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Characteristics and Classification of Some Coastal Soils of Al-Ahsa, Saudi Arabia

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Abstract. This study provides some basic information on the morphology, genesis and classification of the coastal soils of Al-Ahsa district, for better soil surveying and land use planning. Four pedons were taken along a 440 m transect near Al-Ugair port, some 100 km north east of Al-Hofuf city. The first pedon was on beach sand, contained many shells of Molluscs and was classified as Typic Psammaquent. The second pedon was on a small sand dune, had few Molluscs shells in its lower horizons and was classified as Aquic Udipsamment. The third was on a sabkha, contained many Molluscs shells and it was classified as Typic Udipsamment whereas the fourth pedon was on a big sand dune, had no Molluscs shells and was classified as Typic Torripsamment.

Introduction

Al-Ahsa region is one of the most important agricultural areas in Saudi Arabia and is located about 170 km southwest of Dammam on the Arabian Gulf (Fig. 1). The region is bounded by longitudes 49°33' and 49°46'E and latitudes 25°21' and 25°37'N with an elevation of 130-160 m above sea level. The climate of the area is continental with hot summer temperatures and rather cold winters. The mean annual temperature is 25.37 °C. The average annual rainfall is 69.65 mm which occurs mainly during the winter period [1, pp. 26,30]. The soil moisture regime for the soils, lacking a natural high water table, is aridic while the soil temperature regime is hyperthermic. The area receives a high solar energy load which amounts to 176 x 10^3 LY per year and the annual evaporation reaches a total amount of 3310 mm [2].

General information is available about the coastal soils of Al-Ahsa but relatively few detailed characterization data have been collected. A reconnaissance soil survey has been conducted in the region of Al-Ahsa in 1985 in order to help locate

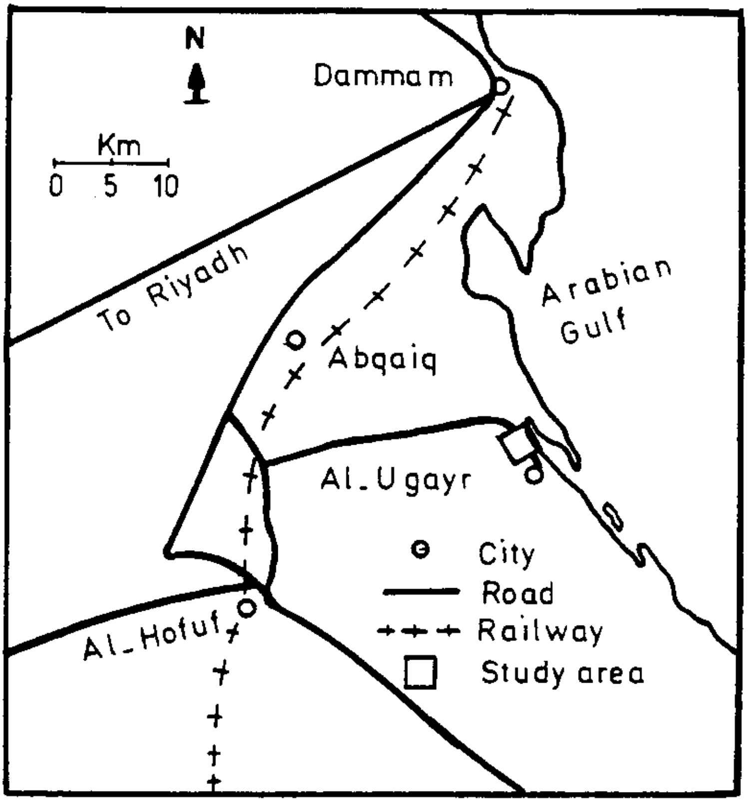


Fig. 1. Location of the study area in Al-Ugayr, north east Al-Hofuf.

arable lands and to provide important information on the use and management of these lands for large-scale irrigation farming [3,p.21]. This survey also highlighted the practices that help overcome or minimize the limitations caused by unfavorable soil and site features.According to this soil survey,most coastal lands of Al-Ahsa were put in one mapping unit called Udipsamments-Torripsamments: marine flats and dunes. This map unit is not suitable for large-scale irrigation farming. The limitations are steep dunes, sand blowing, excess soluble salt, wetness and poor drainage outlets.

The information on the characteristics of these soils is very limited under local conditions. This study was therefore, carried out to develop information about the characteristics, classification and limitations of these soils.

Materials and Methods

Geomorphology

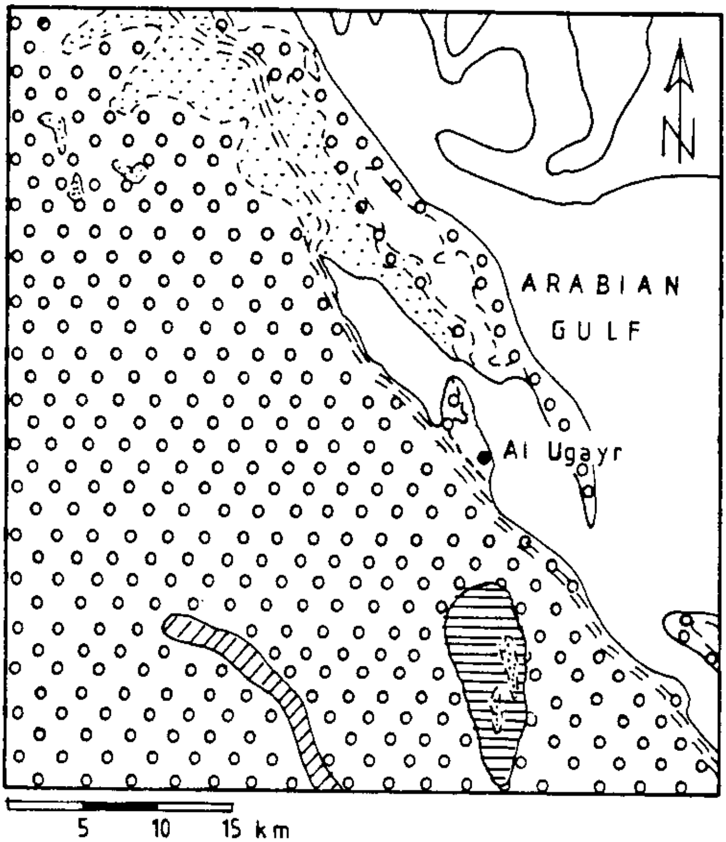
The Arabian Gulf is a broad, shallow epicontinental sea with a maximum depth of 110 meters. The shore is irregular, low, and sandy and the water has many shoals, so that changes in tide and wind direction cause the water front to shift back and forth for several kilometers. Consequently, the low coastal flats are covered by the sea periodically. The elevation of the Arabian Gulf coastal region rises gradually in land at the rate of about one meter per kilometer [4, p.22]. Salt flats or sabkhas are common along the shore line (Fig. 2). The Arabian Gulf coastal region west of Al-Hofuf is bounded by a prominent east facing escarpment extending several kilometers north and south. This cliff is cut in the eastern margin of as Summan plateau. The escarpment is believed to be the result, n part at least, of wave erosion during a higher stand of sea level [4, p. 22]. East of AS Summan Plateau and south of Al-Hofuf city is an area of drifting sand called Al-Jafurah, which widens rapidly to the south where it eventually merges with the sand area of Ar Rub'Al- Khali desert [4, p. 24].

Soils of the area

Variation in sedimentology usually controlled by many factors, such as the morphology of the coastal area and the near shore environment, nature and composition of the inland bed rocks, physicochemical characteristics of the sea water and climate, [5]. Most of the coastal plain deposits on the Arabian Gulf are overlain by more recent coastal marine deposits (Sabkha,beach and tidal flat deposits) (Fig.2). In addition, eolian sand deposits are the most frequent type of recent surface deposits in the area. It was mentioned earlier that the coastal soils of Al-Ahsa were put in the Udipsamment-Torripsamment mapping unit (Fig. 3). [3, p. 20].

In general, this maping unit consists of nearly level soils in concave areas and on flat and gently slopping to steep soils on dunes and other eolian sand deposits, all on coastal plains. The sand dunes are mostly more than 2 meters high. There are no evident drainage nets, other than channels that were formed by storm tides. Large intermittent streams cross some delineations. Individual areas of this map unit are irregular in shape and range from 2,000 to 12,000 hectares in size [3, p. 20].

This map unit is about 50 percent Udipsamments, 30 percent Torripsamments, and 20 percent minor soils, beaches, and water areas. The Udipsamments and Torripsamments are intricately mixed. The Udipsamments and similar soils are in concave areas and on flats on the coastal plains near the sea. Typically, slopes are less than 1 percent, but they range from 0 to 3 percent. The Udipsamment are deep, sandy, strongly saline soils. In most places the surface layer when dry has a crust. Permeability is very high and the difference in water retention is moderately low. A high water table is at a depth of less than 50 centimeters for many days each year.



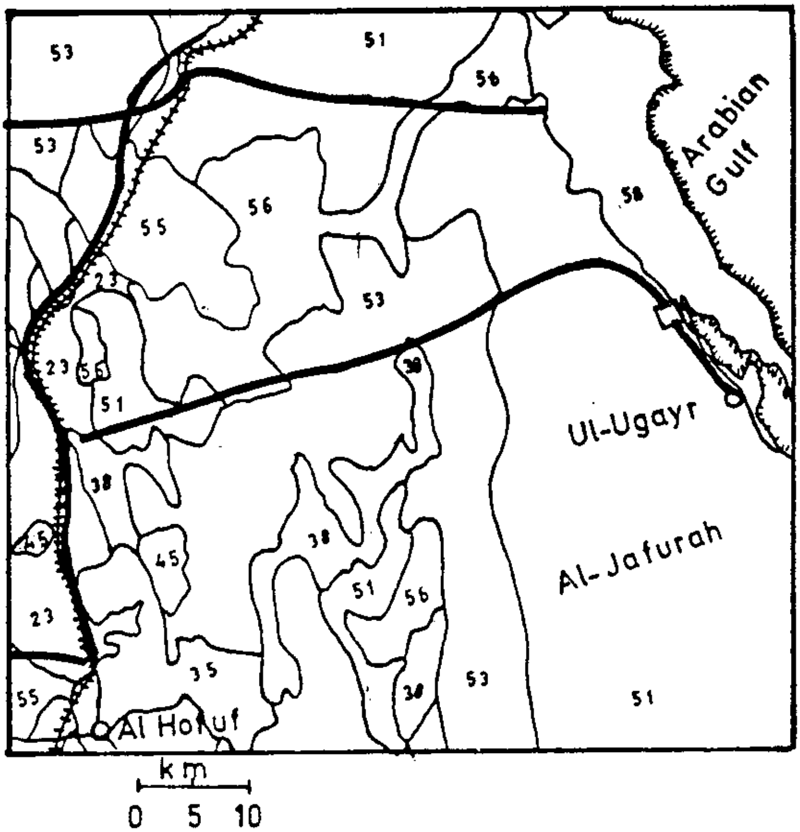
Qes Eolian sand: mobile sand dunes and linear sand ridges and other sand forms.

Qsb Sabkha deposits: saline silt clay and muddy sand.

Td Dam Formation: light coloured marl and dark coloured clay.

Tfh Hofuf Formation: white sandy marl and cream sandylime-stone with calcareous sandstone and shale intercalation.

Fig. 2. Surficial geology of the study area.



No.	Mapping Unit
23	Calciorthids - Torriorthents
35	Haplaquepts - Eutrochrepts
38	Salorthids
45	Torriorthents - Calciorthids
51	Torripsamments
53	Torripsamments - Gypsiorthids
55	Torripsamments - Outcrops
56	Torripsamments - Salorthids
58	Udipsamments - Torripsamments

Fig. 3. Soil Map of part of Al-Ahsa district.

The Torripsamments and similar soils are on dunes, hummocks, and other thick eolian sand deposits on coastal plains. Slopes range from 3 to 60 percent. The Torripsamments are deep, sandy, slightly saline and moderately saline soils. Permeability is very high and the difference in water retention is moderately low.

Included in this map unit are small areas of loamy soils, typically on the inland side of delineations. Soil that are shallow and moderately deep to coral rock are intermixed with the Udipsamments. Also included are very gravelly soils near the seashore and in drainage ways, beaches of washed and rewashed sand, and water areas [3, p. 20].

Field Study

A reconnaissance soil survey covering the entire area of the Kingdom of Saudi Arabia was conducted to determine the extent and location of soils that may be suitable for further consideration in a proposed irrigation development program [3,p.3]. This survey shows the different kinds of soils on landsat images at a scale of 1:250,000.

Each map unit on the soil map sheets represents an area on the landscape and consists of one or more soils and land types for which the unit is named. In the study area, one mapping unit has been identified [3,p.20].Udipsamments-Torripsamments: marine flats and dunes: (Fig. 3).

This study was conducted along a 440 m transect near Al-Uqair port, some 100 km north east of Al-Hofuf city (Fig.1).

This transect represents a toposequence in an eastern direction from sea shore where four sites representing some of the coastal soils of Al-Ahsa were selected (Fig. 4).

The pedon at site 1 was sampled on beach sand adjacent to the backshore, between the intertidal area and a coastal sabkha. It was 12 m west of the sea at the time of sampling (10 a.m). The pedon at site 2 was on a small sand dune. It was 52 m west of site1. The pedon at site 3 was sampled on a depression in a coastal sabkha. It was about 230 m west of site 2. The pedon at site 4 was on a big sand dune, it was about 60 m west of site 3 (Fig.4).

The ground water table was below 125 cm at site 4 while it was at a depth of 40 cm at site 1, 57 cm at site 2 and 105 cm at site 3 (October, 1994). Most of these sites were on 2% slope except site 4 which was on 3-4% slope.The dominant natural plant cover on these sites consists of scattered species of *Halocnemum strobilaceum, Aleuropus lagopoides, Juncus accutus, Phoenix dactylifera, Zygophyllum album Var., Zygophyllum coccineum* and *Salicornia europaea* (L.).

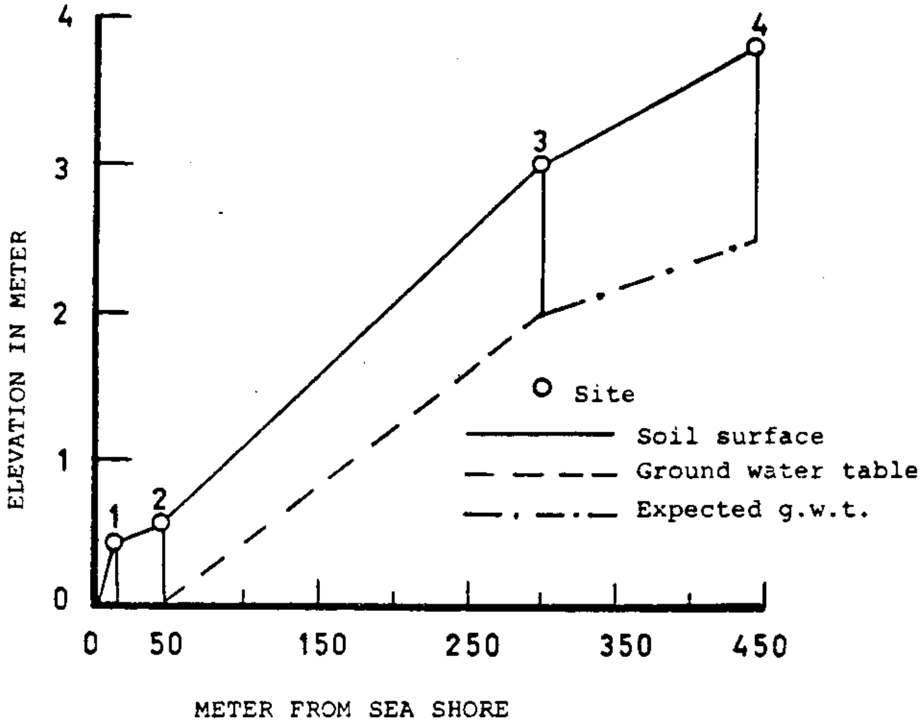


Fig. 4. Cross-sectional diagram showing position of the four pedons in the landscape.

Soil sampling and analysis methods

The soil profiles were exposed by digging a pit at each site and described according to the Soil Survey Manual [6, pp. 2-105]. Soil samples from each horizon were collected and analyzed for particle size without removing $CaCO_3$ [7]. Five water samples, two from the sea water and the others from the ground water of sites 1,2 and 3 were taken. Soil pH and electrical conductivity of the saturation soil extract (Ec_e), calcium carbonate, soluble cations and anions were determined by following methods described in USDA Handbook No.60 [8, pp. 89-102]. Gypsum was determined by precipitation in acetone [9,pp.35-36]. Organic carbon was determined by the Smith-Weldon modification of the Walkey-Black method [10,pp.219-221].

Results and Discussion

The morphological properties of the pedons studied indicated similar features especially in the pedons at sites 1, 2 and 3 (Table 1). The dominant soil colour of the surface horizons of the pedons at sites 1, 2 and 3 is very pale brown whereas that of their sub-horizons is light olive grey due to water logging. No mottles were observed in these pedons. The dominant structure of the soils at sites 1, 2 and 3 was single grain for their surface horizons and massive for their sub-surface horizons. The pedon at site 4 has a single grain structure in the whole profile. Particle size data of the pedons at the four sites are shown in Table 1. In general, sand, silt, and clay did not show any considerable decreasing trend with depth. Clay decreased slightly with depth in the pedon at site 3. Sand was the dominant separate in the soils studied. However, the pedon at site 4 had the highest amount of sand compared to the other pedons. In the pedon at site 3, a horizon consisting mainly of Molluscs shells was observed at a depth of 21-27 cm.

Such shells had been distributed in most of the horizons of the pedons at sites 1 and 3 (Table 1). The shells of two classes of Molluscs phylum were identified. The Gastropods class includes the following species: *Cerithium scarbridum, Pirenella conica, Trochus erythraeus, Mitrella blanda* and *Vermetus sulcatus*, whereas the Bivalves class includes one species of Brachiodontes variabilis.

The results of the physio-chemical analyses are shown in Table 2. In general the variations of EC values correspond to the variations of the sum of the soluble cations and anions in the saturation soil extract. As the (EC_e) was generally higher at the surface and decreased with depth (Table 2), indicating a net upward movement of salts to the surface due to aridity condition in the region. In general, the EC was clearly varied among sites as the lowest EC_e was 4.08 dSm^{-1} (at depth 0-125 cm at site 4), whereas the highest EC_e was 427 dSm^{-1} (at depth 0-4 at site 2). The pH values ranged from 7.2 to 7.4 in the pedons at site 3 and 4, while it ranged from 7.7 to 7.9 in the pedons at sites 1 and 2 with extreme of 8.4 in the surface horizon of the pedon at site 1. Low precipitation and calcareous parent material have resulted in high carbonate contents. The horizons of the pedon at site 1 have more calcium carbonate than those of the other sites.

Gypsum content was low in all the soil horizons and ranged from 0.4% (at 30-40 cm depth of the pedon at site 1) to 2.3% (at 0-3 cm) depth of the same pedon. However, the highest content of gypsum was observed in the upper surface horizons of each pedon (Table 2).

Table 1. Morphological properties and particle size distribution of Pedons at the Four Sampling Sites in Al-Ahsa. Symbols and designations are according to abbreviations given in Soil Survey Staff (1972), p. 139-140

Horizon	Depth (cm)	Colour (moist)	Structure	Consistence	Boundary	Textural class	Sand (%)	Silt (%)	Clay (%)	Remarks
						Site 1 (Typic Psammaquent)				
Cz	0-3	10YR 7/2	sg	wso	c	ls	80	11	9	Shells of different types and sizes.
C	3-30	10YR 7/3	m	wss	a	ls	82	17	1	“ “
Cg	30-40	SY 6/2	m	wss		ls	75	24	1	“ “
						Site 2(Aquic Udipsamment)				
Cz1	0-4	10YR 5/3	sg	wss	cs	sl	69	17	14	puff, crust 1 cm thick
Cz2	4-43	10YR 6/4	m	wso	cs	ls	84	15	1	m.f. roots
Cg1	43-50	2.5Y 7/2	m	dfi	as	ls-s	83	15	2	salt layer, mf & fc roots, shells
Cg2	50-57	5 Y 5/2	m	wss		s	85	13	2	shells
						Site 3 (Typic Udipsamment)				
Cz1	0-4	10YR 5/3	sg	wso	c	l;s	85	10	5	Many shells
Cz2	4-13	10YR 7/3	sg	wso	c	ls	87	9	4	few big shells
C	13-21	10YR 6/4	sg	wso	a	ls	89	9	2	=
	21-27	-	-	-	a	-	-	-	-	Layer of shells
Cgx	27-50	2.5Y 8/2	m	wss,mfi	a	ls	89	10	1	shells
Cg	50-105	5Y 6/2	m	wss		ls	81	18	1	shells
						Site 4 (Typic Torripsamment)				
C	0-125	10YR 5/3	sg	wso		s	98	0.4	1.6	

Table 2. Chemical properties of pedons at the four sampling sites in Al-Ahsa

Horizon	Depth (cm)	pH	Organic carbon %	Gypsum %	$CaCo_3$ %	EC dSm^{-1}	Saturation %	Salts %
							Site 1	
Cz	0-3	8.4	0.02	2.3	61.7	141.9	23.8	2.16
C	3-30	7.7	0.32	0.5	58.9	19.6	14.3	0.18
Cg	30-40	7.7	0.07	0.4	48.4	35.6	21.3	0.38
					Average SAR = 88			
							Site 2	
Cz1	0-4	7.7	nil	2.0	3.4	427.0	36.3	9.92
Cz2	4-43	7.9	nil	1.3	3.2	33.1	36.3	0.77
Cg1	43-50	7.8	nil	1.3	10.0	22.1	30.6	0.43
Cg2	50-57	7.8	0.02	1.3	49.8	30.4	38.0	0.62
					Average SAR = 77			
							Site 3	
Cz1	0-4	7.2	0.003	1.7	3.8	122.7	22.2	1.74
Cz2	4-13	7.3	0.003	1.5	0.3	57.1	24.4	0.89
C	13-21	7.3	0.003	1.0	17.8	12.98	27.7	0.23
	21-27	7.4	0.003	0.9	70.7	8.63	35.5	0.19
Cgx	27-50	7.3	0.007	1.1	17.2	9.38	31.6	0.19
Cg	50-105	7.3	0.003	0.8	29.2	14.7	32.2	0.34
					Average SAR = 42			
							Site 4	
C	0-125	7.4	0.02	0.9	6.6	4.08	17.5	0.05
					Average SAR = 2.8			
Sea shore near site 1		7.15	-	-	-	124.3	-	-
Sea shore near Ugair port		7.2	-	-	-	120.1	-	-
Ground water from site 1		7.0	-	-	-	48.0	-	-
Ground water from site 2		7.1	-	-	-	51.2	-	-
site 3								
135	3.0	153.7	36	30	210	16	36	0.8
250	1.5	11.3	43	35	297	8	118	0.8
Estimated ESP = 56%								
2350	30.0	959.0	13	520	2720	86	167	40.0
225	1.5	80.5	44	26	225	12	38	0.6
150	2.0	166.0	33	17	264	4	52.5	0.5
170	2.5	182	44	23	261	7	52	0.5
Estimated ESP = 53%								

Table 2. (Contd).

Horizon	Depth (cm)	pH	Organic carbon %	Gypsum %	$CaCO_3$ %	EC dSm^{-1}	Saturation %	Satls
1200	7.0	167.0	100	300	928	46	66	3.0
575	3.5	143.5	39	42	628	13	99	1.1
135	2.0	19.0	31	19	103	3	20.6	0.6
50	1.5	44.5	30	14	50	2	10.7	0.5
60	2.0	71.0	32	42	57	2	9.4	1.3
110	3.0	39.0	33	16	98	3	18.0	0.5
Estimated ESP = 38%								
20	3.0	33.4	30	12	13	1.7	2.8	0.4
Estimated ESP = 4%								
970	4.0	241.0	37	184	978	16	-	5.0
900	3.0	324.0	30	173	1007	16	5	-
375	8.0	91.0	36	73	355	10	163	2.0
365	8.0	113.0	37	76	362	11	164	2.1
90	1.0	625.0	34	24	91	4.1	17	0.7

The concentration of soluble Na^+ was higher than that of soluble Ca^{++}, Mg^{++} and K^+ in all the horizons of pedons of sites 1 , 2 and 3, whereas the concentration of K^+ was the lowest as compared to the other cations (Table 2). Soluble Mg^{++} content in the surface horizons of the pedons at sites 1,2 and 3 exceeded that of Ca, as indicated by the Mg/Ca ratio (Table 1).The increasing Mg/Ca ratio is an indication of Ca precipitation from the system, which effectively increases the Mg buildup in the soil solution.

The Mg/Ca ratios in the sea water samples were also more than 1 as well as in the groundwater samples taken from sites 1 and 2. But, the Mg/Ca ratios were less than 1 in the underlying horizons of the studied pedons.

In general, the concentration of soluble Cl^- was higher than that of the other soluble anions in the surface horizons of sites 1, 2 and 3.

Discussion

The coastal soils of Al-Ahsa were developed under the influence of a high ground water table affected by a possible source from sea water. A lack of adequate drainage resulted in their salinization.In general EC_e and soluble cations and anions values showed a decrease with depth from surface horizons to underlying horizons of the pedons at sites 1, 2 and 3. Most of the virgin soils of Al-Ahsa are salt affected, where EC_e values exceed 4 dSm^{-1} in all types of soils including sand dunes [1,pp.175-285].

The pedon at site 4 has eolian sand parent material and it has an EC_e value of 4.08 dSm^{-1} and SAR of 2.8 (Table 2). In general, the salt affected soils of Al-Ahsa were affected by the influence of a shallow ground-water table and over irrigation with highly saline water especially in the cultivated part of the region. Also, a lack of adequate drainage and the presence of an impervious stratum underlying the soils of Al-Ahsa resulted in their salinization [11,2]. In the coastal soils of Al-Ahsa,sea water may create a major source for drainage water. The chemical composition of sea water samples taken near site 1 and Al-Ugair port are presented in Table 2. pH values in the pedons near the seashore (Sites 1 and 2) were higher than that of the sea water. The control of pH in seawater is affected through all of the major ions in it. A decrease in both SAR and ESP was noticed in the pedons studied with an increase in the distance from sea shore. In general, the SAR values decreased with depth in most of the pedons studied and were highest at site 1 and least at site 4. The chemical data indicated that the studied soils could be defined as saline sodic soils.

The surface horizons of the pedons at sites 1, 2 and 3 were much higher in magnesium levels than calcium. The concentration of Mg^{++} was higher than that of Ca^{++} in sea water as well as in the ground water taken from sites 1 and 2 (Table 2). This may indicate that the chemical properties of these soils were affected by the influence of sea water. Also, the presence of different types of Molluscs shells in the horizons of the pedons at sites 1 and 3 indicates their past formation process under the influence of sea water.

A shallow hardpan was noticed just above the ground water in the pedon at site 1. Another hardpan was also noticed at a depth of 27-50 cm in the pedon at site 3 (Table 1). The formation of hardpans in these soils is probably due to physical, chemical, and environmental conditions promoting precipitation of salts and cementing of the soil to form the hardpan. Further research is required to determine the chemical and physical characteristics of these hardpan and mechanisms involved in their formation.

It was mentioned previously that the coastal soils of Al-Ahsa were put in the Udipsamment-Torripsamment mapping unit which consists of about 50 percent Udipsamments, 30 percent Torripsamments and 20 percent minor soils [3, p. 20].

Soils from the four sites were classified according to their properties as described in Table 1 [12, pp. 131-149].

On the basis of annual rainfall and monthly evapotrans-piration/rainfall ratios,the soils of the study area have an aridic moisture regime. The presence of the soils near the sea shore created a shallow ground water in their profiles, except that for the soil at site 4.

The soil at site 1 is more susceptible to sea water than the soil at sites 2 and 3. Therefore the soil at site 1 had an aquic moisture regime while the soils at sites 2 and 3 had a udic moisture regime. Accordingly, the soil at site 1 was classified as Typic Psammaquents, at site 3 as Typic Udipsamments and at site 4 as Typic torripsamments.Both subgroups, Typic Psammaquents and Aquic Udipsamments are new proposed in Al-Ahsa coastal soils.

Most of the studied soils have very limited suitability for cultivation due to some serious cultivation problems. The limitations are steep dunes, sand blowing, excess soluble salts, wetness and poor drainage outlets. Such problems should be taken into consideration in the planning management schemes for these soils.

The smaller dunes can be modified by levelling and sand blowing can be reduced by wind breaks. Such practices can be conducted in the soil at site 4. The rest of the problems are continuing limitations that are not easily corrected unless for very small-scale irrigation farming.

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خصائص وتصنيف بعض أراضي الأحساء الساحلية

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ملخص البحث. إن الغرض من هذه الدراسة هو إعطاء بعض المعلومات الأساسية عن مرفولوجيا ونشأة وتصنيف بعض أراضي الأحساء الساحلية من أجل حصر وتخطيط مستقبلي أفضل لاستعمال هذه الأراضي. تم أخذ أربعة قطاعات تربة على امتداد مسافة طولها ٤٤٠ مترا بالقرب من ميناء العقير الذي يبعد عن مدينة الهفوف بمقدار ١٠٠ كلم تقريبا في الاتجاه الشمالي الشرقي. يقع القطاع الأول في الشاطيء الرملي ويحتوي على أصداف كثيرة من البطن قدميات وتم تصنيف التربة التي يمثلها على أنها **Typic psammaquent**. بينما يقع القطاع الثاني في كثيب رملي صغير وبه أصداف قليلة من البطن قدميات في آفاقه السفلى وتم تصنيف التربة التي يمثلها على أنها Aquic udipsamment هذا وتعتبر كل من المجموعتين السابقتين حديثة الاقتراح في أراضي الأحساء الساحلية. يقع القطاع الثالث في سبخة ويحتوي على أصداف كثيرة من البطن قدميات وتم تصنيف تربته على أنها Typic udipsamnment. بينما تم تصنيف تربة القطاع الرابع والذي يقع في كثيب رملي كبير على أنها Typic torripsamment.