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Contribution of Landsat Imagery to Identify the Physiographic Units and Soil Limitations for Agricultural Utilization at Southern-East Desert Outskirt of El-Fayoum Depression, Egypt

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THIS STUDY was considered a trial to determine the contribution of Landsat Imagery for identifying the main physiographic units and their soil limitations at South-East desert outskirt of El-Fayoum depression, Egypt, which represent the most urgent criteria help in planning the proper agricultural utilization projects. However, this technique is essential to conduct the preliminary soil studies in the wide desert areas for evaluating soil limitations in the current and potential conditions as well as suitable practices for favourable soil management and its sustainable cultivation on both the short and long-terms. So, such area was selected as a model to be identified within the context of physiography, soil classification and land evaluation for irrigated agriculture.

The obtained data show that the area under investigation includes both the continental alluvium of River Nile and desert deposits that were derived from foreign and local parent rocks, respectively. The physiographic units and their soil characteristics were identified based on the visual interpretation of Landsat data ETM7 (Enhanced Thematic Mapper 7) and applying the Landscape feature approaches. The main physiographic units could be categorized into seven units, *i.e.*, piedmont, alluvial terraces (locally over blown sand), El-Fayoum alluvial plain (locally terraced), El-Fayoum alluvial fan, Nile alluvial depressed plain (River bed), Nile alluvial flat plain and rock structures. The rock structures were delineated as dissected cuesta of summits and fronts or as rock outcrops. Thirty-seven mini pits were located and studied for setting up the legend characteristics of mapping units. The differences between these mapping units were represented by twelve soil profiles to be morphologically described and soil samples were selected for laboratory analyses.

Studies of the fieldwork indicated that effective soil depth (45-75 cm) was existed by bedrock in piedmont unit, while it was reached 150 cm in soils of the other physiographic units. The majority of the studied soils are, in general, gravelly loose sand to sandy clay, besides the fine texture soils of El-Fayoum alluvial fan and the Nile alluvial plain. Most of the studied soils are suffering from salinity problems and noticeable decreases in soil organic matter. With exception of soils developed on either El- Fayoum alluvial fan and plain or the Nile alluvial depressed and flat plain that dominated by smectites, the semi-quantitative determination of clays indicated that kaolinite was the predominated one followed by smectites, illite, palygorskite, chlorite and vermiculite.

Soil taxonomic units were identified according to the Key of Soil Taxonomy till the soil family level into:

i) *Aridisols* include a. Lithic calcigypsids, sandy skeletal, carbonitic, hyperthermic and Typic calcigypsids, loamy skeletal, carbonitic, hyperthermic in the piedmont unit and b. Typic Haplocalcids, fine loamy, mixed, hyperthermic and Typic calcigypsids, sandy, mixed, hyperthermic in the alluvial terraces (locally over blown sand) unit.

ii) *Vertisols* include a. Typic Gypsitorrerts, clayey, smectitic, hyperthermic in El-Fayoum alluvial plain (locally terraced) unit; b. Typic Haplotorrerts, fine clayey, smectitic, hyperthermic and Entic Haplotorrerts, clayey, smectitic, hyperthermic in El-Fayoum alluvial fan unit; c. Halic Haplotorrerts, very fine clayey, smectitic, hyperthermic in the Nile alluvial depressed plain (River bed) unit and d. Typic Haplotorrerts, fine clayey, smectitic, hyperthermic in the Nile alluvial flat plain unit.

iii) *Entisols* include a. Typic Torriorthents, sandy skeletal, mixed, hyperthermic and Typic Torripsamments, siliceous, hyperthermic in the alluvial terraces (locally over blown sand) unit and b. Typic Torriorthents, sandy, mixed, hyperthermic in El-Fayoum alluvial plain (locally terraced) unit.

According to the parametric system undertaken the current suitability of the studied soils could be categorized into four suitability classes [*i.e.*, highly (S1), moderately (S2), marginally (S3) and not suitable (N1)], besides eight subclasses, *i.e.*, $N1s_1s_2s_3n$, $S3s_1s_2s_4n$, $S3s_1n$, $S3s_1$, S2n, $S2s_1$, S2 and S1, which were suffering from some soil properties (*i.e.*, soil texture s_1, soil depth s_2, $CaCO_3$ s_3 and gypsum s_4) and salinity/alkalinity (n) as soil limitations with different intensity degrees. So, further land improvement should be executed to achieve the potential suitability, *i.e.*, highly, moderately and marginally suitable classes. In addition, the severity of soil limitations can be corrected by application of organic and inorganic soil amendments as well as drip irrigation system to sustain favourable soil moisture content for plants. These adaptations can be promising for rather higher output as the major land improvements are considered for the land qualities of drainage, salinity and sodicity, to maximize the current land suitability to be potential one after re-evaluating the physigraphic land considering them free of those limitations.

Keywords: Southern-East desert outskirt of El-Fayoum Depression, Physiographic-soil units, Soil taxa and soil evaluation for irrigated agriculture.

The yearly progressive increase of human pressure on the limited cultivated area in El-Fayoum depression requires to a pay the suitable attention to exist spread of productive land outside their desert rims as well as to conserve the productivity status of the cultivated soils inside the depression. That means demands of agricultural soil and water resources are steeply increased everywhere. Thus, the horizontal expansion of agricultural areas, besides maximizing their soil productivity is considered the main important role of the food security versus an uncontrolled population growth. It is well known that the outskirts of El-Fayoum Governorate are mainly desert areas and such have less productive desert sandy or calcareous soils. Such promising areas of virgin sandy and calcareous soils are commonly known to have a poor soil structure, low water holding capacity and their limited fertility. This is due to the main mechanical constituents are the sand fraction, which is not partially capable to retain neither water nor nutrients for growing plants, and active $CaCO_3$ that affect distinctly different soil properties related to plant growth, *i.e.*, crusting, soil-water relations, availability of plant nutrients, etc… (Ragab, 2001).

From a global viewpoint, only few untouched fertile areas are remained by the end of this century, so almost all production needed must come from the existing spread of productive land. Thus, one of the most agricultural utilizations, which have accelerated the direction towards expansion of conventional agriculture, is the fact that using the available low water quality and yielding plant varieties under different conditions of water use efficiencies should be achieved (Tanaka, 1989 and Amer, 1999). Consequently, alternative practices are sought to made agriculture more sustainable, as such, it would be able to protect soil or water resources, and be environmentally safe and profitable (Barrow, 1995). Therefore, the major policy of the local Government aims to attain self-dependence in the natural sources of soil and water needs. To achieve this goal efforts have been directed towards increasing the soil-water management aspects. In addition, another water resources such as agricultural drainage and wastewater should be treated and used in irrigation for the promising desert areas of virgin sandy and calcareous soils. The reuse of contaminated drainage, sewage effluent and industrial-waste waters may be the only possible choice in specific locations such as in the chosen area of the desert outskirts of El-Fayoum Governorate. The positive or negative effects of such water used for irrigation purposes depend mainly on their quality and attained specific elements as well as soil nature (Rajesh & Bajwa, 1997). The desert belt situated between both El-Fayoum and Beni-Suef Governorates comprises a total area of about 382.80 km^2 (957000 feddans). From a scientific view point, the data of the current work must come from the identified physiographic features of a unique area in Egypt by mapping them to be in a harmony of physiography and soil data set, serving the extrapolation approach when other areas will be under study. It is also to find the best adaptation between certain land units with agricultural utilization projects to give the maximum output.

The data of the current work were created to evaluate soil and environmental limitations as well as to support the local knowledge concerning the best land use whether be under demand for agriculture utilization or be planned for later on use. That means this study is a trial for elucidate soil profile development as affected by the prevailing environmental conditions, *i.e.,* origin and landform escape as well as to asses its significance as a guide to explain and correct the problems facing the future agricultural utilization projects in the area of southern-east desert outskirt of El-Fayoum depression by using an updated technique of Landsat imagery. In addition, the present work is undertaken to evaluate the soil potentialities of the identified main physiographic units through determining its main characteristics that may be helpful for identifying the best land use under irrigated agriculture for achieving an agricultural utilization policy of the region under consideration.

Material and Methods

To achieve the aforementioned target, analysis of landsat images covering the area under investigation was done to identify the different physiographic units. Also, fieldwork was performed to describe the soils developed on these physiographic units as well as to collect soil samples for laboratory analyses to recognize the soil properties, which were used as guidelines for soil classification, hence land suitability for irrigated agriculture.

Location

The studied area is a natural desert belt located between El-Fayoum depression and the Nile Valley at Beni-Suef Governorate (southern-east desert outskirt of El Fayoum depression), and it comprises a total area of approximately 264 km^2. Also, it is located between latitudes 29° 24' 22.50" N to 29° 11' 56.11" N and longitudes 30° 51' 51.00" E to 31° 14' 43.19" E, in the eastern part of Western Desert of Egypt. It bounded by the Nile Valley from the Eastern, El-Fayoum depression from the western and Bahr Yousef from the southern sides (Fig. 1). The image (Fig. 1) 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 landscape characteristics whether in the desert or in cultivated areas.

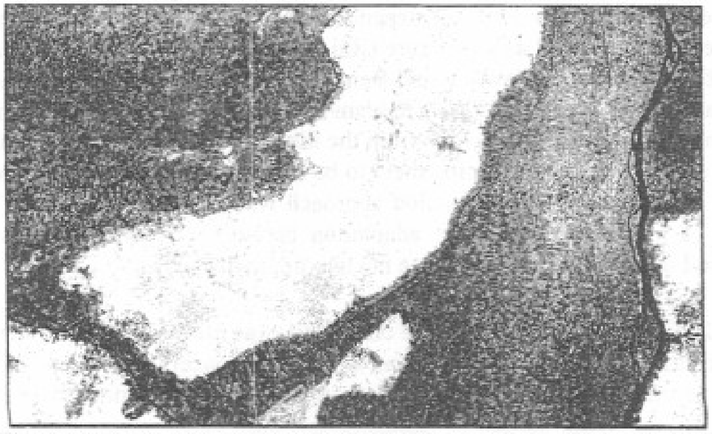

Fig. 1. Landsat TM 7 image of the studied area (RGB, Geocover 2005).

Climate

The studied area (Alahoon) lies within the arid desert belt and characterized by the continental climate. The climatelogical data indicate that the area under investigation is dry and worm in summer and slightly cold in winter, the principal meteorological data recorded at El-Fayoum Station as a last sixth years average reveal that the mean annual temperature ranges between 12.3 and 33.1°C, the annual maximum temperature differs from 22.2 to 37.6°C and the minimum ranges from 9.2 to 13.7°C. The studied area receives a very low amount of rainfall, where the average rate ranges between 14 and 21 mm^3/year. The mean annual relative humidity ranges between 47 and 60 %. Wind velocity ranges between 3.0 and 4.1 km/hr. The rate of evaporation ranges 3 mm/day in winter and 11-13 mm/day in summer.

Remote sensing inventory for identifying the physiographic units

Satellite remote sensing in conjunction with geographic information systems has been widely applied and been recognized as a powerful and effective tool in physiographic analysis method that has been made in developing techniques of photo-interpretation for soil survey (Goosen,1967 and Sabins, 1978). Preliminary space image interpretation was preformed using the physiographic analysis as proposed by Goosen (1967). The aim of these methods is to identify boundaries that are correlated to the differences of the physiographic process. These methods are called "genetic approach", which are based on the dynamic processes rather than the static ones. Visual analysis of Enhanced Images of Landsat Thermatic Mapper (TM 7) Mosaic, after the enhancement process has been made, *i.e.*, filtering process, were acquired during the year of 2005 (RGB, Geocover 2005), and were used for the purpose of visual analysis as well as for the detailed physiographic analysis for modeling the studied area. The overall view for delineating the promising area at the southern - east desert outskirt of El-Fayoum depression is characterized by the spectral signature of an Orthorectified Landsat Thermatic Mapper (TM 7) Mosaic. It was a composite of the bands 7, 4 and 2. The pixel size is a mixture of 28.5 and 30.0 m. 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 active dunes, partly vegetated, wind blown sands, piedmonts and rock structures.

The physiographic analysis technique is followed to perform the image interpretation. Such image analysis is based upon the knowledge of relation between physiographic and soils as upon the studied futures, which are resulted from some dynamic processes (Goosen, 1967). On the false colour with band composites 2, 4 and 7, visual interpretation that depends on many elements such as tone. size, pattern, texture, shadow and association was done to extract the important landscapes (physiographic units) of Alahoon area. The physiographic map has been produced from delineated Landsat TM 7 image, bands 2, 4, and 7 acquired in the year of 2005. The studied area could be categorized into seven physiographic units as shown in Fig. 2 and they are presented as follows: 1.

Piedmont, 2. Alluvial terraces, locally overblown sands, 3. El-Fayoum alluvial plain, locally terraced, 4. El-Fayoum alluvial fan, 5. Nile alluvial depressed plain (River bed), 6. Nile alluvial flat plain and 7. Rock structures.

Fieldwork and sampling

The preliminary image-interpretation map was checked in the field by different ground observation points to confirm the boundaries of the physiographic units or to revise what were shifted. Twelve soil profiles were chosen to represent the different physiographic units under investigation (Fig. 2), *i.e.*, Piedmont (profile Nos. 1 and 2) Alluvial terraces, locally overblown sands (profile Nos. 3, 4, 5 and 6) El-Fayoum alluvial plain, locally terraced (profile Nos. 7 and 8) El-Fayoum alluvial fan (profile Nos. 9 and 10), Nile alluvial depressed plain, River bed (profile No. 11) and Nile alluvial flat plain (profile No. 12). The soil profiles were dug to a depth 150 cm or to lithic contact (bedrock). Soil samples were collected to represent the different morphological variations throughout the soil profile layers and were described according to the nomenclature of USDA (2003) and the Munsell Colour Chart (1975). The disturbed soil samples were air-dried, crushed, sieved through a 2 mm sieve, then the obtained fine earth samples (less than 2 mm) were kept for laboratory analysis.

Laboratory analysis

Particle size distribution was determined using the International Pipette method (Piper, 1950) and sodium hexametaphosphate as dispersing agent as described by Baruah & Barthakur (1997). Calcium carbonate content was measured using the Collin's Calcimeter method (Wright, 1939). Soil organic matter content, saturation soil paste extract and soil pH in the soil water suspension of 1:2.5 were determined according to the methods described by Jackson (1973).

Gypsum content, cation exchange capacity and the exchangeable sodium percentage were determined according to the methods described by Richards (1954). Mineralogical analysis of the clays separated from the selected soil samples were subjected to X-ray diffraction analysis, which was done using Phillips PW 1140/90 X-ray Apparatus, with Ni-filter and Cu-radiation under the following treatments, *i.e.*, Mg-saturated air-dried, Mg-saturated glycerol solvated, K-saturated air-dried and K-saturated and heated to 550 0C for 4 hours. The obtained X-ray diffractograms were interpreted in light of the tables presented by Brown (1961). Semi-quantitative estimation of the clay minerals proportions was then conducted by measuring the peak area as outlined by Giems (1967). Soils under study were classified into taxonomic units according to Soil Taxonomy System (USDA, 1975) and using the keys to Soil Taxonomy (USDA, 2006). Soils under investigation were evaluated using the parametric system for irrigated agriculture land evaluation namely "land Capability Classification" undertaken by Sys & Verheye (1978).

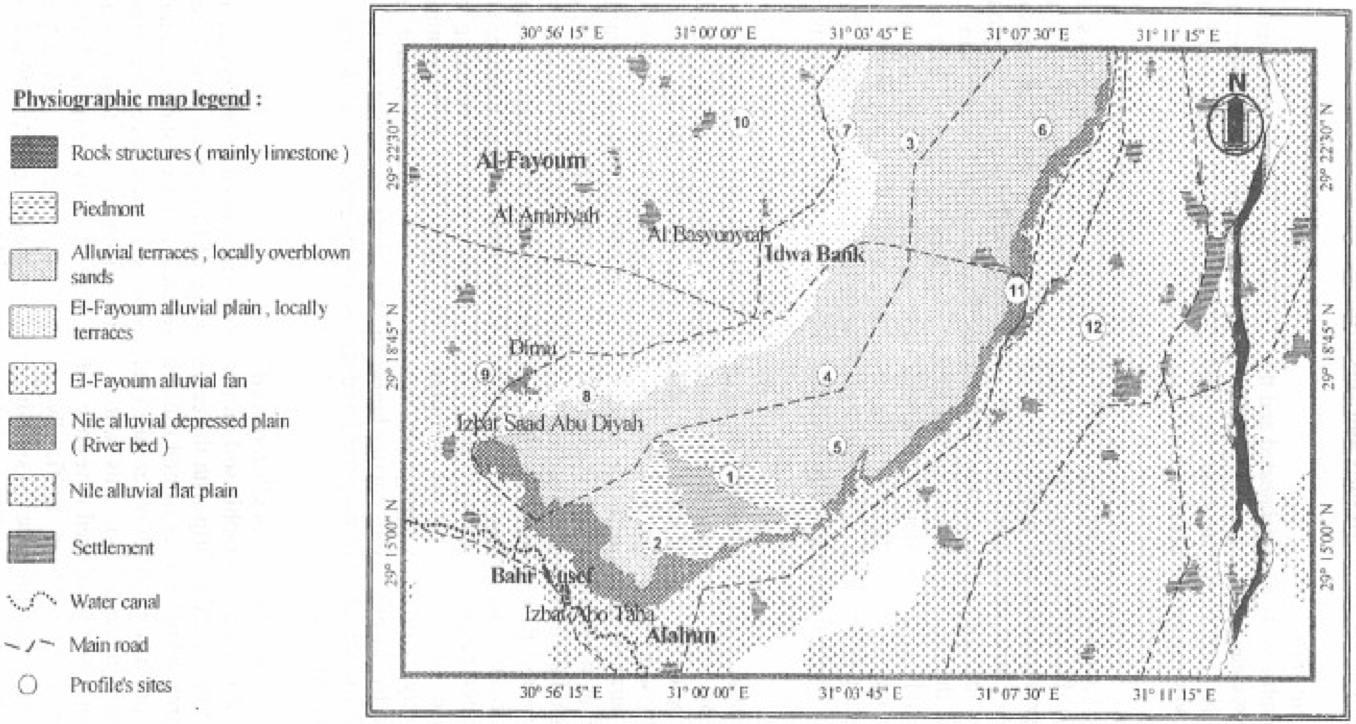

Fig. 2. Physiographic units map of the studied area (Scale 1 : 250 000).

Results and Discussion

Physiographic units

Physiographic units were delineated and their legend have been set up as shown in Fig. 1, associated with the morphological description of the representative soil profiles (Table 1). A brief note about the identified physiographic-soil units of the studied area was carried out as follows:

Piedmont

This unit covers an area of about 19.01 km^2 (about 4753 feddans), the soils developed on this unit represent the foot-slope of the rock structure (hilly area) unit, the representative soil profile Nos. 1and 2 have different effective soil depths. These soils recognized by quite clear relief and the light greytone according to the soil surface cover (limestone fragments and blown sands). According to the surface features of this unit, it could be categorized into two sub-units namely piedmont slope and central piedmont flat. The piedmont slope occupies the narrow area adjacent to the hilly foot, and it is characterized by stony undulating relief covered by limestone fragments and almost barren. The central piedmont flat developed on a limited area around the hill as a strip of barren desert.

Alluvial terraces, locally over blown sands

It represents the biggest unit in the studied area, however, its representative soils are occupied an area of about 176.10 km^2 (about 44025 feddans) and are represented by soil profile Nos. 3, 4, 5 and 6. This unit extends from the northern side with a parallel direction to the border of El-Fayoum depression towards Bahr Youssef at the southern part. These alluvial terraces are occupies the central part of the studied area, and according to Said (2001), they are remnants of formerly deposited floodplain. It can be concluded that, on this terraces plain, consequent streams, that follow the initial slope of the land (east or westwards) were rejuvenated resuming down-cutting, thereby forming terraces, resulting in gullied surfaces of concave convex complex slopes (almost flat in the central part and gently undulating topography on the borders). Also, this unit is characterized by locally sand encroachment within some rock outcrops of original structure, which are transported and deposited by either wind or water action in a limited zone.

El-Fayoum alluvial plain, locally terraced

The area of this physiographic-soil unit is 26.40 km^2 (about 6600 feddans), and it extends as a parallel strip with the eastern ridge of El Fayoum depression as a narrow area, some authors named it old shore zone of the existing remnant of an ancient pre-historic fresh water lake (Lake Moeris), which covered a large part of El-Fayoum depression. This unit is characterized by the depositional deposits of sands and weathered limestone within some of coarse materials. The representative area has been artificially modified in order to change the landscape into depressed terraces to suite-irrigated agriculture soils, this unit has topographic landscape ranges between almost flat to slightly undulating. The soils of this unit are represented by soil profile Nos. 7 and 8.

TABLE 1. Morphological description of the studied soil profiles.

Physio-graphic unit	Profile No.	Soil parent material	Slope gradient	Horizon	Soil depth (cm)	Soil colour	Modified texture class	Soil structure	Soil consistency
Piedmont	1	Eocene limestone	Gently undulating	Aky	0-15	10YR8/4 d	VG SL	Mas	Loose
				Cky	15-45	10YR7/4 d	VG LS		Slightly hard
				R	45-	Limestone (bedrock)			
	2		Gently undulating	Aky	0-20	10YR7/6 d	G SL	Mas	Slightly hard
				Cky1	20-45	10YR7/4 d	G SL		
				Cky2	45-75	10YR7/4 d	VG SL		
				R	75-	Limestone (bedrock)			
Alluvial terraces, locally over blown sands	3		Gently undulating	Ak	0-25		SG SL	Gr	Soft
				Ck1	25-55	10YR7/6 d	SG SCL	Gr	Slightly hard
				Ck2	55-105	10YR7/6 d	SG CL	Gr	Slightlyhard
				Ck3	105-150	10YR7/6 d	SG LS	Sg	Loose
	4		Gently undulating	Ak	0-15	10YR7/4 d	G SCL	Gr	Slightlyhard
				Ck	15-50	10YR8/4 d	G SL	Mas	Loose
				Cky	50-95	10YR7/4 d	G LS	Mas	Loose
				Ckyz	95-150		G SCL	Gr	Slightly hard
	5		Gently undulating	C1	0-20	10YR7/4 m	VG LS	Sg	Slightly hard
				C2	20-65	10YR8/4 m	VG LS		Slightly hard
				C3	65-95	10YR8/4 m	VG LS		Hard
				C4	95-150	10YR6/4 m	ExG S		
	6	Wind blown sands	Gently undulating	C1	0-30	10YR7/6 d	S	Sg	Loose
				C2	30-85	10YR7/6 d			
				C3	85-150	10YR7/6 d			
El-Fayoum alluvial plain, locally terraced	7	Fluvio-lacustrine	Almost flat	Ak	0-35	10YR5/2 d	Cl	Mmsbk	Friable
				Ck	35-75	10YR4/2 m	C	Mmsbk	Friable
				Ck1	75-110	10YR3/3 m		Cstsbk	Firm
				Ck2	110-150	10YR3/3 m		Cstsbk	Firm
	8		Almost flat	Ap	0-25	10YR6/6 d	SCL	Gr	Slightly hard
				C1	25-80	10YR7/6 d	LS	Sg	Loose
				C2	80-150	10YR7/8 d	S	Sg	Loose
El-Fayoum alluvial fan	9	Nile alluvium	Almost flat	Ap	0-25	10YR5/4 d	C	Mmsbk	Slightly hard
				C1	25-80	10YR5/2 m		Mmsbk	Hard
				C2	80-120	10YR5/2 m		Mmsbk	Firm
				C3	120-150	10YR5/2 m		Cstsbk	Firm
	10		Almost flat	Ap	0-20	10YR4/3 d	Clay loam	Mmsbk	Friable
				C1	20-60	10YR5/3 d		Mmsbk	Slightly hard
				C2	60-100	10YR4/2 m	Clay	Cstsbk	Firm
				C3	100-150	10YR5/2 m		Cstsbk	Firm
Nile alluvial depressed plain (River bed)	11	Nile alluvium	Almost flat	Ap	0-15	10YR4/2 m	C	Mmsbk	Firm
				C1	15-50	10YR4/3 m		Cstsbk	Very firm
				C2	50-100	10YR4/2 m		Cstabk	Very firm
				C3	100-150	10YR4/2 m		Cstabk	Very firm
Nile alluvial flat plain	12		Almost flat	Ap	0-25	10YR4/2 m	C	Mmsbk	Hard
				C1	25-60	10YR4/3 m		Mmsbk	Firm
				C2	60-90	10YR4/2 m		Mmsbk	Firm
				C3	90-150	10YR4/2 m		Cstsbk	Firm

Gravel: SG=Slight gravelly, G=Gravelly, VG=Very gravelly and ExG=Extreme gravelly.
Fine earth: S=Sand, LS=Loamy sand, SL=Sandy loam, SCL=Sandy clay loam, CL=Clay loam and C=Clay.
Soil colour: d=Dry and m=Moist.
Soil structure: Sg=Ssingle grain,Mas=Massive, Mmsbk=Medium moderate subangular blocky, Cstsbk=Coarse strong subangular blocky and Cstabk=Coarse strong angular blocky.

El-Fayoum alluvial fan

This physiographic-soil unit occupies an area of about 118.77 km^2 (about 29693 feddans), and it represents the southern east part of El-Fayoum depression. The soils of this unit were formed when the Nile water cut the eastern edge of El-Fayoum depression and enter through an natural canal of Bahr Youssef to fill it with fresh water associated with suspended matter that were deposited in a triangle shape of alluvial fan its top at Alahoon open with an almost flat surface. The Nile alluvium was deposited as the action of water flows that deposited the soil solum along a general south-north descending slopes under a potential power of natural water flow. Naturally and perpetually, the water flow with the same direction without engine, giving the renaissance to the lands of the same origin as a unique natural twine that was globally recognized. The soils of this unit are represented by soil profile Nos. 9 and 10.

From the economical point of view, this unit is the major physiographic unit in the studied area due to it was formed of the Nile alluvium with flat surface, which was paved under periodically inundated with water during high flow periods. However, the soils of this unit are characterized by very deep well drained effective soil depth, well structured that improves aeration in the *Vertisols*, with sufficient moisture regime as improved by a good water holding capacity, being in rich nutrients clayey soils. This harmony of "Land-Water Nile Mode" is considered a very high economical value that can not be designed by man-made action even with a very expensive technology, daily loss of energy and irrigation water resourceful (Afify *et al.*, 2007).

Nile alluvial depressed plain (River bed)

This physiographic unit is found as a narrow strip located at the western rim of the Nile alluvial plain, however, the polygons of this unit occupy the far west areas of the broad Nile alluvial plain as slightly depressed spots, which are most probably represent an old river bed of decayed River Nile Branch. Such depressed plain includes soils of heavy-textured materials, which are subjected to the swelling and shrinkage process, fitting the requirement to be *Vertisols* of the Nile alluvial very fine sediments with strongly saline feature that shift the taxonomic unit to be *Halic* rather than *Typic*. This unit occupies an area of 34.60 km^2 (about 865 feddans), and its surface has some depressed elevation with an almost flat relief (soil profile No. 11) .

Nile alluvial flat plain

This physiographic unit is represented by the Nile valley as a young Nile alluvial flat plain, which is characterized by a unique physiographic-soil characteristics due to its soil materials were formed by the periodically depositional regime of the Nile water flooding. However, the River Nile alluvium was deposited as the action of water flows that deposited the soil solum along a general South-North descending slopes and radial flows of Northern-East and Northern-West descending slope under a potential power of natural water flow. Naturally and perpetually, the water flow with the same direction without engine, giving the renaissance to the lands of the same origin as a unique natural twine that was globally recognized. The soils of this unit are characterized by almost flat and flat surface and represented by soil profile No. 12.

Rock structures

This unit covers an area of about 7.89 km^2, it is located at the southern side of the studied area (Alahoon area) and has a triangle shape. Its elevation reaches 17-20 m above sea level forming a hilly area. It is also occurred as barren limestone (original structure) outcrops with a gently sloping surface associated with the rolling slope. This hilly area is characterized by dense of dendritic pattern for drainage streams. Miscellaneous land types of these rock structures are divided into three features, *i.e.,* a. Cuesta summit that represents the original elevation of the limestone body before the dissection processes, b. Cuesta fronts which are located on rocky slopes and covered by talus as well as pediments with a complex pattern of steep and rolling concave convex surfaces and c. Rock outcrops which are found as isolated local structures, that are mostly located in the pediplain.

Soil morphology

Soil profile, as a soil section controlled by the morphological features of its horizons or layers, is reliable for several modifications through various environmental conditions. Field work studies (Table 1 show that the soil profiles developed on the studied physiographic units of piedmont (soil profile Nos. 1 and 2) alluvial terraces, locally overblown sands (soil profile Nos. 3, 4, 5 and 6), El-Fayoum alluvial plain, locally terraced (soil profile Nos. 7 and 8), El Fayoum alluvial fan (soil profile Nos. 9 and 10), Nile alluvial depressed plain as a river bed (soil profile No. 11) and Nile alluvial flat plain (soil profile No. 12) have topographic features characterized by almost flat, undulating, gently undulating and often steep or rolling slope either for the arable or barren and virgin areas that devoid scattered natural vegetation. The effective soil depth was 150 cm, except some areas had shallow depth due to the existence of bedrock at a depth of 40-70 cm such as in case of piedmont unit.

Exceptional of some areas characterized by either medium or fine textured materials (El-Fayoum alluvial fan, Nile alluvial depressed plain and Nile alluvial flat plain units), in general, the majority of studied soils are gravelly loose sand to sandy loam. The secondary formations of $CaCO_3$, as soft and hard lime nodules or accumulations, are found in subsoil layers of soil profile Nos. 1, 2 (piedmont unit), 3 and 4 (alluvial terraces, locally over blown sands unit). In addition, some secondary formations of gypsum segregations occurred in soil profile Nos. 1, 2 (piedmont unit), and 4 (alluvial terraces, locally over blown sands unit). Moreover, a surface salty crust is characterized the studied soil profile No. 12 which developed on the physiographic unit of Nile alluvial depressed plain (river bed).

Data obtained reveal also that land use periods at soils developed on the cultivated soils treated with organic manure for long-term use under well-drained soil drainage have deep root zone, lacking feature of development such as dark yellowish brown matrix colour, especially in the surface layers.

The orthic signs of both the prevailing environmental conditions and soil genesis played an important role for modifying soil structure, which is considered as a function of soil physico-chemical properties, from single grain to massive, weak or moderate granular, in addition to another type of moderate medium sub-angular blocky to coarse strong angular blocky. The occurrence of the diagnostic horizons of calcic and gypsic in soil profile Nos. 1, 2 (piedmont unit) and 4 (alluvial terraces, locally over blown sands unit); calcic in soil profile No. 3 (alluvial terraces, locally over blown sands unit); gypsic in soil profile No. 7 (El-Fayoum alluvial plain, locally terraced unit) and salic horizon in soil profile No. 11 (Nile alluvial depressed plain as a river bed unit) 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.

Physico-chemical properties

Data in Tables 1 and 2 indicate that the physico-chemical properties of the studied soil profiles are largely responsible for performing a closely relationship between soil origins and the prevailing environmental conditions. However, the original phase of the piedmont (soil profile No. 2), alluvial terraces (soil profile No. 6), El-Fayoum alluvial fan (soil profile No. 9), and the Nile alluvial plain (soil profile Nos. 11 and 12) units have been almost uniform texture throughout the whole profile layers, *i.e.*, sandy loam, sand, clay and clay, respectively. On the other hand, the rest soils developed on either some of these units or the other studied physiographic ones are characterized by different soil textured grades, *i.e.*, sand, loamy sand, sandy loam, sandy clay loam, clay loam and clay), besides different gravel contents (*i.e.*, slight gravelly, gravelly and very gravelly), which are randomly distributed throughout soil profiles, indicate that these soils are of multi-origins or subjected to multi-depositional regimes.

It is worthy to mention that most of the soil chemical properties are more related to the nature of soil origin, relief, texture, land use period, management practices, organic manure, cropping pattern or rotation, irrigation water suitability and system through the different periods of cultivation. In general, soil salinity tended to increase in the most of the studied soil profiles, except of some scattered areas such as those represented with soil profile Nos. 6 (alluvial terraces, locally over blown sands unit), 8 (El-Fayoum alluvial plain, locally terraced unit), 9, 10 (El-Fayoum alluvial fan unit) and 12 (Nile alluvial flat plain unit) which classified as non- (ECe < 4 dS/m) to slightly-saline (ECe $< 4\text{-}8$ dS/m), probably due to its relatively coarse textured grade (soil profile No. 6) and the soil well drainage conditions that alleviated salt accumulations or enhanced the removal of the excess salts.

On the other hand, the rest of the studied soils that developed on the physiographic units under investigation are suffering from salinity (ECe > 12 dS/m). The later conditions are more associated with inherited salts during chemical weathering, miss-management practices such as the absence of adequate soil drainage system and continuous lateral seepage from the relatively high areas (soil profile No. 11). Also, the distinct pattern of soil moisture distribution throughout the irrigation with saline water may be produced a pronounced effect on soil salinization (soil profile No. 8). The distribution pattern of soluble ions and soil sodicity (ESP) were more associated with the intensive of weathering and dominance of soluble Na^+ that stimulated more displacement of Ca and Mg by Na on soil colloidal complexes.

Moreover, continuous lateral seepage from the relatively high areas and the absence of adequate soil drainage system increased these problems. The soluble cations in the studied soils are categorized in an ascending order of $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ vs the soluble anions of $Cl^- > SO_4^{2-} > HCO_3^-$, except of soils of both piedmont and alluvial terraces, locally over blown sands units that showed $SO_4^{--} > Cl^- > HCO_3^-$, indicate that NaCl and Na_2SO_4 are the dominant salts (Table 3).

It is quite noticeable from data presented in Table 2 that the changes in the CEC values were more related to the mechanical composition of soil sediments (coarse or fine texture), as well as a the soil content of organic colloids. Moreover, the studied soils showed relatively low and moderate CEC values extending parallel close to the relatively low and moderate contents of charged silicate clay minerals vs relatively high and moderate contents of quartz and $CaCO_3$ particles in the size of clay fraction, respectively. Soil CEC value showed a relative increase in soil profile layers No. 11 (47.62-56.77 Cmolc kg^{-1} soil), due to the relatively high clay content (56.43-67.00 %).

The obtained data in Table 2 showed a pronounced decrease in soil organic matter content, especially in virgin soils of desert belt. These noticeable decreases may be attributed to the hot climate desert zone, besides the absence of natural vegetation and the directly inhibitive effect of soil salinity stress, which depressed the decomposition rate of organic residues, remained in soil. A reversible trend was observed for both soil $CaCO_3$ and $CaSO_4 . 2H_2O$ contents, where their contents are generally found in relatively high contents in the majority of the studied desert localities, mostly due to the nature of lithic origin (Eocene limestone) as well as the precipitation of dissolved $Ca(HCO_3)_2$ in a form of secondary $CaCO_3$.

TABLE 2. Particle size distribution, organic matter, calcium carbonate, gypsum contents, CEC and soil sodicity (ESP) of the studied soil profiles.

Physiographic units	Profile No.	Depth (cm)	Gravel %	Particle size distribution %				Modified texture class	Organic matter %	$CaCO_3$ %	$CaSO_4$ $2H_2O$ %	CEC (C mole kg^{-1} soil)	Soil sodicity (ESP)
				Coarse sand	Fine sand	Silt	Clay						
Piedmont	1	0-15	47.85	36.57	39.25	13.53	10.65	VG SL	0.17	51.65	5.95	11.38	6.10
		15-45	56.93	46.48	30.74	14.08	8.70	VG LS	0.09	56.37	7.24	8.57	5.54
		45-	Limestone bedrock										
	2	0-20	16.45	32.18	36.07	12.70	19.05	G SL	0.21	45.67	9.35	9.16	3.69
		20-45	29.89	36.94	48.94	10.25	17.75		0.16	21.93	16.84	6.15	4.02
		45-75	35.20	41.56	40.40	5.90	12.68	VG SL	0.10	32.45	10.55	5.82	5.34
		75-	Limestone bedrock										
Alluvial terraces, locally overblown sands	3	0-25	7.50	55.69	19.64	8.75	15.92	SG SL	0.26	14.15	1.22	7.12	9.17
		25-55	9.35	32.71	23.02	16.43	27.84	SG SCL	0.17	27.90	2.90	14.08	7.35
		55-105	6.46	19.85	20.70	22.60	36.75	SG CL	0.14	21.84	4.65	15.12	11.49
		105-150	10.08	50.57	35.05	5.25	9.13	SG LS	0.08	30.50	3.00	5.87	10.82
	4	0-15	31.45	27.60	14.39	31.64	26.37	GS CL	0.17	13.98	2.85	16.54	8.66
		15-50	28.60	34.92	35.10	15.53	14.45	G SL	0.15	14.72	3.70	13.70	6.78
		50-95	26.50	26.80	55.52	7.40	10.28	G LS	0.09	25.64	5.54	16.04	9.54
		95-150	26.52	14.37	20.07	39.81	25.75	G SCL	0.07	17.50	8.43	14.65	11.52
	5	0-20	40.75	32.56	53.05	8.14	6.25	VG LS	0.28	9.97	0.52	18.93	10.91
		20-65	51.83	39.10	47.35	5.60	7.95		0.21	7.20	0.64	25.02	11.25
		65-95	45.95	35.73	53.46	4.35	6.46		0.16	8.75	0.75	20.44	9.69
		95-150	61.42	40.95	52.90	2.84	3.31	ExG S	0.12	6.84	0.83	18.90	10.30
	6	0-30	3.20	20.70	75.25	1.34	2.71	S	0.14	1.69	0.23	3.96	2.56
		30-85	1.70	77.96	12.65	2.85	6.54		0.10	1.35	0.30	4.72	3.87
		85-150	0.55	67.30	29.82	0.73	2.15		0.08	0.97	0.38	3.35	2.41
El-Fayoum alluvial plain, locally terraced	7	0-35	0.00	5.34	35.60	21.34	37.72	CL	0.67	15.75	1.86	17.70	9.20
		35-75	0.00	4.75	33.26	23.04	38.95		0.49	19.54	2.54	15.16	9.42
		75-110	0.00	2.10	20.10	26.55	51.25	C	0.32	37.82	9.75	18.75	10.48
		110-150	0.00	1.82	15.39	29.18	53.61		0.18	28.60	5.10	19.23	11.17
	8	0-25	0.00	6.45	59.15	13.22	21.18	SCL	0.35	1.23	0.54	17.89	4.45
		25-80	0.00	5.71	79.30	5.35	9.64	LS	0.21	0.75	0.37	5.05	5.20
		80-150	0.00	3.84	87.24	4.42	4.50	S	0.10	0.48	0.30	3.71	5.75
El-Fayoum alluvial fan	9	0-25	0.00	6.32	23.15	25.64	44.89	Clay	1.52	5.93	0.64	37.94	9.76
		25-80	0.00	8.64	16.07	29.95	45.34		0.93	4.12	0.57	36.82	10.95
		80-120	0.00	6.75	22.30	24.40	46.55		0.54	3.86	0.41	38.75	12.48
		120-150	0.00	7.81	21.96	29.78	40.45		0.27	2.45	0.29	33.61	11.97
	10	0-20	0.00	4.15	26.85	31.24	37.76	CL	1.85	4.90	0.67	31.14	6.54
		20-60	0.00	3.65	25.72	32.33	38.30		0.76	3.76	0.54	29.32	7.10
		60-100	0.00	2.93	27.10	24.45	45.52	C	0.65	2.80	0.36	38.40	8.36
		100-150	0.00	1.57	25.64	25.71	47.08		0.40	1.54	0.21	39.55	8.93
Nile alluvial depressed plain (River bed)	11	0-15	0.00	2.35	26.70	1452	56.43	C	2.47	2.59	0.23	47.62	12.05
		15-50	0.00	1.84	14.11	21.90	62.15		1.83	2.21	0.57	51.35	13.67
		50-100	0.00	1.32	19.90	13.83	64.87		0.92	1.83	0.84	54.86	14.90
		100-150	0.00	1.15	17.45	14.40	67.00		0.75	1.46	0.96	56.77	14.83
Nile alluvial flat plain	12	0-25	0.00	4.85	22.34	24.56	48.25	C	1.79	3.20	0.94	40.65	8.35
		25-60	0.00	5.34	19.83	25.70	49.13		0.82	2.54	0.75	41.84	7.92
		60-90	0.00	3.71	28.26	20.19	47.84		0.65	2.05	0.61	40.53	9.84
		90-150	0.00	4.95	27.51	22.45	45.09		0.37	1.85	0.52	37.97	10.03

Gravel: SG=Slight gravelly, G=Gravelly, VG=Very gravelly and ExG=Extreme gravelly.
Fine earth: S=Sand, LS=Loamy sand, SL=Sandy loam, SCL=Sandy clay loam, CL=Clay loam and C=Clay.

TABLE 3. Chemical analysis of soil paste extract of the studied soil profiles.

Physiographic unit	Profile No.	Depth (cm)	Soil pH*	ECe (dS/m)	Soluble cations (m mmole L^{-1})				Soluble anions (m mmole L^{-1})			
					Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
Piedmont	1	0-15	7.72	38.76	126.40	90.25	172.70	2.40	0.00	1.75	115.40	274.60
		15-45	7.55	35.40	110.11	76.40	167.54	3.15	0.00	1.60	157.15	198.45
		45-	Limestone bedrock									
	2	0-20	7.90	9.35	29.70	20.20	44.25	0.85	0.00	1.75	40.51	52.74
		20-45	7.85	13.72	42.67	29.53	65.90	1.30	0.00	1.70	61.00	76.70
		45-75	7.53	20.63	65.27	43.52	97.64	1.75	0.00	1.60	90.50	116.08
		75-	Limestone bedrock									
Alluvial terraces, locally overblown sands	3	0-25	7.94	21.54	84.72	31.20	93.70	11.08	0.00	1.60	101.70	117.40
		25-55	7.98	48.12	197.60	68.73	204.32	21.95	0.00	0.95	207.55	284.10
		55-105	8.03	36.90	143.81	54.45	161.90	16.74	0.00	1.10	175.15	200.65
		105-150	8.15	17.83	62.45	27.02	86.68	9.25	0.00	1.75	86.11	97.54
	4	0-15	7.81	69.75	211.10	115.60	346.05	30.50	0.00	1.96	313.60	387.69
		15-50	7.85	74.05	237.42	120.45	352.60	36.25	0.00	2.04	343.93	400.75
		50-95	7.90	113.46	396.70	176.73	527.84	44.70	0.00	0.85	542.70	602.42
		95-150	7.92	147.25	483.42	210.91	719.60	67.42	0.00	1.04	681.40	798.91
	5	0-20	7.76	8.71	31.04	12.30	42.96	1.75	0.00	2.45	39.52	46.08
		20-65	7.79	10.32	37.36	14.65	50.40	2.22	0.00	2.30	47.65	54.70
		65-95	7.85	13.50	50.25	21.08	63.82	3.10	0.00	1.65	69.70	66.90
		95-150	7.89	17.84	62.98	28.60	85.71	3.42	0.00	1.50	86.36	92.85
	6	0-30	7.64	6.73	23.85	11.50	32.40	0.45	0.00	1.75	41.09	25.36
		30-85	7.69	5.81	20.40	10.00	28.20	0.36	0.00	1.80	35.70	21.45
		85-150	7.80	4.96	15.98	9.56	24.65	0.22	0.00	1.70	26.85	21.86
El-Fayoum alluvial plain locally terraced	7	0-35	8.13	13.85	36.15	30.00	70.45	3.50	0.00	2.30	70.50	67.30
		35-75	8.19	16.07	35.33	31.50	91.92	4.75	0.00	2.00	81.65	79.85
		75-110	8.24	17.69	40.00	34.30	100.50	5.00	0.00	1.90	91.20	86.70
		110-150	8.32	19.15	45.23	40.20	102.80	7.42	0.00	1.85	104.25	89.65
	8	0-25	7.91	0.79	3.54	1.16	3.25	0.25	0.00	1.75	4.15	2.30
		25-80	7.96	1.16	5.20	1.87	4.63	0.20	0.00	1.80	5.43	4.67
		80-150	8.02	1.45	5.62	2.02	7.00	0.16	0.00	1.95	7.00	5.85
El-Fayoum alluvial fan	9	0-25	7.76	4.47	15.65	5.80	23.00	0.85	0.00	2.70	29.35	13.25
		25-80	7.79	3.96	13.70	6.17	19.50	0.73	0.00	2.85	26.20	11.05
		80-120	7.81	3.35	12.05	5.10	16.25	0.50	0.00	3.00	21.60	9.30
		120-150	7.86	3.10	10.25	6.00	14.70	0.45	0.00	3.10	20.55	7.80
	10	0-20	7.63	2.37	9.65	3.15	10.20	1.20	0.00	2.55	24.15	15.50
		20-60	7.67	3.40	13.50	4.21	15.74	0.95	0.00	2.60	22.70	9.10
		60-100	7.77	3.65	14.00	4.55	17.50	0.80	0.00	2.75	26.00	8.10
		100-150	7.92	4.12	13.10	8.03	19.68	0.64	0.00	2.84	32.21	6.40
Nile alluvial depressed plain (River bed)	11	0-15	7.68	19.74	33.26	27.54	134.75	3.40	0.00	257	127.60	68.78
		15-50	7.76	18.91	31.80	29.15	127.16	2.93	0.00	2.46	123.45	65.34
		50-100	7.79	16.60	29.05	28.30	108.55	1.70	0.00	2.94	101.17	63.83
		100-150	7.87	15.85	27.32	27.66	113.30	1.62	0.00	3.55	115.30	51.55
Nile alluvial flat plain	12	0-25	7.56	2.72	10.54	3.43	12.92	0.75	0.00	2.25	13.60	11.79
		25-60	7.64	3.04	9.85	4.58	16.07	0.60	0.00	2.20	16.04	12.86
		60-90	7.71	2.51	8.70	2.75	13.45	0.55	0.00	2.40	12.10	10.95
		90-150	7.75	1.96	7.63	2.10	10.00	0.47	0.00	2.35	9.75	8.10

* Soil pH was determined in 1:2.5 soil water suspensions

Mineralogy of clay fraction

The diagnostic criteria used for identification of clay minerals in this study are those of suggested by Brown (1961); Whitting (1965) and Jackson (1965). The X-ray diffractograms of the clay fraction were used as a guide for semi-quantitative determination of clay samples (≤ 2 micron), which taken from the subsurface and deepest layers of the representative soil profiles Nos. 2 (Piedmont), 3, 6 (Alluvial terraces, locally overblown sands), 7 (El-Fayoum alluvial plain, locally terraced), 9 (El-Fayoum alluvial fan), 11 (Nile alluvial depressed plain, River bed) and 12 (Nile alluvial flat plain) are shown in Table 4. The obtained data indicate that smectites were the predominated group in soils of El-Fayoum alluvial plain, El-Fayoum alluvial fan, Nile alluvial depressed plain and Nile alluvial flat plain units, followed by kaolinite group, illite, vermiculite and chlorite minerals as charged silicate clay minerals as well as quartz, feldspars, calcite and dolomite as accessory ones.

On the other hand, kaolinite group was the predominated clay minerals in the rest of the studied soils of Piedmont and alluvial terraces units, followed by smectites, illite, chlorite, vermiculite and palygorskite as charged clay minerals as well as feldspars, quartz, calcite and dolomite for the soils calcareous in nature (soil profile Nos. 2 and 3), while those of siliceous in nature (soil profile No. 6) showed quartz > feldspars as accessory ones. It is noteworthy to mention that palygorskite is present in small amounts in the clay samples taken from soil profile Nos. 2 and 3 which are characterized by calcareous in nature. Also, the occurrence of relatively high smectite contents in soil deposits of El-Fayoum alluvial plain or fan and the Nile alluvial plain may be takes place as a result of chemical weathering that are associated with continuous irrigated agriculture. On the other hand, the well assembling of kaolinite in the clay fractions of the other studied soil sediments suggests the presence of an appreciable amount of coarse crystallized type, which is derived mainly from the weathering products of basic parent materials that attain low Si-content and favourable conditions to form 1:1 clay minerals. The later results are confirmed by the presence of relatively high feldspars content as accessory minerals as well as are in agreement with those obtained by Shendi (1990) who pointed out that such prevailing condition was highly correlated with a relatively low intensive weathered soil materials and undeveloped soil profile (Table 4).

TABLE 4. Semi-quantitative of clay minerals (≤ 2 micron) separated from subsurface and deepest layers of some representative soil profile.

Physiographic units	Profile No.	Depth (cm)	Clay minerals						Accessory minerals			
			Smectites	Kandites	Illite	Vermiculite	chlorite	Palygorskite	Quartz	Feldspars	Calcite	Dolomite
Piedmont	2	20-45	13.68	50.03	7.84	1.73	2.61	1.35	6.96	8.15	4.20	3.45
		45-75	12.70	43.55	10.57	2.70	3.72	1.10	6.85	7.64	6.35	4.82
Alluvial terraces, locally overblown sands	3	25-55	15.35	44.90	9.02	2.54	4.71	2.02	5.10	6.38	5.78	4.20
		105-150	13.07	41.25	9.65	4.29	7.05	3.64	4.56	7.45	5.26	3.78
	6	30-85	19.75	30.80	13.57	3.95	6.53	--	15.09	7.16	2.30	0.85
		85-150	15.34	45.92	10.55	2.56	7.02	--	12.50	4.43	1.26	0.42
El-Fayoum alluvial plain, locally terraced	7	35-75	5155	12.15	9.28	6.11	5.70	--	5.18	4.70	3.05	2.10
		110-150	54.83	14.20	7.36	4.95	4.84	--	4.90	3.35	4.12	1.45
El-Fayoum alluvial fan	9	25-80	53.74	15.89	9.15	5.45	3.20	--	5.02	2.30	3.25	2.00
		120-150	55.40	16.63	8.90	4.04	2.36	--	4.90	4.12	2.01	1.64
Nile alluvial depressed plain (River bed)	11	15-50	59.63	10.07	6.50	5.12	4.06	--	4.95	340	3.67	2.60
		100-150	61.70	7.85	6.72	4.44	2.65	--	5.84	4.93	4.15	1.72
Nile alluvial flat plain	12	25-60	54.92	11.12	9.35	4.91	1.83	--	6.07	5.60	3.90	2.30
		90-150	57.45	12.05	7.90	2.78	1.57	--	5.60	4.80	4.28	3.57

-- Not detected .

Soil taxonomy

By using the aforementioned analytical data as well as Classification System of USDA (1975) and Key of Soil Taxonomy (USDA, 2006), the obtained data in Table 5 show that the studied soil profiles could be classified into three orders, *i.e.*, Aridisols, Vertisols and Entisols as well as their followed sequence classification levels. All the representative soil profiles for piedmont unit (Nos. 1 and 2), in addition to some localities developed on alluvial terraces unit (soil profile Nos. 3 and 4) could be classified into an order of Aridisols, which has one sub-order of Calcids; two great groups of Calcigypsids and Haplocalcids; three sub-great groups of Lithic Calcigypsids, Typic Calcigypsids and Typic Haplocalcids as well as four families, as follows:

i) *Aridisols* include soil families of a. Lithic calcigypsids, sandy skeletal, carbonitic, hyperthermic and Typic calcigypsids, loamy skeletal, carbonitic, hyperthermic in the piedmont unit and b. Typic Haplocalcids, fine loamy, mixed, hyperthermic and Typic calcigypsids, sandy, mixed, hyperthermic in the alluvial terraces (locally over blown sand) unit.

The other two soil sites which developed on the alluvial terraces unit (soil profile Nos. 5 and 6), besides that is located at El-Fayoum alluvial plain unit (soil profile No. 8) are characterized by no evidence of development for pedogenic horizons and could be distinguished under an order of Entisols; two sub-orders of Orthents and Psamments; two great groups of Torri-orthents and Torri-psamments; two sub-great groups of Typic Torri-orthents and Typic Torri-psamments and three families, as follows:

ii) *Entisols* include a. Typic Torriorthents, sandy skeletal, mixed, hyperthermic and Typic Torripsamments, siliceous, hyperthermic in the alluvial terraces (locally over blown sand) unit and b. Typic Torriorthents, sandy, mixed, hyperthermic in El-Fayoum alluvial plain (locally terraced) unit.

On the other hand, some soils developed on the physiographic units of El-Fayoum alluvial plain (soil profile No. 7), El Fayoum alluvial fan (soil profile Nos. 9 and 10), Nile alluvial depressed plain (soil profile No. 11) and Nile alluvial flat plain (soil profile No. 12) could be classified into an order of Vertisols, which has one sub-order of Torrerts; two great groups of Gypsictorrerts and Haplotorrerts; four sub-great groups of Typic Gypsictorrerts, Typic Haplotorrerts, Entic Haplotorrerts and Halic Haplotorrerts as well as four families, as follows:

iii) *Vertisols* include a. Typic Gypsitorrerts, clayey, smectitic, hyperthermic in El- Fayoum alluvial plain (locally terraced) unit; b. Typic Haplotorrerts, fine clayey, smectitic, hyperthermic and Entic Haplotorrerts, clayey, smectitic, hyperthermic in El-Fayoum alluvial fan unit; c. Halic Haplotorrerts, very fine clayey, smectitic, hyperthermic in the Nile alluvial depressed plain (River bed) unit and d. Typic Haplotorrerts, fine clayey, smectitic, hyperthermic in the Nile alluvial flat plain unit (Table 5).

Land suitability for irrigated agriculture

Current land suitability

The current suitability of the studied soils was estimated by matching between the present soil characteristics and their ratings which calculating by using the parametric system outlined by Sys & Verheye (1978), as shown in Table 6.

Suitability indices and classification of the studied soils developed on the studied different physiographic units, which are shown in Table 6, reveal that four soil suitable classes, *i.e.,* highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N1), besides eight subclasses, *i.e.,* $N1s_1s_2s_3n$, $S3s_1s_2s_4n$, $S3s_1n$, $S3s_1$, S2n, $S2s_1$, S2 and S1 were recognized in the studied area. The soils of these sub-classes represent are suffering from some soil properties as soil limitations, *i.e.*, soil texture (s_1), soil depth (s_2), $CaCO_3$ (s_3) and gypsum (s_4) contents as well as salinity/alkalinity (n) with different intensity degrees, *i.e.*, >90 (slight), <90-60 (moderate), <60-40 (severe) and <40 (very severe). Also, it is evident that some localities of piedmont (soil profile No. 1) and alluvial terraces (soil profile Nos. 3, 4, 5 and 6) units have a slight intensity of topography (≈90).

The obtained values of suitability indices show that some of the soils developed on the physiographic units of the alluvial terraces (soil profile No. 3), El-Fayoum alluvial plain (soil profile Nos. 7 and 8), El-Fayoum alluvial fan (soil profile No. 9) and Nile alluvial flat plain (soil profile No. 12) could be evaluated as moderately suitable (S2), with slight soil limitations. On the other hand, some soils of piedmont (soil profile No. 2), alluvial terraces (soil profile Nos. 4, 5 and 6) and Nile alluvial depressed plain (soil profile No. 11) are evaluated as marginally suitable for irrigated agriculture. In addition, the index value indicates a currently not suitable class for some soils of piedmont unit (soil profile No. 1), however, the representative soils have slight intensity of topography, severe intensity of soil texture and effective soil depth as well as moderate intensity for both $CaCO_3$ content and soil salinity/alkalinity limitations.

TABLE 5. Soil taxonomic units of the studied soil profiles.

Order	Sub-order	Great group	Sub-group	Family	Representative soil profiles
Aridisols	Calcids	Calcigypsids	Lithic Calci-gypsids	Lithic calcigypsids, sandy skeletal, carbonitic, hyperthermic	1
			Typic Calci-gypsids	Typic calcigypsids, loamy skeletal, carbonitic, hyperthermic	2
				Typic calcigypsids, sandy, mixed, hyperthermic	4
		Haplo-calcids	Typic Haplo-calcids	Typic Haplocalcids, fine loamy, mixed, hyperthermic	3
Entisols	Orthents	Torri-orthents	Typic torri-orthents	Typic Torriorthents, sandy skeletal, mixed, hyperthermic	5
				Typic Torriorthents, sandy, mixed, hyperthermic	8
	Psa-mm-ents	Torri-psamments	Typic Torri-psamments	Typic Torripsamments, siliceous, hyperthermic	6
Vertisols	Torrerts	Gypsi-torrerts	Typic gypsi-torrerts	Typic Gypsitorrerts, clayey, smectitic, hyperthermic	7
		Haplotorrerts	Typic Haplo-torrerts	Typic Haplotorrerts, fine clayey, smectitic, hyperthermic	9 and 12
			Entic Haplo-torrerts	Entic Haplotorrerts, clayey, smectitic, hyperthermic	10
			Halic Haplo-torrerts	Halic Haplotorrerts, very fine clayey, smectitic, hyperthermic	11

TABLE 6. Rating of soil limitations and its suitability for irrigated agriculture.

Physiographic units	Profile No.	Suitability condition	Topography (t)	Wetness (w)	Physical characteristics				Salinity & alkalinity (n)	Suitability rating	Suitability class	Suitability class and limitations
					Texture (s_1)	Depth (s_2)	$CaCO_3$ (s_3)	Gypsum (s_4)				
Piedmont	1	Current	90	100	55	55	80	100	80	17.42	N1	N1$s_1s_2s_3$n
		Potential	100	100	55	55	80	100	100	24.20	N1	N1$s_1s_2s_3$
	2	Current	90	100	65	75	90	80	80	25.27	S3	S3$s_1s_2s_4$n
		Potential	100	100	65	75	90	80	100	35.10	S3	S3$s_1s_2s_4$
Alluvial terraces, locally overblown sands	3	Current	90	100	85	100	100	100	75	57.37	S2	S2n
		Potential	100	100	85	100	100	100	100	85.00	S1	S1
	4	Current	90	100	65	100	100	100	75	43.87	S3	S3s_1n
		Potential	100	100	65	100	100	100	100	65.00	S2	S2s_1
	5	Current	90	100	45	100	95	90	85	29.43	S3	S3s_1
		Potential	100	100	45	100	95	90	100	38.47	S3	S3s_1
	6	Current	90	100	40	100	95	90	98	30.16	S3	S3s_1
		Potential	100	100	40	100	95	90	100	34.20	S3	S3s_1
El-Fayoum alluvial plain, locally terraced	7	Current	100	100	90	100	100	100	80	72.00	S2	S2n
		Potential	100	100	90	100	100	100	100	90.00	S1	S1
	8	Current	100	100	70	100	85	90	100	53.55	S2	S2s_1
		Potential	100	100	70	100	85	90	100	53.55	S2	S2s_1
El-Fayoum alluvial fan	9	Current	100	100	85	100	95	90	80	58.14	S2	S2n
		Potential	100	100	85	100	95	90	100	72.67	S2	S2
	10	Current	100	100	90	100	95	90	100	76.95	S1	S1
		Potential	100	100	90	100	95	90	100	76.95	S1	S1
Nile alluvial depressed plain (River bed)	11	Current	100	100	65	100	95	90	80	44.46	S3	S3s_1n
		Potential	100	100	65	100	95	90	100	55.57	S2	S2s_1
Nile alluvial flat plain	12	Current	100	100	85	100	95	90	96	69.77	S2	S2
		Potential	100	100	85	100	95	90	100	72.67	S2	S2

S1 = Texture, S2 = Soil depth (cm), S3 = Calcium carbonate status and S4 = Gypsum status.

N = Not capability, S1 = Highly suitability, S2=Moderately suitability and S3 = Limitation suitability.

Potential land suitability

A potential suitability term refers to the suitability future date, after specified major improvements have been completed where necessary (FAO, 1976). Land improvements are activities, which cause beneficial changes in the qualities of the land itself. They are classified as major land improvements. Further land improvements are required to correct or to reduce the severity of limitations exiting in the studied area, such as: a. Leveling of undulating surfaces, b. Leaching of soil salinity and reclamation of alkalinity existing in the soils, c. Construction of efficient open drainage ditches to enhance leaching process of the excess soluble salts as well as to accelerate from the chemical remediation of soil sodicity, d. Continuous application of organic manure to improve soil physico-chemical properties and fertility status, e. Application of modern irrigation systems, *i.e.*, drip and sprinkler to save a pronounced amount of irrigation water as well as to rise the irrigation efficiency.

It is applicable after executing specified major land improvements as proposed in the aforementioned agro-management practices according to their necessity. For establishing potential land suitability classification, the main land improvements for the studied area are considered for the land qualities of drainage, salinity and sodicity. The minor limitations can be improved under specific land management, concerning each of them. So, the obtained potential land suitability sub-classes were sorted for the maximum productive levels (supreme potential land suitability). These levels were designed to be guide charts and maps for the best land utilization alternatives, giving a possible maximum output. The potential land suitability data are shown in Table 5. These adaptations can be described by applying the previous improvement practices, and in turn potential suitability of the studied soils indicates the existing of two suitability classes, *i.e.*, highly (S1) and moderately (S2), however, soil suitable sub-classes of both alluvial terraces (soil profile No. 3) and El-Fayoum alluvial plain (soil profile No. 7) improved from moderately suitable (S2n) to highly suitable (S1) as well as both alluvial terraces (soil profile No. 4) and Nile alluvial depressed plain (soil profile No. 11) improved from marginally suitable ($S3s_1n$) to moderately suitable ($S2s_1$). The later subclass represents some soil profiles developed on some of the different studied physiographic units with severe to moderate intensity of soil texture (relatively coarse) as soil limitations. The severity of soil texture (sand) can be corrected in these subclasses by application of organic and inorganic soil amendments as well as drip irrigation system to sustain a soil moisture content at a favourable conditions for grown plants.

From the abovementioned results, it can be concluded that space images proved to be a useful tool for reconnaissance inventories for large area of many types of landscapes. Furthermore, Landsat data were useful for mapping major geomorphic units as well as its use that has been successfully demonstrated in delineating soil associations on the landscape. Moreover, the data of the current study were 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 findings 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 the southern-east desert outskirt of El-Fayoum depression by mapping them to be a digital model in a harmony of physiographic and soil data set, serving the extrapolation approach when other areas will be under study.

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مساهمة التفسير المرئى لصور الأقمار الفضائية فى تحديد الوحدات الفيزيوجرافية ومحددات التربة للتنمية الزراعية فى الظهير الصحراوى الجنوبى – الغربى لمنخفض الفيوم – مصر

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تعتبر هذه الدراسة محاولة لإستبيان مدى مساهمة التفسير المرئى لصور الأقمار الفضائية فى تحديد أهم الوحدات الفيزيوجرافية ومحددات إنتاجية تربتها فى الظهير الصحراوى الجنوبى- الغربى لمنخفض الفيوم- مصر، والتى تعتبر من أهم الوسائل الضرورية المساعدة فى التخطيط لمشروعات التنمية الزراعية الملائمة ، حيث أن تطبيق هذا التكنيك فى حالة المناطق الصحراوية الواسعة يعتبر من الضرورة لعمل الدراسات الأولية لتقييم محددات إنتاجية التربة بصورتها الحالية والمستقبلية ، وكذا العمليات المناسبة لخدمة التربة وإستدامة إستزراعها على إمتداد كلا المدى القصير والطويل. لذا فان المنطقة تحت الدراسة قد أختيرت كنموذج لتحديد ما بداخلها من وحدات فيزيوجرافية وتقسيمية وتقييمية للأراضى المروية.

وتشير النتائج المتحصل عليها أن المنطقة تحت الدراسة تشتمل على تكوينات أرضية من كلا الترسيبات النهرية والصحراوية الموروثة من صخور خارجية ومحلية كمادة أصل على الترتيب. وقد تم تحديد الوحدات الفيزيوجرافية وخصائص تربتها من خلال تكنيك التفسير المرئى لصور الأقمار الفضائية (Enhanced Thematic Mapper 7) ، وكذلك تطبيق خصائص الملامح الأرضية. كما أمكن تجميع أهم الملامح الأرضية السائدة فى سبعة وحدات فيزيوجرافية هى:

Piedmont, alluvial terraces (locally over blown sand), El-Fayoum alluvial plain (locally terraced), El-Fayoum alluvial fan, Nile alluvial depressed plain (River bed), Nile alluvial flat plain and rock structures. The rock structures were delineated as dissected cuesta of summits and fronts or as rock outcrops.

وقد تم تحديد ودراسة سبعة وثلاثون نقطة ملاحظة أرضية لوضع دليل ملامح الوحدات الخريطية ، ثم حددت الإختلافات بين هذه الوحدات من خلال دراسة إثنى عشر قطاعا أرضيا تم وصفها مورفولوجيا وأخذت منها عينات تربة للتحليلات المعملية.

وتشير الدراسات الحقلية إلى أن العمق الفعال للتربة (٤٥-٧٥ سم) قد تحدد بتواجد المهد الصخرى فى وحدة Piedmont ، بينما وصل إلى ١٥٠ سم فى أراضى الوحدات الفيزيوجرافية الأخرى، وبصفة عامة فان معظم الأراضى تحت الدراسة تتميز بالقوام الرملى السائب- الطينى الرملى الحصوى، بجانب الأراضى ناعمة القوام فى الرسوبيات النهرية لترسيبات الفيوم ذات الشكل المروحى والسهلى، كما وأن معظم هذه الأراضى تعانى من مشاكل الملوحة والنقص الملحوظ فى المحتوى من المادة العضوية. وفيما عدا الأراضى المتكونة على وحدات ترسيبات الفيوم المروحية والسهلية الشكل ، وكذا السهل النهرى المتدرج أو المستوى والتى يسود بها معادن طين مجموعة الـ Smectites، فان التقدير شبه كمى لمعادن الطين يشير إلى أن مجموعة الـKaolinite هى السائدة، يليها Smectites, illite, palygorskite, chlorite and vermiculite

وقد أمكن تحديد الوحدات التقسيمية تبعا لـ Key of Soil Taxonomy (USDA, 2006)حتى مستوى العائلة فيما يلى:

1. *Aridisols* include a) Lithic calcigypsids, sandy skeletal, carbonitic, hyperthermic and Typic calcigypsids, loamy skeletal, carbonitic, hyperthermic in the piedmont unit and b) Typic Haplocalcids, fine loamy, mixed, hyperthermic and Typic calcigypsids, sandy, mixed, hyperthermic in the of alluvial terraces (locally over blown sand) unit
2. *Vertisols* include a) Typic Gypsitorrerts, clayey, smectitic, hyperthermic in El- Fayoum alluvial plain (locally terraced) unit; b) Typic Haplotorrerts, fine clayey, smectitic, hyperthermic and Entic Haplotorrerts, clayey, smectitic, hyperthermic in El-Fayoum alluvial fan unit; c) Halic

Haplotorrerts, very fine clayey, smectitic, hyperthermic in the Nile alluvial depressed plain (River bed) unit and d) Typic Haplotorrerts, fine clayey, smectitic, hyperthermic in the Nile alluvial flat plain unit.

3. *Entisols* include a) Typic Torriorthents, sandy skeletal, mixed, hyperthermic and Typic Torripsamments, siliceous, hyperthermic in the alluvial terraces (locally over blown sand) unit and b) Typic Torriorthents, sandy, mixed, hyperthermic in El Fayoum alluvial plain (locally terraced) unit.

و تبعا للنظام الكمى الرياضى الموضوع بمعرفة Sys & Verheye (1978) ، فان درجة الصلاحية الحالية للأراضى تحت الدراسة يمكن تجميعها فى أربعة رتب هى عالية، متوسطة، هامشية، غير صالحة للزراعات المروية Highly (S1), moderately (S2), marginally (S3) and not suitable (N1)، بجانب ثمانية تحت رتبة هى: $N1s_1s_2s_3n$, $S3s_1s_2s_4n$, $S3s_1n$, $S3s_1$, S2n, $S2s_1$, S2 and S1، والتى تعانى من بعض معوقات إنتاجية التربة ممثلة فى قوام التربة، عمق التربة الفعال ، المحتوى من كربونات الكالسيوم والجبس ، بجانب ملوحة وصودية التربة وذلك بدرجات شدة مختلفة. ولذا فانه من الواجب إجراء تحسين للتربة لتحقيق الصلاحية الكامنة (المستقبلية) وهى عالية، متوسطة، هامشية الصلاحية، مع تصحيح شدة معوقات إنتاجية التربة وذلك باضافة محسنات التربة العضوية وغير العضوية وإتباع نظام الرى بالتنقيط لإستدامة الرطوبة الأرضية المناسبة للنباتات. حيث أن تلك التعديلات يرجى منها الحصول على عائد مرتفع، حيث أن معظم تحسينات التربة تتمثل فى نوعية الصرف وإزالة الملوحة والصودية لتعظيم الصلاحية الحالية للأرض والوصول للصلاحية المستقبلية بعد إعادة التقييم لأراضى الوحدات الفيزيوجرافية وخلوها من هذه المعوقات.