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Characterization and classification of soils of Wadi Qena, Eastern Desert, Egypt

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ABSTRACT

An investigation was carried out to characterize and classify some soils from Wadi Qena, Eastern Desert, Egypt. Twelve representative profiles were chosen based on DEM extracted from the Landsat 8 ETM$^+$ satellite image. The soils were moderately deep to deep in depth, well drained, slightly to strongly alkaline in soil reaction (pH 7.6 – 8.4), slight to moderate saline (EC 3.3- 15.4 dS.m^{-1}). The soils were low in organic matter (0.09 – 0.65%), low in CEC (1.5–8.1 cmol (p+).kg^{-1}) and calcium carbonates ranged from (1.2 – 18.2%). The results revealed that the soils were low in available N (1–21 kg.ha^{-1}), low in available P (1.0 – 9 kg.ha^{-1}), and low to high in available K (105 – 762 kg.ha^{-1}). Further, the soils were low in available micronutrients. Soil classification of the investigated area is done according to the field survey, morphological description and soil analyses. Two soil orders, *viz* Entisols and Aridisols were recognized in the study area. The soils were keyed out as *Typic Torripsamments* and *Typic Haplocalcids* at subgroup level. The obtained results can be used by decision makers to focus on prospective agricultural areas and to achieve land reclamation and better agricultural production.

Key words: Characterization, Classification, Wadi Qena

Agricultural land in Egypt is mainly confined to the land near the Nile River. The soils developed on Quaternary River Nile sediments which only occupy 5% of the Egypt area support more than 90% of the agriculture production. The rapid population growth of the country together with urban expansion at the cost of agricultural land led to intensive use of agricultural land in order to meet the food demand. Consequently, the soils of Nile River valley and delta start to loss their fertility and productivity (Mustafa and Negim 2016). Hence, the sustainable development of the existing agricultural land and the extension of cultivated land for achieving the food security has become a main concern (Abdul Aziz *et al*. 2009).Reclamation programs of the desert land near the Nile River, which intended at increasing the cultivated land of some strategic crops and reducing the pressure on the existing agricultural land, have accelerated rapidly (FAO 2006). The golden triangle project which covers a very wide area in the Eastern Desert is one of the most important reclamation programs (NGage 2016). For such new areas, a lot of efforts are required to study the soils which are proposed to be under reclamation. Generation of data on soils distribution, characteristics and their potentials and problems is a prerequisite for any reclamation program. Furthermore, this information is very important for developing proper soil management practices and land using planning (Denton *et al.* 2017). The use of remotely sensed data as satellite imagery in pre-surveying work is of great importance particularly for such projects which cover a vast land area. Satellite imagery can generate data on topography, drainage patterns, landform boundaries, land use and vegetation cover in the study area (Ibrahim *et al.* 2017). Sporadic information is available on soil characteristics and classification in the Eastern desert. Reports from the Eastern desert indicated that the soil texture is dominated by coarse texture class. Soils are neutral to alkaline in reaction with wide variation in soil EC which ranging from 0.2 to 176.5 dS.m^{-1}. Organic carbon content ranged from very low to medium and calcium carbonates content varied widely from 0.5 to 80.4%. The exchangeable site were dominated by Ca^{+2} and Mg^{+2} followed by K$^+$ and Na$^+$ (Abd El-Aziz 1988; Abd El-Maksoud *et al.* 2000; Ibrahim and Ali 2009; Rabie *et al.* 1986). The information on the soils of Wadi Qena which is a part of the golden triangle project in the Eastern dessert is further limited. Hence, an attempt was carried out to study the morphological, physical and chemical properties and

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classify soils developed on different land forms in the new reclaimed areas along the sides of Sohag-Red Sea road in Wadi Qena area- Eastern desert.

MATERIALS AND METHODS

Site characteristics

This study was started in the year of 2015. The study area is a part of Wadi Qena in the Eastern Desert, Egypt. It lies between the 26º.653- 26º.754 latitudes (N) and 32º.717-32º.911 longitudes (E), and it covers about 204 km^2.

Wadi Qena is covered with Quaternary deposits which is consisting of gravels, sands and cemented by fine clay materials (El-Shamy 1988). Wadi Qena catchment is a typical arid basin, which is characterized with extremely arid climate. The annual rainfall ranges between 2.75 and 50 mm, while heavy showers are recorded occasionally during winter causing flash floods. The minimum temperature is ranging between 5ºC and 14ºC and the maximum is ranging between 28ºC and 42ºC.The relative humidity (RH) ranges between 30% and 56%. The maximum monthly evapotranspiration is 23.5 mm during June, while the minimum value is 3.1 mm during December (Awad 2008). Prevailing winds are dominantly from the northwest to the southeast with an average maximum speed of 10 knots/h. The natural vegetation is sparse and distributed randomly over the area. Moringa, Wild Caper and Salvadoroprisca are the common natural vegetation in the area. Furthermore, agricultural activities are very limited in the area (El-Zawahry *et al.* 2004).

Table 1 Physiographic units of the studied area

Mapping units and Symbols	Area (km^2)	Area (%)
Wadi-Floor (WF)	61. 82	30. 24
Low-elevated Sand Sheet (LSS)	30. 07	14. 71
High-elevated Sand Sheet (HSS)	31. 05	15. 19
Bajada (B)	27. 47	13. 44
Piedmont (P)	27. 45	13. 43
Table Land (TL)	26. 54	12. 98
Total	204. 39	100.00

Identification of physiographic units

Landsat8 ETM$^+$ full scene/Extent satellite image which covers the study area was resized and geometrically corrected/rectified using ENVI 5.0 software to mask and extract the exact area. False Colour Composite (FCC) image was used for Land use-Land Cover (LULC) interpretation, and data visualization. Digital Elevation Model (DEM) extracted then used in density slicing of the image. Density slicing visually enhances elevation differences based on image brightness. Density slice was done to cluster the Digital Elevation Model (DEM) into some ranges expressing the elevation values that range from 185 to 447 m above sea level (masl). Supervised classification technique used to generate the physiographic map of the study area using the DEM. The area under investigation is represented by six landforms/mapping units, i.e. Wadi-Floor (WF), Low-elevated Sand Sheet (LSS), High-elevated Sand Sheet (HSS), Bajada (B), Piedmont (P) and Table Land (TL) (Table 1).

Soil sampling and field work

Depending on the six physiographic units of the study area, 12 soil profiles were selected (two soil profiles from each unit) to represent the studied area. Distribution and landscape characteristics of profiles are summarized in Table 2. Latitudes and longitudes of studied profiles were recorded using GPS "Garmin–eTrix" under WGS84 coordinate system table. Soil profiles were exposed and soil samples were collected from each horizon. Detailed morphological description for all profiles was noted on the basis USDA procedures (Soil Survey Staff 2010).

Soil Samples preparation and laboratory analysis

Soil samples were air dried, grounded and passed through 2 mm sieve. Soil material (<2 mm) was used for determination of soil physical and chemical properties

Table 2 Site characteristics of studied soil profiles

Profile No.	Longitude (E)	Latitude (N)	Elevation (m a.s.l)	Landforms/Mapping units	Slope (%)	Drainage
1	32º.738	26º.682	185	Wadi-Floor (WF)	0-1	Well drained
2	32º.790	26º.719	211		0-1	Well drained
3	32º.738	26º.719	222	Low-elevated Sand Sheet (LSS)	0-1	Well drained
4	32º.843	26º.754	230		0-1	Well drained
5	32º.896	26º.646	236	High-elevated Sand Sheet (HSS)	0-1	Well drained
6	32º.896	26º.682	251		0-1	Well drained
7	32º.790	26º.682	260	Bajada (B)	0-1	Well drained
8	32º.843	26º.682	277		0-1	Well drained
9	32º.738	26º.754	285	Piedmont (P)	0-1	Well drained
10	32º.896	26º.719	302		0-1	Well drained
11	32º.896	26º.754	355	Table Land (TL)	0-1	Well drained
12	32º.818	26º.702	439		0-1	Well drained

as follows: particle size distribution by international pipette method (Jackson 1969). Soil reaction (pH) and electrical conductivity (EC) were determined in 1:1 soil-water suspension, calcium carbonate were estimated volumetrically using Colins's calcimeter (Jackson 1973). Organic matter contents were determined by Walkley and Black method (1934). Cation Exchange Capacity (CEC) was determined by sodium acetate (pH≈8.5) and exchangeable cations by ammonium acetate (pH≈7.0) methods (Black 1982). Available Nitrogen was determined using alkaline potassium permanganate method (Subbiah and Asija 1956). Available phosphorus was extracted with 0.5*M* $NaHCO_3$ (pH≈8.5) following the procedures outlined by Whatanable and Olsen (1965). Available potassium was determined by ammonium acetate (pH≈7.0) method. DTPA extractable micronutrients *viz*iron, manganese, zinc and copper were measured by Atomic Absorption Spectrophotometer. Soil bulk density and soil-water parameters were calculated using SPAW software (Saxton and Rawls 2006).

Soil classification

Based on soils morphological and physico-chemical characteristics, they were classified as per Keys to Soil Taxonomy (Soil Survey Staff 2010).

RESULTS AND DISCUSSION

Morphological characteristics of the soils

The soil profiles described morphologically and their data are summarized in Table 3.The soils depth ranged from moderate deep to deep. Soil samples showed color ranged from pink to light yellowish brown in dry conditions, and from very pale brown to brown in wet conditions. The 10YR and 7.5 YR were the dominant hue in the studied soils. Color value varied from 6 to 7 in dry and from 5 to 6 in moist conditions. Color Chroma varied from 4 to 6 in both dry and moist conditions.The studied soils were characterized with coarse texture which varied from loamy sand to sand. Khalifa *et al*. (2003) found that the texture classes in the eastern side of the Nile valley were sandy loam, loamy sand and sand and soil texture becomes finer with depth. The soil samples were structureless and having a single grain type. The consistency was under loose grade in dry and wet conditions and all soil samples were non sticky non plastic. The boundaries between soil profile layers were clear to gradual in distance, smooth to wavy in the topography. Pores in the horizons are few and having fine size. The studied soils showed strong to violent effervescence when treated with diluted HCl acid in the field. From the previous morphology

Table 3 Morphological characteristics of studied soil profiles

Horizon	Depth (cm)	Soil colour		Structure			Consistence			Boundary	Pores	Effervescence
		Dry	Wet	S	G	T	Dry	Moist	Wet			
Profile 1 (WF)												
A	0 – 20	10YR 7/4	10YR 6/6	f	0	sg	1	1	sopo	cs	ff	Ev
Bc$_K$	20 – 40	10YR 7/4	10YR 6/4	f	0	sg	1	1	sopo	cs	ff	Ev
C1	40 – 60	10YR 7/4	10YR 6/4	f	0	sg	1	1	sopo	gw	ff	Es
C2	60 – 80	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	gw	ff	Es
C3	80 – 130$^+$	10YR 7/4	10YR 6/4	f	0	sg	1	1	sopo	gw	ff	Es
Profile 2 (WF)												
A	0 – 25	7.5YR 7/4	7.5YR 5/4	f	0	sg	1	1	sopo	cs	ff	Ev
Bc$_K$	25 – 50	7.5YR 7/4	7.5YR 5/4	f	0	sg	1	1	sopo	cs	ff	Ev
C1	50 – 70	10YR 6/4	10YR 7/4	f	0	sg	1	1	sopo	gw	ff	Es
C2	70 – 120$^+$	10YR 6/4	10YR 7/4	f	0	sg	1	1	sopo	gw	ff	Es
Profile 3 (LSS)												
A	0 – 10	7.5YR 7/4	7.5YR 6/6	f	0	sg	1	1	sopo	cs	ff	Ev
C1	10 - 35	7.5YR 7/6	7.5YR 6/6	f	0	sg	1	1	sopo	cs	ff	Es
C2	35 - 70	7.5YR 7/4	7.5YR 6/6	f	0	sg	1	1	sopo	gw	ff	Es
C3	70 - 80	7.5YR 7/4	7.5YR 6/4	f	0	sg	1	1	sopo	gw	ff	Es
C4	80 – 130$^+$	7.5YR 7/4	7.5YR 6/4	f	0	sg	1	1	sopo	gw	ff	Es
Profile 4 (LSS)												
A	0 – 25	7.5YR 7/4	7.5YR 5/4	f	0	sg	1	1	sopo	cs	ff	Ev
C1	25 – 50	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	cs	ff	Es
C2	50 – 75	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	gw	ff	Es
C3	75 -130$^+$	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	gw	ff	Es

Contd.

Table 3 (*Concluded*)

Horizon	Depth (cm)	Soil colour		Structure			Consistence			Boundary	Pores	Effervescence
		Dry	Wet	S	G	T	Dry	Moist	Wet			
Profile 5 (HSS)												
A	0 – 25	7.5YR 7/4	7.5YR 5/4	f	0	sg	1	1	sopo	cs	ff	Ev
C2	25 – 75	7.5YR 7/4	7.5YR 6/4	f	0	sg	1	1	sopo	cs	ff	Ev
C3	75 – 100	7.5YR 7/4	7.5YR 6/4	f	0	sg	1	1	sopo	gw	ff	Es
C4	100 – 120^+	7.5YR 7/4	7.5YR 6/4	f	0	sg	1	1	sopo	gw	ff	Es
Profile 6(HSS)												
A	0 – 25	7.5YR 7/4	7.5YR 6/4	f	0	sg	1	1	sopo	cs	ff	Ev
C1	25 – 50	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	cs	ff	Ev
C2	50 – 75	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	gw	ff	Es
C3	75 – 100	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	gw	ff	Es
C4	100 – 120^+	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	gw	ff	Es
Profile 7 (B)												
A	0 – 10	7.5YR 7/4	7.5YR 5/4	f	0	sg	1	1	sopo	cs	ff	Ev
Bc_K	10 – 40	7.5YR 7/4	7.5YR 6/4	f	0	sg	1	1	sopo	cs	ff	Ev
C1	40 – 60	7.5YR 7/4	7.5YR 5/4	f	0	sg	1	1	sopo	gw	ff	Es
C2	60 – 110^+	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	gw	ff	Es
Profile 8 (B)												
A	0 – 20	10YR 7/4	10YR 6/4	f	0	sg	1	1	sopo	cs	ff	Ev
Bc_K	20 – 50	10YR 7/4	10YR 6/4	f	0	sg	1	1	sopo	cs	ff	Ev
C1	50 – 75	7.5YR 7/4	7.5YR 6/4	f	0	sg	1	1	sopo	gw	ff	Es
C2	75 – 120^+	7.5YR 7/4	7.5YR 6/4	f	0	sg	1	1	sopo	gw	ff	Es
Profile 9 (P)												
A	0 – 20	7.5YR 7/4	7.5YR 5/6	f	0	sg	1	1	sopo	cs	ff	Ev
C1	20 – 60	7.5YR 6/4	7.5YR 5/4	f	0	sg	1	1	sopo	cs	ff	Ev
C2	60 – 90	7.5YR 6/6	7.5YR 5/4	f	0	sg	1	1	sopo	gw	ff	Es
C3	90 – 130^+	7.5YR 7/4	7.5YR 6/6	f	0	sg	1	1	sopo	gw	ff	Es
Profile 10 (P)												
A	0 - 25	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	cs	ff	Ev
C1	25 – 50	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	cs	ff	Ev
C2	50 – 75	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	gw	ff	Es
C3	75 – 130^+	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	gw	ff	Es
Profile 11 (TL)												
A	0 – 20	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	cs	ff	Ev
C1	20 – 60	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	cs	ff	Ev
C2	60 – 90	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	gw	ff	Es
C3	90 – 130^+	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	gw	ff	Es
Profile 12 (TL)												
A	0 – 15	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	cs	ff	Ev
C1	15 – 55	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	cs	ff	Ev
C2	55 – 75	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	gw	ff	Es
C3	75 – 130^+	10YR 7/4	10YR 5/4	f	0	sg	1	1	sopo	gw	ff	Es

Texture: S-Sand, LS-Loamy Sand. Structure: Size (S): f – fine; Grade (G): 0 – Structureless; Type (T): sg – single grain. Consistence: Dry: 1 – loose; Moist: 1 – loose; Wet: sopo – non sticky non plastic. Boundary: (cs) clear smooth,(gw) gradual wavy. Pores: (ff) fine-few. Effervescence: Ev – violent effervescence, Es- strong effervescence.

data, it is obvious that all the investigated profiles in the six physiographic units of the study area are having similar morphological features except some differences which might be attributed to the elevation, water or wind erosion which usually contains sediment that are resulted the erosion of the bounded high areas and mountains. The obtained results were in agreement with the work reported by (Kotb and Abdelhady 2006; Shehata 1999).

Soil physical properties

Soil physical properties are shown in Table 4. Gravels content in the studied soils ranged from 3 to 30%, among them tableland (TL) profiles exhibited the highest gravels content. Studied profiles were characterized with coarse texture which was sandy in LSS, HSS and TL units, loamy sand in Wadi-floor (WF) and Bajada (B) and piedmont (P) units The size distribution of soil particles showed that sand content ranged from 78 to 98% (average 88%), silt ranged from 1 to 15% (average 7%) and clay ranged from 1 to 8% (average 4%). The results indicated that Wadi-floor soils exhibited higher content of soil fine particles as compared to other soils which can be attributed to the deposition of soil fine particles from the upper topographic positions. Soil- water parameters were calculated by SPAW software and summarized in Table 4. The obtained data showed that the volumetric water content at wilting point ranged from 0.9 to 12.6%. The water content at field capacity ranged from 6.3 to 31.3%. Available water content in the studied soils ranged from 4.3 to 19.5%. Soil bulk density ranged from 1.39 to 1.47 g/cm^3 (average 1.41 g/cm^3). The obtained results indicated that the soils are having low water supply power which is attributed to the coarse texture and low organic carbon content in soil. Wadi-floor and Bajada soils showed the highest available water due to their finer soil texture and higher organic matter content.

Physico-chemical characteristics of the studied area

The data of the soils physico-chemical properties are summarized in Table 5. The studied soils were slight to strong alkaline in reaction with pH values ranged from 7.6 to 8.4. The soils were characterized with slight to moderate salinity as indicated from EC values (3.3 to 15.3 dS.m^{-1}). Soil organic matter content was low (0.09 to 0.65%) and decreased with soil depth. The low OC was resulted from the low organic matter inputs (poor vegetation cover) and high temperature which increase the decomposition rate of available organic matter. Calcium carbonates in soil ranged from 1.2 to 18.2% with average value of 9%. Abd El-Aziz (1998) found that the total calcium carbonates ranged between 6.07 and 80.4% in some eastern desert soils and it is not in homogeneously distributed through soil profiles. WF, B and P soil profiles showed higher calcium carbonate content as compared to other soils. In addition, the studied soils exhibited higher calcium carbonate content in the

Table 4 Physical properties of the studied profiles

Depth (cm)	Gravels	Sand	Silt	Clay	Texture	Bulk density (g/cm^3)	Wilting point	Field capacity	Available water
		(%)						(v/v %)	
					Profile 1 (WF)				
0 – 20	6.2	82.9	10.5	6.6	LS	1.39	12.6	31.3	18.7
20 – 40	4.5	84.6	12.3	3.1	LS	1.41	10.1	23.6	13.5
40 – 60	5.2	80.9	14.3	4.8	LS	1.45	7.9	18.1	10.2
60 – 80	3.1	79.7	15.1	5.2	LS	1.45	8.3	16.2	7.9
80 – 130$^+$	4.6	80.3	13.6	6.1	LS	1.46	7.9	15.9	8.0
					Profile 2 (WF)				
0 – 25	5.9	81.5	12.8	5.7	LS	1.44	8.5	26.4	17.9
25 – 50	6.0	82	11.9	6.1	LS	1.45	8.0	20.8	12.8
50 – 70	4.5	91.7	4.6	3.7	S	1.45	2.3	7.4	5.1
70 – 120$^+$	5.5	85.9	6.2	7.9	S	1.40	2.0	6.3	4.3
					Profile 3 (LSS)				
0 – 10	6.8	93.9	2.8	3.3	S	1.39	1.4	7.5	6.1
10 - 35	7.3	96.6	2.2	1.2	S	1.39	1.1	7.4	6.3
35 - 70	4.6	95.6	3.1	1.3	S	1.40	0.9	7.4	6.5
70 - 80	5.7	93.9	3.6	2.5	S	1.40	1.0	7.3	6.3
80 – 130$^+$	6.1	95.9	2.4	1.7	S	1.40	1.1	7.2	6.1
					Profile 4 (LSS)				
0 – 25	6.3	96.2	2.1	1.7	S	1.39	1.8	8.0	6.2

Contd.

Table 4 (*Concluded*)

Depth (cm)	Gravels	Sand	Silt	Clay	Texture	Bulk density (g/cm^3)	Wilting point	Field capacity	Available water
		(%)						(v/v %)	
25 – 50	5.8	92.9	4.3	2.8	S	1.39	1.1	7.7	6.6
50 – 75	5.5	91.7	5.1	3.2	S	1.39	1.6	7.4	5.8
75 -130$^+$	5.7	91.1	3.4	5.5	S	1.40	0.9	7.4	6.5
Profile 5 (HSS)									
9.4		94.1	3.7	2.2	S	1.39	2.1	7.9	5.8
25 – 75	8.3	91.6	5.1	3.3	S	1.40	1.9	7.9	6.0
75 – 100	10.1	89.7	6.2	4.1	S	1.40	1.3	7.2	5.9
100 – 120$^+$	9.8	89.9	4.0	6.1	S	1.40	1.5	7.0	5.5
Profile 6 (HSS)									
0 – 25	10.5	91.5	5.4	3.1	S	1.39	1.5	7.6	6.1
25 – 50	8.9	92.4	4.7	2.9	S	1.40	1.6	7.2	5.6
50 – 75	9.6	96.0	2.1	1.9	S	1.40	1.3	7.2	5.9
75 – 100	9.8	92.9	3.0	4.1	S	1.40	1.1	6.9	5.8
100 – 120$^+$	10.0	92.5	3.5	4.0	S	1.40	1.7	7.4	5.7
Profile 7 (B)									
0 – 10	6.7	80.4	14.1	5.5	LS	1.39	11.0	29.8	18.8
10 – 40	7.1	78.7	14.2	7.1	LS	1.39	10.6	30.1	19.5
40 – 60	5.3	84.9	11.9	3.2	LS	1.42	8.6	23.0	14.4
60 – 110$^+$	4.2	98.3	0.9	0.8	S	1.43	3.5	9.4	5.9
Profile 8 (B)									
0 – 20	7.5	78.7	15.2	6.1	LS	1.44	8.2	19.4	11.2
20 – 50	6.6	78.7	15.1	6.2	LS	1.47	8.8	15.7	6.9
50 – 75	5.9	91.0	5.2	3.8	S	1.40	2.0	7.2	5.2
75 – 120$^+$	6.3	86.9	5.5	7.6	S	1.40	1.8	7.2	5.4
Profile 9 (P)									
0 – 20	10.5	84.9	9.5	5.6	LS	1.40	7.6	18.4	10.8
20 – 60	9.7	85.7	8.9	5.4	LS	1.41	6.8	16.2	9.4
60 – 90	8.9	89.4	6.1	4.5	S	1.40	2.1	7.4	5.3
90 – 130$^+$	9.5	92.3	4.9	2.8	S	1.40	2.2	7.1	4.9
Profile 10 (P)									
0 - 25	10.6	82.9	12.3	4.8	LS	1.39	4.4	15.4	11.0
25 – 50	9.8	87.7	6.8	5.5	LS	1.40	4.5	11.3	6.8
50 – 75	9.9	88.8	6.4	4.8	S	1.40	1.5	6.9	5.4
75 – 130$^+$	9.5	90.2	6.0	3.8	S	1.40	1.1	6.9	5.8
Profile 11 (TL)									
0 – 20	20.4	91.3	4.9	3.8	S	1.42	2.9	8.0	5.1
20 – 60	19.8	91.5	5.1	3.4	S	1.43	2.7	7.6	4.9
60 – 90	30.0	91.6	4.9	3.5	S	1.43	2.7	7.7	5.0
90 – 130$^+$	22.4	90.3	5.2	4.5	S	1..43	1.9	7.2	5.3
Profile 12 (TL)									
0 – 15	27.7	92.2	4.7	3.1	S	1.42	3.0	7.9	4.9
15 – 55	30.9	92.9	4.6	2.5	S	1.43	2.8	8.1	5.3
55 – 75	25.8	88.5	6.3	5.2	S	1.43	1.9	6.8	4.9
75 – 130$^+$	21.9	88.4	6.0	5.6	S	1.43	2.3	7.0	4.7

Table 5 Physico-chemical properties of the studied soil profiles

Depth (cm)	pH	EC_e ($ds.m^{-1}$)	SOM (%)	$CaCO_3$ (%)	CEC cmol (p^+).kg^{-1}	Exchangeable bases cmol (p^+).kg^{-1}				Base saturation (%)	ESP (%)
						Na^+	K^+	Ca^{2+}	Mg^{2+}		
Profile 1 (WF)											
0 – 20	8.1	6.5	0.47	12.9	6.8	0.3	0.4	2.6	2.2	80.9	4.4
20 – 40	8.2	5.4	0.44	17.7	4.9	0.3	0.6	2.2	1.3	89.8	6.1
40 – 60	7.9	6.2	0.31	12.1	5.6	0.3	0.5	2.5	1.3	82.1	5.4
60 – 80	7.8	13.1	0.27	14.6	6.3	0.4	0.5	2.6	1.9	85.7	6.3
80 – 130^+	8.3	3.3	0.22	14.5	6.9	0.4	0.8	2.8	1.9	85.5	5.8
Profile 2 (WF)											
0 – 25	8.2	5.4	0.45	13.7	5.6	0.2	0.7	3.4	1.2	98.2	3.6
25 – 50	8.2	7.9	0.29	18.2	6.5	0.4	0.5	3.2	1.5	86.2	6.2
50 – 70	8.3	6.0	0.21	12.7	2.1	0.2	0.2	0.9	0.6	90.5	9.5
70 – 120^+	8.2	15.4	0.19	15.8	3.0	0.4	0.2	1.5	0.8	96.7	13.3
Profile 3 (LSS)											
0 – 10	8.3	6.4	0.32	12.0	3.3	0.2	0.1	1.5	0.8	79.4	6.1
10 - 35	8.2	3.3	0.24	3.7	2.7	0.2	0.1	1.4	0.7	89.3	7.4
35 - 70	8.0	12.8	0.18	4.1	2.7	0.2	0.1	1.2	0.7	81.9	7.4
70 - 80	7.6	11.7	0.14	5.4	3.5	0.2	0.1	1.4	0.9	75.4	5.7
80 – 130^+	8.0	8.9	0.14	5.0	2.2	0.2	0.5	0.5	0.5	77.3	9.1
Profile 4 (LSS)											
0 – 25	8.1	7.1	0.44	6.2	2.6	0.2	0.4	1.5	0.2	88.5	7.7
25 – 50	8.2	9.7	0.38	2.5	2.9	0.4	0.2	1.3	0.6	86.2	13.8
50 – 75	8.3	4.3	0.21	1.2	1.5	0.2	0.1	0.7	0.3	88.7	13.3
75 -130^+	8.3	7.0	0.15	1.2	1.5	0.2	0.1	0.7	0.3	86.7	13.3
Profile 5 (HSS)											
0 – 25	8.2	5.4	0.28	5.3	2.1	0.2	0.2	1.3	0.2	90.5	9.5
25 – 75	7.9	9.8	0.09	8.7	2.1	0.1	0.1	1.2	0.5	90.5	4.8
75 – 100	8.1	9.5	0.09	10.4	2.4	0.2	0.2	1.3	0.6	95.8	8.3
100 – 120^+	8.0	7.5	0.09	8.5	2.6	0.2	0.1	1.5	0.5	88.5	7.7
Profile 6 (HSS)											
0 – 25	8.3	5.1	0.38	8.0	2.3	0.2	0.2	0.9	0.6	82.6	8.7
25 – 50	8.2	8.2	0.13	7.8	2.6	0.3	0.1	1.0	0.7	82.3	11.5
50 – 75	8.2	5.1	0.11	4.5	1.6	0.2	0.1	0.9	0.3	95.6	12.5
75 – 100	8.0	6.1	0.14	5.1	1.5	0.2	0.1	0.9	0.2	94.7	13.3
100 – 120^+	8.2	6.1	0.12	5.6	1.6	0.2	0.1	0.9	0.3	93.8	12.5
Profile 7 (B)											
0 – 10	8.1	5.8	0.44	7.1	6.7	0.5	0.1	3.9	1.9	96.0	7.5
10 – 40	8.2	7.0	0.41	17.3	8.1	1.0	0.2	3.4	3.3	97.5	12.3
40 – 60	8.2	12.2	0.18	8.3	5.6	0.2	0.4	3.4	1.4	96.4	3.6
60 – 110^+	7.8	8.3	0.12	1.2	1.5	0.2	0.1	0.9	0.2	93.3	13.3
Profile 8 (B)											
0 – 20	8.0	5.1	0.38	7.9	5.7	0.3	0.5	3.2	1.1	89.5	5.3
20 – 50	8.2	6.4	0.21	15.7	2.3	0.2	0.3	1.1	0.4	87.0	8.7
50 – 75	8.0	13.4	0.09	7.0	2.3	0.2	0.2	1.3	0.3	87.0	8.7
75 – 120^+	8.1	10.5	0.09	6.9	2.6	0.3	0.2	1.6	0.3	92.3	11.5

Contd.

Table 5 (*Concluded*)

Depth (cm)	pH	EC_e ($ds.m^{-1}$)	SOM (%)	$CaCO_3$ (%)	CEC cmol (p^+).kg^{-1}	Exchangeable bases cmol (p^+).kg^{-1}				Base saturation (%)	ESP (%)
						Na^+	K^+	Ca^{2+}	Mg^{2+}		
					Profile 9 (P)						
0 – 20	8.2	10.0	0.65	14.9	7.9	0.9	0.4	3.1	1.5	74.7	11.4
20 – 60	7.9	8.4	0.50	11.6	5.2	0.4	0.1	2.6	1.3	84.6	7.7
60 – 90	8.0	7.2	0.23	10.8	5.0	0.3	0.4	2.2	1.1	80.0	6.0
90 – 130^+	8.1	6.3	0.23	8.3	3.4	0.2	0.3	1.9	0.3	79.1	5.9
					Profile 10 (P)						
0 - 25	8.2	5.4	0.28	5.3	3.8	0.2	0.1	2.3	0.7	86.8	5.3
25 – 50	7.9	9.8	0.09	8.7	2.9	0.2	0.2	1.5	0.5	82.8	6.9
50 – 75	8.1	9.5	0.09	10.4	2.3	0.2	0.2	1.3	0.4	91.3	8.7
75 – 130^+	8.1	6.0	0.09	9.5	2.5	0.3	0.1	1.7	0.2	92.0	12.0
					Profile 11 (TL)						
0 – 20	8.2	8.0	0.33	9.1	2.6	0.2	0.2	1.5	0.4	88.5	7.7
20 – 60	7.9	6.2	0.13	9.5	2.5	0.2	0.2	1.5	0.4	92.0	8.0
60 – 90	8.1	9.3	0.09	9.1	2.7	0.2	0.2	1.3	0.5	81.5	7.4
90 – 130^+	8.0	9.3	0.09	9.3	2.5	0.2	0.1	1.3	0.6	88.0	8.0
					Profile 12 (TL)						
0 – 15	8.3	7.7	0.32	9.1	2.5	0.2	0.1	1.2	0.5	80.0	8.0
15 – 55	8.2	4.4	0.12	8.7	2.1	0.1	0.1	1.1	0.4	81.0	4.8
55 – 75	8.3	5.4	0.11	11.6	2.8	0.1	0.1	1.1	0.9	78.6	3.6
75 – 130^+	8.4	4.9	0.09	9.5	2.5	0.3	0.1	1.2	0.5	84.0	12.0

upper parts of soil profile which reveal the effect of the adjacent calcareous desert zone through the wind action. In addition, the deposition of calcareous disintegration products carried by the flash floods which are common along the eastern higher relief limestone plateau may also contribute (El-Toukhy 1987). The studied soils were low in CEC which ranged from 1.5 to 8.1 cmol (p^+).kg^{-1}. Cation exchange capacity decreased with soil depth and was directly related to soil texture. Regarding the exchangeable cations in the studied soils, Ca^{+2} and Mg^{+2} were the dominant exchangeable cations followed by Na^+ and K^+. The soil base saturation ranged from 74.7 to 98.2%. Exchangeable Sodium Percentage (ESP) ranged from 3.6 to 13.8% with average value of 8.4%. Ali *et al.* (2006) stated that ESP was ranged between 9.5 and 20.6% in new reclaimed area in eastern Egyptian desert soils.

Fertility status

The data on available macro and micro-nutrients are summarized in Table 6. The soils showed low available nitrogen content (1 to 21 $kg.ha^{-1}$) and low available phosphorus (1 to 9 $kg.ha^{-1}$) while the content of available potassium was ranged from low to high (105.0 to 762.0 $kg.ha^{-1}$). The DTPA extractable Fe ranged from 0.2 to 5.8mg $.kg^{-1}$(average 2.1 $mg.kg^{-1}$). Available Mn varied from 0.1 to 2.5 $mg.kg^{-1}$(average 0.5$mg.kg^{-1}$). Available Zn varied from 0.1 to 0.4 $mg.kg^{-1}$(average 0.3$mg.kg^{-1}$). Available Cu varied from 0.1 to 0.5 $mg.kg^{-1}$(average 0.3$mg.kg^{-1}$). Lindsay and Norvell (1978) proposed the sufficiency level of DTPA-extractable micronutrient as follow 4.5, 1.0, 0.2 and 0.6 mg kg^{-1} for Fe, Mn, Cu and Zn respectively. Hence, the studied soils were deficient with respect to Fe, Mn and Zn. However, available copper might be adequate for crop production. The low fertility status of the studied soils is mainly attributed to the low soil organic carbon content and low nutrients and water holding capacity. Based on the obtained data, the deficiency of macro and micronutrients in the studied soils are expected under the prevailing soil and climate conditions and corrective measurements are urgently required to enhance the soil fertility status. The obtained results were consistent with the data reported by Attia (1988) and Ibrahim *et al*. (2001).

Soil classification

The studied soils are characterized with aridic soil moisture regime. The Wadi-floor and Bajada profiles (profiles 1, 2, 7 and 8) were found to have ochric surface horizon and calcic sub-surface horizon having more than 15% $CaCO_3$ and absolutely 5% $CaCO_3$ than the underlying layer. Thus, these two profiles were keyed out as *Typic Haplocalcides* subgroup level. The remained soils were classified as Entisols. The soils were characterized with texture class coarser than loamy sand and showed < 35% (by volume) rock fragments. Hence they keyed out *aspsamments* suborder and classified as *Typic Torripsamments* at subgroup level as they have aridic soil moisture regime. Similar

Table 6 Depth distribution of macro and micronutrients in studied soil profiles

Depth (cm)	Available macronutrients			Available micronutrients			
	N	P	K	Fe	Mn	Zn	Cu
	kg.ha^{-1}			mg.kg^{-1}			
				Profile 1 (WF)			
0 – 20	21	9	679	5.8	2.5	0.4	0.4
20 – 40	18	7	627	2.8	0.4	0.3	0.2
40 – 60	10	5	560	2.4	0.3	0.1	0.3
60 – 80	5	3	560	1.9	0.5	0.2	0.4
80 – 130^{+}	4	2	762	1.0	0.4	0.1	0.2
				Profile 2 (WF			
0 – 25	19	8	741	2.5	1.0	0.4	0.3
25 – 50	12	5	650	2.4	0.4	0.2	0.1
50 – 70	8	4	446	2.3	0.4	0.2	0.3
70 – 120^{+}	3	3	405	1.8	0.2	0.3	0.2
				Profile 3 (LSS)			
0 – 10	10	6	186	3.1	0.6	0.4	0.4
10 - 35	6	4	148	2.5	0.5	0.3	0.3
35 - 70	5	3	134	2.3	0.3	0.2	0.4
70 - 80	3	3	141	2.2	0.2	0.1	0.3
80 – 130^{+}	3	2	493	2.0	0.4	0.2	0.3
				Profile 4 (LSS)			
0 – 25	9	6	405	4.3	0.5	0.4	0.3
25 – 50	6	3	211	3.0	0.3	0.4	0.2
50 – 75	4	2	159	2.1	0.3	0.2	0.2
75 -130^{+}	2	2	137	0.8	0.2	0.3	0.1
				Profile 5 (HSS)			
0 – 25	8	7	251	2.7	0.5	0.4	0.4
25 – 75	3	3	164	1.8	0.4	0.3	0.3
75 – 100	1	2	226	1.4	0.5	0.3	0.3
100 – 120^{+}	5	4	186	1.4	0.5	0.3	0.3
				Profile 6 (HSS)			
0 – 25	7	6	242	3.8	0.5	0.4	0.5
25 – 50	3	5	152	2.6	0.4	0.3	0.4
50 – 75	2	1	161	1.5	0.4	0.3	0.2
75 – 100	3	4	148	1.1	0.4	0.2	0.2
100 – 120^{+}	2	5	130	1.0	0.3	0.3	0.4
				Profile 7 (B)			
0 – 10	18	8	495	2.5	0.4	0.4	0.4
10 – 40	10	5	289	2.6	0.3	0.4	0.2
40 – 60	5	4	408	1.5	0.3	0.3	0.1
60 – 110^{+}	3	3	168	1.3	0.2	0.4	0.2
				Profile 8 (B)			
0 – 20	15	8	495	3.2	0.8	0.4	0.4
20 – 50	6	6	316	3.0	0.5	0.2	0.3
50 – 75	2	2	215	2.6	0.4	0.1	0.3

Contd.

Table 6 (*Concluded*)

Depth (cm)	Available macronutrients			Available micronutrients			
	N	P	K	Fe	Mn	Zn	Cu
	kg.ha^{-1}			mg.kg^{-1}			
75 – 120^{+}	8	3	228	2.3	0.5	0.2	0.2
			Profile 9 (P)				
0 – 20	20	8	495	2.5	0.5	0.3	0.4
20 – 60	14	7	448	2.3	0.2	0.4	0.3
60 – 90	10	4	410	2.2	0.3	0.3	0.3
90 – 130^{+}	5	3	336	2.1	0.2	0.2	0.3
			Profile 10 (P)				
0 - 25	18	9	395	3.2	0.5	0.4	0.3
25 – 50	7	7	252	2.0	0.5	0.4	0.4
50 – 75	3	3	137	1.9	0.4	0.3	0.1
75 – 130^{+}	5	5	142	1.1	0.3	0.2	0.2
			Profile 11 (TL)				
0 – 20	7	5	251	2.7	1.9	0.4	0.4
20 – 60	4	4	224	1.2	0.4	0.3	0.3
60 – 90	2	1	217	1.3	0.5	0.2	0.4
90 – 130^{+}	4	3	155	1.1	0.3	0.2	0.2
			Profile 12 (TL)				
0 – 15	6	4	110	1.2	0.5	0.4	0.3
15 – 55	3	2	105	0.9	0.3	0.4	0.4
55 – 75	1	1	119	0.3	0.1	0.1	0.2
75 – 130^{+}	3	2	125	0.2	0.2	0.2	0.2

results were reported by Ibrahim *et al.* (2017); Kotb and Abdelhady (2006).

Conclusion

Based on the current study, the soils of Wadi Qena are found to have poor physical and chemical properties. The soils were characterized with low water and nutrients supply capacity which can be attributed to the coarse texture, low OC and CEC and alkaline soil pH. Hence, the generated data in this study can help the decision makers for developing a proper land management practices and effective land use planning for the studied area under the existing climate and soil conditions.

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