.22	1.39	15.93
5	0-25	27.9	0-25	49.58	21.87	17.89	10.66	G SL	0.09	3.80	3.49	7.17
	25-85	21.5	25-85	66.58	14.25	10.20	8.97	G LS	0.08	3.59	3.24	6.33
	85-110	9.8	85-110	65.58	14.35	11.58	8.49	SG LS	0.05	2.43	2.38	6.09
6	0-60	30.7	0-35	66.89	16.57	9.55	6.99	G LS	0.10	4.85	6.84	5.34
	60-75	10.2	35-75	27.23	40.35	20.16	12.26	SG SL	0.07	1.32	4.36	10.97
7	0-40	18.4	0-40	49.88	13.35	11.17	25.60	G SCL	0.22	1.05	2.35	17.64
	40-90	--	40-90	21.04	9.86	23.15	46.63	C	0.37	0.95	3.12	35.16
8	0-25	--	0-25	70.98	14.21	6.88	7.93	LS	0.24	3.95	12.55	5.81
	25-100	--	25-100	67.25	16.00	6.12	10.63	LS	0.16	4.06	10.33	7.16
	100-150	--	100-150	45.99	21.48	27.09	5.44	SL	0.14	5.22	5.32	4.56
9	0-35	--	0-35	46.23	19.45	23.31	11.01	SL	0.17	12.31	8.68	7.35
	35-80	--	35-80	51.68	15.57	19.99	12.76		0.13	8.44	15.32	8.22
	80-150	--	80-150	47.77	17.50	12.74	21.99	SCL	0.12	11.04	11.97	14.84
10	0-30	--	0-30	15.38	31.22	25.87	27.53	SCL	0.21	1.58	4.95	19.61
	30-100	--	30-100	55.88	12.55	9.99	21.58		0.18	1.05	7.21	14.63
	100-150	--	100-150	51.75	16.70	9.15	22.40		0.14	1.00	16.18	15.04
11	0-25	--	0-25	44.35	25.55	19.97	10.13	SL	0.17	4.22	9.01	6.91
	25-90	--	25-90	46.88	17.88	13.26	21.98	SCL	0.13	2.64	12.63	14.83
	90-130	--	90-130	49.68	21.88	17.28	11.16	SL	0.09	1.58	17.07	7.42

**Fine earth:* LS=Loamy sand, SL=Sandy loam, SCL=Sandy clay loam, C=Clay Gravel: SG=Slight gravelly G=Gravelly

Also, a parallel increase in the values of cation exchange capacity proportionally related to the relatively fine texture. In addition, most of the studied soils are suffering from salinity conditions, Table (3), except of some scattered areas that are slightly-moderately saline, *i.e.,* profile Nos. 1 (Alluvial terraces) and 5 (Rock outcrops). Such salinity conditions are probably due to the inherited salts that resulted from intensive chemical weathering and enhanced their accumulations as the excess salts.

Table (3): ESP, pH and chemical analysis of paste extract for the studied soil profiles.

Profile No.	Soil depth (cm)	ESP	Soil pH (1:2.5)	ECe, dS/m	Cations (mmolc L^{-1})				Anions (mmolc L^{-1})		
					Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{--}
1	0-30	9.75	7.74	11.75	24.77	17.68	85.34	0.23	3.20	86.70	38.11
	30-75	11.47	7.60	6.24	15.78	10.12	43.29	0.11	4.88	36.76	25.67
	75-100	10.88	7.75	10.26	28.35	8.10	70.50	0.26	4.75	60.18	42.27
	60-150	11.50	7.90	7.95	27.92	5.52	50.68	0.19	3.56	45.90	34.85
2	0-50	9.84	7.45	41.08	181.68	29.20	294.92	0.65	4.99	387.60	113.86
	50-90	10.02	7.50	44.02	151.95	42.37	319.55	0.48	4.63	291.70	218.04
	90-150	9.55	8.15	42.81	143.74	31.57	310.83	0.51	3.26	272.30	211.10
3	0-50	11.67	7.65	26.05	86.97	14.65	181.89	0.22	3.25	200.88	80.59
	50-100	10.56	7.70	16.64	52.88	11.60	120.78	0.21	3.88	137.68	43.92
	100-150	8.94	7.80	44.53	154.87	18.69	323.29	0.47	3.00	296.76	197.56
4	0-40	6.22	7.90	8.21	22.67	11.13	55.61	0.11	3.38	66.3	19.85
	40-75	7.84	7.78	22.14	75.35	13.15	160.71	0.34	4.50	144.84	100.21
	75-150	8.07	7.75	31.49	127.90	23.24	228.61	0.38	3.56	229.50	147.06
5	0-25	9.56	7.54	14.18	50.05	13.15	102.97	0.21	4.88	119.34	42.16
	25-85	6.11	7.60	3.57	27.90	4.07	25.91	0.13	4.13	18.36	35.53
	85-110	5.34	7.65	4.28	33.22	6.04	31.08	0.10	3.75	16.32	50.37
6	0-35	7.13	7.50	11.08	43.74	14.65	80.42	0.18	4.25	88.72	46.01
	35-75	9.37	7.79	86.83	228.55	217.93	830.50	0.86	3.50	713.84	560.20
7	0-40	12.15	7.45	40.76	135.75	19.20	295.88	0.51	3.75	325.32	122.27
	40-90	13.39	7.52	67.18	145.83	63.08	487.74	0.70	3.00	522.18	172.17
8	0-25	10.57	7.35	39.90	130.58	44.45	289.65	0.35	3.50	390.64	70.89
	25-100	9.67	7.40	51.65	123.80	85.90	374.99	0.65	3.75	537.54	44.05
	100-150	11.74	7.56	18.12	54.59	14.65	131.58	0.23	3.63	163.16	34.24
9	0-35	8.96	7.45	40.55	217.98	105.75	488.50	0.82	3.88	571.90	237.28
	35-80	11.38	7.37	28.66	97.68	33.84	223.50	0.39	3.50	270.22	81.69
	80-150	10.89	7.40	11.51	40.05	15.66	84.00	0.27	3.25	101.96	34.77
10	0-30	9.44	7.55	74.75	217.09	103.73	542.50	0.88	3.25	578.20	282.75
	30-100	11.07	7.45	103.99	293.76	178.29	798.50	0.95	3.50	727.24	540.76
	100-150	10.61	7.35	148.01	647.12	238.67	1074.50	1.80	3.13	1116.88	840.09
11	0-25	11.08	7.49	75.33	214.08	96.03	546.90	0.89	3.75	588.48	265.67
	25-90	9.82	7.43	44.96	195.67	14.65	326.40	0.62	3.38	327.38	206.60
	90-130	10.01	7.30	42.14	123.45	44.84	305.91	0.58	3.00	334.38	137.40

The distribution pattern of soluble cations in the studied soils are, in general, followed the descending order of $Na^{+} > Ca^{2+} > Mg^{2+} > K^{+}$ vs the soluble anions of $Cl^{-} > SO_4^{2-} > HCO_3^{-}$, indicating that NaCl is the dominant salt, Table (3). It is noticed that soil sodicity (ESP) was more associated with the texture grade and the nature of soluble salts, however, the studied soils are mostly classified as non-alkaline, as shown in Table (2). Soil $CaCO_3$ is generally found in relatively low-moderate content in the most of the studied localities, except soil site Nos. 1, 4 and 9. The later cases are attributed with the $CaCO_3$ enriched deposits that were originated from the Eocene limestone of the Eastern Plateau.

III. Soil Taxonomy:

By applying the guidelines of USDA System (1975) and updated Taxonomic Key (2006) as well as soil morphological, physical and chemical data, which are presented in Tables (1, 2 and 3), it could be classified the studied soil profiles into two orders, *i.e.*, Entisols and Aridisols as well as their followed sequence classification levels up to family one (nine families), as follows and shown in Table (4).

Table (4): Soil taxonomic units of the studied soil profiles.

Order	Sub-order	Great group	Sub-group	Family	Physiographic unit	Representative soil profile
Entisols	Orthents	Torriorthents	Typic Torri-orthents	Fine loamy, mixed, hyperthermic	Relatively moderate high hills	3
				Sandy, mixed, hyperthermic	Rock outcrops	5
				Clayey, mixed, hyperthermic		7
Aridisols	Gypsids	Calci-gypsids	Typic Calci-gypsids	Coarse loamy, mixed, hyperthermic	Relatively low terraces	2
		Haplogypsids	Typic Haplo-gypsids	Fine loamy, mixed, hyperthermic	Alluvial terraces (gently undulating)	1
			Leptic Haplogypsids	Coarse loamy, mixed, hyperthermic	Relatively low hills	4
					Questa fronts	6
					Moderately high hills	9
				Sandy, mixed, hyperthermic	Wadies	8
				Fine loamy, mixed, hyperthermic	Moderately high terraces	11
	Salids	Haplo-salids	Cypsic-Haplo-salids	Fine loamy, mixed, hyperthermic	Relatively low terraces	10

Soil taxa of the identified two orders and the sequence taxonomic levels up to family could be summarized as follows:

i) *Entisols:* include three families of *Typic Torriorthents, fine loamy, mixed, hyperthermic* (*i.e.*, Relatively moderate high hills), *Typic Torriorthents, sandy or clayey, mixed, hyperthermic* (*i.e.,* rock outcrops).

ii) *Aridisols:* include five families of *Typic Haplogypsids, fine loamy, mixed, hyperthermic* (*i.e.*, Gently undulating alluvial terraces), *Typic Calcigypsids, coarse loamy, mixed, hyperthermic* (*i.e.*, Relatively low terraces), *Leptic Haplogypsids, coarse loamy, mixed, hyperthermic* (*i.e.*, relatively low terraces), *Leptic Haplogypsids, sandy, mixed, hyperthermic* (*i.e.*, Wadies), *Leptic Haplogypsids, coarse loamy, mixed, hyperthermic* (*i.e.*, Realively low hills, Questa fronts and moderately high hills), *Leptic Haplogypsids, fine loamy, mixed, hyperthermic* (*i.e.*, Moderately high terraces) and *Gypsic Haplosalids, fine loamy, mixed, hyperthermic* (*i.e.,* Relativel low terraces).

***IV. Soil nutrients status*:**

a. Total nutrient contents:

The greatly wide differences in soil characteristics are more related to their various origins represent a typical model to asses the relation between the nature of soil sediments and plant essential nutrients status under the prevailing environmental conditions, in either total or available contents. Data in Tables (2 and 5) show that soil texture as a soil permanent character is greatly affects the total nutrient contents through the distribution pattern of nutrient-bearing minerals, however, their assemblages achieved a wide variation throughout the soil mechanical fractions. That is true, since there are a more evidence for dominated minerals in each soil mechanical fraction and their supplying power for the released nutrients **(Abdel Nasser *et al.*, 2010)**. Accordingly, the soils that developed on a relatively fine texture that are considered of higher potentiality to release total nutrient contents comparable with those are developed on the relatively coarse ones, followed by desertic formations either calcareous or siliceous in nature, respectively.

Table (5): Total nutrient contents of the representative soil sites.

Soil site No.	Depth (cm)	Macronutrients (mg kg^{-1})			Micronutrients (mg kg^{-1})			
		N	P	K	Fe	Mn	Zn	Cu
1	0-30	156.7	310.2	9612.4	15987.8	139.5	57.9	44.7
	30-75	138.9	275.8	8564.2	14835.4	124.7	51.8	39.6
2	0-50	62.3	120.4	3762.5	6543.7	55.6	23.4	18.2
	50-90	104.4	210.7	6512.8	11305.9	95.4	38.7	30.1
3	0-50	135.6	265.9	8204.2	14198.5	120.3	50.6	38.0
	50-100	140.0	275.7	8546.0	1504.6	125.5	53.0	40.5
4	0-40	107.5	215.8	6575.5	11618.7	98.9	39.8	32.5
	40-75	117.8	235.9	7202.6	12510.8	105.7	44.5	33.0
5	0-25	84.3	165.5	5132.5	8891.3	75.5	32.3	24.2
	25-85	67.2	134.8	4107.7	7164.1	60.4	26.1	18.7
6	0-35	55.6	110.4	3415.5	5934.2	49.7	20.9	15.6
	35-75	95.2	190.8	5796.8	10102.4	85.5	36.3	27.1
7	0-40	162.4	325.6	9965.9	17254.8	145.3	61.6	46.2
	40-90	290.1	5784.0	17810.3	31058.4	260.4	110.8	83.0
8	0-25	54.7	109.3	3524.2	6040.7	51.2	21.1	16.5
	25-100	74.8	140.9	4457.5	7698.9	65.6	26.9	20.8
9	0-35	96.5	185.8	5796.9	10102.4	86.9	35.5	27.2
	35-80	97.3	190.5	5984.5	9987.6	84.4	33.1	25.4
10	0-30	173.2	389.5	10902.3	21085.4	175.2	74.8	54.3
	30-100	140.4	280.7	8645.6	15025.7	129.5	53.7	42.0
11	0-25	86.5	170.2	5098.0	9074.8	77.3	35.6	26.9
	25-90	145.8	294.4	8597.8	14982.9	131.2	55.0	43.5

b. Available nutrient contents:

The obtained data of either macronutrient of N, P and K or the DTPA chemically extractable of micronutrients Fe, Mn, Zn and Cu, Table (6), are confirmed the aforementioned trend of the total nutrient contents in the studied soils that are developed on the different soil deposits under consideration. Nevertheless, the unsuitable soil conditions of air-moisture regime, salinity, sodicity, high pH, high $CaCO_3$ content, low organic matter content, relatively coarse texture of low nutrient-bearing minerals, narrow available water range and inhibitive act of biological activity. Such adverseable conditions could have pronounced negatively effects on nutrients releasing, availability, mobility and uptake by plant roots. In addition, releasing the plant essential nutrients from the nutrient-bearing minerals are more affected by the intensity of chemical weathering, which is more attributed to the nature of soil origin. In spite of organic matter content represents a very low soil constituent in such desert area, however, its content ranged between 0.05 and 0.37 %, mainly due to the absence of land vegetative cover, but it is considered as a strategic storehouse for plant nutrients, especially micronutrients.

V. Nutrients status as related to soil constituents:

Actually, plant essential nutrients are found in the soil as either soil solution free form or bounded with soil constituents in different forms. The later ones are categorized into two main forms, *i.e.,* exchangeable and bounded with either organic (*i.e.,* organic matter) or inorganic soil components (*i.e.,* each of carbonate, manganese oxide, soil mechanical fractions, amorphous and crystalline iron oxides). Undoubtedly, although organic matter constituent represents a very low soil component in the studied area (0.05-0.37 %), it plays an important role in the soil fertility status. This is mainly due to it is not only positively affects the soil physio-chemical properties through the active charged organic acids but also it is considered a storehouse source for plant nutrients.

Table (6): Available nutrient contents of the representative soil sites.

Soil site No.	Depth (cm)	Macronutrients (mg kg^{-1})			Micronutrients (mg kg^{-1})			
		N	P	K	Fe	Mn	Zn	Cu
1	0-30	20.84	3.56	236.16	5.25	1.86	1.45	0.85
	30-75	18.65	3.15	210.70	4.64	1.55	1.32	0.76
2	0-50	9.17	1.95	85.38	2.47	0.82	0.68	0.43
	50-90	14.35	2.48	160.85	3.50	1.25	1.00	0.58
3	0-50	17.90	3.05	203.47	4.45	1.62	1.25	0.75
	50-100	18.60	3.15	211.69	4.62	1.70	1.34	0.80
4	0-40	14.15	2.40	161.85	3.52	1.27	1.01	0.61
	40-75	15.68	2.70	175.46	3.89	1.39	1.12	0.64
5	0-25	11.15	1.90	126.65	2.78	0.98	0.80	0.46
	25-85	9.05	1.53	101.37	2.25	0.79	0.63	0.35
6	0-35	8.35	1.40	85.07	2.05	0.67	0.52	0.38
	35-75	12.60	2.16	145.23	3.15	1.13	0.90	0.50
7	0-40	21.58	3.68	245.95	5.38	1.92	1.54	0.88
	40-90	38.67	6.58	487.95	9.64	3.45	2.76	1.58
8	0-25	8.75	1.50	87.54	2.15	0.70	0.58	0.41
	25-100	9.68	1.65	110.32	2.41	0.86	0.69	0.39
9	0-35	11.56	1.95	135.45	2.80	0.95	0.78	0.37
	35-80	10.28	1.78	134.90	2.67	0.84	0.72	0.32
10	0-30	26.05	4.45	296.75	6.49	2.30	1.80	1.05
	30-100	18.60	3.15	211.70	4.63	1.67	1.33	0.76
11	0-25	12.45	1.97	128.48	2.82	1.02	0.87	0.51
	25-90	19.10	3.32	219.84	4.75	1.61	1.40	0.80

Meanwhile, the soil inorganic component, which consist the major portion of soil constituents, is mainly dominated by quartz and partly clay or silt minerals in the relatively coarse and medium textured soils, respectively. In addition, pronounced contents of both amorphous materials and lime particles are found in the fine fraction of some soil sites, especially those developed on the Eocene limestone.

The aforementioned discussion could be emphasized by the statistical analysis, Table (7), which showed positive and highly significant correlations between the studied nutrients of N, P, K, Fe, Mn, Zn and Cu and each of silt fraction, clay fraction and organic matter % as a soil constituent, besides N only with the ECe value. The reverse was true for sand fraction, ECe value and $CaCO_3$ %. That is true, since sand fraction, ECe and $CaCO_3$ content are of lack nutrient-bearing minerals. **El-Sayed (2009)** came to the same conclusion.

Table (7); Simple correlation coefficients between some soil components and total nutrient contents (mg kg^{-1} soil) in the studied soils.

Nutrient	Particle size distribution %			ECe (dS m^{-1})	Organic matter %	$CaCO_3$ %
	Sand	Silt	Clay			
N	-0.782**	0.565**	0.815**	0.521**	0.946**	-0.552**
P	-0.930**	0.762**	0.935**	-0.356*	0.918**	-0.498**
K	-0.910**	0.684**	0.939**	-0.381*	0.891**	-0.370*
Fe	-0.912**	0.738**	0.918**	-0.458**	0.859**	-0.493**
Mn	-0.949**	0.750**	0.964**	-0.481**	0.857**	-0.520**
Zn	-0.939**	0.760**	0.947**	-0.493**	0.856**	-0.512**
Cu	-0.960**	0.781**	0.966**	-0.367*	0.862**	-0.483**

A stepwise regression, as shown in Table (8), indicates that the best contribution as a percentage for each of sand, silt, clay, ECe, organic matter and $CaCO_3$ contents as soil constituents with the total contents of the studied essential plant nutrients. That is confirmed by R^2 that is concerned with both constant values and best contribution. The residual fraction expresses the contribution of other factors affect the total nutrient contents, either included in the stepwise regression or out it.

Table (8): Contribution percentages of some soil components for the total nutrient contents (mg kg^{-1} soil) in the studied soils.

Soil variable	N	P	K	Fe	Mn	Zn	Cu
Sand	--	1.40	--	2.30	1.75	--	--
Silt	--	0.75	--	--	6.50	4.75	2.75
Clay	9.55	62.10	78.45	83.56	79.70	79.35	88.26
ECe	0.85	--	8.97	3.45	1.30	--	--
Organic matter	86.30	25.85	3.15	--	2.32	5.40	2.84
$CaCO_3$	--	7.15	4.93	9.89	1.98	2.85	1.45
R^2	96.70	97.25	95.50	96.90	93.55	92.35	95.30
Residual	3.30	2.75	4.50	3.10	6.45	7.65	4.70

The obtained results in Table (9) indicate that all the studied available nutrient contents positively correlated at highly significant with each of silt fraction, clay fraction, organic matter content and total content of nutrients as soil variables. The reverse was true for each of sand fraction, ECe, $CaCO_3$, pH and ESP.

Table (9); Simple correlation coefficients between some soil variables and available nutrient contents (mg kg^{-1} soil) in the studied soils.

Soil variable	N	P	K	Fe	Mn	Zn	Cu
Sand	-0.833**	-0.688**	-0.992**	-0.740**	-0.729**	-0.752**	-0.772**
Silt	0.659**	0.574**	0.830**	0.630**	0.581**	0.610**	0.631**
Clay	0.845**	0.686**	0.989**	0.733**	0.737**	0.759**	0.775**
ECe	-0.457*	-0.479**	-0.495**	-0.473**	-0.469**	-0.462**	-0.460**
Organic matter	0.990**	0.947**	0.836**	0.895**	0.959**	0.962**	0.969**
$CaCO_3$	-0.496**	-0.572**	-0.499**	-0.519**	-0.504**	-0.549**	-0.562**
pH	-0.387*	-0.566**	-0.462*	-0.491**	-0.556**	-0.497**	-0.495**
ESP	-0.502**	-0.610**	-0.495**	-0.559**	-0.498**	-0.536**	-0.550**
Total content	0.992**	0.848**	0.961**	0.806**	0.810**	0.836**	0.877**

These findings are in harmony with those were discussed before in a part of available nutrient contents as related to the studied soil variables, as well as with the results obtained by **Awadalla *et al.* (2007)**.

A stepwise regression is presented in Table (10) to define the contribution as a percentage for each of the studied soil variables. The obtained data showed that a best contribution as a percentage for each of sand, silt, clay, ECe, organic matter, $CaCO_3$, pH, ESP and total content of nutrients as soil variables with the available contents of the studied essential plant nutrients.

Table (10): Contribution percentages of some soil components for the available nutrient contents (mg kg^{-1} soil) in the studied soils.

Soil variable	N	P	K	Fe	Mn	Zn	Cu
Sand	--	--	5.60	--	--	--	1.50
Silt	--	--	0.90	3.15	5.45	2.75	--
Clay	2.45	4.90	63.60	60.65	8.65	13.50	7.65
ECe	--	--	6.55	--	3.20	1.80	2.40
Organic matter	3.75	54.53	7.15	4.10	52.95	59.30	64.00
$CaCO_3$	--	6.87	1.80	5.70	4.80	2.40	4.20
pH	0.92	7.95	--	7.60	2.70	4.70	3.70
ESP	--	2.55	--	--	--	--	2.15
Total content	88.03	14.25	8.70	9.35	8.90	5.30	7.55
R^2	95.15	91.05	94.30	90.55	86.65	89.75	93.15
Residual	4.85	8.95	5.70	9.45	13.35	10.25	6.85

That is confirmed by R^2 that is concerned with both constant values and best contribution. The residual fraction expresses the contribution of other factors affect the total nutrient contents, either included in the stepwise regression or out it.

VI. Land suitability for agricultural irrigated soils:

a. Current land suitability:

The current suitability of the studied soils was estimated by matching between the present land characteristics and their ratings outlined by **Sys and Verheye (1978)**. Suitability indices and classification of the studied soils developed on the studied different physiographic units are shown in Table (11) and revealed that three suitability classes, *i.e*., moderately suitable (S2), marginally suitable (S3) and not suitable (N), besides four subclasses (Ns_1s_2, $S3s_1$, $S2s_1$ and S2n) were recognized in the studied area. These subclasses represent some soils suffering from soil limitations, *i.e*., some soil properties, *i.e.,* soil texture (s_1) and salinity/alkalinity (n) as soil limitations with different intensity degrees (slight and moderate).

Table (11): Land suitability classes for the studied soil profiles.

Profile No.	Topography (t)		Wetness (w)		Soil characteristics				Salinity& Alkalinity (n)		Suitability index (Ci)		Suitability class (Si)	
	Cs	Ps	Cs	Ps	S_1	S_2	S_3	S_4	Cs	Ps	Cs	Ps	Cs	Ps
Alluvial terraces (gently undulating)														
1	100	100	100	100	90	100	95	100	85	100	72.67	85.50	S2	S1
Relatively low terraces														
2	100	100	100	100	60	100	100	100	75	100	60.00	60.00	$S2s_1$	$S2s_1$
Relatively moderate high hills														
3	100	100	100	100	95	100	95	100	80	100	72.20	90.25	S2n	S1
Relatively low hills														
4	100	100	100	100	80	100	95	100	85	100	64.60	76.00	$S2s_1$	$S1s_1$
Rock outcrops														
5	90	100	100	100	55	100	95	100	85	100	44.41	52.25	$S3s_1$	$S2s_1$
Questa fronts														
6	90	100	100	100	40	75	95	100	85	100	21.80	28.50	Ns_1s_2	$S3s_1s_2$
Rock outcrops														
7	90	100	100	100	80	85	95	100	58	100	33.72	64.60	$S3s_1$	$S2s_1$
Wadies														
8	100	100	100	100	55	100	95	80	75	100	31.35	41.80	$S3s_1$	$S3s_1$
Moderately high hills														
9	100	100	100	100	75	100	100	80	75	100	45.00	60.00	$S3s_1$	$S2s_1$
Relatively low terraces														
10	100	100	100	100	95	100	95	100	75	100	67.69	90.25	S2n	S1
Moderately high terraces														
11	100	100	100	100	80	100	95	100	75	100	57.00	76.00	$S2s_1$	$S1s_1$

Limitations: S_1 =Soil texture, S_2=Soil depth (cm), S_3=Calcium carbonate status and S_4=Gypsum status

Suitability classes: N=Not suitable, S3=Marginally suitable, S2=Moderately suitable, S1=Highly suitable

b. Potential land suitability:

Further land improvements are required to correct or reduce the severity of limitations exiting in the studied area, such as: a) Leaching of soil salinity and reclamation of soil sodicity existing in the soils, b) Construction of efficient open drainage ditches to reduce soil salinity as well as to accelerate from the period of reclamation, c) Continuous application of organic manure to improve soil physico-chemical properties and fertility status, d) Application of modern irrigation systems, *i.e*., drip and sprinkler in the newly reclaimed desert soils to save a pronounced amount of irrigation water as well as to rise the irrigation efficiency.

By applying the previous improvement practices, potential suitability of the studied soils indicate the existing of three suitability classes, *i.e*., highly suitable (S1), moderately suitable (S2) and marginally suitable (S3), besides four subclasses ($S3s_1s_2$, $S3s_1$, $S2s_1$ and $S1s_1$) were recognized in the studied area, as shown in Table (11). These subclasses represent some soil profiles developed on all the different studied physiographic units with slight to moderate intensity for soil limitations. The severity of relatively soil coarse texture can be corrected in these subclasses by application of organic and inorganic soil amendments as well as either drip or sprinkler irrigation systems to sustain soil moisture content at a favourable condition for grown plants in the relatively coarse texture soil.

VII. Land suitability for certain crops:

Firstly, Land suitability for agricultural irrigated soils is the appraisal of specific areas of land from a general point of view without mentioning the specific kind of use. So, some soils may be suitable for a specific crop and unsuitable for another. The ideal approach for land evaluation is based on evaluating the land for utilization types which used as guides for the most beneficial use for a specific productivity by replacing a less adapted land utilization type by another promising one, and was applied in this study according to **Sys (1991) and Sys *et al.* (1993)**. The evaluation indices of land characteristics are done by rating them and specifying their limitations for certain crops by matching the calculated rating with the crop requirements in different suitability levels as proposed by **Sys *et al.* (1993)**.

a. Current land suitability classification (Cs):

In the studied area, without major land improvements, the crop requirements were matched with the present land qualities for processing the current land suitability of the different land units. This approach enables management of different alternatives for specific utilizations that are adapted to the existing limitations to give maximum output. The current land suitability classification of different physiographic units for the different specific utilizations is shown in Tables (12 and 13).

Table (12): Current and potential land suitability for some field crops.

Physiographic unit	Profile No.	Wheat		Barley		Maize		Alfalfa		Sorghum	
		CS	PS	CS	PS	CS	PS	CS	PS	CS	PS
Alluvial terraces (G. undulating)	1	Ns	S2x	S2x	S2x	Ns	S2x	S3s	S1y	S2sx	S2x
Relatively low terraces	2	Ns	S3x	Ns	S3x	Ns	S2xcy	Ns	S2y	Ns	S3x
Relatively moderate high hills	3	Ns	S2x	Ns	S2x	Ns	S2x	Ns	S1y	Ns	S1y
Relatively low hills	4	Ns	S3x	Ns	S3x	Ns	S2x	Ns	S1s	Ns	S2x
Rock outcrops	5	S3x	S3x	S3x	S3x	S2sx	S2x	S2s	S1y	S3x	S3x
Questa fr**onts**	6	Ns	S3x	Ns	S3x	Ns	S3x	Ns	S2xy	Ns	S3x
Rock outcrops	7	Ns	S2x	Ns	S2x	Ns	S1m	Ns	S1xy	Ns	S1m
Wadies	8	Ns	S3x	Ns	S3x	Ns	S3y	Ns	S2y	Ns	S3x
Moderately high hills	9	Ns	S3xy	Ns	S3xy	Ns	S3y	Ns	S3y	Ns	S3xy
Relatively low terraces	10	Ns	S2xy	Ns	S2xy	Ns	S2y	Ns	S2y	Ns	S2y
Moderately high terraces	11	Ns	S3x	Ns	S2xy	Ns	S2xy	Ns	S2y	Ns	S2xy

CS: Current suitability, PS: Potential suitability, Soil limitations [x : texture, p : soil depth, c : calcium carbonate %, y : gypsum % s : salinity (EC), m : Accumulation of minor limitations], S1: Highly suitable, S2: Moderately suitable, S3 : Marginally suitable, N : Currently not suitable, N2: Potentially not suitable.

b. Potential land suitability classification (Ps):

As for this purpose, the land utilization is applicable after executing specified major land improvements as proposed in the study according to their necessity. Potential land suitability classification can be established if the main improvements for the studied area are considered regarding land qualities of drainage, salinity and sodicity. The potential land suitability classification of different physiographic units for the different specific utilizations is shown in Tables (12 and 13) for the studied area.

The obtained potential land suitability subclasses were sorted in two productive levels. These two levels were designed to be guide charts for the best land utilization alternatives giving a possible maximum output. The two potential land suitability levels are as follows:

1. Supreme potential suitability for specific utilizations:

Matching charts for the supreme potential suitability for specific utilizations with the different physiographic-soil units of the current study are shown in Tables (12 and 13). The resultant adaptations are as follows:

* Highly suitable (S1) adaptations:

- Some soils of the alluvial terraces are suitable for alfalfa and olive.
- Some soils of the relatively low terraces are suitable for olive.
- Some soils of the relatively moderate high hills are suitable for alfalfa, sorghum and olive.
- Some soils of the relatively low hills are suitable for alfalfa.
- Some soils of the rock outcrops are suitable for maize, alfalfa and sorghum.
- Some soils of the relatively low terraces are suitable for olive.
- Some soils of the moderately high terraces are suitable for olive.

Table (13): Current and potential land suitability for some vegetable and fruit crops.

Physiographic unit	Profile No.	Tomato		Mango		Citrus		Olive		Palm	
		CS	PS	CS	PS	CS	PS	CS	PS	CS	PS
Alluvial terraces	1	S3xy	S3xy	Ns	S3y	Ns	S3xy	S1s	S1m	Ns	S3xy
Relatively low terraces	2	Ns	S3xcy	Ns	S3y	Ns	S3xcy	Ns	S1m	Ns	N2y
Relatively moderate high hills	3	Ns	S3y	Ns	S3y	Ns	S3xy	Ns	S1m	Ns	S3y
Relatively low hills	4	Ns	S3y	Ns	S3yp	Ns	S3xyp	Ns	S2p	Ns	S3xy
Rock outcrops	5	S2xy	S2xy	S2sy	S2yp	S3sxy	S3xyp	S2p	S2p	Ns	S3xy
Questa fr**onts**	6	Ns	S3xy	Ns	S3yp	Ns	S3xyp	Ns	S3p	Ns	N2yp
Rock outcrops	7	Ns	S2y	Ns	S3xp	Ns	S2xyp	Ns	S2xp	Ns	S3yp
Wadies	8	Nsy	S3x	Nsy	N2y	Ns	N2y	Ns	S2x	Ns	N2y
Moderately high hills	9	Nsy	N2y	Nsy	N2y	Ns	N2y	Ns	S2xyp	Ns	N2y
Relatively low terraces	10	Nsy	N2y	Nsy	N2y	Ns	N2y	Ns	S1m	Ns	N2y
Moderately high terraces	11	Nsy	N2y	Nsy	N2y	Ns	N2y	Ns	S1m	Ns	N2y

CS: Current suitability, PS: Potential suitability, Soil limitations [x : texture, p : soil depth, c : calcium carbonate %, y : gypsum % s : salinity (EC), m : Accumulation of minor limitations], S1: Highly suitable, S2: Moderately suitable, S3 : Marginally suitable, N : Currently not suitable, N2: Potentially not suitable.

* Moderately suitable (S2) adaptations:

- Some soils of the alluvial terraces are suitable for wheat, barley, maize and sorghum.
- Some soils of the relatively low terraces are suitable for maize and alfalfa.
- Some soils of the relatively moderate high hills are suitable for wheat, barley and maize.
- Some soils of the relatively low hills are suitable for maize, sorghum and olive.
- Some soils of the rock outcrops are suitable for wheat, barley, maize, tomato, mango and olive.
- Some soils of the wadies are suitable for alfalfa and olive.
- Some soils of the moderately high hills are suitable for olive.
- Some soils of the relatively low terraces are suitable for wheat, barley, maize, alfalfa and sorghum.
- Some soils of the moderately high terraces are suitable for barley, maize, alfalfa, sorghum.

* Marginally suitable (S3) adaptations:

- Some soils of the alluvial terraces are suitable for tomato, mango, citrus and palm.
- Some soils of the relatively low terraces are suitable for wheat, barley, sorghum, tomato, mango and citrus.
- Some soils of the relatively moderate high hills are suitable for tomato, mango, citrus and palm.
- Some soils of the relatively low hills are suitable for wheat, barley, tomato, mango, citrus and palm.

- Some soils of the rock outcrops are suitable for wheat, barley, sorghum, mango, citrus and palm.
- Some soils of the questa fronts are suitable for wheat, barley, maize, sorghum, tomato, mango, citrus and olive.
- Some soils of the wadies are suitable for wheat, barley, maize, sorghum and tomato.

- Some soils of the moderately high hills are suitable for wheat, barley, maize, alfalfa and sorghum.
- Some soils of the moderately high terraces are suitable for wheat

2. Subsequent prior potential suitability for specific utilizations:

* *Moderately* suitable *(S2) adaptations:*

- Some soils of the alluvial terraces are suitable for wheat, barley, maize and sorghum.
- Some soils of the relatively low terraces are suitable for maize and alfalfa.
- Some soils of the relatively moderate high hills are suitable for wheat, barley and maize.
- Some soils of the relatively low hills are suitable for maize, sorghum and olive.
- Some soils of the rock outcrops are suitable for wheat, barley, maize, tomato, mango, citrus and olive.
- Some soils of the questa fronts are suitable for alfalfa.
- Some soils of the wadies are suitable for alfalfa and olive.
- Some soils of the moderately high hills are suitable for olive.
- Some soils of the relatively low terraces are suitable for wheat, barley, maize, alfalfa and sorghum.
- Some soils of the moderately high terraces are suitable for barley, maize, alfalfa, sorghum.

* *Marginally suitable (S3) adaptations:*

- Some soils of the alluvial terraces are suitable for tomato, mango, citrus and palm.
- Some soils of the relatively low terraces are suitable for wheat, barley, sorghum, tomato, mango and citrus.
- Some soils of the relatively moderate high hills are suitable for tomato, mango, citrus and palm.
- Some soils of the relatively low hills are suitable for wheat, barley, tomato, mango, citrus and palm.
- Some soils of the rock outcrops are suitable for wheat, barley, sorghum, mango, citrus and palm.
- Some soils of the questa fronts are suitable for wheat, barley, maize, sorghum, tomato, mango, citrus and olive.
- Some soils of the wadies are suitable for wheat, barley, maize, sorghum and tomato.
- Some soils of the moderately high hills are suitable for wheat, barley, maize, alfalfa and sorghum.
- Some soils of the relatively low terraces are suitable for wheat, barley, maize, alfalfa and sorghum.
- Some soils of the moderately high terraces are suitable for wheat.

Finally, it can be concluded that space images proved to be a useful tool for reconnaissance inventories for large area of many landscape types. Furthermore, Landsat data were useful for mapping major geomorphic units as well as its use has been successfully demonstrated in delineating soil associations on the landscape. Therefore the data of this study are created to update and support the local knowledge, particularly the best use of land whether be under demand for agriculture use or be planned for later on use. That means the obtained results represent the best adaptation between certain land units with specific soil properties to give the maximum outputs. Also, identifying the physiographic features of a unique area in a desert zone by mapping them to be a digital model is a harmony of physiographic and soil data set, serving the extrapolation approach when other areas will be under study

References

Abdel Nasser, A.A.A.; M.A.M. El Bassiony and H.A. Awadalla (2010). Significance of inherited soil pedogenic aspects as related to some nutrients status in both soils and grown plants at El Fayoum area, Egypt. Fayoum J. Agric. Res. & Dev., 24 (2): 38-63.

Awadalla, A.A.; A.A.A. Wahdan and S.A.M. Mousa 2007. Originated soil material constituents as a function of supplying power capacity for nutrients at the main sediments of El-Fayoum depression, Egypt. Fayoum J. Agric. Res. & Dev., 21 (1): 78-97.

Baruah, T.C. and H.P. Barthakur (1997). A Tex Book of Soil Analysis. Vikas Publishing Housing, PVTLTD, New Delhi, pp. 35-67.

Black, C.A.; D.D. Evans; L.E. Ensminger; J.L. White and F.E. Clark (1965). Methods of Soil Analysis. Am. Soc. of Agron. Inc., Madison, Wisconsin, USA.

Bower, C.A. and R.B. Huss (1948). A rapid conductometric method for estimating gypsum in soils. Soil Sci. 66: 199-240.

Burnigh, P. (1960). The applications of aerial phothographs in soil surveys. Man. of Photogr. Interpr., Washington, D.C., USA.

El-Sayed, Shimaa K.H. (2009). Geographic information system for nutrient requirements in El-Fayoum district, El-Fayoum Governorate, Egypt. M. Sc. Thesis, Fac. of Agric., El-Fayoum Univ., Egypt.

El-Shakweer, M.H.A. and A.A.A. Abdel-Hafeez (2008). Evaluation of salinity and sodicity hazards due to drainage water reuse for irrigation purposes in El-Fayoum Governorate, Egypt. Alex. J. Agric. Res., 53(2): 119-128.

FAO (1976). A framework for land evaluation. Soil Bull. No.32, FAD, Rome, Italy.

Follett, R.H. and W.L. Lindsay (1971). Changes in DTPA-extractable zinc, iron, manganese and copper in soils following fertilization. Soil Sci. Soc. Amer. Proc., 35: 600-607.

Gee, G.W. and J.W. Bauder (1986). Particle size analysis. In: Methods of Soils Analysis, Part I, Klute, A. (Ed.), Agronomy No. 9.

Goosen, A.A.I. (1967). Aerial photo-interpretation in soil survey. FAO Soil Bulletin No. 6, Rome, Italy.

Hesse, P.R. (1971). A Text Book of Soil Chemical Analysis. John Murroy (Puplish), London, UK.

Houba, Z.L.; M.J. Wilson; C.O. Campbell; A.C. Edwards and S.J. Chapman (1995). Distribution of phosphorus in soil aggregate fractions and its significance with regard to phosphorus transport in agricultural runoff. Water Air Soil Pollut., 83: 69-84.

Jackson, M.L. (1973). Soil Chemical Analysis. Prentice India Private LTD, New Delhi, Indian.

Kimber, Clarissa (2004). Geographical Review. Vol. 94, Issue 3, 263-283 pp.

Lindsay, W.L. and W.A. Norvell (1978). Development of DTPA soil test for Zn, Fe, Mn and Cu. Soil Sci. Soc. Am. J., 42: 421.

Ministry of irrigation (1997). Report, Reuse of Drainage Water for Irrigation. Drainage Research Institute, Cairo, A.R.E.

Mount, J.F. (1995). California Rivers and Streams. The Conflict Between Fluvial Process and Land Use, Chapter 4, Publisher Unvi. of California, USA.

Munsell Soil Colour Charts (1975). Edition Munsell Colour, Macbeth Division of Kollmorgen Corp., 2441 North Calvert Street, Baltimore, Maryland, USA.

National Water Resources Plan for Egypt, NWRP (1999). Inception Report, The National Water Research Center (NWRC).

Petroski, H. (2006). Levees and Other Raised Ground. Vol. 94, American Scientist, pp. 7 -11

Richards, L.A. (1954). Diagnosis and Improvement of Saline and Alkali Soils. U.S. Dep. of Agric., Hand Book No. 60, pp. 102.

Said, R. (1990). The Geology of Egypt. Published for the Egyptian Central Petroleum Corporation, Conoco Hurghada Inc. by Balkema, A.A., Roterdam, The Netherlands.

Sanchyan, S.J. and M.R. Trench (1978). Landsat applied to landslide mapping. Photogramm. Engin. And Remote Sensing, 44: 735.

Siegal, B.S. and M.J. Abrams (1976). Geological mapping using landsat data. Photogramm. Engin. And Remote Sensing, 44: 325.

SPSS 2003. Statistical Package for Social Sciences, Version 12, SPSS technical Support, http://www.spss.com/tech/.

Soltanpour, P.N. and A.B. Schwab (1977). A new soil test for simultaneous extraction of micronutrients in alkaline soils. Comm. Soil Sc. and Plant Annal., 8: 195.

Sys, C. and W. Verheye (1978). An attempt the evaluation of physical land characteristics for irrigation according to the FAO framework for land evaluation. Int. Train Course for Post Grad. Soil, Sci. Univ., Ghent, Belgium.

Sys, C. (1991). Land evaluation. Parts I, II and III, Lecture Notes, Ghent Univ., Ghent, Belgium.

Sys, C.; E. Van Ranst; J. Debaveye and F. Beernaert (1993). Land evaluation. Part III., Crop Requirements Agricultural Publication No.7, General Administration for Development Cooperation, Ghent, Belgium.

U.S.D.A. (1975). Soil Taxonomy Basic System of Soil Classification. U.S. Dept., Agric. Handbook No. 436, USDA. Washington, D.C. 20402.

U.S.D.A. (2006). Keys to Soil Taxonomy. 10th (Ed), United States Department of Agriculture, Nature Resources Conservation Service.

Westin, F.C. and C.J. Frazee (1976). Landsat data, its use in a soil survey program. Soil Sci. Soc. Amer. J., 40: 81.

Worcester, B.K. and D.G. Moore (1978). Delineation of Soil landscape in the Sudan Region of Sudan on landsat imagery. Proc. Of Twelfth Int. Sym. Remote Sensing of Environ., 1: 1155-1166.

Wright, C.H. (1939). Soil Analysis. Thomas Murby & Co., London.