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GEOMORPHOLOGICAL, PEDOLOGICAL STUDIES AND EVALUATION OF SOME SOILS IN WADI SUDR, SINAI PENINSULA, EGYPT

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ABSTRACT: *Wadi Surd is one from the largest and important wadis in the south-western side of Sinai Peninsula due to its promising soils and water potentialities. The current work aims at study the geomorphology, Pedology and evaluation of the soils of Wadi Sudr. The geomorphological studies indicated that, there are four main geomorphologic units in the area. These units are dry Sabkha, Out wash plain, Oolitic sand and Delta plain. Ten Soil profiles were selected representing these units. The soil profiles were morphological described and samples were collected for physical and chemical analyses.*

According to Soil Survey Staff (2014), the obtained results revealed that all studied soils could be categorized into order Aridisols. These soils are classified up to family level under four sub-greats namely, Gypsic Haplosalids, Calcic Haplosalids, Typic Haplocalcids, Sodic Haplocalcids. The studied Soils were evaluated for their suitability for agriculture use. They categorized into two classes namely, marginally suitable (S3) and not suitable (N). These soils are suffering from limitations of texture, carbonates, gypsum, salinity and alkalinity with different intensity. The severity of these limitations could be corrected by further land improvements. Accordingly, the potential suitability of the most studied soils could be improved to moderately suitable (S2) and marginally suitable (S3). Moreover, the suitability of 11 main crops in these soils was evaluated in the current and potential situation. The results indicated that these soils are not suitable for growing these crops in the current situation. The potential suitability of the soils for these crops could be improved according to the satisfaction conditions between soil properties and crops requirements.

Key words: *Geomorphic units, Soil Classification, land evaluation, suitability for agriculture.*

INTRODUCTION

One of the important strategies of the Egyptian government is expanding the agricultural area, sustainable utilization of available water resources and increasing crop productivity to meet the needs of the rapid increase in population.

Sinai Peninsula is one from the important parts for agricultural expansion in Egypt. Wadi Sudr is considered as the most promising Wadi in the south western side of Sinai due to its land and water potentialities.

Location: Wadi Sudr is situated in a long axis between latitudes 29° 30' and 29° 25' North and longitudes 32° 40' and 32° 50' East. It has an area of about 625 sq.km (150.000 feddans), Fig (1). This Wadi is about 4 km in width, 4-8 km in length and oriented roughly in an east west direction.

Climate: The studied area is characterized by a long hot rainless summer and short rainly mild winter. The maximum temperature is often exceed about 36 C° during summer. The average minimum temperature during the winter is about 8 C°. The area have high evaporation rate and low relative humidity. The average evaporation rate is about 10.2 mm.d^{-1}. The relative humidity ranges between 48.2% in April and 63.5% in October. The average annual rainfall at Ras Sudr is 25.2 mm. The actual rainy months are November to April

with maximum rainfall in March and April (CLAC, 2014).

Geology: The surface of Wadi Surd is essentially formed of sedimentary rocks and deposits belonging to the Tertiary and Quaternary epochs. Quaternary deposits are divided into recent deposits (aeolian sand and lacustrine deposits); Plestocene deposits (crust formations that are composed of calcareous sand of marine origin and dry Sabkha as adjacent to the Oolitic dunes. Tertiary deposits are differentiated into Pliocene deposits (clays and sands); Upper Miocene deposits (coarse sands and gravels with thin clay and carbonate intercalations), Middle Miocene (argillaceous limestone with shale and marl in terbeds), and Lower Miocene (marl and sandstone fossiliferour, Carbonate in the lower part and yellow marly limestone and conglomeratic of base), El-Shazly *et al.,* 1974; Dames and Moore, 1985; Said 1990 and Geological Survey of Egypt, 1994.

Geomorphology: Hammad (1980) and Dames and Moore (1985) reported that, Wadi Sudr embodies broadly five distinct geomorphic units namely, mountains and escarpment, present channels, terraces, deltaic plains, coastal formation and outwash plain.

Water supply: The underground water is considered the main source of water supply in Wadi Sudr. It exist in several aquifers, namely bsament rocks, Nubian sandstones and Quaternary deposits. (Dames and Moore, 1985).

This work was performed to study the geomorphology and pedology of Wadi Sudr soils. Land evaluation and its suitability for growing certain crops were also achieved in the current and potential situations.

MATERIALS AND METHODS

Image interpretation:

Geomorphic map of the studied area (Fig,1) was produced using digital image processing of Land Sat ETM image (Path/Row, 176/39) dated 2010 and topographic maps (scale 1:20000). Arc GIS 10.4 and ERDAS imagine 8.7 software were used to produce the geomorphic map. The DEM was generated from digitized data of contour line in the topographic maps and spots hights recorded by GPS using Arc – GIS software. These procedures were carried out according to Dobos *et al.* (2002).

Ten soil profiles were chosen representing the main geomorphic units of the studied area and 60 minipits were carried out to check the accuracy of geomorphic boundary Fig (2).

The soil profiles were morphologically described according to FAO (2006). Samples were collected from profiles according to the vertical variations. The soil samples were air dried, crushed and sieved to get the fine earth fractions (< 2 mm). These fractions were analyzed to determine their physical and chemical characteristics according to Burt (2004). The morphological features and characteristics data are presented in Tables (1 and 2).

The studied soils were classified up to family level according to Soil Survey Staff (2014).

The evaluation of land suitability for irrigated agriculture was performed according to Sys and Verheye (1978). Also, the suitability of the studied soils for growing eleven crops were achieved according to Sys *et al.,* (1993).

RESULTS AND DISCUSSION

Geomorphology of the study area:

The geomorphic mapping units (Fig., 2) were identified on the bases of the DEM value map results. The geomorphic map interpretation indicated that, the investigated area includes 8 geomorphic units namely, Delta plain, Dry Sabkha, Lower terraces, Upper terraces, Oolitic sand, Out Wash Plain, Ridges and Escarpment (Fig., 2). The main four studied geomorphic units in this work were dry sabkha, Out Wash plain, Oolitic sand and Delta plain.

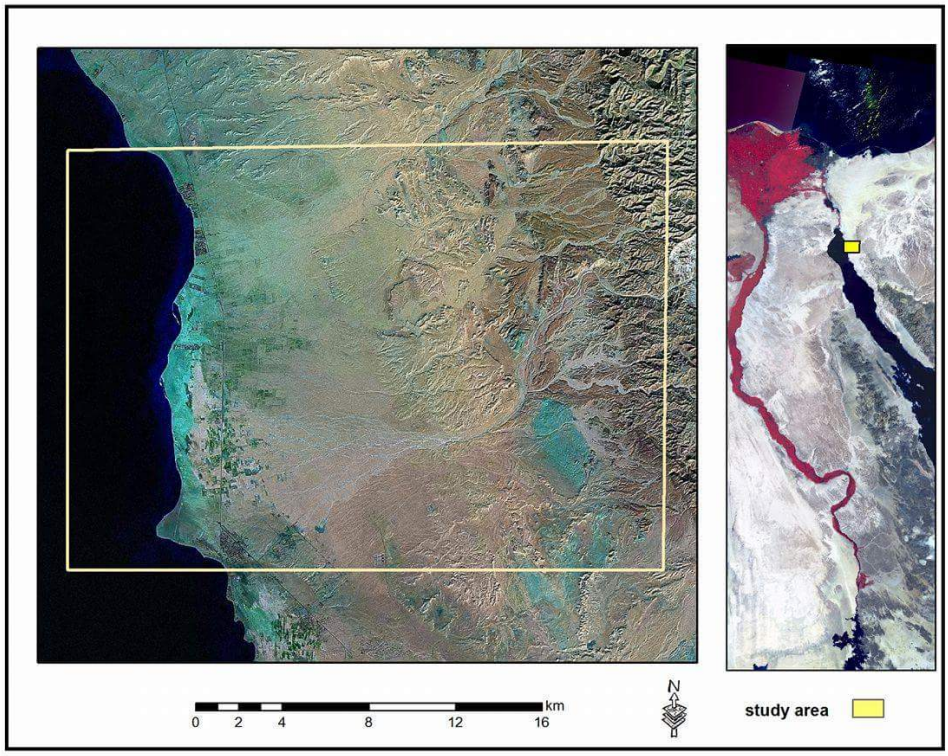

Fig. (1): Location of the study area in Egypt.

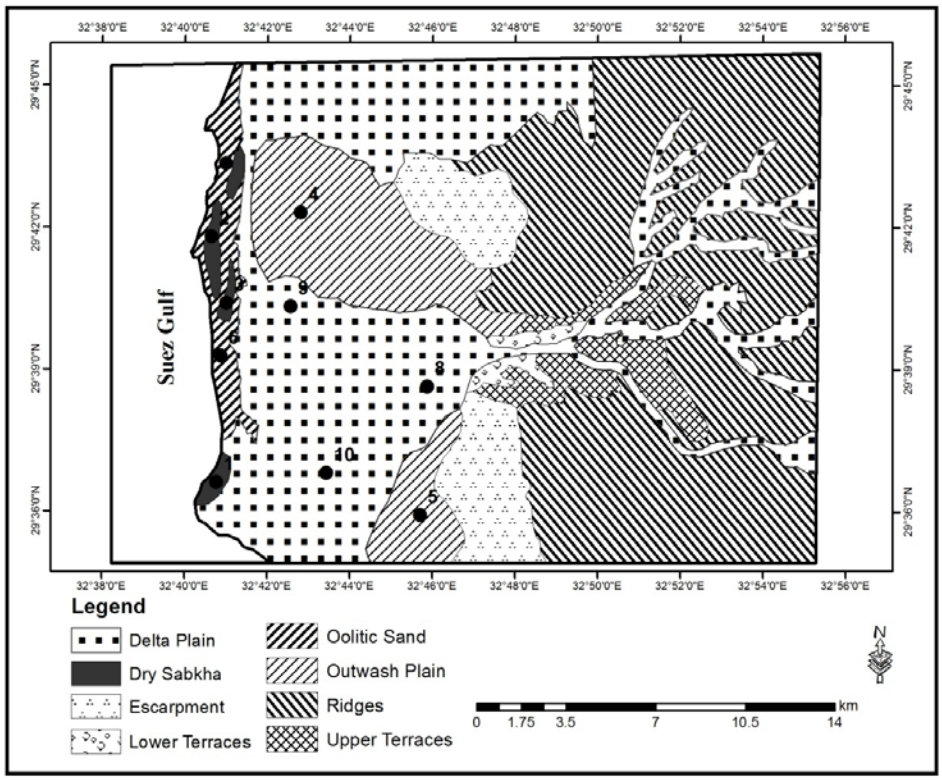

Fig. (2): Geomorphic Units and profiles locations of the study area.

TABLE 1

TABLE 1

TABLE 2

TABLE 2

Soil characteristics:

The morphological description of soil profiles and samples representing the studied geomorphic units in the studied area are presented in Table (1). The physico-chemical properties of these profiles are shown in Table (2). Characteristics of the soils representing each of studied geomorphic units can be disputed as follows.

Soils of dry Sabkha

This unit is located in the western side of the studied area. The soils of this unit are represented by three soil profiles (1,2 and 3). Topography of the landscape is almost flat to slightly undulating. The soil colour varied from brown (10 YR 4/3) to very pale brown (10 YR8/4) in dry status. Moist colour ranged from light brown (10YR 6/3) to brown (7.5 YR 5/4). Texture of the soils representing with profiles l and 3 varied from sand to sandy loam. The texture of profile 2 varied between silty clay and clay loam in the upper layer changed to sand in the deepest one. These soils have 2 to 5% fine and medium gravels. Soil consistence varied from soft to hard (dry) and friable (moist). The soils are highly calcareous as indicated by calcium carbonate content which varied from 35.76 to 70.7% without distribution pattern with depth. Organic matter content is very low (< 0.72%).

Soil reaction are generally neutral to moderately alkaline which the pH values ranged from 7.1 to 8.4. The soils are non-saline to very extremely saline as indicated by ECe values, that ranged from 1.75 to 172.5 dsm^{-1}. Gypsum content varied from 0.15 to 8.9%.

Cation exchange capacity coincided with soil texture, and varied from 5.9 to 20.3 Cmole kg^{-1}. Exchangeable Sodium Percentage (ESP) values of profiles 1 and 2 are more than 15% indicating sodicity effect. While it is < 15% in profile 3 indicating non sodic soils.

Soils of out wash plain

This unit is located in the north and south parts of the study area close to the faulted escarpments of the sedimentary rock structure. The sediments are transported and deposited by torrential streams. The soils of this unit are represented by profiles 4 and 5 (Tables 1and 2). Topography is gently undulating and gently sloping towards the west. The surface is covered with many gravels and few stones. Soil colour is yellow (10YR 7/8) to reddish yellow (7.5 YR 7/6) dry and yellowish brown (10 YR 5/8) to pink (7.5YR7/4) moist. Soil texture is slightly gravelly sandy loam in the surface changed to extremely gravelly loamy sand with soil depth.

Soil structure is generally massive or single grains. Consistence varied from soft or hard dry to friable moist.

Calcium carbonate content ranged from 22.62 to 55.24% without specific pattern with soil depth. Organic matter and gypsum contents were < 0.51 % and < 3.07%, respectively. The soils are slightly to moderately alkaline (pH between 7.5 and 8.1), They are slightly saline to extremely saline, (ECe between 3.64 and 32.70 dsm^{-1}). CEC ranged between 6.5 and 11.5 Cmole kg^{-1}. ESP varied from 3.31% to 13.68% indicating non sodicity effect.

Soils of Oolitic sand

This unit includes coastal forms, that are mainly deposited under the sea and wind actions. These sediments occupy a narrow strip of complex pattern along the shoreline of Red Sea coastal plain and Suez Gulf. This pattern is dominated by beaches, covered with over blown sand and scattered natural vegetation.

The soil surface is almost flat or nearly level. This geomorphic unit is represented by profiles 6 and 7. Data in Tables (1 and 2) indicate that, soil colour varied from reddish yellow (7.5 YR 7/8) to pink (7.5 YR 7/3) dry and light brown (7.5YR 6/4) to reddish

brown (7.5 YR 7/4) moist. These soils have sandy texture throughout the entire profiles depths. They are extremely calcareous having 65.23% to 85.75% $CaCO_3$. Organic matter and gypsum contents ranged from 0.13 to 0.78% and 1.33 to 2.5%, respectively. They are slightly to moderately alkaline (PH 7.7 to 8.3). The soils are moderately saline to very extremely saline having ECe values between 15.52 and 160.7 dsm^{-1}. Cation exchange capacity was very low and differ from 5.4 to 6.85 Cmole kg^{-1}. ESP varied from 16.12 to 25.84% indicating that, these soils have sodicity effect.

Soils of Delta plain

Delta plain unit and their tributaries are found in the middle of the study area at the lowest level of Wadi Sudr. It extends from the limestone rocks highland eastwards to the Red Sea and the Gulf of Suez westwards.

It is filled with alluvial material formed by weathering factors on the parent rocks and transported by flood water to the lowlands. It is represented by three soil profiles 8,9 and 10.

Data in Tables (1 and 2) revel that soil colour is yellow (10YR8/6) to reddish yellow (7.5 YR 6/6) dry and brownish yellow (10YR6/6) to light brown (7.5 YR6/4) moist. The soils have sand to sandy loam texture and single grains to massive structure. These soils contain 2 to 40% fine to medium gravels and few stones. Calcium carbonate content is very high and differ from 35.8 to 70.3% without specific pattern with depth, It tends to increase with depth in profile 8. Organic matter and gypsum contents not exceeds 0.43% and 1.39%, respectively. The soils are slightly to moderately alkaline (PH 7.65 to 8.4). They are very slightly saline to extremely saline (ECe ranged from 3.1 to 50.2 dsm^{-1}). CEC ranged from 3.39 to 8.89 Cmole kg^{-1}. These soils have sodicity effect (ESP > 15%).

Soil classification

The studied soils are classified according to the diagnostic criteria of Soil Survey Staff (2014). Based on the prevailing climatic conditions, morphological features, and analytical data of these soils, they classified under Aridisols order (Table, 3). These soils have an Ochric epipedon and one or more from the diagnostic horizons of Salic, Calcic, Sodic and Gypsic. Therefore, the soils are classified up to family level under four sub-great groups namely, Gypsic Haplosalids (profile, 1), Calcic Haplosalids (profiles, 2, 3, 5, 6, 7, 8 and 10), Typic Haplocalcids (profile 4) and Sodic Haplocalcids (profile, 9) as shown in Table (3).

Land Evaluation:

Evaluation of land suitability for irrigated agriculture

Quantitative estimation of soil characteristics were used for evaluation land suitability index according to Sys and Verhey (1978). The soil characteristics used were topography, wetness, texture, soil depth, $CaCO_3$, gypsum and salinity and alkalinity. Classification of the soils to suitability grades was applied according to their calculated suitability indexes (Ci) as the following criteria:

Ci (%)	Order	Class	Soil grades
75-100	S	S1	Highly suitable
50-<75		S2	Moderately suitable
25->50		S3	Marginally suitable
<25	N	N	Not suitable

Suitability indexes (Ci) of the studied soils were calculated for their current (Cs) and potential situations (Ps) as shown in Table (4).

Table (3): Classification of the studied soils according to Soil Survey Staff (2014).

Geomorphic Unit	Profiles	classification	
		Sub-great group	Family
Sabkha	1	Gypsic Haplosalids	Coarse loamy over fine clay, carbonatic, hyperthermic
	2	Calcic Haplosalids	Fine silty over sandy, carbonatic, hyperthermic
	3		Coarse loamy over sandy, carbonatic, hyperthermic
Out wash plain	4	Typic Haplocalcids	Sandy-skeletal, carbonatic, hyperthermic
	5	Calcic Haplosalids	Sandy-skeletal, carbonatic, hyperthermic
Oolitic plain	6 and 7	Calcic Haplosalids	Sandy, carbonatic, hyperthermic
Deltaic plain	8 and 10		Sandy-skeletal, carbonatic, hyperthermic
	9	Sodic Haplocalcids	Sandy-skeletal, carbonatic, hyperthermic

1. Current Suitability

Data in Table (4) indicated that the soils represented the studied geomorphic unit were placed into two suitability classes and grades namely, marginally suitable (S3) and non-suitable (N), Fig. (3).

Marginally suitable soils (S3):

These soils have suitability index (Ci) values ranged from 30.38 to 35.10%. These are the soils of profiles 2,3 (Sabkha), and 4,5 (out wash plain). The soils have a moderate intensity of texture, calcium carbonate and salinity & alkalinity limitations.

Non suitable soils (N1):

These soils have suitability index (Ci) values varied from 10.8 to 23.4%. These are the soils profiles 1 (sabkha); 6 and 7 (Oolitic sand); 8, 9 and 10 (delta plain). These soils have a severe intensity of salinity and alkalinity, moderate to severe intensity of Ca CO_3 and texture limitations.

2. Potential land suitability:

Further land improvements are required to correct or reduce the severity of soil limitations exiting in the studied area. These improvements are such as leaching of salts, addition of organic and conditioners amendments as well as applying of modern irrigation systems. Accordingly, the potential suitability evaluation of the most studied soils could be upgrade to the following grades as shown in Table (4) and Fig. (4).

Moderately suitable soils (S2)

This grade has the soils of Sabkha (profiles 1 and 2) with potential suitability index value (52%).

Marginally suitable soils (S3)

This grade has the soils of sabkha (profile 3), outwash plain (profiles 4 and 5), Oolitic sand (profile 6) and Delta plain, (profiles 8, 9 and 10). Potential Suitability index (Ps) values are varied from 27% to 49%.

The soils of Oolitic sand (profile 7) are still non-suitable (N2) having Ci value of 24.0%. These soils have a severe intensity of texture and moderate intensity of calcium carbonate limitations.

TABLE 4

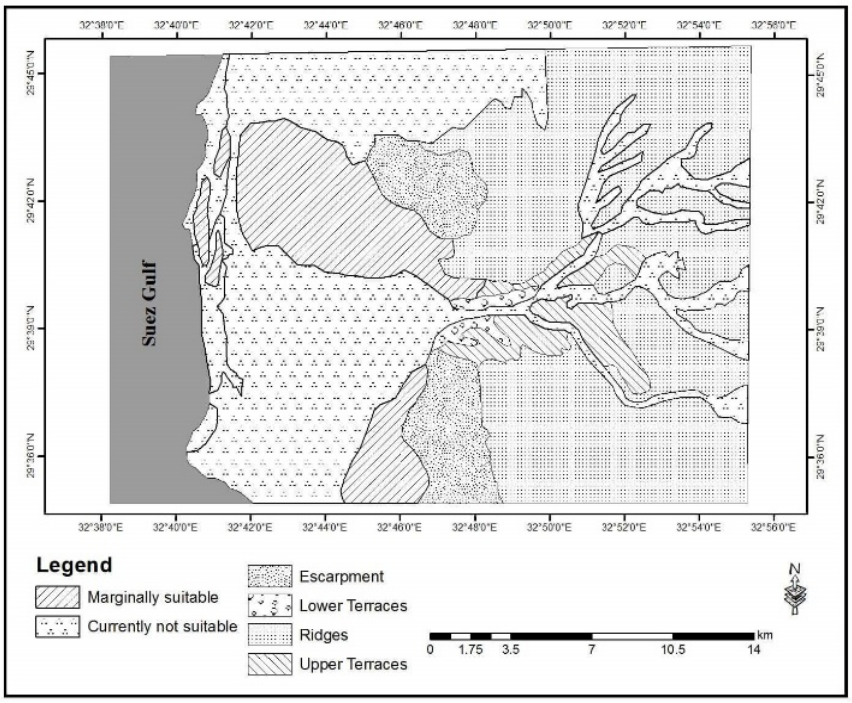

Fig. (3): Current Soil suitability for irrigated agriculture of the studied area.

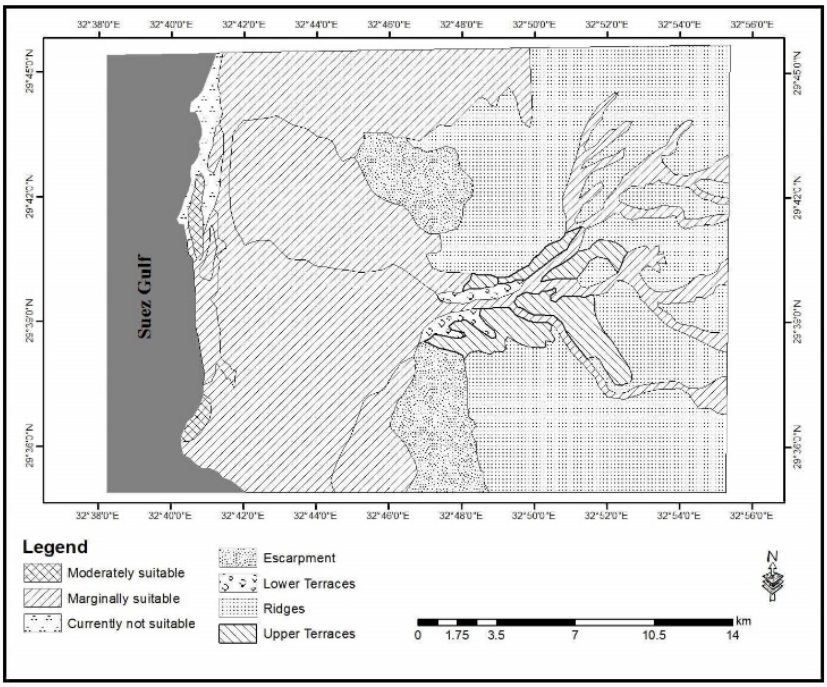

Fig. (4): Potential Soil suitability for irrigated agriculture of the studied area.

II. Evaluation of land suitability for growing some main crops

Eleven main field, vegetable and fruit crops were selected to predict their suitability for cultivation in the current and potential situation of the studied soils according to Sys *et. al.* (1993). The obtained data are presented in Table (5).

1- Current suitability for growing crops:

Data in Table (5) revealed that, all the studied soils are not suitable (N) for growing all the studied corps.

2- Potential suitability for growing crops:

After verifying, the aforementioned land improvements, the potential suitability of the studied soils for growing studied main crops can be explained as follows, Table (5).

a- Soils of sabkha are marginally suitable (S3) for maize, wheat, barley, sunflower, alfalfa, onion, palm and olives. Whereas they are not suitable (N) for tomato, citrus and mango.

b- Soils of out wash plain are moderately suitable (S2) for plam and olives. They are marginally suitable (S3) for maize, wheat, barley, sunflower, alfalfa, onion, tomato, citrus and mango.

Table (5): Ratings and classes of soil suitability for growing main crops in the soils of studied geomorphic units.

Certain crops	Sabkha				Outwash plain				Oolitic sand				Delta plain			
	[1]Ci	[2]Cs	[3]Pi	[4]Ps	Ci	Cs	Pi	Ps	Ci	Cs	Pi	Ps	Ci	Cs	Pi	Ps
	Field crops															
Maize	5.35	N	48.32	S3	4.86	N	40.51	S3	2.50	N	36.70	S3	12.45	N	55.31	S2
Wheat	4.85	N	35.92	S3	5.54	N	30.4	S3	3.62	N	33.41	S3	6.12	N	50.16	S2
Barley	3.26	N	29.72	S3	4.17	N	30.6	S3	4.66	N	36.35	S3	14.32	N	51.72	S2
Sunflower	3.35	N	38.51	S3	6.14	N	40.91	S3	4.22	N	27.92	S3	10.54	N	52.35	S2
Alfalfa	5.39	N	45.5	S3	3.15	N	47.81	S3	5.91	N	42.32	S3	8.16	N	51.15	S2
	Vegetable crops															
Onion	2.55	N	29.30	S3	6.19	N	42.51	S3	3.91	N	25.6	S3	5.55	N	57.92	S2
Tomato	1.88	N	1244	N	8.82	N	37.9	S3	2.35	N	15.23	N	7.82	N	52.18	S2
	Fruit trees															
Citrus	3.26	N	15.85	N	5.81	N	41.32	S3	2.24	N	16.72	N	4.29	N	49.31	S3
Mango	2.75	N	15.66	N	4.54	N	39.91	S3	3.78	N	28.8	S3	8.90	N	52.62	S2
Palm	10.12	N	40.35	S3	22.51	N	60.71	S2	9.11	N	30.12	S3	14.82	N	48.22	S3
Olives	10.02	N	49.30	S3	8.13	N	65.62	S2	4.51	N	39.95	S3	9.45	N	52.62	S2

[1]Ci= Current index, [2]Cs= Current suitability, [3]Pi= Potential, index, [4]Ps= Potential suitability.

c- Soils of Oolitic sand are marginally suitable (S3) for maize, wheat, barley, sunflower, alfalfa, onion, mango, palm and olive. These soils are not suitable (N) for tomato and citrus.

d- Soils of Delta plain are moderately suitable (S2) for maize, wheat, barely, sun flower, alfalfa onion, tomato, mango and olives. These soils are marginally suitable (S3) for citrus and palm.

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دراسات جيومورفولوجية وبيدولوجية وتقييم بعض الأراضي في وادي سدر – شبه جزيرة سيناء - مصر

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الملخص العربي

وادي سدر أحد أوسع وأهم الأودية الواقعة في جنوب غرب شبه جزيرة سيناء بسبب مصادره الأرضية والمائية الواعدة، ولقد أجريت هذه الدراسة بغرض التعرف علي الوحدات الجيومرفولوجية المميزة لهذه المنطقة ودراسة الخصائص البيدولوجية وتقييم الأراضي الممثلة لأهم هذه الوحدات.

ولهذا الغرض اختير عشر قطاعات ممثله لأراضي أهم أربع وحدات جيومورفولوجية في المنطقة وهي السبخة الجافه وسهل الغسيل والسهل الرملي والسهل الدلتاوي، ووصفت هذه القطاعات مورفولوجياً وجمعت منها عينات حسب الاختلافات المورفولوجية الرأسية لطبقات القطاعات المختلفة لإجراء التحليلات الطبيعية والكيميائية، ويمكن تلخيص نتائج الدراسة فيما يلي:

قسمت أراضي مناطق الدراسة طبقاً لنظام التقسيم الأمريكي الحديث (2014) ، وتشير النتائج إلى أن الأراضي تحت الدراسة تقع تحت رتبة الأراضي الجافة Aridisols وأربعة تحت المجاميع الكبرى وتشمل Calcic Haplosalids, Gypsic Haplosalids, Sodic Haplocalcids, Typic Haplocalcids وقد أجريت عملية التقسيم حتى مستوى العائلات (سبعة عائلات).

أوضحت نتائج تقييم ملائمة هذه الأراضي للاستغلال الزراعي الي أن بعضها ينتمي الي رتبة الأراضي هامشية الصلاحية (S3) والبعض الأخر الي رتبة الأراضي عديمة الصلاحية (N) حيث أنها تعاني من وجود محددات في القوام ومحتوي الكربونات والجبس والملوحة والقلوية بدرجات شده مختلفة، ومع إمكانية إجراء عمليات تحسين مختلفة لتقليل حدة هذه المحددات وإصلاحها وذلك بإضافة المواد العضوية والمحسنات غير العضوية وغسيل الأملاح واستخدام نظم الري الحديثة فإن درجة الملائمة الكامنة لمعظم هذه الأراضي يمكن أن تتحسن الي متوسطة الصلاحية (S2) وهامشية الصلاحية (S3).

ولقد قدرت مدي ملائمة هذه الأراضي بوضعها الحالي لزراعة إحدى عشر محصولاً رئيسياً من محاصيل الحقل والخضر والبساتين فوجد أنها غير صالحه لزراعة هذه المحاصيل، إلا أنه بإجراء عمليات تحسين وإصلاح خصائص هذه الأراضي فإن ملاءمتها الكامنة لزراعة المحاصيل يمكن أن تتحسن بدرجه كبيره.

Table (1) : Main morphological features of the represented soil profiles in Wadi Sudr

Geomorphic units	Profile No	Depth (cm)	Colour		Texture[1]	Structure[2]	Consistence[3]			Effervescence	Lower boundary[4]	Soil classification
			Dry	Moist			Dry[3-1]	Moist[3-2]	Wet[3-3]			
Sabkha	(1)	0-15	7.5 YR 7/6	7.5 YR 7/4	LS	ma.	so.	fr	n.st.n.pl.	+++	cs	Gypsic Haplosalids
		15-40	7.5 YR 6/8	7.5 YR 7/4	SL	ma.	so.	fr	sl.s.sl.pl.	+++	cs	
		40-70	7.5 YR 6/6	7.5 YR 5/4	SL	ma.	so.	fr	sl.s.sl.pl.	+++	cs	
		70-150	7.5 YR 7/6	7.5 YR 5/4	L	ma.	so.	fr	st.pl.	+++	-	
	(2)	0-20	10 YR 6/3	10 YR 6/4	SiC	w.c. ang	h.	fr	sl.pl.	+++	cs	Calcic Haplosalids
		20-25	10 YR 8/3	10 YR 6/3	SiCl	w.c. ang	h	fr	sl.pl.	+++	cs	
		50-75	10 YR 8/4	10 YR 6/3	CL	w.c. ang	h.	fr	sl.pl.	+++	cs	
		75-150	10 YR 7/6	10 YR 5/6	S	ma.	so.	fr	n.st.n.pl.	+++	-	
	(3)	0-30	10 YR 7/4	10 YR 6/4	L	ma.	so.	fr	st.s.sl.pl.	+++	cs	
		30-70	10 YR 4/3	10 YR 3/3	SL	ma.	so.	fr	n.st.n.pl.	+++	cs	
		70-150	10 YR 7/4	10 YR 6/4	S	ma.	so.	fr	n.st.n.pl.	+++	-	
Out wash plain	(4)	0-30	7.5 YR 6/6	7.5 YR 6/4	SL	ma.	so.	fr	sl.st..sl.pl.	+++	cs	**Typic Haplocalcids**
		30-70	7.5 YR 7/6	7.5 YR 74	LS	Ma	h	fr	n.st.n.pl.	+++	cw	
		70-150	7.5 YR 6/6	7.5 YR 6/4	S	ma.	h	fr	n.st.n.pl.	+++	-	
	(5)	0-25	10 YR 7/8	10 YR 6/6	SL	ma.	so	fr	sl.st..sl.pl.	+++	cs	**Calcic Haplosalids**
		25-65	10 YR 6/8	10 YR 5/6	LS	ma.	so	fr	n.st.n.pl.	+++	c	
		65-150	10 YR 7/8	10 YR 6/6	LS	ma.	lo.	fr	n.st.n.pl.	+++	-	

Abbreviations (FAO, 2006): **Texture[1]:** S : sand, LS : loamy sand, SL : sandy loam, L : loam, SiC : silty clay, SiCL : silty clay loam, CL : clay loom; **Structure[2]**: ma : massive, s.g. : single grain, w.c. ang. b: weak coarse angular blocky; **Consistence[3]** : **Dry[3-1]**: so. : soft, h. : hard, lo. : loose, **Moist[3-2]:** fr.: friable, fi.: firm**, Wet[3-3]:** n. st. : non sticky, n.pl. : non plastic, sl.st.: slightly slicky, sl.pl. : slightly plastic; **Lower boundary[4]:** cs : clear smooth, cw: clear wavy, ds: diffuse smooth; **Effervescences:** +++ strongly calcareous .

Table (1): cont.

Geomorphic units	Profile No	Depth (cm)	Colour		Texture	Structure	Consistence			Effervescence	Lower boundary	Soil classification
			Dry	Moist			Dry	Moist	Wet			
Oolitic sand	(6)	0-20	7.5 YR 7/6	7.5 YR 6/4	S	s.g.	lo	fr	n.st.n.pl.	+++	cs	Calcic Haplosalids
		20-50	7.5 YR 7/8	7.5 YR 7/4	S	ma.	so	fr	n.st.n.pl.	+++	cs	
		50-150	7.5 YR 7/8	7.5 YR 6/4	S	s.g	lo.	fr	n.st.n.pl.	+++	-	
	(7)	0-35	7.5 YR 7/6	7.5 YR 6/4	S	s.g	lo.	fr	n.st.n.pl.	+++	cs	
		35-70	7.5 YR 7/8	7.5 YR 7/4	S	ma.	so.	fr	n.st.n.pl.	+++	cs	
		70-150	7.5 YR 7/6	7.5 YR 6/4	S	s.g	lo	fr	n.st.n.pl.	+++	-	
Delta plain	(8)	0-35	7.5 YR 7/6	7.5 YR 6/4	SL	ma.	so.	fr	sl.st..sl.pl.	+++	ds	Calcic Haplosalids
		35-70	7.5 YR 7/6	7.5 YR 6/4	LS	s.g	lo.	fr	n.st.n.pl.	+++	ds	
		70-150	7.5 YR 6/8	7.5 YR 6/4	S	s.g	lo	fr	n.st.n.pl.	+++	-	
	(9)	0-25	7.5 YR 6/6	7.5 YR 6/4	LS	ma.	so.	fr	n.st.n.pl.	+++	cs	Sodic Haplocalcids
		25-70	7.5 YR 7/4	7.5 YR 7/2	S	s.g	lo	fr	n.st.n.pl.	+++	cw	
		70-100	7.5 YR 7/8	7.5 YR 6/4	S	Ma	so	fr	n.st.n.pl.	+++	ds	
		100-150	7.5 YR 7/6	7.5 YR 6/4	S	s.g	lo		n.st.n.pl.	+++	-	
	(10)	0-30	10 YR 7/6	10 YR 6/6	LS	ma.	so.	fr	n.st.n.pl.	+++	cs	Calcic Haplosalids
		30-50	10 YR 6/8	10 YR 5/8	LS	ma.	so.	fr	n.st.n.pl.	+++	cs	
		50-75	10 YR 7/4	10 YR 6/3	S	ma.	so.	fr	n.st.n.pl.	+++	cs	
		75-150	10 YR 8/6	10 YR 6/6	S	s.g	lo	fr	n.st.n.pl.	+++	-	

Abbreviations (FAO, 2006): **Texture[1]:** S : sand, LS : loamy sand, SL : sandy loam, L : loam, SiC : silty clay, SiCL : silty clay loam, CL : clay loom; **Structure**[2]: ma : massive, s.g. : single grain, w.c. ang. b: weak coarse angular blocky; **Consistence[3]** : **Dry**[3-1]: so. : soft, h. : hard, lo. : loose, **Moist[3-2]:** fr.: friable, fi.: firm**, Wet[3-3]:** n. st. : non sticky, n.pl. : non plastic, sl.st.: slightly slicky, sl.pl. : slightly plastic; **Lower boundary[4]:** cs : clear smooth, cw: clear wavy, ds: diffuse smooth; **Effervescences:** +++ strongly calcareous .

Table (2): Some physical and chemical properties of the studied soil profiles

Geomorphic units	Profile No.	Depth (cm)	Gravels %	Particle size distribution (%)				Texture class	$CaCO_3$ %	OM %	PH	ECe dsm^{-1}	Gypsum %	CEC $Cmolekg^{-1}$	ESP (%)
				C.S	F.S	Silt	Clay								
Sabkha	(1)	0-15	2	69.45	12.02	10.76	7.77	Ls	60.17	0.72	7.5	110.30	3.75	8.45	12.84
		15-40	2	29.35	48.00	11.36	11.28	Sl	35.76	0.52	7.1	172.50	4.60	5.90	22.65
		40-70	2	12.91	50.36	20.50	16.23	Sl	50.18	0.32	7.2	90.35	8.90	9.855	20.70
		70-150	2	10.40	30.03	32.94	26.63	L	65.15	0.08	7.5	70.20	0.15	17.60	22.22
	(2)	0-20	5	4.40	4.60	45.00	46.00	Sic	60.30	0.60	7.5	22.10	0.52	17.70	17.80
		20.50	2	6.80	12.40	46.20	34.60	Sicl	55.20	0.45	7.7	35.50	0.25	20.30	21.20
		50-75	2	20.35	12.45	35.60	31.60	Cl	62.23	0.58	7.6	35.60	0.75	12.22	32.42
		75.150	5	85.75	10.42	1.58	2.25	S	70.10	0.25	8.4	15.90	0.25	5.21	20.85
	(3)	0-30	2	8.20	30.55	35.43	25.82	L	53.12	0.43	8.2	11.75	0.30	8.30	7.96
		30-70	5	40.43	31.80	10.12	17.65	Sl	50.54	0.12	7.9	32.35	0.82	9.70	6.84
		70-150	5	79.25	15.18	1.07	4.50	S	51.95	0.07	7.9	15.21	1.46	6.65	4.35
Oatwash plain	(4)	0-30	5	65.00	17.45	8.82	8.73	Sl	45.43	0.35	8.1	3.93	2.49	11.50	13.65
		30-70	10	45.15	40.40	6.75	7.70	Ls	25.62	0.21	7.9	17.35	2.75	7.90	11.86
		70-150	40	78.33	14.57	2.23	4.87	S	52.65	0.13	8.1	12.81	2.89	6.84	3.31
	(5)	0-25	2	70.75	13.95	3.30	12.00	Sl	50.55	0.51	8.1	3.64	2.27	9.40	9.59
		25-65	50	60.25	23.85	3.40	12.50	Ls	34.30	0.17	7.7	32.70	3.07	9.20	7.36
		65-165	50	75.80	9.80	4.27	10.13	Ls	55.24	0.12	7.5	25.35	2.97	6.50	13.50

Table (2): Cont.

Geomorphic units	Profile no	Depth (cm)	Gravels %	Particle size distribution (%)				Texture class	CaCO3 %	OM %	PH	ECe dsm^{-1}	Gypsum %	CEC $Cmolekg^{-1}$	ESP (%)
				C.S	F. S	Silt	Clay								
Oolitic sand	(6)	0-20	2	75.10	15.20	4.0	5.20	S	65.23	0.78	7.7	160.07	2.50	5.40	21.22
		20.50	2	90.15	5.22	0.13	4.50	S	71.52	0.50	7.9	50.80	2.03	6.52	25.84
		50.150	2	90.67	2.49	2.22	4.63	S	82.60	0.35	7.7	29.20	1.33	5.90	25.51
	(7)	0-35	-	90.20	4.60	2.20	3.00	S	85.30	0.60	7.9	85.65	2.30	5.59	25.63
		35-70	2	85.90	7.35	1.78	4.97	S	80.70	0.35	8.3	15.52	1.65	6.23	16.12
		70-150	2	82.10	11.47	3.13	3.30	S	85.75	0.13	7.5	150.60	1.88	6.85	16.43
Delta plain	(8)	0-35	2	53.65	28.12	2.41	15.82	Sl	35.80	0.15	9.70	18.90	1.26	7.65	16.54
		35-75	40	70.75	19.15	2.10	8.00	Ls	49.55	0.12	7.70	42.20	1.06	6.72	20.98
		75-150	40	90.05	1.97	0.08	7.00	S	58.15	0.08	7.80	40.00	0.81	5.05	5.72
	(9)	0-25	2	70.50	17.35	3.55	8.60	Ls	44.12	0.35	8.40	3.10	1.39	8.89	9.21
		25-70	40	81.70	11.03	1.35	5.90	S	60.75	0.20	8.01	9.86	1.07	6.80	5.47
		70-100	2	85.80	6.30	1.58	6.32	S	40.89	0.12	8.12	4.45	1.07	4.27	59.47
		100-150	40	85.25	7.20	1.05	6.50	S	70.30	0.12	8.12	3.75	0.52	5.15	26.98
	(10)	0-30	2	60.15	25.55	5.80	8.50	Ls	43.12	0.73	7.75	7.50	0.89	6.80	17.24
		30-50	2	62.60	23.13	4.25	10.62	Ls	45.50	0.25	7.65	50.20	1.28	6.45	8.26
		50-75	2	71.00	19.70	1.73	7.57	S	50.50	0.20	7.8	32.40	0.74	3.39	17.99
		75-150	25	85.00	9.03	0.75	5.22	S	43.11	0.13	7.9	20.70	0.15	4.69	46.34

Table (4): Rating of limitations and land suitability of the studied soil profiles.

Geomorphic units	Profile No.	Topography		Wetness		Physical properties				Salinity & Alkalinity		Suitability index (ci)		Grades	
		[1]Ci	[2]Pi	Ci	Pi	Texture	Soil depth	$CaCO_3$	Gypsum	Ci	Pi	Ci	Pi	[3]CS	[4]PS
Dry sabkha	1	100	100	100	100	65	100	80	100	45	100	23.40	52.00	N1	S2
	2	100	100	100	100	65	100	80	90	75	100	35.10	52.00	S3	S2
	3	100	100	100	100	55	100	80	100	75	100	33.00	44.00	S3	S3
Outwash plain	4	100	100	100	100	45	100	90	100	75	100	30.38	40.50	S3	S3
	5	100	100	100	100	45	100	90	100	75	100	30.38	40.50	S3	S3
Oolitic sand	6	100	100	100	100	30	100	90	100	45	100	12.15	27.00	N1	S3
	7	100	100	100	100	30	100	80	100	45	100	10.80	24.00	N1	N
Delta plain	8	100	100	100	100	50	100	80	100	45	100	18.00	40.00	N1	S3
	9	100	100	100	100	50	100	80	90	45	100	16.20	36.00	N1	S3
	10	100	100	100	100	55	100	90	100	45	100	22.28	49.50	N1	S3

[1]Ci = current index, [2]pi = potential index, [3]Cs: current suitability, [4]Ps=potential suitability